

PROCESSING SUITABILITY OF CHILI VARIETIES FOR VALUE ADDED PRODUCTS

Dissertation

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**DOCTOR OF PHILOSOPHY
in
FOOD TECHNOLOGY
(Minor Subject: Processing and Food Engineering)**

By

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(L-2016-A-33-D)**

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CERTIFICATE I

This is to certify that the dissertation entitled, “**Processing suitability of chili varieties for value added products**” submitted for the degree of Ph.D., in the subject of **Food Technology** (Minor subject: **Processing and Food Engineering**) to the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ms. Manpreet Kaur (L-2016-A-33-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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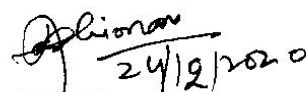
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ABSTRACT

The present investigation entitled “Processing suitability of chili varieties for value-added products” was carried out with the objectives to assess the physicochemical, phytochemical and antioxidant activity of Punjab Sindhuri and CH-27 chili varieties, development of chilli paste with enhanced shelf stability, drying characteristics of chili varieties and preparation of value added products with greater shelf stability and to extract oleoresins by using conventional and non-conventional methods. The CH-27 contained highest total soluble solids (5° Brix), total solids (20.7%), ash content (1.47%), total sugars (4.4mg/100 gm), crude fibre (9.81%), total phenolics (276 mg/100ml), ascorbic acid (132.17 mg/100 gm) and capsaicin (1.17%), while Punjab sindhuri contained highest total chlorophyll (10.43), carotenoids (12.05mg/100 gm), β -carotene (5.85mg/100 gm) and lycopene (3.2 μ g/100 gm). Among different drying techniques, freeze drying at -40°C showed significantly highest retention of physicochemical, phytochemical and antioxidant properties in both chili varieties. During 8 months storage (room as well as refrigeration), honey chili sauce containing CH-27 (red) showed utmost retention of total phenolics (679.46mg/100ml), β -carotene (308 mg/100 gm), lycopene (4.59 μ g/100 gm), per cent inhibition of DPPH (52.02%), FRAP (3.43 mM/100 gm), while honey chili sauce containing Punjab sindhuri (red) significantly retained maximum total solids (84.49%) ascorbic acid (5.54mg/100 gm), color *a* value (4.84), ash content (2.86%) and total sugars (63.56 gm/100 gm). Red and green form of both chili varieties were processed into the paste and stored at the room as well as refrigeration temperature. The chili paste yield was found significantly higher for Punjab sindhuri (green and red) than CH-27. Treatment containing 0.2gm KMS + 0.2gm sodium benzoate + 1ml acetic acid + 5gm NaCl per 100 gm of chili paste was found to be effective for the better retention of physicochemical, phytochemical and antioxidant activity during 10 months duration of storage. Highest oleoresin yield i.e.7.1% from Punjab sindhuri red variety was observed with ultrasonication method.

Keywords: CH-27, Punjab sindhuri, Drying, Honey chili sauce, Paste, Oleoresins

Signature of Major Advisor

Signature of the Student

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	: ਮੁੱਲ ਵਧਾਉਣ ਵਾਲੇ ਉਤਪਾਦਾਂ ਲਈ ਮਿਰਚਾਂ ਦੀਆਂ ਕਿਸਮਾਂ ਦੀ ਪ੍ਰੋਸੈਸਿੰਗ ਯੋਗਤਾ
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ਨਿਮਨ ਵਿਸ਼ਾ	: ਪ੍ਰੋਸੈਸਿੰਗ ਐਂਡ ਫੂਡ ਇੰਜੀਨੀਅਰਿੰਗ
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“ਮੁੱਲ ਵਧਾਉਣ ਵਾਲੇ ਉਤਪਾਦਾਂ ਲਈ ਮਿਰਚਾਂ ਦੀਆਂ ਕਿਸਮਾਂ ਦੀ ਪ੍ਰੋਸੈਸਿੰਗ ਯੋਗਤਾ” ਸਿਰਲੇਖ ਹੇਠਾਂ ਮਿਰਚਾਂ ਦੀਆਂ ਕਿਸਮਾਂ ਜਿਵੇਂ ਕਿ ਪੰਜਾਬ ਸਿੰਧੂਰੀ ਅਤੇ ਸੀਐਚ-27 ਦੇ ਫਿਜ਼ੀਓਕੈਮੀਕਲ, ਫਾਈਟੋ ਕੈਮੀਕਲ ਅਤੇ ਐਂਟੀਆਕਸੀਡੈਂਟ ਗਤੀਵਿਧੀ ਦਾ ਮੁਲਾਂਕਣ, ਵਧੇਰੀ ਸ਼ੈਲਫ ਸਥਿਰਤਾ ਵਾਲੀ ਮਿਰਚਾਂ ਦੇ ਪੇਸਟ ਦਾ ਵਿਕਾਸ, ਸੁੱਕਣ ਵਾਲੀਆਂ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਦਾ ਜਾਇਜਾ, ਵਧੇਰੀ ਸ਼ੈਲਫ ਸਥਿਰਤਾ ਵਾਲੇ ਮੁੱਲ-ਜੋੜ ਉਤਪਾਦਾਂ ਦੀ ਤਿਆਰੀ, ਰਵਾਇਤੀ ਅਤੇ ਗੈਰ-ਰਵਾਇਤੀ ਵਿਧੀਆਂ ਦੀ ਵਰਤੋਂ ਦੁਆਰਾ ਓਲੀਓਰੇਸਿਨ ਕੱਢਣ ਦੇ ਉਦੇਸ਼ਾਂ ਨਾਲ ਮੌਜੂਦਾ ਖੋਜ ਕੀਤੀ ਗਈ। ਸੀਐਚ-27 ਵਿੱਚ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਕੁੱਲ ਟੀਐਸਐਸ (5% ਬ੍ਰਿਕਸ), ਕੁੱਲ ਠੋਸ (20.7%), ਐਸ ਸਮੱਗਰੀ (1.47%), ਕੁੱਲ ਸ਼ੱਕਰ (4.4 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), ਕੱਚਾ ਫਾਈਬਰ (9.81%), ਕੁੱਲ ਫੀਨੋਲਿਕਸ (276 ਮਿਲੀਗ੍ਰਾਮ / 100 ਮਿਲੀਲੀਟਰ), ਐਸਕੋਰਬਿਕ ਐਸਿਡ (132.17 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), ਖਣਿਜਾਂ ਅਤੇ ਕੈਪਸੈਸਿਨ (1.17%), ਜਦਕਿ ਪੰਜਾਬ ਸਿੰਧੂਰੀ ਵਿੱਚ ਸਭ ਤੋਂ ਵੱਧ ਕੁਲ ਕਲੋਰੀਫਿਲ (10.43), ਕੈਰੋਟੀਨੋਇਡਜ਼ (12.05 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), ਬੀਟਾ-ਕੈਰੋਟੀਨ (5.85 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ) ਅਤੇ ਲਾਇਕੋਪੀਨ (3.2 ਮਾਈਕਰੋਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ) ਪਾਇਆ ਗਿਆ। ਮਿਰਚਾਂ ਨੂੰ ਵੱਖ ਵੱਖ ਤਰੀਕੇ ਨਾਲ ਸੁਕਾਉਣ ਵਿੱਚੋਂ, ਚੁਣੀ ਹਰ ਕਿਸਮ ਦੀਆਂ ਮਿਰਚ ਦੇ ਫਿਜ਼ੀਓਕੈਮੀਕਲ, ਫਾਈਟੋ ਕੈਮੀਕਲ ਅਤੇ ਐਂਟੀਆਕਸੀਡੈਂਟ ਗਤੀਵਿਧੀਆਂ ਦੇ ਲਈ ਫ੍ਰੀਜ ਵਿਧੀ ਰਾਹੀਂ -40 ਡਿਗਰੀ ਸੈਲਸੀਅਸ ਤਾਪਮਾਨ 'ਤੇ ਸੁਕਾਉਣ ਵਾਲੇ ਤਰੀਕੇ 'ਚ ਸਭ ਤੋਂ ਵੱਧ ਸਥਿਰਤਾ ਪਾਈ ਗਈ। ਕਮਰੇ ਵਿੱਚ ਤੇ ਫਰਿਜ਼ ਦੇ ਤਾਪਮਾਨ ਤੇ 8 ਮਹੀਨਿਆਂ ਦੀ ਸਟੋਰੇਜ ਵਿੱਚ, ਸੀਐਚ -27 ਲਾਲ ਦੇ ਨਾਲ ਤਿਆਰ ਕੀਤੀ ਸ਼ਹਿਦ-ਮਿਰਚ ਚਟਨੀ ਨੇ ਕੁੱਲ ਫੈਨੋਲਿਕਸ (679.46 ਮਿਲੀਗ੍ਰਾਮ / 100 ਮਿਲੀਲੀਟਰ), β -ਕੈਰੋਟੀਨ (308 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), ਲਾਈਕੋਪੀਨ (4.59 ਮਾਈਕਰੋਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), ਡੀਪੀਪੀਐਚ (52.02%), ਐਫਆਰਪੀ (3.43 ਐਮ ਐਮ / 100 ਗ੍ਰਾਮ) ਨੇ ਉੱਚ ਸਥਿਰਤਾ ਦਿਖਾਈ, ਜਦੋਂ ਕਿ ਪੰਜਾਬ ਸਿੰਧੂਰੀ ਲਾਲ ਦੇ ਨਾਲ ਤਿਆਰ ਕੀਤੀ ਸ਼ਹਿਦ-ਮਿਰਚ ਦੀ ਚਟਨੀ ਨੇ ਕੁੱਲ ਠੋਸ (84.99) ਐਸਕਰਬਿਕ ਐਸਿਡ (5.54 ਮਿਲੀਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ), *ਏ ਵੈਲਿਊ ਮੁੱਲ (4.84), ਐਸ ਸਮੱਗਰੀ (86.86%) ਅਤੇ ਕੁੱਲ ਸ਼ੱਕਰ (63.56 ਗ੍ਰਾਮ / 100 ਗ੍ਰਾਮ) ਨੇ ਉੱਚ ਸਥਿਰਤਾ ਦਿਖਾਈ। ਦੋਨੋਂ ਮਿਰਚ ਦੀਆਂ ਕਿਸਮਾਂ ਦੇ ਲਾਲ ਅਤੇ ਹਰੇ ਰੂਪ ਨੂੰ ਪੇਸਟ ਵਿੱਚ ਪ੍ਰੋਸੈਸ ਕੀਤਾ ਗਿਆ ਸੀ ਅਤੇ ਕਮਰੇ ਨਾਲ ਨਾਲ ਫਰਿਜ਼ ਤਾਪਮਾਨ ਵਿੱਚ ਸਟੋਰ ਕੀਤਾ ਗਿਆ। ਪੰਜਾਬ ਸਿੰਧੂਰੀ (ਹਰੇ ਅਤੇ ਲਾਲ) ਲਈ ਮਿਰਚ ਦੇ ਪੇਸਟ ਦਾ ਝਾੜ ਸੀ.ਐਚ. -27 ਨਾਲੋਂ ਕਾਫ਼ੀ ਜ਼ਿਆਦਾ ਪਾਇਆ ਗਿਆ। ਇਲਾਜ 0.2 ਗ੍ਰਾਮ ਕੇ.ਐੱਮ.ਐੱਸ. + 0.2 ਗ੍ਰਾਮ ਸੋਡੀਅਮ ਬੇਨਜ਼ੋਆਏਟ + 1 ਮਿਲੀਲੀਟਰ ਐਸੀਟਿਕ ਐਸਿਡ + 5 ਗ੍ਰਾਮ ਲੂਣ ਪ੍ਰਤੀ 100 ਗ੍ਰਾਮ ਮਿਰਚ ਪੇਸਟ ਨੂੰ 10 ਮਹੀਨਿਆਂ ਦੀ ਸਟੋਰੇਜ ਦੌਰਾਨ ਫਿਜ਼ੀਓਕੈਮੀਕਲ, ਫਾਈਟੋ ਕੈਮੀਕਲ ਅਤੇ ਐਂਟੀ ਆਕਸੀਡੈਂਟ ਕਿਰਿਆਸ਼ੀਲ ਦੀ ਬਿਹਤਰ ਸਥਿਰਤਾ ਬਣਾਈ ਰੱਖਣ ਲਈ ਪਾਇਆ ਗਿਆ। ਓਲੀਓਰੇਸਿਨ ਕੱਢਣ ਲਈ ਅਲਟਰਾਸੋਨੀਕਸ਼ਨ ਅਤੇ ਰੀਫਲੈਕਸਿੰਗ ਵਿਧੀਆਂ ਵਰਤੀਆਂ ਗਈਆਂ ਸਨ। ਪੰਜਾਬ ਸਿੰਧੂਰੀ ਲਾਲ ਕਿਸਮ ਵਿੱਚ ਉੱਚ ਓਲੀਓਰੇਸਿਨ ਦਾ ਉਤਪਾਦਨ (7.1%) ਅਲਟਰਾਸੋਨੀਕਸ਼ਨ ਵਿਧੀ ਨਾਲ ਦੇਖਿਆ ਗਿਆ।

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CHAPTER-I

INTRODUCTION

Chili is a spice widely cultivated in the world. It is an important commercial and export crop in India (Orobiyi *et al* 2013, Reddy *et al* 2014). *Capsicum annum L* belongs to *Solanaceae* family, considered most essential commercial business crop mainly produced in India, China, Mexico and Southeast Asia accounts for 16.7 per cent total spice production. (Parle and Kaura 2012, Chitravathi *et al* 2014, Chitravathi *et al* 2015, Ahmed *et al* 2000 and Ahmed *et al* 2002a). The worldwide area under chili production is 2020 thousand hectares with production 3762 thousand tons. Out of this, the production area for India is 792 thousand hectares with production 1376 thousand tons (Geetha and Selvarani 2017). In 2018, chili production in Punjab was 14.08 thousand metric tons. In India, production of green and red chili is 37.20 thousand metric tons and 12.89 lakhs tons respectively.

The worldwide consumption of chili is expanding constantly for fresh fruits along with its processed product including paste, puree, powder, and oleoresins etc. it is consumed daily as a single ingredient or as a food supplement. The blend of different characteristics such as colour, taste, pungency etc. is responsible for the chili popularity. Apart from taste and pungency, chili has some medicinal and therapeutic properties such as anticancer, antibacterial, analgesic, anti-inflammatory, antitumor and antiviral. The phytochemical components of chili representing the medicinal and pharmaceuticals properties are flavonoids, carotenoids, phenolics, vitamins, saponins, cyanogenic glycosides, stilbenes, tannins, alkaloids, amines, betalains (Sricharoen *et al* 2015, Omolo *et al* 2014). Chili is a good source of vitamin C, A, B6, K and minerals like calcium, magnesium, folate, potassium, thiamine, iron, copper etc. The pungency of the chili is due to capsaicinoids compounds that also has great medicinal properties. The primary capsaicinoids in chili is capsaicin ($C_{18}H_{27}NO_3$) followed by dihydrocapsaicin, nordihydrocapsaicin, homodihydrocapsaicin and homocapsaicin. The application of capsaicinoids in pharmaceuticals is attributed to their anticancer, antioxidant, antiarthritic and analgesic properties (Swapan *et al* 2017; Reyes-Escogido *et al* 2011).

Chili is an exceedingly perishable crop with a short shelf life. There is an extensive increase in the necessity of chili as industrial products and industries tries to tackle the needs by creating diversification of chili processed product based on customer's need (Renate 2019). Thermal processing and canning of chili puree can extend its shelf life with retention of natural color and pungency. As an approach of preservation, chili puree and paste can retain the natural colour, flavor and particular pungency in the semisolid form that is advantageous to utilize. These processed products could retain the quality close to the fresh chili. Evaporation along with the addition of hydrocolloids, the desirable concentration of

chili puree can be obtained. It can either be used in Asian cooking as a mainstreaming topping or as an ingredient in soup, stews and food dishes that add flavor and pungency to the dish (Ahmed *et al* 2002, Mazlina *et al* 2014; Ismail and Revathi 2006, Ali *et al* 2014).

From the preservation point of view, the drying of agricultural commodities like chili is required. Drying is defined as the removal of moisture due to simultaneous transfer of heat and mass (Guzman-Valdivia *et al* 2016, Kumar *et al* 2017). The initial 70-80 per cent moisture content of chili is reduced to 10 per cent to increase its shelf life (Mangaraj *et al* 2001). Dried chili is a spice product and in the Asian cuisines, it is used as flavoring and coloring component (Toontom *et al* 2012). India being a tropical country enjoys a substantially good solar radiation whole year and receives 3000-3200 hours of sunshine yearly that provide 2000 kWh/m²/yr of solar radiation (Kumar and Rai 2016). The broadly utilized and economic method for drying of chili is conventional open sun drying, but this method has inherent drawbacks mainly related to prolonged drying time results in high losses including inadequate drying, damage by insects, fungi, rodents; structural damage like shrinkage, loss of volatile components etc. Degraded quality products found in sun drying (Castillo-Tellez *et al* 2017). To overcome the limitations of traditional sun drying, mechanical methods are adapted to dry the commodity under controlled conditions (Rao and Satayanarayan 2018). Cabinet type tray dryer, laboratory tray dryer, continuous fluidized beds dryer etc. were used for the drying of chilies (Charmongkolpradit *et al* 2010; Wiriya *et al* 2009; Kumar *et al* 2017). Freeze drying is claimed to be the best method for the retention of dried chili quality. However, it is the most expensive process of drying (Toontom *et al* 2016). Freeze drying was found to be the best method for maintaining bright color quality, higher ascorbic acid, capsaicin and β -carotene than samples dried in mechanical and sun dryers (Toontom *et al* 2012; Maurya *et al* 2018).

The natural mixture of essential oils and resins responsible for the total flavor profile of spice is known as oleoresins. The oleoresins are 5-20 times stronger in flavor than corresponding spice. These oleoresins can be extracted by using hydrocarbon solvents and/or supercritical fluid extraction with solvent (Shahidi and Hossain 2018; Peter 2012). Capsaicin is the principle pungent constituent of the chili. Capsaicin is an alkaloid or predominant capsaicinoid with a minor amount of dihydrocapsaicin, norhydrocapsaicin, homodihydrocapsaicin and homocapsaicin. The capsaicinoids are well known for their usage as a natural food additive, dietary supplement, a constituent in self-defence products; clinical applications including antioxidant, anti-inflammatory, antimicrobial etc. The capsaicin oleoresin can be extracted from dried chili with solid-liquid extraction with subsequent removal of solvent (Rafajlovska *et al* 2011). Capsanthin is the four terpenoids orange-red pigment and one of the major carotenoids of the red chili. Capsanthin is a natural pigment that gains great attention and widely used in food, cosmetic and dye industries. In

pharmaceuticals, capsanthin is used for anti-oxidative, anti-tumour, anti-cancer and anti-radiation properties. The capsanthin from the dried chillies can be extracted with different solvents of different concentration like ethanol, acetone, petroleum ether etc. (Shah *et al* 2014). Various extraction methods like water extraction, organic-solvent extraction, microwave-assisted extraction, ultrasound-assisted extraction, supercritical fluid extraction etc. are used for the extraction of oleoresins (Melgar-Lalanne *et al* 2017). Out of these methods, the Supercritical fluid extraction method has received increasing attention due to high solubility, improves mass transfer rate and increase selectivity with a small change in time-temperature of process. Due to the various advantages including inertness, non-toxicity, non-flammability, non-explosiveness and availability with high purity at low cost, carbon dioxide is widely used in supercritical fluid extraction (Uquiche *et al* 2004).

CH-27 is a multiple disease resistant chili hybrid developed by Punjab Agricultural University, Ludhiana. CH-27 is pungent, high in dry matter and rich in extractable color (Dhaliwal *et al* 2015). Punjab Sindhuri is a tall, thick-skinned and dark green chili variety developed by Punjab Agricultural University, Ludhiana. Punjab sindhuri is pungent variety and rich in vitamin C content (Dhaliwal *et al* 2013). Modern lifestyle, economic growth and changing dietary habits demand for convenient foods. Processed food product like chili puree, paste, sauces etc. save household time in the meal preparation and clean up. Chili is a commercial crop that has a wide range of price fluctuation. In the peak season, low prices result in a huge loss of crop. Drying of chili is a solution of such situations and a common method of perishable chili preservation. Oleoresins are resin-like viscous material that is 15-20 stronger in flavor and colour than their corresponding spice. Oleoresins have application in the flavor, food and pharmaceutical industry. There are limited studies available regarding processing of newly developed CH-27 and Punjab sindhuri chili varieties. Keeping in view above mentioned point, the present study was framed with the following objectives:

1. To study the physicochemical, phytochemical and antioxidant activity of chillies
2. Development of chilli paste and assessing its shelf stability
3. To assess the drying characteristics of recommended varieties i.e. Punjab Sindhuri and CH-27 and ascertain the shelf life study of prepared value added products
4. To extract oleoresins by using conventional and non-conventional methods

CHAPTER-II

REVIEW OF LITERATURE

This chapter compiles the work done by scientist related with the present research work “Processing suitability of red and green chili varieties for value added products”. The literature has been reviewed under following categories:

2.1 Physicochemical, phytochemical and antimicrobial properties of chilies

2.2 Processing of chilies into puree, paste, sauce and their preservation

2.3 Storage of chilies and chili product

2.4 Drying of chilies

2.5 Chili Oleoresin extraction and determination of its compounds

Chili is a spice that cultivated widely throughout the world. Chili is consumed fresh, dried or in the powder form. Chili is rich in proteins, lipids, carbohydrates, mineral, vitamins and phytochemicals including ascorbic acid, carotenoids, tocopherols, flavonoids, and capsaicinoids. Chilies have antioxidant, anti-mutagenesis, hypocholesterolemic and immunosuppressive properties (Orobiyi *et al* 2013).

2.1 Physicochemical, phytochemical and antimicrobial properties of chilies

Don *et al* (2019) investigated the physical, nutritional characteristics and bioavailability of fresh chilli pepper cultivar grown in Eastern cote d'Ivoire. The colour *a* value for fresh green and red cultivar was in the range of -0.33 to 1.68. The length of the fruit in green and red form was 51.93 and 31.5 cm respectively. The total solids were in the range of 14 to 20 per cent. The fiber content was recorded in the range of 2.19 to 2.74 per cent.

As reported by Parle and Kaura (2012), the life and soul of all delicious Indian dishes is green chilies. Green chili is a fruit of *Capsicum frutescens* flowering plant that has been cultivated for thousands of years. The chilies form an excellent combination with of essential nutrients and healthy components. Green chilies are the good source of vitamin A, B, C, E, iron, magnesium, potassium, dietary fiber and micronutrients. Capsaicin, an active constituent of green chilies, provides it intense pungent taste. Capsaicin of the chili generally recognized as a potent local stimulant with no narcotic effect. Medicinal properties of the green chili include anti-cancer, anti-ulcer, analgesic, immunity booster; anti-epileptic, anti-hemorrhoidal etc. green chilies are also beneficial in management of burn, chronic migraine, diabetes and heart disorders.

Chamikara *et al* (2016) review the dietary, anticancer and medicinal properties of the phytochemical in the chili pepper. The chili pepper is used as an important spice, flavour enhancer and as herbal medicine. Phytochemicals present in the germ plasm of chili is known for their medicinal properties. The major phytochemicals present in chili are capsaicinoids, carotenoids, vitamins and flavonoids. Capsaicinoids is the most important group of

phytochemicals. In this group capsaicin and dihydrocapsaicin are prominent in the pungency and medicinal value. The chili peppers are also known for their anti-inflammatory, antidiabetic, antimicrobial, anticlotting, anticholesteremic and antioxidant properties. The inhibition of cancer proliferation, induction of apoptosis and detention of cell cycle conferred the anticancer activity of the chili pepper.

Shaimaa *et al* (2016) examined the phytochemical screening, antioxidant activities and in-vitro anticancer potential of Egyptian capsicum spp. *Capsicum annuum* and *Capsicum frutescens*. Both cultivars were evaluated at maturity stages for the total phenolic, flavonoids, vitamin C, beta carotene, capsaicin, antioxidant and anticancer activities of the aqueous extract of peppers. The phenolic and flavonoids content was in the range of 11.09-26.14 mg GAE/g and 2.7-5.0 mg QE/g respectively. By HPLC, 12 flavonoid compounds, 11 organic acids and 26 phenolic and aromatic compounds were identified. DPPH scavenging activity and ABTS assay of the pepper samples were in the range of 96-98% and 77-93% respectively. The anticancer activity of pepper extract and capsaicin was tested against prostate and breast carcinoma cell in vitro. The sweet pepper showed higher anticancer activity against prostate cancer, while chili pepper showed higher anticancer activity for breast cancer cells.

Omolo *et al* (2014) conducted research about the antimicrobial properties of chili peppers. According to the researchers, the chili peppers are worldwide famous for the pungent flavour, aroma and to prolong food spoilage. The capsaicin content of the chili peppers ranges from zero to millions of Scoville heat units. It was found that the capsaicin content of chili pepper was effective against the inhibition of *Helicobacter pylori*.

The antimicrobial agents always depicted the clinical significance. Agarwal *et al* (2017) investigated the antimicrobial activity of capsaicin, major pungent component of chilies. Due to the increase in antibiotic resistance among common pathogenic microbial strains, the effectiveness of antibiotics in the future will be unpredictable. Capsaicin, the major active component of chilies has various biological properties. Due to its characteristic pungent nature, capsaicin has attracted interest in the antimicrobial study field. Pure capsaicin at concentration of 5, 10, 15, 100 and 500 µg/ml and the soxhlet extract of Bhut jolokia (hottest chili) was screened for their antimicrobial effects on *Salmonella paratyphi* A, B, *Proteus mirabilis* and *Micrococcus luteus*. The capsaicin was found to have antimicrobial properties with *M. luteus* showing maximum susceptibility.

2.2 Processing of chilies and preservation of processed products

Ahmed *et al* (2000) studied the rheological characteristics and kinetic of color degradation of green chili puree. During investigation, rheological characteristics as a function of particle size at 25°C, effect of pre-treatments and temperature on the color degradation kinetics of green chili puree was conducted. The chili puree behaved as a

thinning fluid. As the particle size of the puree decreased, the consistency index decreased with increased flow behavior index. During the thermal processing of chili puree, color degradation followed a first order reaction kinetics. The color degradation was described by the combination of L , a and b values. Rate constant during the thermal processing of chili puree followed the Arrhenius relationship. For the water blanched and lye treated chili puree, the activation energy values were 11.4 and 16.0 kJ/g mol respectively. The colour degradation rate was retarded in lye treated chili puree.

Ismail and Revathi (2006) conducted study to check the effect of blanching time, evaporation time, temperature and hydrocolloid on the physical properties of the chili puree. According to the researchers, the thermal processing of the chili and canning of chili puree can be used as an alternate process of producing a product with extended shelf life with the retention of favourable qualities of the end product. Chilies were blanched at different time temperature combination in a steam jacketed kettles. After blanching, samples were cooled, drained and tested for peroxidase and lipooxygenase enzyme activity. The RSM (response surface methodology) was used for the investigation of effect of time, temperature and amount of pectin on the physical properties of chili puree subjected to the evaporation process. The viscosity of the puree was improved using pectin as a thickening agent. At 100°C for 6 minutes, the complete inactivation of enzymes was observed. The first-order reaction kinetics fitted adequately to predict the loss of color and addition of pectin was observed to improve the viscosity and total soluble solids (TSS) of the chili puree.

Sari *et al* (2018) examined the effect of soaking techniques, pasteurization with and without acids on some quality attributes of chili puree prepared from *Capsicum annum* variety Kulai. The dried chilies were reconstituted using cold water and boiled water soaking followed by crushing, stone grinding into fine puree. The prepared puree was pasteurized with and without two acids i.e. citric and acetic acid. The evaluated results showed the significant ($p \leq 0.05$) effect of soaking methods on pH, color value, moisture content, extractable color etc. chili puree prepared with boiled water soaking represented lower capsaicin and dihydrocapsaicin concentration compare to cold water soaking. The effect of pasteurization was non-significant ($p \leq 0.05$) on hunter color lab and pungency of chili puree. Boiled soaking chili and pasteurization of mixture with 1% acetic acid and 0.2% citric acid was found to be best to maintain the chili puree quality.

An alternative method to preserve sweet pepper paste quality was studied by Uzel 2017. The red pepper paste was prepared by various techniques using starter cultures. The prepared paste filled at different temperature, with and without protective agent was stored at 37°C up to 60 days and analyzed for salinity, acidity, color, invert sugar, brown pigment formation, microbial content etc. no *E. coli* was detected in raw material and final product, while mold and yeast growth was observed during the storage of product. The total sugar

content significantly ($p \leq 0.05$) increased during the storage. The protective agent i.e. sodium benzoate and potassium sorbate caused the increase in acidity results in lower pH. Red pepper paste treated with 0.2% sodium benzoate and potassium sorbate protective agents at higher temperature was found to be best in terms of flavour and color quality scores.

Apichartsrangkoon *et al* (2013) studied the aroma volatile profile of Thai chili paste preserved by ultra-high pressure, pasteurization and sterilization. The volatile component of the green chili paste was extracted using solid phase microextraction and identified using gas chromatography mass spectrophotometry. Diallyl sulfide, allyl methyl sulfide, allyl methyl trisulfide was the largest sulphide compound group and observed in the untreated chili paste. The earlier mentioned compound concentration significantly ($p \leq 0.05$) increased with the thermal treatment. During heating many other components i.e. 3-methyl-2(5H)-furanone, 2-hexyl-5-methyl-[2H]-furan-3-one, 2-methyl-tetradecane and 1,2-dimethyl cyclohexane was generated. Most desirable esters and sulphides components were significantly ($p \leq 0.05$) retained in the pasteurized chili paste. Brown undesirable volatile Maillard compounds such as 2-hexyl-5-methyl-[2H]-3-one significantly ($p \leq 0.05$) disappear after the pasteurization process. Among various aldehydes, the benzaldehyde was present in the highest quantity. Some volatile compounds such as 3,4-dimethylthiophene, methyl propyl disulphide, alpha-himachalene and gamma-himachalene was relatively stable in all the treatments.

2.3 Storage of chilies and chili product

Chitravathi *et al* (2014) studied the post-harvest shelf life extension of green chilies using shellac based surface coatings. Development of the shellac coating was developed using a combination of starch, EDTA and sodium alginate. The shelf life extension of green chilies was conducted at a temperature of $26 \pm 2^\circ\text{C}$ for duration of 12 days. The developed shellac coating was found to be effective in the extension of shelf life of green chilies. The coated samples (5.60-6.90%) showed less weight loss compare to control samples (12.35%). The higher retention of ascorbic acid, firmness and chlorophyll content was higher in the coated samples, but the phenolic content was significantly ($p \leq 0.05$) higher in the control samples up to 12 days of storage. During the ambient temperature storage, Shellac-sodium alginate based coating was found to be superior in the maintenance of fresh quality of the green chilies.

Chitravathi *et al* (2015) studied the influence of passive modified atmosphere packing on the shelf life of green chilies. Micro porous, low density polyethylene, polyolefin and anti-fog films were used during the research. Among the control and modified atmosphere packed samples stored at $8-18^\circ\text{C}$, the respiration rate of the samples varied significantly ($p \leq 0.05$). Due to the delay of senescence, the anti-fog film packed chilies showed low respiration rate. A significant ($p \leq 0.05$) change was observed in weight loss, firmness, skin color, ascorbic acid content among control and modified atmosphere packing. With the progress in senescence during storage, a significant ($p \leq 0.05$) increase in total phenolic content with decrease in total

antioxidant activity and capsaicin content was observed. The maximum stability in the pigment was observed in anti-fog film packed samples. As compared to 15 days storage of control samples, a shelf life of 16, 18, 22 and 28 days was observed in micro porous, low density polyethylene, polyolefin and anti-fog films respectively. At 8-18°C temperature and 85-95% relative humidity, anti-fog films were able to maintain the post-harvest quality of green chilies.

Sarker *et al* (2012) studied the effect of processing treatment on shelf life and nutritional quality of green chili powder. Various common processing treatment used in the study was a) without pedicle and cut longitudinally + treated with 0.01% KMS b) sliced without pedicle c) whole without pedicle d) with pedicle whole chili. All samples were packed in HDPE (high density polyethylene) and LDPE (low density polyethylene) packages and stored at room temperature. During storage, it was observed that chili powder prepared from without pedicle, longitudinally cut chili treated with 0.01% KMS and packed in HDPE was highly stable up to 195 days of storage. At $p < 0.0001$, it was observed that processing treatments had a significant ($p \leq 0.05$) effect on proximate composition and mineral content of stored chili powder with exception in vitamin C. During storage, green chili powder samples retained better nutritional quality than red chili powder. In all samples, vitamin C content reduced up to 50%, while beta-carotene content increased significantly ($p \leq 0.05$) in comparison to fresh green chilies.

2.4 Drying of chilies

Wade *et al* (2014) conducted comparative study of drying characteristics of red and green chilies. In green chilies, 22, 19, 13 and 8 hours was required to achieve 9.7, 7.4, 4.6 and 2.9% moisture content in open sun drying, indirect solar cabinet dryer and hot air oven respectively. Similarly, in red chilies 21, 18, 13 and 8 hours were required to reach at moisture content (db) 8.7, 5.7, 4.5 and 2% in open sun drying, indirect solar cabinet dryer and hot air oven drying respectively. The drying rate was higher in solar drying followed by hot air oven, indirect solar cabinet dryer and open sun drying at similar climatic conditions. The cost of drying chilies was higher in hot air oven drying (Rs 4.95/hr), followed by indirect solar cabinet (Rs 2.20/hr), open sun (Rs 1.93/hr) and solar tray dryer (Rs 1.87/hr).

Hassain and Bala (2006) studied the drying of hot chili using solar tunnel drier. Forced convection solar tunnel drier was used for the drying of green and red chilies under the tropical weather conditions of Bangladesh. Plastic covered flat plate collector and drying tunnel was connected in series along with two photovoltaic module fans to supply hot air directly into the drying tunnel. The moisture content of red chili was reduced from 2.85 to 0.05 kg kg⁻¹ in 20 hours in solar tunnel drier. In green chili, in 22 hours, the moisture content was reduced from 7.6 to 0.06 kg kg⁻¹. The solar tunnel drier samples were better in the retention of colour and pungency in comparison to products dried under the sun.

Dehydration of the red chili using an indirect-type forced convection solar dryer was studied by Castillo-Tellez *et al* (2017). Red chili, appreciated for the particular organoleptic properties was used in this study. The laboratory oven and indirect tunnel-type solar drier at 45, 55 and 65°C was used in this study. For temperature range of 55 and 65°C, the drying kinetics was 2.75 and 3.0 hours respectively, while in case of 45°C temperature range, drying time was 6.25 hours. For drying kinetics at 45°C, the best fit was Wang and Sing's model while for 55 and 65°C, best model was Page model. Solar drying process consists of two ranges of air velocity, high velocity 1.4 to 2.6m/s and low velocity 0.7 to 1.48m/s. In both drying process, temperature range between 31 and 45°C was obtained. For 31 and 45°C temperature range, the drying time was 16 and 21 hours respectively.

Toontom *et al* (2012) studied the effect of different drying method on the physical, chemical, hotness and volatile characteristics of dried chilies. The samples were dried at 37°C in sun drying, 60°C in hot air drying, freeze drying and there effect on the moisture content, color, ascorbic acid, capsaicin content and volatile flavour were investigated. As reported by the researchers, the freeze dried samples were brighter containing higher ascorbic acid. The effect of the drying method was non-significant ($p \leq 0.05$) on moisture content and capsaicin. Headspace solid phase microextraction (HS-SPME) with gas chromatography-mass spectrometry were used for the monitoring of types and concentration of volatile flavour components including acids, alcohol, ketones, aldehyde, esters, furan and hydrocarbons. Unique volatile flavour in the dried samples was found green, sweet and alcohol-like.

Ahmed *et al* (2002) studied the kinetic conversion kinetic model for thermal degradation of color in red chili puree and paste. The thermal treatment of red chili puree was conducted at 60, 70, 80 and 90°C for 20 minutes that evaluated using a fraction conversion model. Storage of the red chili paste was at 5, 25 and 37°C up to 6 months. The heat treatment at different time-temperature combination was conducted in well stirred water bath. After 20 minutes, samples were removed, cooled and analyzed for color degradation using hunter lab colorimeter. With the standard formulation, red chili paste was prepared with 8 per cent addition of common salt along with required volume of citric acid for brining pH 4.0. Chili paste was thermal processed at 85°C for 15 minutes, hot filled in glass bottles and storage at selected temperature up to 6 months period. The color of the samples was expressed as a tristimulus combination and total color difference. The fraction conversion model adequately described the kinetic color change during thermal processing and storage of chili puree. During thermal treatment, the process activation energies were 24.2 and 24.8 kJ/mol for color difference and L, a, b values respectively, during storage, the respective values were 24.1 and 25.0 kJ/mol. With no major changes in the physic-chemical properties, chili paste was microbiologically stable up to 6 months.

Nimrotham *et al* (2017) conducted experimental research of drying red chili by solar

drying and low temperature system drying (27-30°C and 45-50% RH). In Solar drying during day time (green house dryer) and at night time, climate control system used to coordinate with air conditioner in drying. The low temperature drying system consist the ultrasonic humidity control unit, air conditioner, temperature sensor, relative humidity sensor, heating coil and microcontroller unit. The temperature and relative humidity of low temperature drying process was controlled by climate control system. The dehumidification process by controlling temperature of the surface evaporator was decreased to dew point temperature, results in air water vapours condensation to water drops. To reduce moisture content 74 to 13.5%, the solar drying and low temperature system took 52 hours. In solar drying during day time, temperature and relative humidity was 50°C and 36% respectively, while at night, with climate control system coordinated with air conditioning system, temperature and relative humidity range was 27-30°C and 45-50% respectively. These processes were found to have average drying temperature, relative humidity, moisture condensation rate and specific energy consumption 27.55°C, 47.37%, 2.16kg water/hour and 0.75 MJ/kg respectively.

Singh (2018) studied the drying characteristics of chemical treated chopped green chilies under different dryer. The drying techniques used in study were hot air oven and tray dryer at 50, 60 and 70°C for both dryer. The chopped chilies were dipped into butylated hydroxyl anisole and potassium carbonate solution prior to drying. The overall drying rate was increased with temperature in both dryer. The drying time was more in hot air oven than tray dryer. In both dryer, 60 minutes less time was taken at 70°C drying than 50 and 60°C drying. Drying of dipsol green chili took place in falling rate period.

Jalgaonkar and Mahawar (2017) investigated the physicochemical properties of selected dried chili cultivars i.e. Guntur, Guntur brown and Byadgi. These varieties were different in the axial dimensions, weight, seed and stalk content. The single chili weight of Guntur, Guntur brown and Byadgi chilies were 0.85, 1.37 and 1.35gm, while length was 95.90, 113.05 and 113.20mm respectively. The length/breath ratio of the chili cultivars was 6.71 to 8.58. The seed and stalk content was highest in Byadgi cultivar (51.50 and 10.98%) followed by Guntur brown (30.80 and 6.97%) and Guntur (13.95 and 7.07%). The bulk density was highest in Guntur compared to Guntur brown and Byadgi. The colour value (*L*, *a*, *b*) of destalked Byadgi chili powder (32.28, 98.47, 36.12) was much better than whole Byadgi chili powder (32.28, 91.70, 38.65). The carotenoids content and total extractable colour was highest in Guntur brown followed by Guntur and Byadgi. It was found that the presence of chili stalk has deteriorated the quality of chili powder and its removal is necessary for further industrial applications.

Gupta *et al* (2017) studied the drying behaviour of red chili variety Punjab Sindhuri. The raw material was divided into two lots with one lot as whole chilies with another silted to half. The red chilies were dried by three different techniques i.e. sun drying,

improved sun drying and mechanical drying at 50, 60 and 70°C. The final moisture content was ranged within 1.74 to 6.06% on dry weight basis. The equilibrium moisture content was achieved with in 33, 26, 19, 16 and 9 hours for whole chilies and 30, 20, 16, 13 and 6 hours for slit chilies for sun drying, improved sun drying and mechanical drying at 50, 60 and 70°C respectively. Mechanical drying at 50°C showed best results followed by mechanical drying at 60°C. The final quality of the product was significantly ($p \leq 0.05$) affected by mechanical and sun drying at 70°C. In terms of drying behavior, improved sun drying was better than sun drying technique. The drying data was well fitted in page model.

Anoraga *et al* (2018) studied the effect of different pre-treatments on dried chili quality. In this study, chili samples were water blanched and steam blanched before drying. The main reason of pre-treatment was to inactivate the enzymes that results in prevention of color and vitamin C losses. The changes in moisture, color and vitamin C was observed by gravimetry, chromameter and iodine titration method respectively. At 60°C for 20 hours, steam blanched pretreated chilli dried rapidly in comparison to other samples. Better color and higher vitamin C content was observed in untreated chili samples.

2.5 Chili Oleoresin extraction and determination of its compounds

Wesolowska *et al* (2011) studied chemical composition of pepper fruit extract of *Capsicum annum L.* Chemical group of alkaloid compound capsaicinoids are responsible for pungency of capsicum species. The capsaicinoids were extracted with acetone and hexane from dry pepper and analyzed with gas chromatography-mass spectrophotometry. Major components of the extract were found capsaicin, dihydrocapsaicin, noivamide (pelargonic cid vanillyamide).

Reddy and Sasikala (2013) conducted research regarding the extraction of capsaicin and colour of different varieties of green and red chili peppers of Andhra Pradesh. Different 12 varieties of green, red ripe and red dry naming Indam-5, Indam-10, Indam-42, Indam-48, Indam-51, Indam-67, Indam-2006-1, Davanur delux, NS-1701 and US-341 were used for the extraction of capsaicin and colour components. The pungency of each chili variety was estimated with the quantification of capsaicin content and given in Scoville units. BSS-304 and Davanur delux varieties showed maximum pungency that was subjected to the extraction of capsaicin. Colour was extracted from the pericarp of the chilies and colour intensity was depicted in American Spice Trade Association (ASTA) and colour units (CU). The colour units for Davanur delux were 35,380.

Koleva Gudeva *et al* (2013) studied the effect of different methods of extractions of capsaicin on its content in capsicum oleoresins. According to scientists, there are several types of capsaicinoids that can be present in extracted oleoresins from *Capsicum annum L.* (Solanaceae). Out of various components, capsaicin (69%) represents its major proportion in oleoresin extract. Different methods were used for the extraction of oleoresins from chilies,

but Soxhlet method was found to be most appropriate in comparison to vacuum filtration. For the extraction and quantification of capsaicin for food and pharmaceutical grade, ethanol was found to be appropriate.

Riquelme and Mataiacevich (2017) studied the characterization and evaluation of some properties of oleoresins from *Capsicum annum* var. cacho de cabra. Due to the color and pungency, the oleoresins of *Capsicum* sp. are considered as food additive. Capsaicin, the major component of chili oleoresin, is mainly characterized for its antimicrobial and antioxidant properties. The purpose of this study was to characterize oleoresin of Cacho de cabra variety. Hexane was used for the solvent extraction. Capsaicin was used for the comparison of antimicrobial and antioxidant properties of Cacho de cabra. It was observed that Cacho de cabra has good optical properties compared with other commercial oleoresins, with better antimicrobial properties than pure capsaicin.

Othman *et al* (2011) determined the capsaicin and dihydrocapsaicin in *Capsicum* fruit samples collected from city markets of Riyadh, using high performance liquid chromatography method. In this study, pungency level in Scoville heat units and average daily intake of capsaicin for Riyadh population also evaluated. Hot chilies, red chilies, green chilies, green peppers, red peppers and yellow pepper samples were used in the study. Capsaicinoids were extracted with ethanol that was separated, identified and quantitated using High performance liquid chromatography. The limit of detection of method was 0.09 and 0.10 $\mu\text{g/g}$ for capsaicin and dihydrocapsaicin respectively. The limit of quantification was 0.30 and 0.36 $\mu\text{g/g}$ for capsaicin and dihydrocapsaicin respectively. The highest pungency level (67984.60 SHU) and higher concentration of capsaicin (4249 $\mu\text{g/g}$) was observed in hot chilies, whereas green pepper had the lowest capsaicin concentration (1.0 $\mu\text{g/g}$). The green, red and yellow peppers were non pungent. For the population of Riyadh, the mean consumption value of peppers was 15.5g/person/day, while daily capsaicin intake was 7.584 mg/person/day.

Saha *et al* (2015) studied the capsaicinoids, tocopherol, sterols content in chili by gas chromatography-mass spectrometric determination. A simple extraction technique was used for rapid screening and quantitative determination of capsaicinoids, vitamin E and phytosterols was conducted by using gas chromatography-mass spectrophotometry. The components were extracted with the use of acetonitrile and were injected into gas chromatography attached with mass spectrometry with mean recovery between 90.6-99.7 per cent. Major capsaicinoids in chili was capsaicin, dihydrocapsaicin, nordihydrocapsaicin with minor capsaicinoids nonivamide, nornordihydrocapsaicin, homodihydrocapsaicin I and II. Three phytosterols i.e. campesterol, γ -sitosterol, stigmasterol along with α - tocopherols were detected in samples. This method was found to be effective for simultaneous estimation of capsaicinoids, tocopherols and phytosterols in a single run.

Three liquid phase extraction and separation of capsanthin and capsaicin from *Capsicum annuum* L. was studied by Dang *et al* (2014). Three liquid phase of acetone/K₂HPO₄/n-hexane was used in the study. It was found that when system consisted of 22% acetone/ 20% K₂HPO₄/ 10% n-hexane, capsanthin was extracted in the top n-hexane rich phase, with 98.15% yield at 25°C temperature. The capsaicin was mainly distributed in middle acetone rich phase, with less than 0.01% in top phase and no sign of presence in bottom salt rich phase. The yields of the capsanthin and capsaicin were 105 and 88% respectively. The capsanthin and capsaicin was easily obtained after the evaporation of particular solvent.

Deng *et al* (2008) conducted study on the extraction of capsaicin from leaching solutions of hot peppers. The commercial dry hot peppers were used for the extraction and purification of capsaicin, 95% ethanol was used as leaching solvent, n-hexane and n-butyl acetate was used as extractants. The effect of pH value and phase ration on the capsaicin yield in simulation and real system was studied. The results showed that the acidification extraction was the control step. When n-butyl acetate was used, the yield of capsaicin in simulation system was reached above 90% at pH 11 with phase ratio 7:1. The capsaicin content was increased, when n-butyl acetate was used as an extractant. The trend of extraction yield in real system was almost similar to simulation system but around 20% capsaicin could not be extracted. When 50gm hot pepper was used, the capsaicin yield with 250 ml of 95% ethanol twice leaching was 97.0%. after extraction, leaching solution was concentrated, dissolved in hydroxide solution and extracted by n-butyl acetate at pH 13 and the phase ratio was 1:1, when pH of the aqueous phase was adjusted to 11 with hydrochloride, the capsaicin yield with n-butyl acetate extraction at phase ratio 1:5 was achieved 80% of leached amount.

Sang *et al* (2008) studied the extraction of capsanthin from hot red pepper. The natural red pigment, capsanthin was extracted from hot red peppers using organic solvents. The effect of different solvents i.e. acetone, n-hexane, ethyl acetate, petroleum ether, 95% ethanol and methanol on extraction of capsanthin was investigated. It was found that the petroleum ether at 60-90°C was best solvent for capsanthin extraction and the extraction time was 4 hours. The pure capsanthin was obtained with the use of column chromatography with the mixing of solvent petroleum ether and acetone.

Barbero *et al* (2006) studied extraction of capsaicinoids from peppers using pressurized liquid extraction. The capsaicinoids compounds were determined by reverse phase high performance liquid chromatography, with detection by fluorescence spectrophotometry and mass spectrometry. The capsaicin and dihydrocapsaicin stability was studied at 50-200°C. Several extraction variables including different extraction solvents (methanol, ethanol and water), different percentage of water in methanol (0-20%) and in the ethanol (0-20%), and the number of extraction cycles has been studied through the

experiment. The study has evaluated the repeatability (RSD< 7%) and reproducibility (RSD< 7%) of the method. In pressure liquid extraction pressure, extraction was carried out at different pressure and temperature conditions to accelerate the extraction of compounds. The pressure liquid extraction method has been applied for the quantification of capsaicinoids present in hot peppers, quantifying five capsaicinoids: nordihydrocapsaicin, capsaicin, dihydrocapsaicin, an isomer of dihydrocapsaicin and homodihydrocapsaicin.

Grande-Villanueva *et al* (2015) studied the oleoresin extraction from Jalapeno peppers using supercritical carbon dioxide and its effect on the global yield, capsaicinoid content and antioxidant activity was checked. *Capsicum annuum* is rich source of components with biological activities i.e. capsaicinoids, phenolic component and antioxidants. Due to the several advantages over conventional extraction techniques, supercritical fluid extraction used as an alternative for the extraction of oleoresins. The major principle for this study was to evaluate the influence of pressure and temperature on the global yield, capsaicinoid content and antioxidant activity of the extract. Highest global yield with supercritical fluid extraction conditions was observed at 20MPa/60°C and 30MPa/60°C, approximately reaching to 85% of the soxhlet yield. At 15MPa/60°C, maximum capsaicin content was extracted. The maximum antioxidant activity of extract was observed at pressure 25 and 30 MPa and temperature 60°C. To fit the experimental supercritical fluid extraction curves, the broken and intact cell model was selected. The total of 83.5% of the extract was recovered in the first step of supercritical fluid extraction process.

Daood *et al* (2002) conducted research on the extraction of pungent spice paprika by supercritical (SC) carbon dioxide and supercritical propane. For SC-CO₂, temperature and pressure range used was 35-55°C and 100-400 bars respectively, while for SC-propane, temperature and pressure range was 25°C and 30-50 bars respectively. High Performance Liquid Chromatography was used for the evaluation of carotenoids, tocopherols, capsaicinoids and heat principles of paprika. In SC-CO₂, at 55°C and 300 bars, the yield of the oleoresin extract was low while at 400 bars, maximum yield of the extract was obtained. The solvent/solid ratio used for the paprika oleoresin extraction was 8:10 and 1:1.2 for SC-CO₂ and SC-Propane respectively. SC-CO₂ extraction method was inefficient for the extraction of diesters of xanthophyll. For the pigment moieties, the solvating power of the SC-Propane was 10 times higher than SC-CO₂. The extraction conditions did not affect substantially the solubility of tocopherols in either solvent, except at 55°C and low pressure. The SC-CO₂ easily extracted the capsaicinoids, while in SC-Propane the capsaicinoids was up to limited extent.

Lu and Cui (2019) extracted and purified the capsaicin from capsicum oleoresins using a combination of Tunable Aqueous Polymer-Phase Impregnated Resin extraction and chromatography technology. The major component of pepper, capsaicin, is known for their

anticancer, antioxidant and anti-obesity properties. Lu and Cui 2019 constructed a comprehensive technology for the extraction and purification of capsaicin from the capsicum oleoresins. For the extraction process, the tunable aqueous polymer phase impregnated HZ816 was selected. In the extraction process, 3 gm of impregnated HZ816 macro porous resin was employed per system. The results depicted that the higher molecular weight polyethylene glycol and 1-ethyl-3-methyl limidazolium acetate was more effective for the improvement of capsaicin yield. Screening experiments using fractional factorial designs represented that the sample quantity, pH, and concentration of polyethylene glycol and 1-ethyl-3-methyl limidazolium acetate significantly ($p \leq 0.05$) affected the yield of capsaicin extraction from oleoresins mathematical models of capsaicin yield in tunable aqueous polymer-phase impregnated resins were established and response surface methodology was used to obtain the optimum conditions. The optimum impregnated phase was polymer phase of an aqueous two phase system containing 18.5% polyethylene glycol, 15% sodium citrate and 10% 1-ethyl-3-methyl limidazolium acetate at 6.5 pH. When the extraction system contains 0.25gm capsicum oleoresins, capsaicin yield reached 95.86% under optimal conditions. Reverse phase resin chromatographic column was used for the capsaicinoids extract purification. The recovery and purity of capsaicin in this study was 85% and 92% respectively.

The effect of enzyme pre-treatment on the yield and quality of green chili oleoresin and capsaicinoids content was studied by Baby and Ranganathan (2016). In this investigation, Cellulast 1.5L, Pectinex Ultra SP.L, Viscozymel, Protease and equal combination of Cellulast 1.5L, Pectinax Ultra SP.L and Viscozymel was used for the pre-treatment. With varying enzyme concentration, reaction temperature, pH and incubation, the optimization of the enzyme activity was carried out. The extracted oleoresins were evaluated with the use of High Performance Liquid Chromatography with combination of Photo diode Array detector. To check the effect of enzyme on the cell wall of chili, the Scanning Electron Microscopic study was conducted. The chili treated with Viscozymel showed maximum (22%) capsaicinoids recovery in the extract followed by Cellulast (20%), Pectinex (17.5%) and Protease (14%) treated chili samples. It was revealed that the Viscozymel and Cellulast enzyme caused the rupturing of cell wall that makes the extraction medium more susceptible.

CHAPTER-III

MATERIALS AND METHODS

This chapter includes a list of raw materials, processing techniques used for the preparation of the product, analytical procedures and sensory evaluation methodology used at various stages of research for the fulfillment of research objectives.

3.1 Procurement of raw material

CH-27 and Punjab sindhuri were procured from Department of Vegetable Science, College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana. The chili varieties were classified based on the skin color of chilies i.e. CH-27 green, red and Punjab sindhuri green, red. The raw material was selected based on uniform color and size. Both varieties were procured from College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana. Green form of CH-27 and Punjab Sindhuri was harvested in the month of February while the red form of both varieties was harvested 2 weeks after the harvesting of green form. The samples were collected in perforated gunny bags and stored into cold store ($4\pm 2^{\circ}\text{C}$) for further analysis and processing.

Another material like honey, salt, garlic etc. was procured from the local market. Extra pure (99.9%) methanol was obtained from Samir Tech-Chem (Vadodara). 2,2-diphenyl-1-picrylhydrazyl and antioxidant standard Trolox were purchased from Sigma-Aldrich (Steinheim). 2,6-Dichlorophenolindophenol and the ascorbic acid standard was purchased from Loba Chemie Pvt. Ltd, (Mumbai). Gallic acid standard was obtained from Sisco Research Laboratories Pvt, Ltd., (Maharashtra). All reagents used were of analytical grade. The retort pouch (200 gm capacity), glass container (100 gm) and high-density polyethylene packages were procured from the local market.

3.2 Physicochemical analysis

3.2.1 Total soluble solids (TSS)

The total soluble solids of the samples were determined using hand refractometer ranging between 0-32°B (Erma, Tokyo). The results were expressed as °Brix at 20°C (AOAC 2016).

3.2.2 Total solids

The total solids of the samples were analyzed to AOAC (2016) method. The sample (5 gm) was weighed and dried in a hot air oven at $100\pm 5^{\circ}\text{C}$ until the steady weight was achieved. The difference between the initial weight and final weight was used for the calculation of total solids using the following formula

$$\text{Total solids (\%)} = \frac{W_1 - W_2}{W_1 - W} \times 100$$

W= Weight of empty aluminum dish

W1= Weight of empty aluminum dish + fresh sample

W2= Weight of empty aluminum dish + dried sample

3.2.3 pH

The pH of samples was determined with pH meter (Mettler Toledo). Before use, the pH meter was calibrated with a buffer solution (pH 4 and 7). The electrode of the pH meter was dipped into the beaker containing the sample until a stable reading reached.

3.2.4 Titrable acidity

The titrable acidity was determined by titrating a known quantity of water extract sample (5 ml) against 0.1N NaOH using 2-3 drops of phenolphthalein solution as an indicator to the pink endpoint which should persist 15 seconds. The results were expressed as per cent citric acid (Ranganna 2017).

Titrable acidity (%) =

$$\frac{\text{Titre value} \times \text{normality of NaOH} \times \text{volume made} \times \text{equivalent weight of acid} \times 100}{\text{Weight of sample} \times \text{Aliquot used} \times 1000}$$

3.2.5 Total sugar

Total sugars were determined by using the method described by Dubois *et al* (1956). The sample (5 gm) was refluxed using 80 per cent isopropyl alcohol for 2 hours. The refluxed sample was then cooled and filtered using Whatman no. 4 filter paper. The final volume of the extract was made 100ml using distilled water. From this, a definite amount was taken (0.2 ml) followed by further dilution up to 1 ml using distilled water. 1 ml of 5 per cent phenol and 5 ml of concentrated sulphuric acid added to the prepared aliquots. The intensity of the developed color was noted at 490nm against a blank. The total sugar in the sample was calculated using the standard curve of glucose (Fig.3.1).

$$\text{Total sugars}(\%) = \frac{\text{Concentration from standard graph} \times \text{volume made} \times 100}{\text{Weight of sample} \times \text{aliquot taken}}$$

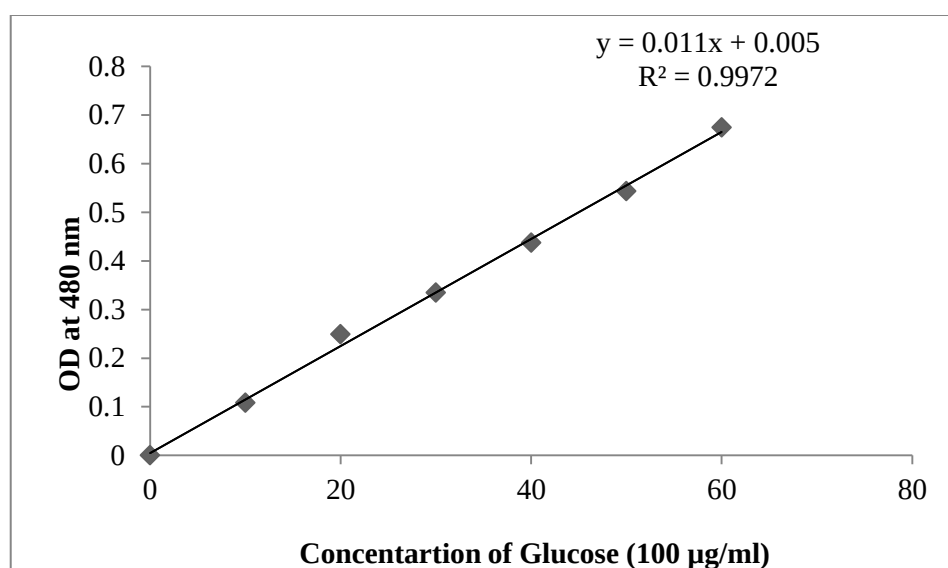


Fig. 3.1 Standard curve of glucose

3.2.6 Reducing Sugar

The reducing sugars were determined with Nelson (1944) and Somogyi (1952) method. The known quantity of sample (5 gm) was refluxed using 80 per cent isopropyl alcohol for 2 hours followed by cooling and filtration using Whatman no. 4 filter paper. The final volume was made 100ml using distilled water. A known aliquot (0.5 ml) was taken and diluted up to 1 ml using distilled water. 1ml of freshly prepared copper reagent was added and kept in hot water bath for 20 minutes followed by cooling. 1 ml of Nelson reagent was added and developed color noted at 620nm against blank. The reducing sugar concentration was calculated using standard glucose curve (Fig.3.2).

$$\text{Reducing sugars(\%)} = \frac{\text{Concentration from standard graph} \times \text{volume made} \times 100}{\text{Weight of sample} \times \text{aliquot taken}}$$

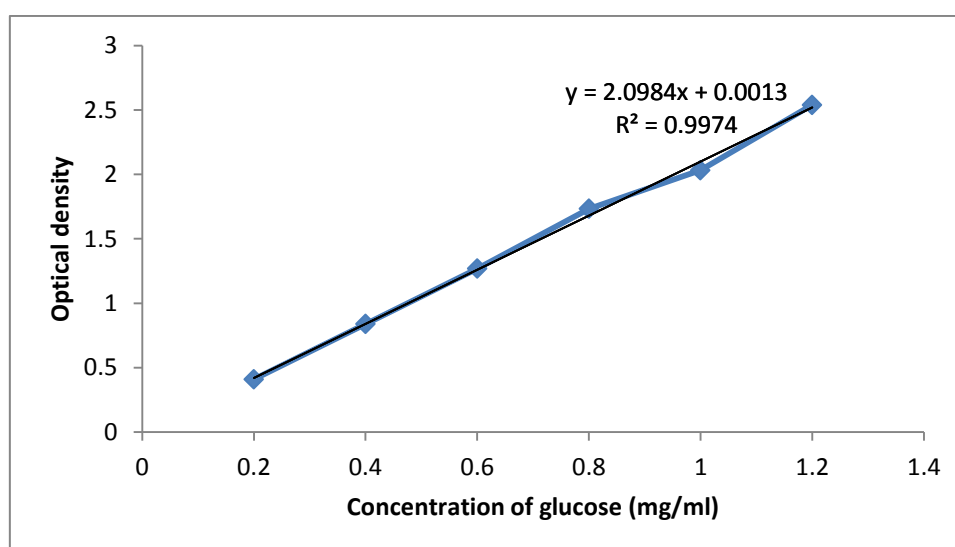


Fig. 3.2 Standard curve of glucose for reducing sugar

3.2.7 Ash content

The per cent ash content was determined using AOAC 2016 standard method. A known quantity of sample (5 gm) was charred over flame using silica crucible and then ashed in muffle furnace at 500-550°C for 5-6 hours. The samples were cooled at ambient temperature and weight was recorded. The total ash content was calculated using following formula

$$\text{Ash content (\%)} = \frac{W1 - W2}{W1 - W} \times 100$$

W= Weight of empty crucible

W1= Weight of empty crucible + fresh sample

W2= weight of empty crucible + ashed sample

3.2.11 Electrical conductivity

Electrical conductivity of the sample was measured using conductivity meter ranging from 0 to 100ms. Instrument was calibrated using standard KCl solution. The sample was

placed in the glass beaker and the instrument probe was dipped into the sample that results in reading on instrument display.

3.2.9 Viscosity

The Brookfield viscometer was utilized for the determination of viscosity of samples. The rotational viscometer measures viscosity by sensing the torque requires rotate a spindle at a constant speed while immersed in the sample. The torque is proportional to the viscosity of sample. The selected spindle was attached to the viscometer. The sample was poured into 250 ml of beaker. The spindle was lowered to the center of sample, motor was switched on and allowed to rotate until a stabilize reading was attained. Reading was noted and viscosity was calculated using following formula

$$\text{Viscosity (cP)} = \text{Dial reading} \times \text{factor}$$

In present investigation, spindle number and speed was 4 and 12 respectively. The factor for the respective values is 500.

3.2.10 Water activity

Water activity was measured using Aqua lab water activity meter. The meter was warmed up to 30 minutes of duration. The sample was filled into sample cup up to the half. The care was taken that the temperature of the sample was not to exceed 4°C than the chamber temperature. The sample cup was placed inside the sample drawer. The instrument was switched ON and reading was displayed within the 40 seconds.

3.2.11 Crude fibre

The fibre content of the samples was determined with Fibretec (Foss Instrument, Sweden) using standard procedure (AOAC 2016). The dried and defatted sample (1gm) was taken into capsule and acid extraction was done using of 1.25 per cent H₂SO₄ for 30 minutes followed by hot water washing. In the same way, alkali extraction was conducted using 1.25 per cent NaOH solution for 30 minutes followed by hot water washing. The capsules containing samples were dried in hot air oven at 130°C for 2 hours. Dried capsules were placed into muffle furnace at 500-550°C for 5 hours. The samples were cooled at ambient temperature and weight was noted. The total crude fibre content was calculated using following formula

$$\text{Crude fibre (\%)} = \frac{(W3 - (W1 - C) - (W5 - W4 - D)) \times 100}{W2}$$

W1= Weight of empty capsule

W2= Weight of sample

W3= After extraction, capsule + dry sample weight

W4= Weight of empty crucible

W5= After ashing crucible + sample weight

C= Capsule solubility (1.001849)

D= Capsule ash (0.004)

3.3 Colour analysis

The colour of the sample was measured with Minolta colorimeter CR-300 (Konica Minolta, Osaka, Japan). In this system, the specimen surface is illuminated diffusely and uses a pulse xenon arc illumination. Before use, the colorimeter was calibrated using calibration tiles. The results depicted in *L*, *a* and *b* values according to hunter colour lab system. The hunter scale, *L* measures 100 for brightness and zero for dark. The negative *a* value means greenness, 0 means grey and positive means redness. Similarly, negative *b* value represents blueness, with positive value as yellowness. The samples were placed in glass petridishes without any air bubble and colour was measured with colorimeter.

3.4 Phytochemical analysis

3.4.1 Ascorbic acid

The ascorbic acid content was determined by titrimetric method described by Ranganna 2017. The 2, 6-dichlorophenol-indophenol dye was used for the titration. The 5 gm sample was macerated with small amount of 0.4 per cent oxalic acid and volume made up to 100 ml with 0.4 per cent oxalic acid followed by filtration through whatman no. 4 filter paper. 5 ml aliquot was taken and titrated against standardized dye until pink colour appears that should persist for 15 seconds at end point. For the determination of dye factor, standard ascorbic acid was prepared with concentration 100 mg/100ml of distilled water. A known quantity of standard ascorbic acid was titrated against dye till end point.

$$\text{Dye factor} = \frac{\text{mg of ascorbic acid in solution}}{\text{ml of dye used}}$$

$$\text{Ascorbic acid (mg/100gm)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made} \times 100}{\text{Aliquot taken} \times \text{weight of sample}}$$

3.4.2 Total phenolics

The total phenolics/phenols were determined with Folin-Ciocalteu method described by Singleton *et al* 1999. The total phenolics were extracted through refluxing (30°C/3hours) using 80 per cent methanol. The extract was filtered with Whatman no. 4 filter paper and volume made up to 100 ml using 80 per cent methanol. 0.2 ml aliquot was taken and volume made 1 ml using distilled water. To this, 5 ml Folin-ciocalteu reagent (1:10 FC reagent: water) was added and incubated at room temperature for 5 minutes. After incubation, 4ml saturated sodium carbonate added and incubated for 10 minutes. The developed colour was read on 715nm against blank (1 ml distilled water + 5 ml FC reagent + 4 ml saturated sodium carbonate). Similar procedure was followed for the Gallic acid standard solution and calibration was plotted at different concentration of Gallic acid. The results were expressed as mg of Gallic acid/100 ml of extract. The total phenolics of samples were calculated from linear equation obtained from the calibration curve between concentrations of gallic acid.

$$\begin{aligned} & \text{Total phenolics (mg/100gm Gallic acid equivalent)} \\ &= \frac{\text{concentration from graph} \times \text{final volume} \times 100}{\text{weight of sample} \times \text{aliquot taken}} \end{aligned}$$

3.4.3 Total chlorophyll and carotenoids content

The standard method described in Ranganna (2017) was used for the estimation of total chlorophyll and carotenoids content of samples. A known amount of sample was ground with 80 per cent acetone (20-40 ml). The extract was centrifuged at 2000 rpm for 10 minutes followed by supernatant separation. The residue again ground with 80 per cent acetone until colourless residue was not obtained. The absorbance of the supernatant read at 480, 645 and 663nm against 80 per cent acetone as blank. The total chlorophyll and carotenoid content was calculated using following formula

$$\text{Total chlorophyll} = 20.2 (A645) + 8.02 (A663)$$

$$\text{Chlorophyll a} = 12.7 (A663) - 2.69 (A645)$$

$$\text{Chlorophyll b} = 22.9 (A645) - 4.68 (A663)$$

$$\text{Chlorophyll (mg/gm)} = \frac{12.7 (A663) - 2.69 (A645) \times \text{volume made}}{1000 \times \text{weight of sample}}$$

$$\text{Total carotenoids (mg/gm)} = \frac{(A480 + 0.144 A663) - (0.638 A645) \times \text{volume made}}{1000 \times \text{weight of sample}}$$

A480 = Absorbance at wavelength of 480nm

A645 = Absorbance at wavelength of 645nm

A663 = Absorbance at wavelength of 663nm

3.4.5 β Carotene content

The beta carotene of the samples was determined by standard method given in Ranganna (2017). A known quantity of sample with pinch of sodium sulphate was taken and macerated with 10-15 ml of acetone until colourless residue was not obtained. Centrifugation was done at 2000 rpm for 5 minutes to obtain clear supernatant. The supernatant was transferred into separating funnel followed by addition 5-10 petroleum ether. Distilled water added and kept undisturbed for few minutes to obtain two separate layers. The lower layer discarded and same procedure was repeated. After 2-3 washing, the upper layer taken into volumetric flask and volume made up to 100ml with petroleum ether. The absorbance was noted at 452 nm against blank and total β -carotene was calculated with following formula

$$\beta - \text{Carotene } (\mu\text{g}/100\text{gm}) = \frac{\text{optical density at 452} \times 10^4 \times 100}{\text{weight of sample} \times 560 \times 1000}$$

3.4.6 Lycopene

The lycopene content of samples were determined by standard method given in Raganna (2017). The known quantity of the sample was extracted with acetone in pestle motor to colourless residue. The extract was taken into separating funnel along with 10-15ml

petroleum ether. Carotenoids pigments were separated into petroleum ether phase by diluting acetone (lower phase) with water. Lower phase was transferred into another separating funnel and petroleum ether extract was collected into amber bottle. Acetone phase extraction was repeated until it became colourless. Acetone phase was discarded. To the petroleum ether extract, small quantity of sodium sulphate was added and transferred to 50ml volumetric flask. Dilution was done up to mark with petroleum ether. From this 5ml sample was taken and further diluted to 50ml. The optical density was noted at 503nm and lycopene content was calculated using following formula

$$\text{Lycopene (mg/100gm)} = \frac{3.1206 \times \text{optical density} \times \text{volume made} \times \text{dilution} \times 100}{1 \times \text{weight of sample} \times 1000}$$

3.4.7 Total extractable colour

Total extractable colour (ASTA) measurement was carried out by American Spice Trade Association method. 1 gm of crushed sample was taken into 100ml volumetric flask and filled with acetone up to mark. The samples were incubated in dark for 14 hours. The absorbance of the extract was noted at 460nm against acetone as blank. ASTA units were calculated using following equation

$$\text{Total extractable colour (ASTA)} = \frac{\text{Absorbance} \times 16.4}{\text{weight of sample}}$$

3.4.8 Capsaicin content

0.5 gm of sample was taken into 50 ml volumetric flask and filled with acetone up to mark. The samples were kept in dark for overnight. Next day, columns were prepared using glass wool, aluminium oxide and sodium sulphate at top. The columns were activated by keeping them in hot air oven for 2-3 hours. After cooling, the 2 ml of the sample extract runs through glass column with 15 ml acetone as mobile phase. The collected extract was taken into 50 ml volumetric flask and filled up to mark using acetone–methanol mixture (75:25). From this stock solution, 10ml was taken into beaker and kept overnight for evaporation at

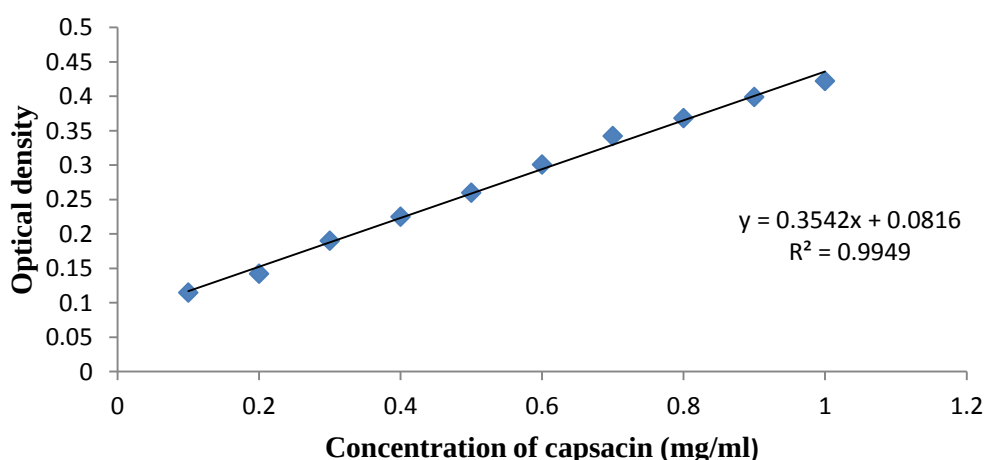


Fig. 3.3 Standard curve of capsaicin

room temperature. After evaporation, the remained drops were mixed with 1 ml Folin-Ciocalteu reagent (1FC reagent: 1 distilled water), 6.5 ml distilled water and 1ml of saturated sodium carbonate. The samples were incubated in dark up to 3-4 hours for colour development. Blue colour developed after incubation and absorbance was noted at 760nm using acetone-methanol as blank.

3.5 Antioxidant activity

Antioxidant assays used for the estimation of free radical scavenging activity of the samples were DPPH (1,1-diphenyl-2-picryl-hydrazyl) and FRAP (Ferric reducing antioxidant power).

3.5.1 per cent inhibition of DPPH (1,1-diphenyl-2-picryl-hydrazyl)

The free radical scavenging activity of the samples was estimated using method described by Yi *et al* (2008). 5 gm sample was refluxed with 50 ml of 80 per cent methanol for 2 hours. The samples were filtered using whatman no. 4 filter paper. The remaining residue again refluxed with 80 per cent methanol. After filtration, the extract was combined with earlier filtrate and volume made up to 100 ml with 80 per cent methanol. An aliquot of 1 ml of sample solution was mixed with 3 ml of methanolic solution of DPPH (0.2 mM) and incubated in dark conditions for 30 minutes. The absorbance was measured at 517nm using methanol and water as blank. Similar procedure was followed for control, as sample was replaced with methanol. The per cent inhibition of DPPH radicals were calculated using following formula

$$\% \text{ inhibition of DPPH radicals} = \frac{A_c - A_s}{A_c} \times 100$$

A_c = Absorbance of control

A_s = Absorbance of sample

3.5.2 FRAP (Ferric reducing antioxidant power)

Procedure described by Stratil *et al* (2006) was used for the estimation of extract ability to reduce FeCl_3 . Same extract, as mentioned above procedure, was used for the

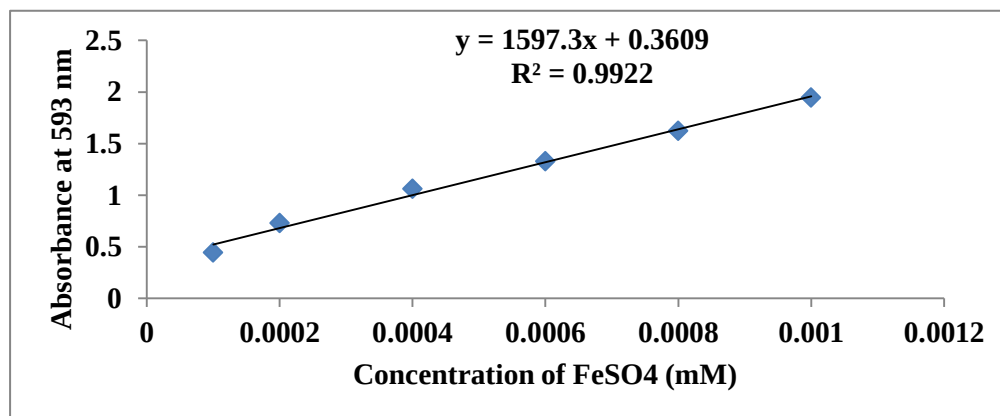


Fig. 3.4 Standard curve of FeSO_4

FRAP. In 0.5 ml extract, 1.8 ml FRAP solution containing freshly prepared Acetate buffer (300 mM), TPTZ (2,4,6- Tri (2-pyridyl)-s-triazine (10 mM dissolved in 40 mM HCL) and FeCl_3 (20 mM) dissolved in the ratio of 10:1:1 was added. Extract containing FRAP solution incubated at 37°C for 15 minutes and absorbance was recorded at 593nm. Fresh FeSO_4 solution was used for calibration and calculation of antioxidant activity of the samples.

3.6 Mineral content

The mineral components (calcium, chromium, copper, iron, magnesium, manganese, nickel, phosphorous, potassium, sodium and zinc) were determined by the inductively coupled plasma atomic emission spectroscopy (ICP-AES), at Department of Soil Science, Punjab Agricultural University, Ludhiana. In 1 gm of sample, 10 ml nitric acid-perchloric acid (3:1) mixture was added and incubated at room temperature overnight. Digestion was conducted at hot plate (150°C) till solution became crystal clear. The final volume made up to 25 ml using double distilled water. Then the mineralogical analysis was conducted through ICP-AES.

3.7 Microbiological analysis

The total plate count is considered as parameter for deciding the microbial efficacy of samples. The results are represented as colony forming units per ml (cfu/ml). The pour plate method was used for the enumeration of the microbial count. All the glassware, water blanks (9 ml), medium are sterilized at 121°C for 15 minutes at 15 psi. Nutrient agar was used as a growth medium. 1 gm of sample was added to 9 ml water blank and mixed. From this, 1ml was taken and added to next water blank to make dilutions (10^{-1} , 10^{-2} , 10^{-3} ..So on). From selected dilutions, 1 ml samples were taken into disposable petridish, and nutrient agar was poured. The plates were swirled clockwise and anticlockwise once. After the solidification of medium, the plates were incubated at 37°C in inverted position up to 48 hours (AOAC 2016). All experiment was conducted under aseptic conditions using laminar air flow. The colonies were calculated using following formula

$$\text{Total plate count (cfu/ml)} = \frac{\text{no. of colonies} \times \text{dilution factor}}{\text{sample taken}}$$

3.8 Fourier transform infrared (FTIR) spectroscopy

The structural components of the fresh samples and changes in the composition of samples during processing were accessed with Fourier transform infrared spectrometer (Thermo Scientific Nicolet 6700 spectrometer) using an attenuated total reflection accessory and deuterated triglycine sulphate detector. FTIR was carried out at Electron Microscopy and Nano science Laboratory, Punjab Agricultural University, Ludhiana. Fresh chili and dried chili samples were crushed into fine paste and powder respectively for FTIR spectroscopy. The honey chili sauce was ground into viscous homogenous mass prior to spectroscopy. Standard ascorbic acid, gallic acid, beta carotene, capsaicin, dihydrocapsaicin,

nordihydrocapsaicin, capsanthin were run along with all samples. The spectra were collected in the 4000-400 cm^{-1} , with a 4 cm^{-1} and 32 scans at room temperature.

3.9 Processing of chilies

3.9.1 Drying of chilies

The chilies were dried without pedicels. After sorting and washing, the chilies were dried in tray drier (60°C and 85°C) and freeze drier (-40°C) up to a constant weight. After drying, the chilies were packed into HDPE packs and stored into covered plastic buckets for further analysis.

3.9.2 Preparation of honey chili sauce

3.9.2.1 Standardized recipe for honey chili sauce

The honey chili sauce was prepared using standardized recipe shown in Table 3.1.

Table 3.1 Standardized recipe for honey chilli sauce

Ingredient	Amount
Honey	70ml
Water	30ml
Garlic (fresh and crushed)	10gm
Salt	3gm
Acetic acid	2.5ml
Chili flakes	1.5gm
Xanthan gum	1gm

Method of preparation

The warm water was used for the mixing of gum. All the ingredients were mixed together. Hand blender was used for the proper mixing of xanthan gum and to prevent formation of clots. The samples were packed into glass jars (50gm) and stored at ambient as well as refrigeration temperature. The analysis was carried out for 8 months with an interval of two month. The calculated cost of the prepared product is as given in Annexure I.

3.9.3 Extraction of oleoresins

Dried red form of both varieties i.e. CH-27 and Punjab sindhuri were used for the extraction of oleoresins. Refluxing and ultrasonication methods were utilized for the extraction purpose as discussed below:

3.9.3.1 Refluxing technique

The extraction of the oleoresins was carried out by refluxing method described by Dhanani *et al* (2017) with slight modifications. Extraction was carried out using ethanol and acetone with concentration 50 and 90 per cent at 25-60°C. The extraction was carried out using two phases. In the first phase, 5 gm of samples was refluxed with 75 ml of each solvent concentration for 2 hours followed by filtration using whatman no. 4 filter paper. The

remaining residue from filter paper collected and again refluxed with each solvent. The extracts were then centrifuged at 5000 rpm and then vacuum evaporated at 60°C and stored in amber bottles at refrigeration temperature (4°C) for further analysis.

3.9.3.2 Ultrasonication

The extraction of oleoresins with sonicator was conducted by using “MAC” sonicator. The crushed sample was taken into glass beaker of 500ml capacity and appropriate solvent was poured into the same. The instrument was turned ON. The beaker with sample was placed on the lift and moved upward to make the probe dipped into the sample. The pre-set document (frequency 20 KHZ, watt 90, maximum temperature 60°C) was selected from the document selection interface and OK button was pressed. The temperature probe was inserted into the sample beaker to make sure that the sample temperature should not rise from the pre-set temperature range (60°C) (Figure 3.5). The sample was treated for 1 hour duration. After duration, instrument was turned off and the lift was moved downward followed by removal of sample from the instrument cabinet.



Figure 3.5: Extraction of oleoresins using ultrasonicator

The extracted sample was filtered using Whatman no. 4 filter paper followed by vacuum concentration at 60°C. The concentrated sample was collected in eppendorf tube and stored at refrigeration temperature (4°C) for further analysis.

3.9.4 Preparation of chili paste

After sorting and removal of pedicels, the chilies were washed with running water. Water blanching was done in for 5-7 minutes followed by crushing into wet grinder. After

grinding, the chili paste was heated to reach at desired total soluble solids concentration (°Brix). The following treatments (Table 3.2) were given to chili paste for the storage:

Table 3.2 Treatments for chili paste with Class I and II preservatives

T1.	Control (without any treatment)
T2.	(0.2 gm KMS + 0.2 gm Sodium benzoate + 1 ml acetic acid + 5 gm NaCl) per 100 gm
T3.	(0.3 gm KMS + 0.3 gm Sodium benzoate + 1.5 ml acetic acid + 10 gm NaCl) per 100 gm
T4.	0.5 ml acetic acid per 100 gm + hot filling
T5.	1 ml acetic acid per 100 gm + hot filling

All samples following treatments were packed into retort pouches. The samples were divided into two lots and stored at ambient as well as refrigeration temperature for 10 months of storage.

3.10 Storage study

The processed chili paste was packed into retort pouches, stored at ambient temperature (18-38°C) and refrigeration temperature (4±2°C) for 10 months. The dried chili samples were packed into HDPE packs. The prepared honey chili sauce was packed into glass jars (50 gm), stored at ambient (18-38°C) as well as at refrigeration temperature (4±2°C) for 8 months storage period.

3.11 Sensory evaluation

The honey chili sauce was evaluated by semi-trained panelists from the Department of Food Science and Technology, PAU Ludhiana. The nine point hedonic scale (9 = liked extremely to 1 = disliked extremely) was used and scores were recorded in terms of colour, flavour, consistency and overall acceptability.

3.12 Statistical analysis

SPSS 16.0 software was used for the statistical analysis of the collected data. The results of present investigation are expressed as means of three independent variables ± standard deviation. Univariate analysis of variance was performed for the statistical estimation. Post-Doc Tukey's and $p \leq 0.05$ performed to check the significance level.

CHAPTER –IV

RESULTS AND DISCUSSION

The research experiments conducted for assessing the processing suitability of chili varieties into the value added products have been discussed under the following headings:

- 4.1 Physicochemical, bioactive components, antioxidant activity, colour and mineral analysis of fresh CH-27 and Punjab sindhuri chili varieties
- 4.2 Drying characteristics of CH-27 (green and red) and Punjab sindhuri (green and red)
- 4.3 Physicochemical, bioactive components, antioxidant activity, colour and mineral analysis of dried CH-27 and Punjab sindhuri chili varieties
- 4.4 Physicochemical, bioactive components, antioxidant activity, colour, mineral and FITR analysis of honey chili sauce
- 4.5 Physicochemical, bioactive components, antioxidant activity, colour, mineral analysis of chili paste
- 4.6 Optimization of method for the extraction of oleoresins

4.1 Physicochemical, bioactive components, antioxidant activity, colour and mineral analysis of fresh CH-27 and Punjab sindhuri chili varieties

The revealing of proximate analysis, colour values, presence of bioactive compounds, antioxidant activities and various mineral in CH-27 (green and red) and Punjab sindhuri (green and red) is given in Table 4.1-4.5.

4.1.1 Size

The mean size of chillies varieties ranged from 6.1 to 9.4 cm. The sizes of varieties significantly ($p \leq 0.05$) differed for the two chilli varieties CH-27 and Punjab Sindhuri, but did not differ significantly ($p \leq 0.05$) between the same chilli varieties with different degree of maturation. The highest value of size (9.4 cm) was recorded for the Punjab Sindhuri red variety and the lowest value (6.1) was recorded for the CH-27 red variety. The similar size results were reported by Dhaliwal *et al* (2013) and Dhaliwal *et al* (2015) for the same chili varieties.

4.1.2 Total soluble solids (°Brix)

Table (4.1) reveals that the total soluble solid of both chili varieties were vary from 3 to 6°Brix. The total soluble solid was significantly ($p \leq 0.05$) recorded highest for CH-27 (red) variety followed by Punjab sindhuri red. There was non-significant difference between green CH-27 and Punjab sindhuri. A significant ($p \leq 0.05$) increase in the rise of total soluble solids during maturation was observed. Perez-Grajales *et al* (2019) reported total soluble solids of Manzano hot pepper in the range of 5.80-7.40°Brix.

4.1.3 Total solids (%)

As per given in Table 4.1, total solids per cent of the both chilli variety were

significantly ($p \leq 0.05$) different. The highest percentage of total solids (20.7%) was observed for the CH-27 (red) variety, while lowest (14%) was for Punjab sindhuri (green). The total solid per cent of CH-27 green and Punjab sindhuri green was 17.1 and 18.1 respectively. The results depicted that the total solids range increased with the maturation as the red varieties shown more total solids per cent in comparison to green varieties.

Table 4.1: Physicochemical analysis of fresh CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties

Sr. No	Variety	Size (cm)	TSS (°B)	Total Solids (%)	Titratable acidity (%)	Total sugars (gm/100 gm)	Ash Content (%)	Crude fibre (%)
1	CH 27 GREEN	6.3±0.37 ^b	3±0.26 ^c	17.1±0.10 ^c	0.17±0.01 ^d	2.2±0.15 ^c	0.94±0.08 ^d	6.65±0.65 ^b
2	CH 27 RED	6.1±0.36 ^b	5±0.35 ^a	20.7±0.20 ^a	0.25±0.01 ^c	4.4±0.21 ^a	1.47±0.13 ^a	9.81±0.53 ^a
3	PS GREEN	9.2±0.46 ^a	3±0.27 ^c	14±0.12 ^d	0.47±0.01 ^b	2.3±0.13 ^c	0.96±0.03 ^c	5.36±0.50 ^c
4	PS RED	9.4±0.56 ^a	4.5±0.30 ^b	18.1±0.10 ^b	0.56±0.04 ^a	3.4±0.20 ^b	1.44±0.08 ^b	5.18±0.41 ^c

PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; °B*= Degree Brix; Values in a column and row of table with different superscripts differ significant ($p \leq 0.05$)

4.1.4 Titratable acidity

The Table (4.1) summarizes acidity value for each variety of chillies. A significant ($p \leq 0.05$) difference in titratable acidity was evident for all the chillies varieties. The acidity was recorded maximum for the Punjab sindhuri (red) variety with a value of 0.56 per cent, while minimum value was 0.17 per cent for CH-27 green variety. The titratable acidity range for the CH-27 red and Punjab sindhuri green was 0.25 and 0.47 respectively. Hameed *et al* (2013) stated that the fresh green chili have 0.42 per cent of acidity that too increase during its storage. Edusei *et al* (2013) reported 0.78 per cent titratable acidity in fresh green chili pepper.

4.1.5 Total sugars

Table (4.1) shows that the total sugar in both varieties of CH-27 (red) and Punjab Sindhuri (red) was significantly ($p \leq 0.05$) higher than green varieties of CH-27 and Punjab sindhuri. The highest value of total sugar was observed for CH-27 red variety (4.4 gm/100 gm), while lowest (2.2 gm/100 gm) was observed for the CH-27 green. The Punjab sindhuri green and red contains 2.3 and 3.4 gm/100 gm of the total sugars respectively. A non-significant difference was observed in CH-27 and Punjab sindhuri green. The maturity of chili varieties from green to red showed an increase in total sugar content. Faustion *et al* (2007) reported 2.40-4.98 gm/100 gm total sugars in the fresh green peppers.

4.1.6 Ash content

The analysis data of different chilli varieties (Table 4.1) show significant ($p \leq 0.05$) difference was observed for the ash content. The ash content was highest for the CH-27 red variety (1.47%), while the lowest was for 0.94 per cent for CH-27 green. Punjab sindhuri red and green showed ash content 1.44 and 0.96 per cent respectively. Reis *et al* (2013) reported 0.51 per cent ash content in the fresh Cumari pepper. The ash content of fresh red hot pepper in the range of 0.5-1.5 per cent was reported by Korkutata *et al* (2015).

4.1.7 Crude fibre

The data showed that the significantly ($p \leq 0.05$) highest percentage of crude fibre was observed for CH-27 red variety with a value of 9.81 per cent, while the lowest percentage of 5.18 was recorded for Punjab sindhuri red variety. Litoriya *et al* (2014) reported fibre in the range of 5.4-6.8 per cent of the fresh green chili. Ananthan *et al* (2014) reported total fibre content various red chili varieties in the range of 4.65-6.25 per cent.

4.1.8 Colour analysis

The results regarding the lightness (L), redness (a) and yellowness (b) of different chilli varieties are illustrated in the Table 4.2. The lightness (L) value of the CH-27 green variety was recorded highest (53.77), while lowest (34.88) was noted for the Punjab Sindhuri green variety. The values of redness (a) of different varieties were significantly ($p \leq 0.05$) varied, with highest value (21.56) of CH-27 variety (red). The lowest a value depicts the greenness of chili varieties. The negative value of Punjab sindhuri green (-2.37) depicts dark green colour. The highest yellowness (b) value (22.97) was observed for the variety of CH-27 green, while lowest (0.87) was noted for Punjab Sindhuri (green). Ergunes and Tarhan (2006) reported that the fresh red pepper had L , a and b values of 33.66, 37.79 and 15.71 respectively.

Table 4.2 Color analysis of fresh CH-27 (green and red) and Punjab sindhuri (Green and red) chili varieties

Sr. No.	Variety	L	a	b
1	CH 27 GREEN	53.77 $\pm$ 1.66 ^c	-11.32 $\pm$ 0.72 ^d	22.97 $\pm$ 1.14 ^a
2	CH 27 RED	42.11 $\pm$ 2.10 ^a	21.56 $\pm$ 1.72 ^a	6.17 $\pm$ 0.49 ^b
3	PS GREEN	34.88 $\pm$ 2.61 ^b	-2.37 $\pm$ 0.18 ^c	0.87 $\pm$ 0.06 ^c
4	PS RED	39.87 $\pm$ 1.99 ^b	16.48 $\pm$ 1.48 ^b	5.03 $\pm$ 0.47 ^b

PS= Punjab Sindhuri; n = 3; Values are Mean $\pm$ Standard Deviation; Values in a column and row of table with different superscripts differ significantly ($p \leq 0.05$); L indicate lightness of the samples; 100 = white, 0 = black; a designate redness when positive; greenness when negative; b represent yellowness when positive, blueness when negative.

4.1.9 Ascorbic acid

The data of ascorbic acid for different varieties was observed to be varying significantly ($p \leq 0.05$). The variety CH-27 (red) was found to be significantly ($p \leq 0.05$)

superior (132.6 mg/100mg) followed by Punjab sindhuri red (107.63mg/100 gm) and CH-27 green (99.5mg/100 gm). The lowest ascorbic acid content was noted in the green form of Punjab sindhuri that was 73.8mg/100 gm. Orobiyi *et al* (2015) reported that the different chili pepper varieties contain 84.64-192.64 mg/100 gm of the ascorbic acid content. A range of 76.3-161.3 mg/100 gm of fresh weight of ascorbic acid in various varieties of green chili was reported by Litoriya *et al* (2014).

4.1.10 Total phenolics

The Table 4.3 shows the total phenolics of different varieties of chilies differed at statistically significant ($p \leq 0.05$) levels and ranging from 143.47 to 276.06 mg/100ml GAE. The red form of both CH-27 and Punjab sindhuri had the highest total phenolic content of 276.06 and 233.56 mg/100ml GAE respectively, while for green form of CH-27 and Punjab sindhuri, total phenolics were 143.47 and 181.89 mg/100ml GAE respectively. The change in the color due to maturity showed an increase in the total phenolics of chilies. The results of the present study are in agreement of Kumar *et al* (2010) who reported total phenolics increase during ripening of chili pepper. The scientists reported that the green chili pepper contains total phenolics in the range of 64-188 mg/100 gm of fresh weight while the same varieties of red form showed total phenolics in the range of 110-266 mg/100 gm.

4.1.11 Total chlorophyll, chlorophyll *a* and chlorophyll *b* content

The total chlorophyll, chlorophyll *a* and chlorophyll *b* of CH-27 and Punjab Sindhuri were recorded as per shown in Table 4.3. Punjab sindhuri green was significantly ($p \leq 0.05$) higher than that of CH-27 green. The total chlorophyll content of CH-27 and Punjab sindhuri was 10.43 (1.04 mg/gm) and 4.41(0.44 mg/gm) respectively. The maximum chlorophyll *a* was recorded for the variety of Punjab sindhuri green (7.18), while CH-27 green showed 3.25 chlorophyll '*a*'. Similar trend was observed in chlorophyll *b* with 3.24 in Punjab sindhuri green and 1.16 in CH-27 green. Mullainathan *et al* (2015) reported 0.13 mg/gm of fresh weight chlorophyll in chili. Manolopoulou *et al* (2016) reported 0.2, 0.6 and 0.8 mg/gm of chlorophyll *a*, chlorophyll *b* and total chlorophyll in the fresh green pepper.

4.1.12 Total carotenoids

Total carotenoids content of both varieties vary significantly ($p \leq 0.05$) as per given in Table 4.3. Highest value for the total carotenoids was observed in Punjab sindhuri red (12.05 mg/100 gm) followed by CH-27 red form (6.43 mg/100 gm). The green form of both the varieties was less in the carotenoids content. Green form of CH-27 and Punjab sindhuri showed 6.43 and 6.82 mg/100 gm of total carotenoids respectively. The ripening of the green chili to red results in the increase of the total carotenoid content. The results are in agreement of Hornero-Mendez *et al* (2000).

4.1.13 β -Carotene

A significant ($p \leq 0.05$) difference was observed among each variety. The highest beta

carotene content was observed in 5.85 mg/100 gm followed by 3.06 mg/100 gm in CH-27 red. The green form of CH-27 and Punjab sindhuri showed 1.99 and 2.17 mg/100 gm of beta carotene. Pritwani and Mathur (2017) reported 0.9-1.017 mg/100 gm of β -carotene in the green chili.

4.1.14 Lycopene

The lycopene was significantly ($p \leq 0.05$) highest (3.2 μ g/100 gm) in Punjab sindhuri red, while in CH-27 red, the lycopene content was 1.7 μ g/100 gm. Ozgur *et al* (2011) reported 1.3 mg/100 gm of lycopene content in the red hot pepper.

4.1.15 Total extractable color

The values for the total extractable color was shown an increase during the maturity of the chili varieties as the highest extractable color was observed in red form of CH-27 and Punjab sindhuri (Table 4.3). The values significantly ($p \leq 0.05$) differ among each form of both varieties. The maximum extractable color was observed in Punjab sindhuri red (429 ASTA) followed by CH- 27 red (328 ASTA), CH-27 green (241 ASTA) and Punjab sindhuri green (178 ASTA). Similar results were reported by Dhaliwal *et al* (2013) and Dhaliwal *et al* (2015).

4.1.16 Capsaicin content

The capsaicin content of chili is the only parameter that determined the chili quality at the international market. The capsaicin content varies significantly ($p \leq 0.05$) among both varieties. The highest capsaicin percentage (1.27%) was observed in CH-27 green, while the CH-27 red showed 1.17 per cent of capsaicin content. Punjab sindhuri green and red showed 1.05 and 0.84 per cent of capsaicin content respectively. It was observed that the red form of each variety contains less capsaicin content in comparison to green form. Litoriya *et al* (2014) reported capsaicin content of 0.12-0.42 per cent among different varieties of green chili. The results are in close agreement with Dhaliwal *et al* (2013) who reported 1 per cent capsaicin content Punjab sindhuri, while Dhaliwal *et al* (2013) published that the CH-27 green and red contain 0.42 and 0.68 per cent capsaicin content respectively.

4.1.17 Antioxidant activity

The antioxidant activity of both varieties were analysed in the terms of DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (Ferric reducing antioxidant power). The results were calculated in terms of percentage and mM/100 gm for DPPH and FRAP respectively as given in Table 4.4.

4.1.17.1 per cent inhibition of DPPH radicals

2,2-diphenyl-1-picrylhydrazyl (DPPH) values significantly ($p \leq 0.05$) vary among each variety. The highest antioxidant activity in terms of DPPH was observed for CH-27 red (89.91%) followed by CH-27 green (88.96%), Punjab sindhuri red (80.6%) and Punjab

Table 4.3: Bioactive component analysis of fresh CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties

Sr. No.	Variety	Ascorbic acid (mg/100 gm)	Total phenolics (mg/100ml GAE)	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll (mg/gm)	Total carotenoids (mg/100 gm)	β carotene (mg/100 gm)	Lycopene (μ g/100 gm)	Total extractable color (ASTA)	Capsaicin (%)
1	CH 27 GREEN	99.5 $\pm$ 4.97 ^c	143.47 $\pm$ 2.50 ^d	4.41 $\pm$ 0.44 ^b	3.25 $\pm$ 0.25 ^b	1.16 $\pm$ 0.03 ^b	0.44 $\pm$ 0.03 ^b	6.43 $\pm$ 0.32 ^d	1.99 $\pm$ 0.11 ^d	-	241 $\pm$ 9.64 ^c	1.27 $\pm$ 0.10 ^a
2	CH 27 RED	132.6 $\pm$ 1.98 ^a	276.06 $\pm$ 16.02 ^a	0	0	0		9.7 $\pm$ 0.29 ^b	3.06 $\pm$ 0.15 ^b	1.7 $\pm$ 0.15 ^b	328 $\pm$ 16.4 ^b	1.17 $\pm$ 0.07 ^{ab}
3	PS GREEN	73.8 $\pm$ 3.68 ^d	181.89 $\pm$ 12.70 ^c	10.43 $\pm$ 0.52 ^a	7.18 $\pm$ 0.52 ^a	3.24 $\pm$ 0.25 ^a	1.04 $\pm$ 0.08 ^a	6.82 $\pm$ 0.20 ^c	2.17 $\pm$ 0.10 ^c	-	178 $\pm$ 8.9 ^d	1.05 $\pm$ 0.06 ^b
4	PS RED	107.63 $\pm$ 5.50 ^b	233.56 $\pm$ 14.00 ^b	0	0	0		12.05 $\pm$ 0.48 ^a	5.85 $\pm$ 0.29 ^a	3.2 $\pm$ 0.25 ^a	429 $\pm$ 38.61 ^a	0.84 $\pm$ 0.05 ^c
PS= Punjab Sindhuri; n = 3; Values are Mean $\pm$ Standard Deviation; Values in a column and row of table with different superscripts differ significantly (p $\leq$ 0.05) ; GAE= Gallic acid equivalent; ASTA= American Spice Trade Association												

Table 4.4: Antioxidant activity of fresh CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties

Sr. No.	Variety	% inhibition of DPPH	FRAP (mM/100 gm)
1	CH 27 GREEN	89.91 $\pm$ 4.49 ^a	2.29 $\pm$ 0.18 ^a
2	CH 27 RED	88.96 $\pm$ 4.44 ^b	2.28 $\pm$ 0.10 ^a
3	PS GREEN	76.5 $\pm$ 6.12 ^d	1.62 $\pm$ 0.12 ^c
4	PS RED	80.6 $\pm$ 7.21 ^c	2.10 $\pm$ 0.17 ^b
PS= Punjab Sindhuri; n = 3; Values are Mean $\pm$ Standard Deviation; Values in a column and row of table with different superscripts differ significantly (p $\leq$ 0.05); DPPH= 2,2-diphenyl-1-picrylhydrazyl; FRAP= Ferric reducing antioxidant power			

sindhuri green (76.5%). Sim and Sil 2008 reported the antioxidant activity (%) of red pepper in the range of 20-72 per cent.

4.1.17.2 FRAP

A non-significance difference was observed in the FRAP value of CH-27 green and red with range of 2.28-2.29 mM/100 gm. The FRAP value of Punjab sindhuri vary significantly ($p \leq 0.05$). The values for the green and red form were observed 1.62 and 2.10 mM/100 gm respectively. Keles *et al* 2016 reported FRAP range of 0.26-3.76 mM/gm among 52 genotypes of pepper.

4.1.18 Mineral content

The calcium content was significantly ($p \leq 0.05$) superior (30.31 ppm) in CH-27 (red) variety as compared to other varieties (Table 4.5).

Table 4.5 Mineral content (ppm) of fresh CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties

Sr. no	Mineral	CH-27 green	CH-27 red	PS green	PS red
1	Arsenic	0.026±0.002 ^a	0.01±0.0008 ^b	0.011±0.0007 ^{bc}	0.005±0.0002 ^c
2	Boran	0.373±0.02 ^b	0.478±0.03 ^a	0.276±0.003 ^c	0.365±0.03 ^b
3	Calcium	23.44±1.87 ^c	30.31±2.12 ^a	21.48±1.7 ^d	26.79±2.14 ^b
4	Cadmium	0.003±0.0002 ^a	0.002±0.0001 ^a	0.002±0.0001 ^a	0.002±0.0001 ^a
5	Chromium	0.012±0.005 ^a	0.013±0.002 ^a	0.005±0.0003 ^b	0.006±0.0003 ^b
6	Copper	0.154±0.01 ^a	0.147±0.01 ^a	0.18±0.012 ^a	0.096±0.007 ^b
7	Iron	1.284±0.08 ^b	1.205±0.10 ^d	1.258±0.006 ^c	1.466±0.04 ^a
8	Magnesium	33.86±2.37 ^a	32.08±2.2 ^b	27.43±1.92 ^c	20.3±1.21 ^d
9	Maganese	0.194±0.011 ^b	0.224±0.01 ^a	0.168±0.01 ^d	0.182±0.01 ^c
10	Sodium	3.644±0.29 ^d	5.766±0.51 ^a	5.206±0.41 ^b	4.625±0.27 ^c
11	Nickel	0.023±0.001 ^c	0.048±0.003 ^a	0.043±0.002 ^b	0.016±0.0008 ^d
12	Phosphorus	61.95±4.3 ^c	58.77±2.9 ^b	73.37±4.40 ^a	50.39±3.02 ^d
13	Lead	0.019±0.001 ^b	0.017±0.0007 ^b	0.015±0.0009 ^b	0.027±0.002 ^a
14	Sulphur	38.25±3.06 ^b	33.74±1.34 ^c	46.42±3.71 ^a	38.86±1.91 ^b
15	Zinc	0.433±0.021 ^d	0.499±0.03 ^{bc}	0.787±0.058 ^a	0.548±0.016 ^b

PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly ($p \leq 0.05$)

The lowest (21.48) was observed in Punjab sindhuri green variety. The iron was observed in the range of 1.205 and 1.466 ppm. The highest and lowest iron content was observed in Punjab sindhuri red and CH-27 red variety respectively. The magnesium content of CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 33.86, 32.08, 27.43 and 20.3 ppm respectively. The sodium content vary significantly ($p \leq 0.05$) among each

variety with highest value in CH-27 red followed by Punjab sindhuri green, Punjab sindhuri red and lowest in the CH-27 green. The phosphorus content was the observed in abundance in all four varieties as compared to other mineral. The highest value (73.37) of phosphorus content was observed in Punjab Sindhuri (green) variety, while the lowest (50.39) was also noted in Punjab sindhuri variety but of red color variety. The zinc content varied from 0.787 to 0.499 ppm. The highest one was recorded in Punjab sindhuri (green) variety and lowest was observed in CH-27 (green) variety. Swapan *et al* (2017) reviewed nutritional composition of fresh green and red chili. They found that the green and red chili contains calcium 8.1 and 6.3mg, iron 0.5mg (for both), magnesium 11.2 and 10.4mg, phosphorous 20.7 and 19.4mg, potassium 153 and 145mg, sodium 3.2 and 4mg, zinc 0.1mg (for both) per kg respectively. Don *et al* (2019) reported mineral content of green and red pepper. They found sodium 2.16 and 2.30, magnesium 13.34 and 12.64, phosphorous 15.39 and 15.67, potassium 32.27 and 34.24, calcium 2.11 and 1.70, manganese 1.06 and 1.13, iron 1.09 and 1.13, zinc 0.10 and 0.11 mg/100 gm in green and red pepper respectively.

4.1.19 FTIR spectra of fresh CH-27 (green & red) and Punjab sindhuri (green & red)

FT-IR spectra, characteristics peaks and functional groups of CH-27 (green and red) and Punjab sindhuri (green and red) at particular peaks are represented in Figure 4.1 along with Table 4.6. The phenols presence was determined by the presence of band in the range of $3430\text{--}3674\text{ cm}^{-1}$ in CH-27 and Punjab sindhuri chili varieties. The presence of amino acids was revealed in CH-27 green and red due to the presence of band with the range of 3430 and 3453 cm^{-1} respectively. C-H medium stretching with a band at 2918.5 and 2851.4 cm^{-1} attributes the presence of Alkanes in Punjab sindhuri red variety. The presence of isothiocyanates was detected in both forms of CH-27 and Punjab sindhuri with generation of peak with the wavelength range of 2077 cm^{-1} . The band at 1728 cm^{-1} in case of CH-27 green and Punjab sindhuri red representing the α , β unsaturated ester, while C=O stretching at

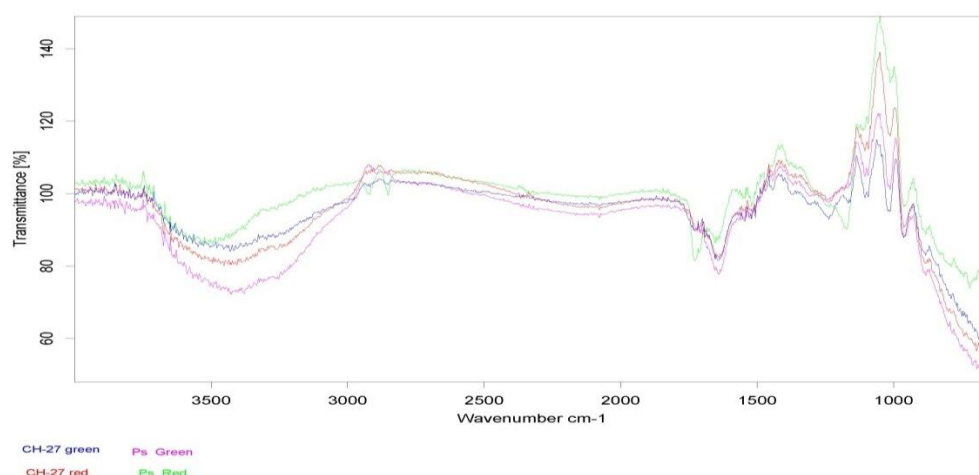


Figure 4.1: FTIR spectrum of fresh CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red

Table 4.6 FTIR frequency range, compound class and functional groups of fresh CH-27 and Punjab sindhuri chili varieties

Compound class	Functional groups	Frequency range (cm ⁻¹)			
		CH-27 Green	CH-27 Red	PS Green	PS (Red)
Alcohol, phenols	O-H stretching vibration	3933.3	-	-	-
		3882.4	-	3888.5	-
		3815.5	-	3815.4	3803.0
		3779.2	-	3779.5	
		3720.8	-	3733.2	3734.0
Alcohol, phenols	O-H stretching (medium sharp)	3645.9	3674.2	3674.1	3674.2
Alcohol , phenols	O-H stretching (medium sharp)	3568.2	3661.3	3661.2	-
Amine	N-H (Medium)	3430.3	3453.1	-	-
Alkanes	C-H stretching (medium)				2918.5
Alkanes	C-H stretching (medium)	-	-	-	2851.4
Isothiocynates	N=C=S stretching (strong)	2077.1	2077.2	2077.4	2077.1
α,β unsaturated ester	C=O stretching (strong)	1728.4	-	-	1728.0
Conjugated aldehydes	C=O stretching (strong)		1706.9		
Primary amide	C=O stretching (strong)	-	-	-	1691.3
Alkene	C=C stretching (weak)	-	-	-	1664.2
Alkene	C=C stretching (strong)	1643.4		1638.1	-
Nitro compound	N-O stretching (strong)	1544.8	-	-	-
Nitro compound	N-O stretching (strong)	1519.9	-	1521.8	1520.8
Nitro compound	N-O stretching (strong)	1506.4	1506.0	-	-
Alkanes	C-H bend	1443.6	1442.2	1442.8	1467.5
Alkyl aryl ether	C-O stretching (Strong)	1236.8	1242.4	1239.9	
Alcohol RR'R''C-OH (3°)	C-O stretch	1165.8	-	-	1170.7
Alcohol C=C-CRR'-OH	C-O stretch (Medium to strong)	1104.8	1104.9	1104.9	-
Alkyl halide R-F	C-F stretch (Very strong)	1013.3	-	-	-
Alkenes <i>trans</i> RCH=CHR'	=C-H bend	962.7	961.8	962.3	962.2
1,2,3 trisubstituted	C-H bending (Strong)	882.5	-	-	
Benzene derivative		-	-	-	720.5
Alkyl halide	C-Cl (Strong)	-	-	-	661.8
*PS= Punjab sindhuri					

1706.9 cm^{-1} band in CH-27 red represents the conjugated aldehydes. In Punjab sindhuri red, 1691.3 cm^{-1} band range attributes the presence of primary amides. N-O stretching with the range of peak wavelength from 1506.4 to 1544.8 cm^{-1} in both forms of CH-27 and Punjab sindhuri chili varieties represents the nitro compounds. Alkyl aryl ether presence was detected in CH-27 green, red and Punjab sindhuri green with the band range of 1236.8, 1242.4 and 1239.9 cm^{-1} respectively. C-O stretch detection in both chili varieties results in the presence of alcohol. C-F stretch with band 1013.3 cm^{-1} in CH-27 green attributes the presence of alkyl halides. =C-H bend with the peak range of 961.8 to 962.7 cm^{-1} in both forms of CH-27 and Punjab sindhuri reveals the presence of alkenes. Benzene derivatives and alkyl halide were detected in Punjab sindhuri red with band range of 720.5 and 661.8 cm^{-1} respectively. Similar results were reported by Linhegowda *et al* (2012), El Kaaby *et al* (2016).

4.2 Drying characteristics of CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties

Now a days, drying and dehydration of crops and foods are the major operation in the food industry. The major advantages of the dried foods are their stability at ambient temperature, easy transportation, prolongs shelf life, requirement of less storage area, easy incorporation into food formulation etc. The CH-27 (green and red) and Punjab sindhuri (green and red) was dried in laboratory tray dryer at 65°C and 85°C and freeze dryer (-40°C). The dried samples were packed into high density polyethylene packs and stored at room temperature for the further analysis.

4.2.1 Drying curve of CH-27 and Punjab sindhuri dried in tray dryer at 65°C

Figure 4.2 depicts the moisture content of CH-27 and Punjab sindhuri and time taken by the respective chili variety to dry properly. The initial moisture content of the whole

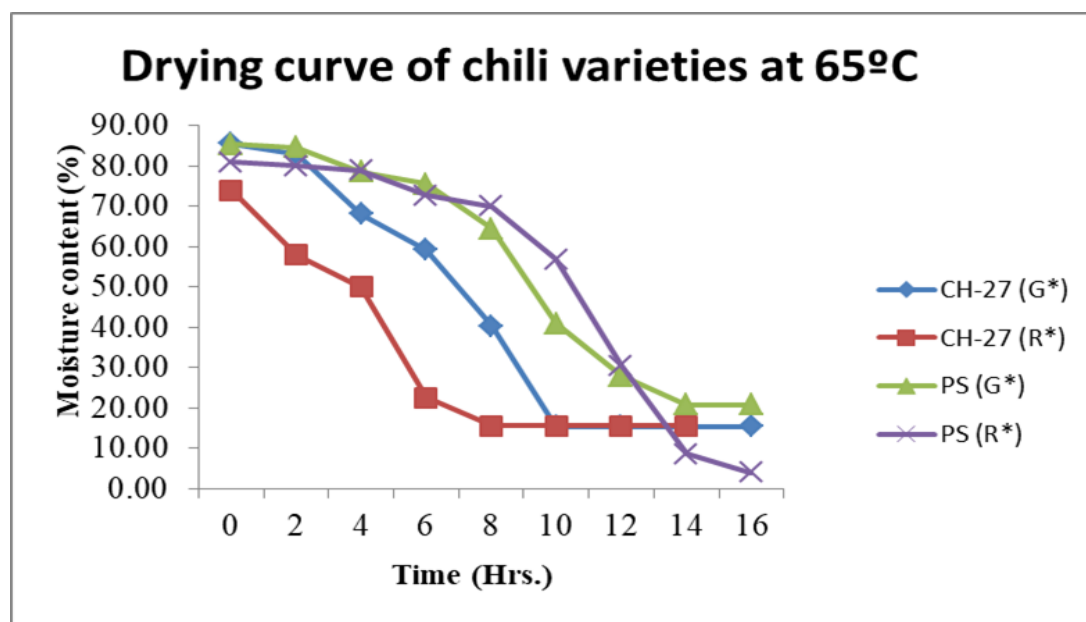


Fig. 4.2 Drying curve of CH-27 and Punjab sindhuri chilli varieties at 65°C

CH-27 green, red, Punjab sindhuri green and red was 85.53, 76.3, 85.36 and 80.87 per cent respectively. The chili varieties were dried until constant moisture content was obtained. The time taken by CH-27 green and red was 10 hours. As the Punjab sindhuri chili is a thick skinned chilli variety. The time taken by Punjab sindhuri green and red was significantly ($p \leq 0.05$) more than CH-27 variety. The Punjab sindhuri green variety was dried after 14 hours, while Punjab sindhuri showed constant moisture content after 16 hours of drying. The final moisture content was noted 10 per cent for CH-27 (green and red) and Punjab sindhuri green while for Punjab sindhuri red, the final moisture content reached to 8 per cent.

4.2.2 Drying curve of CH-27 and Punjab sindhuri dried in tray dryer at 85°C

Figure 4.3 showed the moisture content per cent versus time (hrs.) for CH-27 green, red, Punjab sindhuri green and red dried in laboratory tray dryer at 85°C. The initial moisture content for the CH-27 green, red, Punjab sindhuri green and red was noted 87.79, 76.47, 85.54 and 81.72 per cent on wet weight basis respectively. To reach the constant moisture content of chili varieties, the drying hours were less than drying at 65°C. The time taken by CH-27 green and red was 10hrs, while for Punjab sindhuri green and red, the time was 12 hours. After a constant weight, the final moisture content in CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 12.20, 23.52, 15 and 19 per cent respectively.

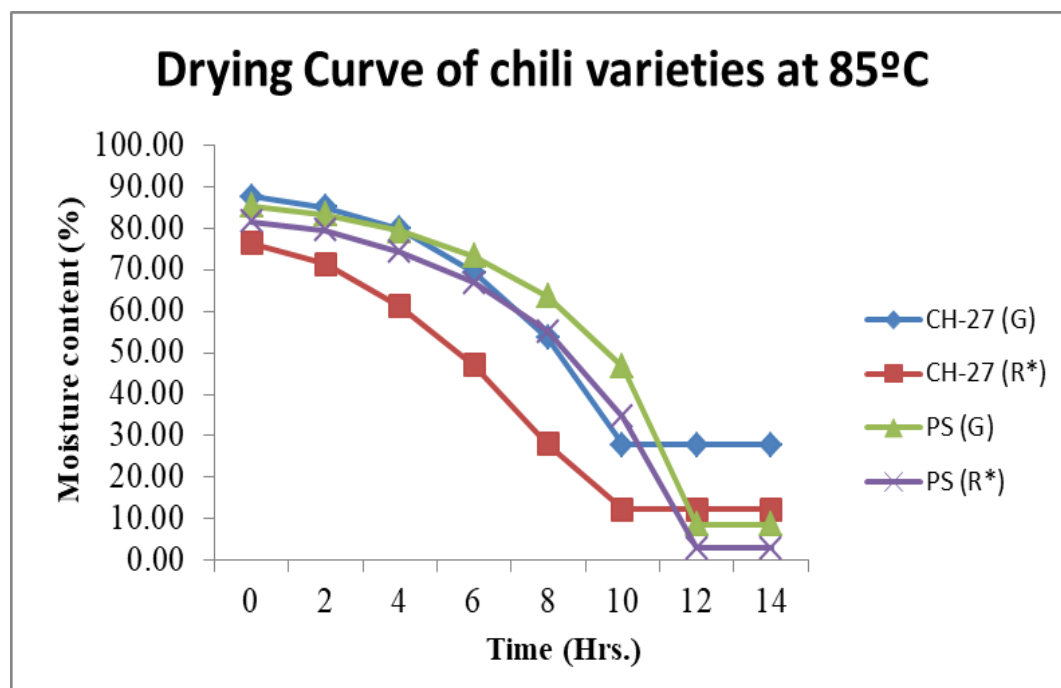


Fig. 4.3 Drying curve CH-27 and Punjab sindhuri of chilli varieties at 85°C

4.2.3 Drying curve of CH-27 and Punjab sindhuri dried in freeze dryer

Figure 4.4 depicted the drying characteristics of CH-27 (green & red) and Punjab sindhuri (green & red) dried at -40°C. The samples were crushed before drying to increase the surface area. The time taken by the freeze dryer for the drying of chili varieties was significantly ($p \leq 0.05$) longer than tray dryer, but the nutritional component retention was

better than tray dryer. The initial moisture content for the CH-27 green, red, Punjab sindhuri green and red was 87.93, 76.47, 85.54 and 81.72 per cent respectively. The constant moisture content in CH-27 green and red was reached after 28 hours of drying, while the thick skinned Punjab sindhuri took 34 and 32 for green and red form of chili variety respectively. The final moisture content in freeze dried samples was in the range of 9 to 20 per cent.

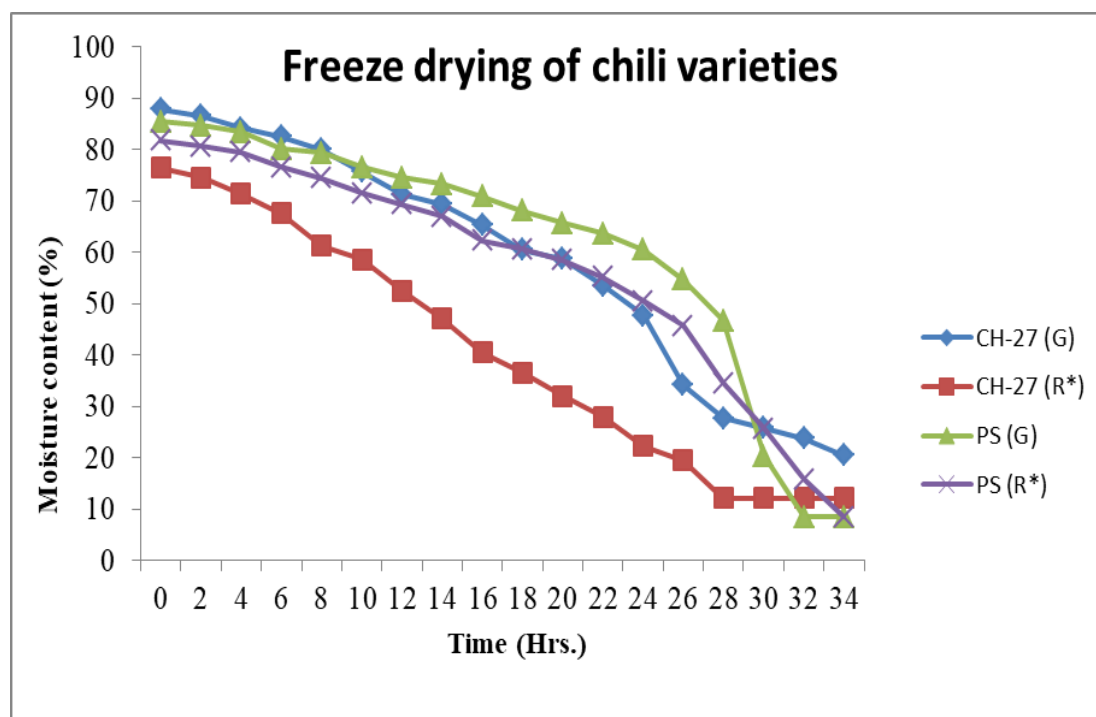


Fig. 4.4 Drying curve of CH-27 and Punjab sindhuri chilli varieties at -40°C

4.3 Physicochemical, bioactive components, antioxidant activity, colour and mineral analysis of dried CH-27 and Punjab sindhuri chili varieties

The proximate analysis, bioactive components, antioxidant activity (DPPH and FRAP), colour values and mineral content of chili varieties dried at 65, 85 and -40°C was conducted. The results are presented from Table 4.7 to 4.11.

4.3.1 Physicochemical analysis of dried CH-27 and Punjab sindhuri

Each form of both varieties i.e. CH-27 and Punjab sindhuri was dried at 65 and 85°C and freeze drying temperature (-40°C). The data for total twelve samples of both varieties evaluated for physicochemical properties (total soluble solids, total soluble solids, pH, acidity and ash content) is represented in Table 4.7. Individually CH-27 and Punjab sindhuri red dried at 65°C, 85°C freeze drying temperature was non-significantly vary in the total soluble solid content but significantly vary from the green form of both varieties dried at each temperature. The total soluble solids increment during drying was observed at each drying condition. A 44 to 50 per cent increase in the total soluble solids from the fresh chili varieties was observed. The condensation of total sugars during the dehydration process results in the increase of total soluble solids (Sharma *et al* 2015 and Suna *et al* 2014).

Table 4.7: Physicochemical analysis of dried CH-27 (green and red) and Punjab sindhuri (green and red)

Variety	Form	Temp.	TSS (°B)	Total Solids (%)	pH	Titrateable Acidity (%)	Ash Content (%)
CH-27	Green	65°C	6±0.30 ^b	95.21±0.03 ^a	5.92±.25 ^{ab}	0.30±0.10 ^{cd}	5.28±0.11 ^{ab}
	Red		9.5±0.90 ^a	92.61±0.02 ^{ab}	5.81±0.15 ^{ab}	0.41±0.05 ^{bcd}	4.37±0.12 ^{ab}
	Green	85°C	6±0.90 ^b	93.83±0.14 ^a	5.82±0.10 ^{ab}	0.36±0.02 ^{cd}	5.61±0.06 ^{ab}
	Red		8.5±0.10 ^a	93.88±0.01 ^b	5.74±0.01 ^{ab}	0.48±0.16 ^{bcd}	5.25±0.15 ^{ab}
	Green	FD	5.8±0.46 ^b	87.01±5.22 ^d	5.72±0.40 ^{ab}	0.23±0.02 ^d	3.94±0.35 ^{ab}
	Red		9±1.05 ^a	90.92±0.19 ^c	6.33±0.02 ^a	0.30±0.08 ^{cd}	4.15±0.30 ^{ab}
PS	Green	65°C	6.1±0.21 ^b	92.77±0.01 ^{abc}	5.93±0.01 ^{ab}	0.59±0.01 ^{abc}	3.84±0.10 ^{ab}
	Red		9.1±0.10 ^a	92.27±0.01 ^{abc}	6.18±0.05 ^{ab}	0.70±0.02 ^c	5.48±0.13 ^{ab}
	Green	85°C	6.5±0.10 ^b	92.37±0.06 ^{abc}	6.03±0.01 ^{ab}	0.81±0.01 ^a	3.69±0.11 ^{ab}
	Red		9.1±0.06 ^a	91.43±0.11 ^{bc}	5.55±0.15 ^b	0.75±0.05 ^b	5.78±0.12 ^a
	Green	FD	6.2±0.37 ^b	86.26±6.90 ^d	6.02±0.30 ^{ab}	0.55±0.05 ^{abc}	3.45±0.24 ^b
	Red		8.8±0.06 ^a	93.84±0.35 ^{ab}	6.39±0.06 ^a	0.62±0.07 ^{ab}	5.80±0.10 ^a

PS= Punjab sindhuri; FD= Freeze drying; n = 3; Values are Mean ± Standard Deviation; °B= Degree Brix; Values in a column and row of table with different superscripts differ significantly

The total solids were significantly ($p \leq 0.05$) superior (95.21) in CH-27 (green) variety dried at 65°C as compared to other varieties. A non-significance difference in the total solids of CH-27 green dried at 65 and 85°C was observed. Punjab sindhuri green and red dried at 65°C and green at 85°C was non-significant ($p \leq 0.05$) different. The lowest total solids were recorded for the freeze dried green form of CH-27 and Punjab sindhuri chili variety. A significant ($p \leq 0.05$) increase in the total solids of dried samples comparison to fresh chili was observed. An increment in the total solids followed by dehydration in figs was observed by El-gendy (2014).

The highest pH value was observed in freeze dried CH-27 red. It was observed that in all other samples, the drying temperature and method has a non-significant effect on the pH value. According to the results published by Toontom *et al* (2012), the dried chili showed 3.21 to 4.87 pH values. They found the significant effect of drying method on the pH value of chili samples. According to Kennao *et al* (2020), the chili pepper dried at 40 and 70°C represents pH value 4.57 and 4.60 respectively. Gamuchirai *et al* (2019) reported pH value of dried chili in the range of 4.8 to 5.1 using different drying conditions and methods. Similarly, a significant effect of drying method and temperature was observed on the titrateable acidity of chili varieties. Highest titrateable acidity of 0.81 per cent was observed in Punjab sindhuri green dried at 85°C followed by 0.75 per cent in Punjab sindhuri red dried at same temperature. The CH-27 green and red dried at 65°C represented 0.30 and 0.41 per cent

titratable acidity respectively. The CH-27 green and red dried at 85°C showed 0.36 and 0.48 per cent titratable acidity respectively. Freeze dried CH-27 varieties represented acidity in the range of 0.23-0.30 per cent. The Punjab sindhuri chili varieties of both form dried at 65°C in laboratory tray dryer represented titratable acidity in the range of 0.59-0.70 per cent. The freeze dried sample of same variety showed 0.55-0.62 range of titratable acidity. The major organic acid present in chili is citric acid and its condensation during drying results in an increased titratable acidity. Toontom *et al* (2012) observed titratable acidity of dried chili in the range of 0.15-0.59 per cent.

The ash content of freeze dried Punjab sindhuri (red) was highest (5.78%), as compared to other varieties dried at different temperature. The lowest (3.45%) ash content was recorded for freeze dried Punjab sindhuri green. A significant effect of drying method and conditions observed as an increase in the ash content compare to fresh chili varieties was recorded. With the range of 74 to 82 per cent increment in the ash content compare to fresh chili varieties was recorded during drying process. An increase in ash content with the drying process was also reported by Ajayi *et al* (2017). Up to 72 per cent increase in ash content of ginger was observed during drying. Al-sabaei *et al* (2017) reported more than 87 per cent increase in the ash content of green chili varieties dried using different drying methods and conditions.

4.3.2 Colour analysis of dried CH-27 and Punjab sindhuri

Table 4.8 depicted the *L*, *a* and *b* values of the dried chili varieties. A significant effect of drying method and temperature was noted on the colour values for each form of both chili varieties. The *L* value represents the darkness to lightness of analysed samples. The 0 value represents the darkness while 100 values represent the lightness of respective sample. The highest *L* value was observed for freeze dried CH-27 green and Punjab sindhuri red chili variety. As compare to fresh chili variety, the drying cause a significant ($p \leq 0.05$) increase in the *L* value of dried chili samples. The *a* value represents the redness of samples when positive and greenness when negative.

The maximum retention of redness in red form of both CH-27 and Punjab sindhuri varieties were observed in freeze dried samples. As reported by Toontom *et al* (2012, this is because of the low temperature of freeze drying that cause poor heat transfer in the dry layer of the sample. A significant ($p \leq 0.05$) effect of laboratory tray drying method on the redness of red form of CH-27 and Punjab sindhuri was observed. During drying at 65°C, CH-27 red varieties' *a* value reduced to 0.42 while in red form of Punjab sindhuri variety, a value was 11.66. When temperature increased to 85°C, *a* value for the CH-27 and Punjab sindhuri red form was 6.35 and 0.1 respectively. In case of green form of both varieties, freeze dried samples were able to retain the greenness in comparison to the fresh chili. As reported by Topuz *et al* (2004), the reason for the darkness of green chili during drying is due to reaction

of non-reducing sugar and amino acid of the pericarp results in non-enzymatic browning. The drying at 65 and 85°C results in the decomposition and oxidation of pigment of the green chili. The *b* values for CH-27 green& red was 1.94 & -0.84 1.44 & 0.29 and 9.36 & 1.47 at 65°C, 85°C and freeze drying temperature respectively. Similarly for the Punjab sindhuri green and red *b* value at 65, 85 and freeze drying temperature was 0.85 & 1.58, 1.19 & -1.89 and 3.48 & 10.84 respectively.

Table 4.8: Colour analysis of dried CH-27 and Punjab sindhuri chili variety

Variety	Form	Temp.	<i>L</i>	<i>a</i>	<i>b</i>
CH-27	Green	65°C	37.35±0.95 ^e	1.03±0.57 ^f	1.94±0.02 ^d
	Red		37.23±2.53 ^{de}	0.42±0.03 ^{gh}	-0.8±0.10 ^h
	Green	85°C	38.34±1.01 ^{cde}	1.3±0.25 ^f	1.44±0.03 ^{ef}
	Red		40.99±0.81 ^b	6.35±0.10 ^d	0.29±0.04 ^g
	Green	FD	48.93±2.41 ^a	3.41±0.27 ^e	9.36±0.65 ^b
	Red		37.98±0.98 ^{de}	7.38±0.20 ^c	1.47±0.07 ^{ef}
PS	Green	65°C	36.85±0.71 ^{de}	0.72±0.02 ^{fg}	0.85±0.28 ^{fg}
	Red		40.25±0.72 ^b	11.66±0.48 ^b	1.58±0.01 ^{ef}
	Green	85°C	38.26±1.01 ^{bcde}	1.24±0.16 ^f	1.19±0.01 ^{efg}
	Red		38.82±0.89 ^{bcd}	0.1±0.57 ^{gh}	-1.89±0.03 ⁱ
	Green	FD	41.7±2.91 ^{bc}	-0.67±0.04 ^h	3.48±0.31 ^c
	Red		45.63±0.98 ^a	12.73±.11 ^a	10.84±0.07 ^a

PS= Punjan sindhuri; FD= Freeze Drying; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; L* indicate lightness of the samples; 100 = white, 0 = black; a* designate redness when positive; greenness when negative; b* represent yellowness when positive, blueness when negative.

4.3.3 Phytochemical analysis of dried CH-27 and Punjab sindhuri

Bioactive components including ascorbic acid, total phenolics, total chlorophyll, chlorophyll *a*, chlorophyll *b*, total carotenoids, beta-carotene, lycopene, capsaicin and total colour matter is presented in Table 4.9. Ascorbic acid is a powerful antioxidant compound that can relatively stable ascorbyl free radical by donating a hydrogen atom. The maximum ascorbic acid in samples under present study was observed in freeze dried Punjab sindhuri red that showed 660.16 mg/100 gm of ascorbic acid. The lowest ascorbic acid as noted in sample of CH-27 green dried at 65°C. CH-27 green and red dried at 65°C showed 75.27 and 100 mg/100 gm of ascorbic acid respectively, while CH-27 red dried at 85°C represented 92.28 mg/100 gm of ascorbic acid.

Freeze dried CH-27 green and red showed 86.23 and 119.80 mg/100 gm of ascorbic acid respectively. The ascorbic acid content in Punjab sindhuri green and dried at 65 and 85°C

was 200.54, 370.06, 190.23 and 590.34 mg/100 gm respectively. The freeze dried Punjab sindhuri green showed 420.80 mg/100 gm. An increment of ascorbic acid content followed by drying was observed in the present study. Shofian *et al* (2012) found a significant retention of ascorbic acid during freeze drying.

As represented in Table 4.9, the total phenolic content of all samples differ significantly, ranging from 425 to 689 mg/100 ml GAE. The superior content was observed in freeze dried CH-27 green as compared to other samples. A non-significant difference in the total phenolics content of Punjab sindhuri red freeze dried, 65°C temperature drying and CH-27 red dried at 65°C was observed. The least content of phenolics 341 mg/100 ml GAE was noted in CH-27 green variety dried at 85°C.

CH-27 green dried at 65°C showed 425.66 mg/100ml GAE total phenolics, while CH-27 red dried at 85°C showed 470.77 mg/100ml GAE value. The total phenolics of freeze dried CH-27 red, Punjab sindhuri green and red dried at 65°C and 85°C respectively showed non-significant variation. The total phenolics in Punjab sindhuri green dried at 85°C were 380.95 mg/100ml GAE. The freeze dried Punjab sindhuri green showed 580.64 mg/100ml GAE of total phenolics. A significant ($p \leq 0.05$) increase in the total phenolics during drying was observed when compared to the fresh commodity. Wiriya *et al* (2009) reported total phenols in the range of 252 to 316 mg/100 gm of dried chili. Kamal *et al* (2019) previously reported that the increment in the total phenolics during drying might be due to the conversion of flavonoids into secondary form of phenolic compounds. The inter conversion of polyphenol compounds to precursors of polyphenols during non-enzymatic browning is one of the reasons in the hike of phenols in dried chili comparison to fresh one.

A significant ($p \leq 0.05$) variation in total chlorophyll content among each dried chili variety was observed respective of drying temperature and method. The total chlorophyll content was significantly highest in Punjab sindhuri green freeze dried and at 65°C temperature drying. The samples of Punjab sindhuri green variety dried at 85°C and freeze dried CH-27 green showed 15.52 and 11.61mg/gm of total chlorophyll. CH-27 green dried at 65 and 85°C showed 10.19 and 9.98 mg/gm for total chlorophyll content. The red form of both varieties dried at different temperature and method did not vary significantly. Chlorophyll 'a' was observed significantly highest in Punjab Sindhuri green variety dried at 65°C, 85°C and at freeze drying conditions. CH-27 green variety dried at 65, 85 and freeze drying conditions represented 5.70, 5.64 and 6.65 mg/gm values respectively and showed non-significant difference. A non-significant variation was observed in each sample of red form. Similarly, chlorophyll 'b' was highest in Punjab sindhuri green dried at 65, 85 and freeze drying conditions and a non-significant difference was observed. Similar trend was observed for CH-27 green form. The lowest values were observed for red form of both varieties among each drying condition and temperature. A significant increase in the total

chlorophyll, chlorophyll 'a' and chlorophyll 'b' after drying was observed respective of fresh samples. The results are in agreement those reported by Roshanak *et al* (2016).

A significant ($p \leq 0.05$) difference was found in the carotenoids content among both varieties. Maximum carotenoids content was found in freeze dried Punjab sindhuri (20 mg/100 gm). A non-significant difference was observed in total carotenoids Punjab sindhuri red dried at 65 and 85°C. The carotenoids content of CH-27 red dried at 65, 85 and freeze dried samples were 15.45, 14.79 and 16.69 mg/100 gm respectively. The carotenoid content of CH-27 green dried at 65, 85 and freeze dried conditions were 9.98, 9.50 and 11.31 mg/100 gm respectively. For Punjab sindhuri green dried at 65, 85 and freeze dried samples were 10.65, 9.77 and 11.74 mg/100 gm respectively. Evaporation of moisture leaves the higher concentration of carotenoids comparison to fresh commodity. The results are in accordance with Kevresen *et al* (2009) as they found the increase in total carotenoids followed by drying of red pepper.

Lycopene content of red dried chilies of Punjab sindhuri and CH-27 was analysed as represented in Table 4.9. Maximum lycopene content was found in freeze dried and 85°C temperature dried Punjab sindhuri red with values 5.44 and 5.10 µg/100 gm respectively. The value for Punjab sindhuri red dried at 65°C was 4.72 µg/100 gm. A non-significant variation was found in the lycopene content of CH-27 dried at different temperature.

As shown in Table 4.9, the values of total extractable color significantly ($p \leq 0.05$) varied between 80 and 495 ASTA. The excessive (495 ASTA) value was observed in freeze dried Punjab sindhuri red, while the lowest was recorded in sample CH-27 green variety dried at 85°C. The freeze dried samples were able to retain more total extractable color as compare to other drying method. The freeze dried CH-27 green and red represented 261 and 337 ASTA of total extractable color respectively, while freeze dried Punjab sindhuri green showed 193 values for total colouring matter. Reduction of extractable color during drying at 85°C was observed, but it was higher than the extractable color in fresh samples. Punjab sindhuri green and red dried at 65°C showed 139 and 335 ASTA of total extractable color respectively, while at 85°C values were 61 and 150 ASTA respectively. According to Babu *et al* (2014), the dried chili contains total extractable color in the range of 48-156 ASTA. Ibrahim *et al* (1997) found 30-260 ASTA total colouring method of paprika dried with different drying methods.

The pungency level of the chili is determined by the per cent of capsaicin content present in the particular sample. In the present study, the maximum capsaicin content was found in the freeze dried samples. Green form of freeze dried CH-27 and Punjab sindhuri showed 5.66 and 5.84 per cent of capsaicin content respectively and varies non-significantly. The freeze dried CH-27 red showed 5.27 per cent of capsaicin content. A non-significant variation in the capsaicin content was observed in CH-27 green and red dried at 65°C, CH-27

Table 4.9 Bioactive component analysis of dried CH-27 (green and red) and Punjab sindhuri (green and red)

Variety	Form	Temp. (°C)	Ascorbic acid (mg/100 gm)	Total phenols (mg/100ml GAE)	Total chlorophyll	chlorophyll a	chlorophyll b	Chlorophyll (mg/gm)	Carotenoids (mg/100 gm)	β-carotene (mg/100 gm)	Lycopene (µg/100 gm)	Total colouring color (ASTA)	Capsaicin content (%)
CH-27	Green	65	75.27±0.87 ^g	425.66±79.30 ^{cd}	10.19±0.05 ^{cd}	5.70±0.01 ^b	4.48±0.01 ^b	1.019±0.001 ^b	9.98±0.001 ^d	2.85±0.01 ^{fg}		187±0.01 ^{de}	3.25±0.01 ^{abc}
	Red		100.00±1.17 ^{fg}	559.12±113.32 ^b	1.05±0.01 ^e	0.45±0.01 ^c	0.60±0.10 ^c	0.10±0.001 ^c	15.45±0.002 ^{bcd}	6.95±0.26 ^c	2.45±0.001 ^c	255.84±0.008 ^c	3.24±0.01 ^{abc}
	Green	85	69.07±1.10 ^g	341.25±27.13 ^d	9.98±0.007 ^d	5.64±0.02 ^b	4.34±0.01 ^b	0.98±0.002 ^b	9.50±0.001 ^d	3.60±0.02 ^f		80±0.008 ^{gh}	2.95±0.01 ^{abc}
	Red		92.28±1.13 ^{fg}	470.77±0.75 ^{bc}	2.01±0.02 ^e	0.69±0.02 ^c	1.32±0.07 ^c	0.20±0.001 ^c	14.79±0.001 ^{abcd}	7.56±1.17 ^{bc}	2.53±0.001 ^c	105.6±0.17 ^{fgh}	2.06±0.001 ^{bc}
	Green	FD	86.28±4.31 ^{fg}	689.3±34.46 ^a	11.61±0.69 ^c	6.65±0.39 ^b	4.96±0.29 ^b	1.16±0.07 ^{ab}	11.31±0.67 ^{cd}	5.85±0.35 ^d		261±15.66 ^c	5.66±0.45 ^a
	Red		119.80±2.02 ^f	495.64±42.51 ^{bc}	1.94±0.21 ^e	0.72±0.01 ^c	1.22±0.22 ^c	0.19±0.006 ^c	16.69±0.001 ^{abc}	8.00±0.22 ^b	2.89±0.001 ^c	337±0.95 ^b	5.27±0.001 ^{ab}
PS	Green	65	200.54±1.01 ^e	499.42±4.69 ^{bc}	16.74±0.22 ^{ab}	9.80±0.07 ^a	6.93±0.01 ^a	1.64±0.004 ^{ab}	10.65±0.001 ^d	2.65±0.13 ^{fg}		139.84±0.007 ^{efg}	3.42±0.01 ^{abc}
	Red		370.06±0.80 ^d	559.31±58.58 ^b	1.85±0.06 ^e	0.64±0.01 ^c	1.20±0.01 ^c	0.18±0.010 ^c	18.76±0.004 ^{ab}	4.65±0.21 ^e	4.72±0.003 ^b	335±0.11 ^b	2.84±0.01 ^{abc}
	Green	85	190.23±0.99 ^e	380.95±3.02 ^{cd}	15.52±0.19 ^b	9.28±0.01 ^a	6.24±0.01 ^a	1.55±0.013 ^{ab}	9.77±0.026 ^d	2.86±0.01 ^{fg}		61±0.07 ⁱ	2.25±0.38 ^{bc}
	Red		590.34±1.03 ^b	499.80±0.77 ^{bc}	2.54±0.13 ^e	0.77±0.01 ^c	1.77±0.02 ^c	0.25±0.001 ^c	18.43±0.003 ^{ab}	5.50±0.26 ^d	5.10±0.001 ^{ab}	150±0.01 ^{def}	2.04±0.01 ^c
	Green	FD	420.80±37.87 ^c	580.64±40.6 ^{ab}	18.37±1.28 ^a	10.55±0.74 ^{ab}	7.82±0.62 ^a	1.83±0.10 ^a	11.74±0.93 ^{cd}	3.10±0.18 ^{fg}		193±9.65 ^d	5.84±0.46 ^a
	Red		660.16±0.99 ^a	565.13±0.34 ^b	1.41±0.04 ^e	0.37±0.02 ^c	1.04±0.01 ^c	0.14±0.003 ^c	20.00±0.004 ^a	9.80±0.37 ^a	5.44±0.001 ^a	495±1.30 ^a	5.25±0.01 ^{abc}

n = 3; Values are Mean ± Standard Deviation; PS= Punjab sindhuri; FD= Freeze drying Values in a column and row of table with different superscripts differ significantly; GAE= Gallic acid equivalent; ASTA= American Spice Trade Association

green dried at 85°C, Punjab sindhuri green and red dried at 65°C and Punjab sindhuri red freeze dried. The least capsaicin content was observed in Punjab sindhuri red dried at 85°C. During the drying process, an increase in the capsaicin content was observed. The results are in accordance with Popelka *et al* (2017).

4.3.4 Antioxidant activity of dried CH-27 and Punjab sindhuri

Antioxidant activity in terms of DPPH and FRAP of dried CH-27 and Punjab sindhuri is represented in Table 4.10. A non-significant difference in the per cent inhibition of DPPH for CH-27 green, red form dried at 65°C, 85°C and freeze drying temperature was found. Similarly Punjab sindhuri green and red form dried with freeze drying method showed non-significant difference in terms of per cent inhibition of DPPH. A value of 80-82 per cent inhibition of DPPH was found in Punjab sindhuri green and red dried at 65°C and Punjab sindhuri green dried at 85°C. Punjab sindhuri red dried at 85°C showed 85 per cent DPPH value. A significant ($p \leq 0.05$) increase in the antioxidant activity with the drying process was observed in comparison to fresh sample. The maximum increase was observed for the freeze drying method in both chili varieties. The results are in agreement with Lutz *et al* (2015). Wangcharoen and Morasuk (2009) found that during drying process, non-enzymatic browning occurs that results in the formation of free radical scavenging activity compounds like melanoidins. The formation of such compounds results in the increment of antioxidant activity of dried commodity corresponding to fresh material. Similarly for the FRAP, the maximum values were observed for CH-27 and Punjab sindhuri varieties dried using freeze drying method. The FRAP values for CH-27 green and red form dried at 65°C was varied

Table 4.10: Antioxidant activity of dried CH-27 and Punjab sindhuri chili variety

Variety	Form	Temp.	% inhibition of DPPH	FRAP (mM/100 gm)
CH-27	Green	65°C	91.76±4.75 ^a	7.38±0.72 ^{cd}
	Red		90.26±6.25 ^a	7.49±0.81 ^{cd}
	Green	85°C	90.80±4.10 ^a	8.34±0.49 ^{bcd}
	Red		89.91±4.98 ^a	8.32±1.03 ^{bcd}
	Green	FD	91.25±7.30 ^a	12.58±0.88 ^a
	Red		92.51±4.09 ^a	11.36±0.94 ^{ab}
PS	Green	65°C	80.06±2.12 ^c	7.34±0.49 ^{cd}
	Red		82.64±7.92 ^c	7.36±1.05 ^{cd}
	Green	85°C	82.77±4.18 ^c	7.48±1.00 ^{cd}
	Red		85.27±4.37 ^{bc}	7.28±0.88 ^{cd}
	Green	FD	89.36±4.14 ^{ab}	10.51±0.63 ^{abc}
	Red		91.34±6.35 ^a	11.37±0.77 ^{abcd}

PS= Punjab sindhuri; FD= Freeze drying; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; DPPH= 2,2-diphenyl-1-picrylhydrazyl; FRAP= Ferric reducing antioxidant power.

Table 4.11 Mineral content (ppm) of dried CH-27 (green and red) and Punjab sindhuri (green and red)

Variety	CH-27						Punjab sindhuri					
Form	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red
Temp.	65°C		85°C		FD		65°C		85°C		FD	
	1	2	3	4	5	6	7	8	9	10	11	12
Arsenic	4.73±0.01 ^a	1.82±0.02 ^c	0.52±0.002 ^e	0.2±0.03 ^f	0.1±0.03 ^{gh}	0.1±0.008 ^{gh}	2.002±0.01 ^b	0.91±0.02 ^d	0.22±0.01 ^f	0.1±0.03 ^g	0.05±0.01 ^{hc}	0.05±0.002 ^{hc}
Boron	0.31±0.01 ^h	0.40±0.001 ^g	3.12±0.001 ^b	4.00±0.03 ^a	1.74±0.006 ^e	1.76±0.08	0.23±0.001 ⁱ	0.31±0.003 ^h	2.313863 ^d	3.06±0.003 ^c	1.5±0.10 ^f	1.33±0.01 ^f
Cadmium	0.008±0.001 ^a	0.011±0.001 ^a	0.0087±0.001 ^a	0.011±0.002 ^a	0	0	0.0080±0.002 ^a	0.01±0.01 ^a	0.0080±0.001 ^a	0.01±0.001 ^a	0	0
Calcium	16.35±0.10 ^b	10.9±0.27 ^e	22.2±0.03 ^a	14.8±0.12 ^d	15.8±0.07 ^c	9.09±0.63 ^e	10.9±0.19 ^e	10.9±0.32 ^e	14.8±0.02 ^d	14.8±0.27 ^d	15.9±0.79 ^c	15.8±0.14 ^c
Chromium	0.22±0.03 ^a	0.23±0.001 ^a	0.06±0.003 ^{cd}	0.065±0.001 ^{cd}	0.065±0.002 ^c	0.06±0.03 ^{cd}	0.091±0.002 ^{bc}	0.11±0.004 ^b	0.025±0.002 ^e	0.03±0.005 ^{de}	0.04±0.01 ^{de}	0.03±0.002 ^{de}
Copper	0.70±0.001 ^f	0.67±0.01 ^{gh}	1.10±0.002 ^b	1.05±0.005 ^c	0.91±0.002 ^d	0.82±0.05 ^e	0.82±0.001 ^e	0.44±0.01 ⁱ	1.29±0.01 ^a	0.69±0.03 ^{fg}	0.5±0.04 ^h	±0.6±0.01 ^h
Iron	2.11±0.002 ^g	1.98±0.004 ⁱ	3.17±0.01 ^b	2.97±0.02 ^d	2.55±0.02 ^e	2.15±0.12 ^g	2.076±0.01 ^h	2.42±0.02 ^f	3.10±0.002 ^c	3.62±0.01 ^a	3.8±0.22 ^a	3.11±0.02 ^{bc}
Lead	0.21±0.001 ^a	0.205±0.001 ^{ab}	0.08±0.001 ^d	0.079±0.001 ^{de}	0.04±0.001 ^{ef}	0.035±0.002 ^f	0.175±0.001 ^{bc}	0.130.03 ^c	0.06±0.001 ^{def}	0.05±0.005 ^{def}	0.02±0.01 ^g	0.03±0.002 ^f
Magnesium	7.73±0.02 ^j	8.93±0.01 ⁱ	62.03±0.35 ^d	71.63±0.01 ^b	64±0.57 ^c	75.02±5.25 ^a	6.70±0.01 ^k	7.26±0.01 ^j	53.72±0.03 ^g	58.2±0.22 ^e	56.9±4.55 ^f	52±0.14 ^h
Manganese	0.07±0.002 ^g	0.11±0.03 ^e	0.46±0.001 ^e	0.735±0.001 ^b	0.58±0.001 ^c	0.80±0.06 ^a	0.10±0.003 ^{gh}	0.09±0.002 ^{gh}	0.66±0.03 ^c	0.59±0.03 ^d	0.39±0.03 ^f	0.47±0.003 ^e
Nickel	0.05±0.003 ^e	0.12±0.003 ^c	0.043±0.001 ^e	0.09±0.003 ^d	0.09±0.001 ^d	0.12±0.01 ^c	1.00±0.02 ^a	0.04±0.004 ^e	0.75±0.002 ^b	0.03±0.005 ^e	0.03±0.01 ^e	0.03±0.003 ^e
Phosphorous	27.66±0.11 ⁱ	26.24±0.008 ⁱ	229.89±0.18 ^b	218.09±0.29 ^c	183.10±0.29 ^f	170±10.2	32.76±0.10 ^h	22.5±0.24 ^j	272.28±0.19 ^a	187±1.5 ^d	140±7.00	157±0.25 ^g
Potassium	17.02±0.29 ^h	15.23±0.005 ⁱ	275.14±0.27 ^e	246.18±0.21 ^e	427.51±0.02 ^c	419±33.5 ^c	13.44±0.34 ^j	24.2±0.04 ^g	217.22±0.18 ^f	391±2.08 ^d	782±54.74 ^a	679±0.75 ^b
Sodium	33.66±0.01 ^c	29.69±0.02 ^d	13.48±0.13 ^e	11.89±0.02 ^f	8.64±0.02 ^g	7.68±0.53 ^h	40.85±0.17 ^a	34.2±0.03 ^b	16.36±0.02 ^e	13.7±0.12 ^f	6.96±0.55 ⁱ	9.96±0.003 ^g
Zinc	1.12±0.001 ^h	1.29±0.013 ^e	1.20±0.004 ^{fg}	1.384±0.006 ^d	1.16±0.001 ^{gh}	1.30±0.08 ^e	2.03±0.02 ^b	1.42±0.002 ^d	2.18±0.001 ^a	1.52±0.004 ^c	1.02±0.05 ⁱ	1.28±0.04 ^{ef}

n = 3; PS= Punjab sindhuri; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; FD= Freeze dried

non-significantly. Similar results were found in Punjab sindhuri green and red form dried at 65 and 85°C. CH-27 green and red form dried at 85°C showed 8.34 and 8.32 mM/100 gm of FRAP values respectively. A range of 72 to 84 per cent increase in FRAP values during drying process was observed in contrast to fresh commodity.

4.3.5 Mineral content of dried CH-27 and Punjab sindhuri

The data of mineral content of different samples of chilli variety is illustrated in Table 4.11. The calcium content after drying was observed in the range of 10.9 to 22.2 ppm. The highest (22.2 ppm) content was observed in sample of CH-27 (red) variety dried at 85°C followed by sample of CH-27 green variety dried at 65°C (16.35 ppm), CH-27 (red) and Punjab Sindhuri (red) freeze dried (15.8 ppm). The iron content found out to be non-significant only in samples of CH-27 (green) dried variety at 85°C (3.17 ppm), Punjab Sindhuri (green) variety dried at 85°C (3.10 ppm) and Punjab Sindhuri (red) variety freeze dried. The magnesium content fluctuated between 6.70 and 71.63 ppm. The content was low in samples of CH-27 (green) dried at 65°C (7.73 ppm), CH-27 (red) dried at 65°C (8.93 ppm), Punjab Sindhuri (green) dried at 65°C (6.70 ppm) and Punjab Sindhuri (red) dried at 65°C (7.26 ppm) as compared to other samples of chilli varieties. The zinc content was highest (2.18 ppm) in sample of Punjab Sindhuri (green) dried at 85°C, while lowest was noted in sample of (1.12) CH-27 (green) variety. Dried chili samples represented higher mineral content compared to fresh commodity due to the increase of dry matter. The similar results were reported by Ozcan *et al* (2005).

4.4 Physicochemical, bioactive components, antioxidant activity, colour, mineral and FITR analysis of honey chili sauce

The honey chili sauce (Figure 4.5) was prepared using the dried CH-27 (green and red) and Punjab sindhuri (green and red). The samples were packed into glass containers and stored at room (10-38°C) and refrigeration (4±2°C) temperature. The samples were analyzed for physicochemical, phytochemical, colour, mineral and FTIR spectra with one month's interval.



Fig. 4.5 The samples depicts as: Glass: 1= Honey chili sauce containing CH-27 green, 2= Honey chili sauce containing CH-27 red 3= Honey chili sauce containing Punjab sindhuri green 4= Honey chili sauce containing Punjab sindhuri red

4.4.1 Effect of storage period and temperature on total soluble solids (°Brix) of honey chili sauce

The total soluble solids (°Brix) of stored honey chili sauce are represented in Table 4.12. During the initial time, the TSS of the samples ranged from 68 to 68.08°Brix. There was non-significant difference in the individual TSS of stored samples even after 8 months of storage. The maximum mean value for TSS of honey chili sauce after 8 months of storage was for Punjab sindhuri red and CH-27 green samples followed by CH-27 red and Punjab sindhuri green. The effect of the month storage and variety (CH-27 and Punjab sindhuri) was found to be significant ($p \leq 0.05$) while the effect of storage condition (room and refrigeration temperature) was non-significant as evident from the data in Table 4.12. As explained by Singh *et al* (2006), the presence of acid cause the solubilisation of insoluble constituents that results in slight increase in the total soluble solids content of the stored product.

4.4.2 Effect of storage period and temperature on total solids (%) of honey chili sauce

The data including total solids per cent of honey chili sauce with CH-27 and Punjab sindhuri chili varieties are represented in Table 4.13. The initial total solids were in the range of 81.67 to 87.57 per cent. The maximum total solids were in Punjab sindhuri red samples (87.57%), while the minimum for CH-27 green (81.67%). The overall mean total solids of all samples varied significantly ($p \leq 0.05$). Overall mean total solids were highest in honey chili sauce with Punjab sindhuri red (84.93%) followed by CH-27 green (82.70%), Punjab sindhuri green (82.41%) and CH-27 red (81.72%). Monthly, the mean values for the total solids at 0, 2, 4 and 6th month varied non-significantly while at 8th month, the values were significantly ($p \leq 0.05$) varied. As evident from the data of Table 4.13, a significant ($p \leq 0.05$) effect of month, variety and storage condition on the total solids were observed. Loss of moisture or solubilisation of product constituents during storage might be related with the increased total solids during storage (Lakhanpal Vaidya 2015).

4.4.3 Effect of storage period and temperature on pH of honey chili sauce

The data regarding pH of stored honey chili sauce is depicted in Table 4.14. The pH values of all samples were in the range of 3.80 to 3.98. During storage, a significant ($p \leq 0.05$) decrease in the pH value of all samples was notified. Statistically, the maximum mean pH value was observed in Punjab sindhuri red (2.98) followed by Punjab sindhuri green (2.90), CH-27 red (2.89) and CH-27 green (2.74). Monthly, the pH value varies significantly ($p \leq 0.05$). The maximum pH value was observed at 0 month of storage (3.85) followed by second month (2.77), third month (2.66). The pH value of sixth and eighth month of storage varied non-significantly. As per the review of Evahelda *et al* (2017), pH variation in the stored product is due to the reduction of solids in salts or bases. Also during storage, the glucose and fructose converts to carbon dioxide and alcohol that further hydrolyzed to oxygen and acetic acid results in the reduction in pH value.

Table 4.12: Effect of storage period, storage condition and chili variety on total soluble solid (°Brix) of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	68±3.4 ^{aM}	69±1.00 ^{aM}	69.5±1.36 ^{aM}	70±1.00 ^{aM}	68.9± 0.64291 ^{aM}	69.42±1.16^X	69.09±4.1^{wx}
	Refrigeration temperature	68±3.4 ^{aN}	68.8±1.1 ^{aMN}	69±0.75 ^{aMN}	70±0.87 ^{aM}	69±1.00 ^{aMN}	68.77±1.38^Y	
CH 27 RED	Room temperature	68±4.08 ^{aM}	68.3±0.55 ^{aM}	69±1.36 ^{aM}	69.5±0.61 ^{aM}	68.6±1.050 ^{aM}	68.83±1.07^X	68.81±4.1^y
	Refrigeration temperature	68±0.5 ^{aM}	68.1±1.0 ^{aN}	69±0.288 ^{aMN}	70.5±1.1 ^{aM}	68.5±0.95 ^{aMN}	68.78±1.23^Y	
PS GREEN	Room temperature	68±0.76 ^{aM}	68.3±.50 ^{aM}	68.8±0.84 ^{aM}	69±0.87 ^{aM}	68.5±2.6 ^{aM}	68.49±0.83^Y	68.71±5.4^z
	Refrigeration temperature	68±0.7 ^{aM}	68.3±0.65 ^{aM}	68.8±0.83 ^{aM}	69.5±0.55 ^{aM}	68.5±0.96 ^{aM}	68.93±0.93^X	
PS RED	Room temperature	68±1.52 ^{aM}	69±0.70 ^{aM}	69.5±1.05 ^{aM}	70.5±0.70 ^{aM}	69.2±1.30 ^{aM}	69.28±1.3^Y	69.43±4.2^w
	Refrigeration temperature	68±0.3 ^{Am}	69±1.05 ^{aM}	69.4±0.602 ^{aM}	70.6±0.62 ^{aM}	69.1±0.85 ^{aM}	69.58±0.89^X	
	Total	68.08±1.10^C	68.84±1.04^B	69.16±0.92^B	70.07±0.79^A	68.90±0.93^B		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; °B*= Degree Brix; Values in a column and row of table with different superscripts differ significantly where w,x,y,z= Overall effect of conditions on chili variety; X,Y= effect of storage condition; a,b,c....=effect within month; A,B,C...= Overall effect of month storage; M,N,O,P= Month v/s month.								

CD_(0.05)

Month= <.001; Storage condition=NS; Variety=.018; Month * Storage condition=NS; Month * Variety=NS; Storage condition * Variety=NS; Month * Storage condition * Variety= NS

Table 4.13: Effect of storage period, storage condition and chili variety on total solids (%) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	81.67±1.05 ^{bNO}	83.79±1.02 ^{bMN}	85±1.00 ^{aM}	81.56±1.02 ^{aNO}	80.25±0.65 ^{aO}	82.42±1.92 ^Y	82.70±2.76 ^x
	Refrigeration temperature	81.67±1.18 ^{bNO}	89.13±0.99 ^{aM}	80.09±0.80 ^{dO}	83.1±1.24 ^{aN}	81±1.0 ^{aNO}	83.00±3.45 ^X	
CH 27 RED	Room temperature	82.85±1.03 ^{bMN}	80.75±0.47 ^{bMN}	83.31±1.00 ^{abcM}	81.96±0.95 ^{aMN}	80.25±0.64 ^{aMN}	81.30±1.24 ^Y	81.72±1.33 ^y
	Refrigeration temperature	82.85±1.00 ^{bM}	80.17±0.051 ^{bN}	81.18±1.10 ^{bcdMN}	83.08±0.98 ^{aM}	80.95±1.01 ^{aMN}	81.61±1.43 ^X	
PS GREEN	Room temperature	82.48±1.02 ^{bN}	80.18±0.59 ^{bM}	84.4±1.05 ^{aMN}	82.79±1.34 ^{aN}	81.05±0.99 ^{aN}	81.78±1.78 ^Y	82.41±1.64 ^{xy}
	Refrigeration temperature	82.85±1.00 ^{bM}	80.17±0.051 ^{bM}	81.18±1.10 ^{bcdM}	83.08±0.98 ^{aM}	80.95±1.01 ^{aM}	82.38±1.49 ^X	
PS RED	Room temperature	87.57±0.966 ^{aM}	88.06±4.71 ^{abM}	80.34±0.67 ^{cdM}	84.39±0.97 ^{aM}	81.75±0.96 ^{aM}	82.46±2.78 ^Y	84.49±5.06 ^w
	Refrigeration temperature	87.57±1.04 ^{aMN}	85.22±1.11 ^{abM}	85.62±0.95 ^{aMN}	84.38±1.1 ^{aNO}	82.68±0.99 ^{aO}	83.73±2.02 ^X	
	Total	83.50±2.64 ^A	83.49±3.29 ^A	83.07±2.1 ^A	82.93±1.34 ^A	81.17±1.03 ^B		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C,...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=.022; Variety= <.001; Month * Storage condition= .015; Month * Variety= <.001; Storage condition* Variety=NS;
Month * Storage condition* Variety= <.001

Table 4.14: Effect of storage period, storage condition and chili variety on pH of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	3.83±0.03 ^{aM}	2.54±0.08 ^{dN}	2.51±0.05 ^{bcN}	2.49±0.01 ^{bcN}	2.46±0.04 ^{bcN}	2.76±0.55 ^X	2.74±0.16 ^y
	Refrigeration temperature	3.83±0.06 ^{aM}	2.63±0.07 ^{cdN}	2.5±0.10 ^{cNP}	2.37±0.05 ^{cP}	2.35±0.041 ^{cP}	2.73±0.58 ^Y	
CH 27 RED	Room temperature	3.96±0.2 ^{aM}	2.76±0.07 ^{bcN}	2.74±0.065 ^{aN}	2.59±0.02 ^{bN}	2.55±0.035 ^{Bn}	2.87±0.479 ^Y	2.89±0.17 ^x
	Refrigeration temperature	3.96±0.05 ^{aM}	2.87±0.056 ^{abN}	2.69±0.052 ^{abcO}	2.59±0.10 ^{abO}	2.57±0.045 ^{abO}	2.94±0.54 ^X	
PS GREEN	Room temperature	3.8±0.07 ^{aM}	2.73±0.065 ^{bcN}	2.70±0.10 ^{abcNP}	2.56±0.04 ^{bP}	2.53±0.05 ^{bP}	2.86±0.499 ^Y	2.90±0.23 ^x
	Refrigeration temperature	3.8±0.10 ^{aM}	2.92±0.65 ^{abN}	2.73±0.070 ^{abP}	2.63±0.06 ^{abP}	2.61±0.05 ^{abP}	2.93±0.463 ^X	
PS RED	Room temperature	3.98±0.0435 ^{aM}	2.81±0.056 ^{abN}	2.72±0.65 ^{aP}	2.60±0.06 ^{abP}	2.57±0.03 ^{abP}	2.93±0.463 ^Y	2.98±0.24 ^w
	Refrigeration temperature	3.98±0.118 ^{aM}	2.97±0.041 ^{aN}	2.77±0.032 ^{aP}	2.76±0.05 ^{aP}	2.73±0.06 ^{aP}	3.01±0.476 ^X	
	Total	3.85±0.127^A	2.77±0.148^B	2.66±0.11^C	2.57±0.11^D	2.55±0.114^D		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month= <.001; Storage condition=.006; Variety=<.001; Month * Storage condition=.030; Month * Variety=.033; Storage condition * Variety= .020; Month * Storage condition* Variety= NS]

4.4.4 Effect of storage period and temperature on titratable acidity (%) of honey chili sauce

The titratable acidity (%) of honey chili sauce is presented in Table 4.15. During the storage, a significant ($p \leq 0.05$) increase in the titratable acidity was observed. At the initial stage of storage, the titratable acidity of the samples was in the range of 0.82 to 2.30 per cent. The maximum mean value of titratable acidity per cent after 8 months of storage was for honey chili sauce sample with CH-27 green (2.60%) followed by CH-27 red (2.18%). For the Punjab sindhuri green and red, the values were 1.26 and 1.22 per cent respectively. For the storage condition, the samples stored at room temperature showed increase in titratable acidity in comparison to refrigerated stored samples. Monthly, the maximum mean titratable acidity was observed at 8 and 6th month of storage that vary non-significantly. As shown in Table 4.14 for titratable acidity, the effect of month storage and variety was significant ($p \leq 0.05$), while the effect of storage condition was non-significant. The variation in pH during storage results in the increase of titratable acidity. According to Evahelda *et al* (2017), during storage, some solids reduced to salts or bases results in the variation of product acidity.

4.4.5 Effect of storage period and temperature on total sugars (gm/100 gm) of honey chili sauce

The data representing the total sugars of honey chili sauce with dried CH-27 and Punjab sindhuri is depicted in Table 4.16. As shown in Table, the total sugar content of all samples was in the range of 58.50 to 63.27 gm/100 gm of the sample. The total sugar content of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 60.48, 63.27, 60.05 and 58.50 gm/100 gm respectively. A significant ($p \leq 0.05$) increase followed by decrease in the total sugar content of the samples was observed during the 8 months of storage. At 8th month of storage, the maximum total sugar content (67.54 gm/100 gm) was for honey chili sauce with Punjab sindhuri red stored at refrigeration conditions. According to overall mean value, the maximum total sugar content was in sample with Punjab sindhuri green (63.56gm/100 gm), followed by CH-27 green (62.90gm/100 gm), CH-27 red (61.74gm/100 gm) and Punjab sindhuri red (58.88gm/100 gm). Monthly, highest total sugar values was observed in 6th month of storage i.e. 69.19 gm/100 gm followed by 4th month of storage (65.74 gm/100 gm). As shown in Table 4.16, the effect of month and chili variety was significant, while the effect of storage condition was non-significant. Similar results were found by Islam *et al* (2013). The moisture loss of the product or the conversion of complex carbohydrates into simpler sugars during storage results in the higher concentration of the total sugars.

Table 4.15: Effect of storage period, storage condition and chili variety on titratable acidity (%) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	2.30±0.10 ^{aM}	2.0±0.90 ^{abM}	2.73±0.090 ^{aM}	2.94±0.060 ^{aM}	3.00±0.70 ^{aM}	2.63±0.60^X	2.60±0.437^w
	Refrigeration temperature	1.79±0.04 ^{bN}	1.85±0.04 ^{abcN}	2.3±0.10 ^{bcN}	2.54±0.050 ^{cM}	2.60±0.40 ^{bcM}	2.57±0.17^Y	
CH 27 RED	Room temperature	0.82±0.01 ^{cO}	1.1±0.11 ^{bcNO}	1.5±0.10 ^{dMN}	1.75±0.04 ^{dM}	1.79±0.047 ^{cdM}	2.19±0.37^X	2.18±0.19^x
	Refrigeration temperature	0.92±0.01 ^{cO}	0.99±0.14 ^{cO}	1.3±0.10 ^{deN}	1.32±0.090 ^{fNM}	1.35±0.045 ^{dM}	2.16±0.27^Y	
PS GREEN	Room temperature	2.3±0.1 ^a	2.43±0.06 ^{aO}	2.5±0.10 ^{abN}	2.75±0.04 ^{bM}	2.79±0.036 ^{bM}	1.39±0.39^X	1.26±0.39^y
	Refrigeration temperature	1.79±0.02 ^{bO}	1.94±0.06 ^{abN}	2.26±0.090 ^{cN}	2.40±0.10 ^{cM}	2.45±0.045 ^{bcM}	1.14±0.20^Y	
PS RED	Room temperature	0.82±0.03 ^{cN}	1.13±0.10 ^{bcN}	1.16±0.055 ^{eM}	1.31±0.030 ^{fM}	1.35±0.040 ^{dM}	1.17±0.290^X	1.22±0.23^y
	Refrigeration temperature	0.92±0.025 ^{cP}	1.06±0.22 ^{bcN}	1.32±0.037 ^{deN}	1.52±0.035 ^{eM}	1.57±0.030 ^{dM}	1.12±0.25 ^Y	
	Mean	1.47±0.66^C	1.56±0.59^C	1.87±0.60^B	2.06±0.635^A	2.11±0.70^A		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month= <.001; Storage condition=NS; Variety=<.001; Month * Storage condition=.028; Month * Variety=NS; Storage condition * Variety= .015; Month * Storage condition* Variety= NS

Table 4.16: Effect of storage period, storage condition and chili variety on total sugars (gm/100 gm) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	60.48±1.01 ^{bN}	62.72±1.04 ^{abcN}	66.47±1.01412 ^{aM}	62.93±2.12 ^{abN}	60.26±1.04 ^{abN}	62.62±2.34 ^Y	62.90±2.47 ^x
	Refrigeration temperature	60.48±1.01 ^{bN}	63.22±1.15 ^{abcMN}	68.59±1.69 ^{aM}	65.68±2.81 ^{abMN}	63.24±0.95 ^{abN}	63.18±2.64 ^X	
CH 27 RED	Room temperature	63.27±1.00 ^{aM}	63.34±0.95 ^{abM}	64.50±0.94 ^{aM}	58.31±1.27 ^{bN}	55.24±1.002 ^{bO}	60.98±3.69 ^Y	61.74±3.81 ^x
	Refrigeration temperature	63.27±1.00 ^{aM}	63.85±1.00 ^{aM}	68.77±2.69 ^{aM}	66.05±4.48 ^{abM}	65.54±5.90 ^{abM}	62.51±3.907 ^X	
PS GREEN	Room temperature	60.05±0.911 ^{bO}	59.70±1.01 ^{cO}	66.62±1.06 ^{aMN}	68.53±1.006 ^{aM}	65.55±1.00 ^{aN}	64.02±3.75 ^X	63.56±3.80 ^w
	Refrigeration temperature	60.05±0.911 ^{bMN}	59.78±1.02 ^{bcN}	64.14±1.67 ^{aMN}	62.06±3.76 ^{abM}	60.55±3.06 ^{abMN}	63.10±3.49 ^Y	
PS RED	Room temperature	58.50±0.925 ^{cO}	56.66±2.01 ^{dO}	65.83±3.01 ^{aM}	61.11±1.00 ^{abMN}	59.45±0.99 ^{abN}	58.41±1.36 ^Y	58.88±4.70 ^y
	Refrigeration temperature	58.50±0.925 ^{cNO}	57.17±2.06 ^{dO}	63.36±3.21 ^{aM}	69.07±4.56 ^{abN}	67.54±4.82 ^{abMN}	59.35±6.15 ^X	
	Mean	59.37±3.798^D	59.47±4.49^D	65.74±1.944^A	69.19±3.87^B	61.09±3.94^C		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=<.001; Month * Storage condition=NS; Month * Variety=<.001; Storage condition * Variety=NS; Month * Storage condition * Variety=NS

4.4.6 Effect of storage period and temperature on reducing sugars (gm/100 gm) of honey chili sauce

The reducing sugar content (gm/100 gm) of honey chili sauce containing dried CH-27 and Punjab sindhuri is represented in Table 4.17. The values regarding total sugars of all samples ranged from 46.37 to 54.29 gm/100 gm. The maximum reducing sugar at initial stage was observed in Punjab sindhuri green while lowest for red form of both varieties. A significant ($p \leq 0.05$) increase in reducing sugars up to 4th month of storage was observed after that a significant ($p \leq 0.05$) decrease in the reducing sugars up to 8th month of storage was observed. Similar results were observed by Fei *et al* 2015. The overall mean reducing sugars were found to be highest in sample with Punjab sindhuri green (55.20 gm/100 gm) followed by CH-27 green (54.03 gm/100 gm), CH-27 green (52.87 gm/100 gm) and Punjab sindhuri red (50.29 gm/100 gm). Monthly, the maximum reducing sugars was observed at 4th month of storage (58.49 gm/100 gm) followed by 6th month storage (52.90 gm/100 gm). The individual effect of month storage, storage condition and variety Table 4.23, was significant ($p \leq 0.05$).

4.4.7 Effect of storage period and temperature on viscosity (cP) of honey chili sauce

The data representing the viscosity of honey chili sauce with CH-27 and Punjab sindhuri chili varieties is depicted in Table 4.18. The viscosity (cP) of all samples was in the range of 12500 to 12750. A significant ($p \leq 0.05$) increase in the viscosity of all samples was observed at both storage conditions. At 8th month of storage, the highest viscosity (19965 cP) was observed for honey chili sauce with Punjab sindhuri green stored at refrigeration condition followed by CH-27 red (19649 cP). The lowest value for the viscosity was observed for CH-27 green and Punjab sindhuri red. The overall value for the viscosity was significantly higher in honey chili sauce with CH-27 green (15270 cP) followed by Punjab sindhuri green (15114 cP), Punjab sindhuri red (14901 cP) and CH-27 red (14881 cP). According to monthly values, the maximum and minimum viscosity was observed at 8th and 0th month of storage. As shown in Table 4.18, the effect of month, variety and storage condition was significant ($p \leq 0.05$). Hydrogen bond strength and intermolecular spacing due to the intermolecular forces between molecules and water solutes intensely dependent on the concentration and temperature and strongly influenced the viscosity of the product. An increment in total solids due to moisture loss during storage results in hydrated molecules and hydrogen bonding with hydroxyl group of solutes elevation that result in an increased viscosity of product (Sharma *et al* 2014).

4.4.8 Effect of storage period and temperature on water activity of honey chili sauce

The data representing the water activity (a_w) of honey chili sauce with dried CH-27 and Punjab sindhuri is depicted in Table 4.19. As depicted in Table, the water activity (a_w) content of all samples was in the range of 0.781 to 0.797. Initially, the water activity (a_w)

Table 4.17: Effect of storage period, storage condition and chili variety on reducing sugars (gm/100 gm) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	51.93±1.01 ^{bN}	52.04±0.055 ^{eN}	59.37±1.42 ^{abM}	53.46±0.02 ^{dN}	52.56±0.035 ^{eN}	53.91±3.04 ^Y	54.03±4.3 ^x
	Refrigeration temperature	54.29±0.065 ^{aP}	54.53±0.0055 ^{aO}	57.88±0.11 ^{bcdM}	42.4±0.02 ^{fN}	40.55±0.030 ^{gO}	54.15±3.11 ^x	
CH 27 RED	Room temperature	52.88±0.58 ^{bN}	53.02±0.056 ^{bN}	59.56±0.10 ^{abM}	57.9±0.80 ^{aO}	55.65±0.027 ^{aP}	49.92±7.29 ^Y	52.87±3.7 ^y
	Refrigeration temperature	46.37±0.045 ^{cN}	46.39±0.085 ^{fN}	59.29±0.065 ^{bcM}	54.98±0.01 ^{bcM}	52.65±0.04 ^{eN}	55.83±1.48 ^x	
PS GREEN	Room temperature	51.93±0.0755 ^{bP}	52.28±0.075 ^{dP}	59.9±0.15 ^{aM}	54.29±0.03 ^{cdN}	52.34±0.03 ^{fO}	55.8±2.74 ^x	55.20±3.3 ^w
	Refrigeration temperature	54.29±0.045 ^{aO}	54.59±0.075 ^{aO}	57.9±1.09 ^{cdM}	57.55±0.020 ^{aN}	55.34±0.035 ^{bN}	54.61±1.84 ^Y	
PS RED	Room temperature	52.88±0.035 ^{bP}	52.73±0.06 ^{cP}	57.75±0.81 ^{cdM}	55.43±0.025 ^{bN}	54.59±0.036 ^{dO}	51.93±5.186 ^x	50.29±4.0 ^z
	Refrigeration temperature	46.37±0.050 ^{cP}	46.18±0.050 ^{gQ}	56.89±0.01 ^{dM}	47.24±0.020 ^{eN}	46.65±0.040 ^{dO}	48.66±4.27 ^Y	
	Mean	51.37±3.084 ^C	51.45±3.18 ^C	58.49±1.297 ^A	52.90±5.137 ^B	51.29±4.94 ^C		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4.18: Effect of storage period, storage condition and chili variety on viscosity (cP) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	12500±500.00 ^{bQ}	12900±500.00 ^{bP}	15500±500.08 ^{aO}	17750±160.07 ^{aN}	19545±7.637 ^{cM}	15641±819.85 ^X	15270±763.5 ^w
	Refrigeration temperature	12750±500.0 ^{aP}	12750±462.00 ^{cO}	13750±600.55 ^{efO}	17000±445.50 ^{bcN}	18265±500.00 ^{gM}	14900±344.69 ^Y	
CH 27 RED	Room temperature	12500±500.00 ^{bP}	13500±480.55 ^{aP}	15000±500.0 ^{bO}	16750±710.121 ^{cdM}	18598±281.307 ^{fM}	14903±379.79 ^X	14881±1190.3 ^y
	Refrigeration temperature	12500±470.52 ^{bQ}	12750±590.23 ^{cP}	14000±470.52 ^{cO}	17500±300.1 ^{abN}	19649±500.00 ^{bM}	14859±754 ^Y	
PS GREEN	Room temperature	12500±470.03 ^{bQ}	12000±300.41 ^{gP}	12500±460.45 ^{gO}	17500±400.10 ^{abN}	19965±100.00 ^{aM}	15262±263 ^X	15114±1209 ^x
	Refrigeration temperature	12750±500.50 ^{aP}	12250±600.02 ^{fP}	13500±400.10 ^{fo}	16500±500.08 ^{cdN}	19288±300.055 ^{dM}	14966±603.68 ^Y	
PS RED	Room temperature	12500±510.11 ^{bQ}	12750±555.1 ^{cP}	14250±620.11 ^{cO}	16000±558.621 ^{deN}	19287±400.58 ^{eM}	15274±926.0 ^X	14901±894.0 ^z
	Refrigeration temperature	12500±520.99 ^{bP}	12500±380.03 ^{eP}	14000±272.50 ^{eO}	15500±500.08 ^{eN}	18254±400.50 ^{gM}	14527±244.50 ^Y	
	Mean	12564±115.52 ^E	12675±429.83 ^D	14045±876.13 ^C	16820±774.134 ^B	19104±625.42 ^A		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; cP= centipoise ; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4.19: Effect of storage period, storage condition and chili variety on water activity (a_w) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	0.784±0.0213 ^{aM}	0.730±0.01 ^{cN}	0.682±0.010 ^{dO}	0.654±0.0100 ^{aO}	0.62±0.010 ^{bP}	0.69±0.05^Y	0.71±0.051^y
	Refrigeration temperature	0.784±0.007 ^{aM}	0.763±0.009 ^{abcMN}	0.742±0.022 ^{abNO}	0.712±0.011 ^{aOP}	0.70±0.010 ^{aP}	0.73±0.03^X	
CH 27 RED	Room temperature	0.797±0.025 ^{aM}	0.754±0.010 ^{abcM}	0.702±0.007 ^{bcdN}	0.647±0.0087 ^{aO}	0.62±0.012 ^{bO}	0.70±0.06^X	0.72±0.056^{wx}
	Refrigeration temperature	0.797±0.010 ^{aM}	0.776±0.010 ^{aMN}	0.745±0.026 ^{abNO}	0.726±0.012 ^{aO}	0.71±0.010 ^{aO}	0.74±0.03^Y	
PS GREEN	Room temperature	0.788±0.035 ^{aM}	0.746±0.010 ^{bcMN}	0.695±0.008 ^{cdNO}	0.658±0.010 ^{aNP}	0.62±0.011 ^{bP}	0.70±0.06^Y	0.72±0.052^{xy}
	Refrigeration temperature	0.788±0.007 ^{aM}	0.762±0.009 ^{abM}	0.735±0.009 ^{abcM}	0.715±0.012 ^{aNO}	0.705±0.01041 ^{aO}	0.73±0.03^X	
PS RED	Room temperature	0.781±0.010 ^{aM}	0.768±0.014 ^{abcM}	0.712±0.010 ^{abcdN}	0.671±0.012 ^{aO}	0.650±0.009 ^{bO}	0.71±0.05^Y	0.732±0.045^w
	Refrigeration temperature	0.781±0.10 ^{aM}	0.788±0.0157 ^{aM}	0.752±0.010 ^{aN}	0.723±0.0020 ^{aO}	0.715±0.0125 ^{aO}	0.75±0.03^X	
	Mean	0.784±0.060^A	0.75±0.0189^B	0.72±0.027^C	0.68±0.033^D	0.668±0.042^E		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=NS; Storage condition* Variety=NS; Month * Storage condition* Variety=NS

content of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 0.784, 0.797, 0.788 and 0.781 respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the water activity (a_w) content of the samples was observed. At 8th month of storage, the maximum water activity (a_w) content was for honey chili sauce with CH-27 green, CH-27 red and Punjab sindhuri green stored at refrigeration conditions. According to overall mean value, the maximum water activity (a_w) content was for sample with Punjab sindhuri red (0.732), followed by Punjab sindhuri green (0.720), CH-27 red (0.720) and Punjab sindhuri red (0.710). The overall mean values for CH-27 red and Punjab sindhuri green was non-significantly different. Monthly, highest water activity (a_w) values was observed in initial stage of storage i.e. 0.784 followed by 2nd month of storage 0.750 and for 8th month, the mean value was 0.668. As shown in Table 4.19, the effect of month, variety and storage condition was significant ($p \leq 0.05$).

4.4.9 Effect of storage period and temperature on ash content (%) of honey chili sauce

The Table 4.20 representing the ash content (%) of honey chili sauce with dried CH-27 and Punjab sindhuri. The ash content (%) content of all samples was in the range of 2.41 to 2.45. Initially, the ash content (%) of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 2.41-2.45, 2.26-2.35, 2.33-2.24 and 2.41-2.45 per cent respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) increase in the ash content (%) content of the samples was observed. According to overall mean value, the maximum ash content (%) was for honey chili sauce with Punjab sindhuri red (2.86%), followed by Punjab sindhuri green (2.74%). The overall mean ash content of CH-27 green and red showed non-significant difference. Monthly, highest ash content of 3.12 percent was observed at 8th month of storage. As shown in Table 4.20, the individual effect of month, storage condition and variety was significant ($p \leq 0.05$). The evaporation or loss of moisture during the storage might results in the ash content increment.

4.4.10 Effect of storage period and temperature on electrical conductivity ($\mu\text{S/cm}$) of honey chili sauce

The data representing the electrical conductivity ($\mu\text{S/cm}$) of honey chili sauce with dried CH-27 and Punjab sindhuri is depicted in Table 4.21. As depicted in Table, the electrical conductivity ($\mu\text{S/cm}$) content of all samples was in the range 2.20-2.95 $\mu\text{S/cm}$. Initially, the electrical conductivity ($\mu\text{S/cm}$) content of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 2.20, 2.61, 2.95 and 2.75 $\mu\text{S/cm}$ respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) increase in the electrical conductivity ($\mu\text{S/cm}$) content of the samples was observed. According to overall mean value, the maximum electrical conductivity ($\mu\text{S/cm}$) content was for honey chili sauce with Punjab sindhuri green (3.36 $\mu\text{S/cm}$), followed by

Table 4.20: Effect of storage period, storage condition and chili variety on ash content (%) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	2.41±0.146 ^{aN}	2.45±0.11 ^{aN}	2.55±0.010 ^{cN}	2.88±0.10 ^{abM}	3.00±0.064 ^{aM}	2.66±0.26 ^Y	2.68±0.244 ^y
	Refrigeration temperature	2.45±0.105 ^{aO}	2.54±0.10 ^{aO}	2.62±0.10 ^{cNO}	2.88±0.07 ^{bMN}	3.00±0.07 ^{aM}	2.70±0.23 ^X	
CH 27 RED	Room temperature	2.26±0.080 ^{aO}	2.36±0.11 ^{aO}	2.63±0.010 ^{cN}	2.86±0.08 ^{abMN}	2.99±0.13 ^{aM}	2.61±0.30 ^X	2.67±0.301 ^y
	Refrigeration temperature	2.35±0.100 ^{aN}	2.49±0.30 ^{aN}	2.94±0.12 ^{abM}	2.86±0.01 ^{abM}	3.05±0.08 ^{aM}	2.47±0.29 ^Y	
PS GREEN	Room temperature	2.33±0.110 ^{aN}	2.37±0.11 ^{aN}	2.73±0.10 ^{bcN}	2.99±0.12 ^{abMN}	3.15±0.10 ^{aM}	2.71±0.34 ^Y	2.74±0.378 ^x
	Refrigeration temperature	2.24±0.10 ^{aN}	2.42±0.01 ^{aN}	2.98±0.11 ^{abM}	2.99±0.169 ^{abM}	3.26±0.131 ^{aM}	2.78±0.41 ^X	
PS RED	Room temperature	2.41±0.10 ^{aN}	2.49±0.122 ^{aN}	3.01±0.07 ^{aM}	3.11±0.11 ^{abM}	3.26±0.10 ^{aM}	2.85±0.36 ^Y	2.86±0.349 ^w
	Refrigeration temperature	2.45±0.11 ^{aO}	2.52±0.01 ^{aO}	2.91±0.12 ^{abN}	3.11±0.063 ^{aMN}	3.29±0.10 ^{aM}	2.87±0.34 ^X	
	Mean	2.365±0.124 ^E	2.44±0.99 ^D	2.81±0.20 ^C	2.966±1433 ^B	3.12±0.136 ^A		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=NS; Month * Variety=<.001; Storage condition* Variety=NS; Month * Storage condition* Variety= NS

Table 4.21: Effect of storage period, storage condition and chili variety on electrical conductivity ($\mu\text{S}/\text{cm}$) analysis of honey chili sauce

Storage period (months)								
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	2.20±0.100 ^{bO}	2.40±0.18 ^{cO}	2.58±0.085 ^{cO}	2.96±0.140 ^{dN}	3.10±0.12 ^{deM}	2.67±0.36 ^X	2.64±0.31 ^z
	Refrigeration temperature	2.20±0.131 ^{bp}	2.47±0.01 ^{bOP}	2.62±0.10 ^{cNO}	2.78±0.11 ^{eMN}	2.96±0.08 ^{eM}	2.60±0.267 ^Y	
CH 27 RED	Room temperature	2.61±0.098 ^{aNO}	2.80±0.10 ^{bO}	2.97±0.19 ^{abNO}	3.19±0.111 ^{cdMN}	3.25±0.09 ^{dM}	2.69±0.176 ^Y	2.97±0.2707 ^y
	Refrigeration temperature	2.61±0.11 ^{aP}	2.85±0.04 ^{bOP}	2.96±0.140 ^{abNO}	3.16±0.100 ^{cdMN}	3.35±0.01 ^{cdM}	2.99±0.2655 ^X	
PS GREEN	Room temperature	2.95±0.121 ^{aO}	3.17±0.01 ^{aO}	3.38±0.1677 ^{aO}	3.67±0.11 ^{aN}	3.85±0.15 ^{aM}	3.38±0.34 ^X	3.36±0.3308 ^w
	Refrigeration temperature	2.95±0.20 ^{aP}	3.14±0.13 ^{aOP}	3.35±0.169 ^{aNO}	3.56±0.100 ^{abMN}	3.79±0.06 ^{abM}	3.33±0.32 ^Y	
PS RED	Room temperature	2.75±0.10 ^{aP}	2.92±0.01 ^{abOP}	3.10±0.10 ^{aNO}	3.29±0.105 ^{bcdN}	3.52±0.10 ^{bcM}	3.31±0.28 ^X	3.16±0.3236 ^x
	Refrigeration temperature	2.75±0.100 ^{aO}	2.95±0.136 ^{abO}	3.20±0.109 ^{aN}	3.42±0.055 ^{avcN}	3.72±0.01 ^{abM}	3.21±0.35 ^Y	
	Mean	2.646±0.28 ^E	2.845±0.27 ^D	3.01±0.29 ^C	3.24±0.29 ^B	3.43±0.31 ^A		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C,...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=<.001; Month * Storage condition=NS; Month * Variety=NS; Storage condition* Variety=.021; Month * Storage condition* Variety=NS

Punjab sindhuri red (3.16 $\mu\text{S}/\text{cm}$), CH-27 red (2.97 $\mu\text{S}/\text{cm}$) and CH-27 green (2.64 $\mu\text{S}/\text{cm}$). Monthly, highest electrical conductivity ($\mu\text{S}/\text{cm}$) values was observed at 8th month i.e. 3.43 $\mu\text{S}/\text{cm}$. As data depicted in Table 4.21 showed that the individual effect of month and variety was significant ($p \leq 0.05$), while the effect of storage condition was non-significant. The electrical conductivity of the sample is related to the presence of ash and acid content. The outcomes of the present investigation are in line with as reported by Qamar *et al* (2013)

4.4.11 Effect of storage period and temperature on colour *L* value of honey chili sauce

The *L* value of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.22. The *L* value of all samples was varied from range 24.79 to 31.83. The *L* value of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 31.83, 28.18, 30.44 and 24.79, respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the lightness was observed that means samples become little dark during the storage of samples. After 6th months of storage, a significant ($p \leq 0.05$) decrease in the *L* value of sample was observed. As observed in the overall mean value, the maximum *L* value was for honey chili sauce with CH-27 green (3.43), followed by CH-27 red (28.81), Punjab sindhuri green (26.61) and Punjab sindhuri red (24.40). Monthly, the highest and lowest *L* value was at 6th and 8th months of storage i.e. 28.84 and 27.56 respectively. Statistically, the individual effect of month, storage condition and variety was significant ($p \leq 0.05$) (Table 4.22).

4.4.12 Effect of storage period and temperature on colour *a* value of honey chili sauce

The *a* value (colour analysis) of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.23. The *a* value depicts the redness of samples if it is positive and greenness if it is negative. The *a* value of all samples was varied from range 1.67 to 4.1. The *a* value of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 2.32, 4.1, 1.67 and 3.15 respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) increase followed by decrease in *a* value was observed. As observed in the overall mean value, the *a* value for honey chili sauce with red form of both varieties was depicted non-significant difference, but green form of both varieties showed significant different. The value for the honey chili sauce with CH-27 green and Punjab sindhuri green was 2.94 and 1.47 respectively. The effect of month, storage condition and variety on color *a* value was found to be significant ($p \leq 0.05$).

4.4.13 Effect of storage period and temperature on colour *b* value of honey chili sauce

The *b* value of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.24. The *b* value depicts the yellowness of samples if it is positive and blueness if it is negative. The *b* value of all samples was varied from range -0.26 to 7.74. The *b* value of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 7.74, 4.15, 6.07 and -0.26 respectively. During storage, a significant

Table 4.22: Effect of storage period, storage condition and chili variety on color analysis (L value) of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	31.83±1.17 ^{aM}	32.79±1.06 ^{aM}	32.41±1.04 ^{aM}	32.79±1.17 ^{aM}	31.79±1.11 ^{aM}	32.12±1.04 ^Y	32.2417±1.11 ^w
	Refrigeration temperature	31.83±1.17 ^{aM}	32.3±0.76 ^{aM}	33.67±0.84 ^{aM}	32.67±1.33 ^{aM}	31.67±1.04 ^{aM}	32.36±1.21 ^X	
CH 27 RED	Room temperature	28.18±1.11 ^{aN}	34.29±1.11 ^{aM}	26.33±0.79 ^{bN}	34.29±0.67 ^{aM}	32.29±1.198 ^{aM}	31.23±3.42 ^X	28.81±3.56 ^x
	Refrigeration temperature	28.18±1.11 ^{aM}	25.98±0.97 ^{bcMN}	25.68±0.91 ^{bN}	26.68±1.17 ^{bMN}	25.68±0.90 ^{bcN}	26.38±1.42 ^Y	
PS GREEN	Room temperature	30.44±1.05 ^{aM}	23.41±1.1 ^{cMO}	26.34±1.007 ^{bN}	25.41±0.79 ^{bNO}	24.41±0.86 ^{bcNO}	26.08±2.61 ^Y	26.61±2.56 ^y
	Refrigeration temperature	30.44±1.05 ^{aM}	28.27±1.01 ^{bMN}	26.42±0.94 ^{bN}	26.41±1.17 ^{bN}	23.41±0.82 ^{cO}	27.14±2.49 ^X	
PS RED	Room temperature	24.79±1.28 ^{bMN}	23.55±1.34 ^{cN}	26.2±0.927 ^{bM}	26±1.06 ^{bMN}	24±1.03 ^{bcMN}	24.92±1.58 ^Y	24.40±1.45 ^z
	Refrigeration temperature	24.79±1.28 ^{bM}	25.44±1.07 ^{bcM}	26.33±0.95 ^{bM}	26.33±0.98 ^{bM}	26.33±0.86 ^{bM}	25.88±1.17 ^X	
	Mean	28.72±2.90 ^{AB}	28.19±4.27 ^{ABC}	28.0017±3.139 ^{BC}	28.84±3.59 ^A	27.56±3.621 ^D		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month; L* indicate lightness of the samples; 100 = white, 0 = black;								

CD_(0.05)

Month=<.001; Storage condition=0.01; Variety=<.001; Month * Storage condition=<.011; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4.23: Effect of storage period, storage condition and chili variety on color analysis (*a* value) of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	2.32±0.14 ^{cMN}	2.32±0.06 ^{dMN}	2.45±0.045 ^{dM}	2.4±0.057 ^{cMN}	2.2±0.10 ^{aM}	2.3±0.121 ^Y	2.98±0.97 ^x
	Refrigeration temperature	2.32±2.3 ^{cN}	2.48±0.01 ^{dN}	4.58±0.045 ^{cM}	4.5±0.40 ^{bM}	4.2±0.10 ^{Am}	3.6±1.03 ^X	
CH 27 RED	Room temperature	4.1±0.09 ^{aO}	4.7±0.10 ^{cN}	4.88±0.02 ^{bMN}	4.8±0.036 ^{abM}	4.5±0.20 ^{aM}	4.59±0.31 ^Y	4.48±0.51 ^w
	Refrigeration temperature	4.1±4.1 ^{aO}	5.15±0.00 ^{aN}	5.5±0.10 ^{aM}	5.45±0.27 ^{bMN}	5.35±0.07 ^{aMN}	5.10±0.54 ^X	
PS GREEN	Room temperature	1.67±1.6 ^{dM}	1.67±0.03 ^{eM}	0.73±0.055 ^{fM}	0.73±0.040 ^{dM}	0.7±4.24 ^{aM}	1.57±1.82 ^X	1.47±1.30 ^y
	Refrigeration temperature	1.67±1.6 ^{dM}	1.12±0.02 ^{fM}	1.44±0.055 ^{eM}	1.4±0.40 ^{dM}	1.2±0.60 ^{aM}	1.37±0.33 ^Y	
PS RED	Room temperature	3.15±3.1 ^{bN}	5.12±0.09 ^{abM}	5.05±0.060 ^{bM}	4.98±0.051 ^{abM}	4.95±0.035 ^{aM}	4.64±0.77 ^Y	4.84±0.867 ^w
	Refrigeration temperature	3.15±3.1 ^{bO}	4.98±0.02 ^{bN}	5.65±0.055 ^{aM}	5.6±0.36 ^{aM}	5.4±0.20 ^{aN}	4.93±0.95 ^X	
	Mean	2.81±0.94 ^D	3.44±1.62 ^C	1.86±0.381 ^E	3.72±1.82 ^B	3.85±1.94 ^A		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C,...= Overall month; M,N,O,P= Month v/s month; a* designate redness when positive; greenness when negative;								

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=<.001; Month * Storage condition=<.017; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=NS

Table 4.24: Effect of storage period, storage condition and chili variety on color analysis (*b* value) of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	7.74±0.045 ^a	10.22±0.055 ^a	7.75±0.04 ^b	7.7±0.20 ^b	7.9±0.20 ^a	8.26±1.02 ^y	8.71±1.070 ^w
	Refrigeration temperature	7.74±0.045 ^a	8.46±0.03055 ^b	10.02±0.056 ^a	9.89±0.049 ^a	9.75±0.03055 ^a	9.17±0.93 ^x	
CH 27 RED	Room temperature	4.15±0.050 ^c	6.37±0.04 ^c	2.47±0.45 ^d	2.41±0.0305 ^c	2.35±0.04041 ^b	3.54±1.61 ^x	3.071±1.35 ^x
	Refrigeration temperature	4.15±0.050 ^c	1.94±0.030 ^f	2.01±0.058 ^e	2.45±0.045 ^c	2.4±0.10 ^b	2.59±0.83 ^y	
PS GREEN	Room temperature	6.07±0.056 ^b	3.72±0.055 ^d	0.65±0.00 ^g	0.7±0.100 ^e	0.5±3.20 ^b	2.68±2.42 ^y	2.82±2.077 ^x
	Refrigeration temperature	6.07±0.056 ^b	3.44±0.0152 ^e	1.63±0.065 ^f	1.91±0.075 ^d	1.81±0.010 ^b	2.96±1.73 ^x	
PS RED	Room temperature	-0.26±0.040 ^d	3.66±0.0404 ^e	1.69±0.01 ^f	2±0.100 ^d	1.5±0.100 ^b	1.71±1.29 ^x	1.70±1.20 ^y
	Refrigeration temperature	-0.26±0.040 ^d	1.16±0.010 ^g	2.64±0.060 ^c	2.7±0.30 ^c	2.5±0.100 ^b	1.69±1.15 ^y	
	Mean	4.4250±3.05 ^B	4.87±3.04 ^A	3.61±3.2210 ^E	3.68±3.10 ^D	3.8154±3.15 ^C		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month; b* represent yellowness when positive, blueness when negative.								

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

($p \leq 0.05$) increase followed by decrease in the b value was observed. As observed in the overall mean value, the b value for honey chili sauce with red form of CH-27 and Punjab sindhuri varieties was 3.07 and 1.70 respectively while for green form of CH-27 and Punjab sindhuri varieties showed significant different with value 8.71 and 2.82 respectively. The month storage and variety was found to have a significant ($p \leq 0.05$) effect on color b value but the effect of storage condition was non-significant (Table 4.24).

4.4.14 Effect of storage period and temperature on ascorbic acid (mg/100 gm) of honey chili sauce

The ascorbic acid content (mg/100 gm) of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.25. The ascorbic acid content (mg/100 gm) of all samples was varied from 6.1 to 6.9 mg/100 gm. The ascorbic acid (mg/100 gm) of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 6.1, 6.5, 6.4 and 6.9 mg/100 gm respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the ascorbic acid content (mg/100 gm) was observed. After 8 months of storage, the maximum ascorbic acid retention was observed in sample with Punjab sindhuri red variety followed by CH-27 red. According to overall mean value, the maximum ascorbic acid content (mg/100 gm) was for honey chili sauce with Punjab sindhuri red (5.54 mg/100 gm), followed by CH-27 red (5.32 mg/100 gm). The overall mean ascorbic acid content of green form of both varieties showed non-significant difference. Monthly, highest and lowest ascorbic acid content 6.48 and 4.44 mg/100 gm value was observed at initial and 8th month of storage respectively. Data shown in Table 4.25 depicted that the effect of month, storage condition and variety was significant ($p \leq 0.05$). Vitamin C is well known for its antioxidant and reducing properties but it is very sensitive towards light, oxygen, enzymes, pH, temperature etc. results in its reduction or oxidation. The results of the present study are in agreement with Kaur *et al* (2019).

4.4.15 Effect of storage period and temperature on total phenolics (mg/100 gm GAE) of honey chili sauce

The data representing the total phenolics of honey chili sauce is depicted in Table 4.26. The total phenolics content was in the range of 710.1 to 732.1 mg/100 gm of the sample. Initially, the total phenolics content of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 719.66, 732.1, 728.4 and 710.1 mg/100 gm GAE respectively. A significant ($p \leq 0.05$) decrease in the total phenolics content of the samples was observed during the 8 months of storage. At 8th month of storage, the maximum total phenolics content (625.5 mg/100 gm GAE) was for honey chili sauce with CH-27 green, CH-27 red and Punjab sindhuri green stored at refrigeration conditions. According to overall mean value, the maximum total phenolics content was in sample with CH-27 red (679.46 mg/100 gm GAE), followed by Punjab sindhuri green (677.35 mg/100 gm GAE), CH-

Table 4.25: Effect of storage period, storage condition and chili variety on ascorbic acid (mg/100 gm) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	6.1±0.15 ^{cM}	5±0.20 ^{cMN}	5.2±0.10 ^{aMNO}	4.23±0.185 ^{cdNO}	4.00±0.70 ^{bO}	4.730±0.88^Y	5.16±0.789^y
	Refrigeration temperature	6.1±0.10 ^{cM}	5.8±0.10 ^{aMN}	5.6±0.050 ^{aMN}	4.81±0.12 ^{abNO}	4.69±0.121 ^{aP}	5.25±0.70^X	
CH 27 RED	Room temperature	6.5±0.057 ^{abM}	5.5±0.15 ^{abMN}	5.12±0.10 ^{aNO}	4.51±0.122 ^{bcNO}	4.15±0.083 ^{bP}	4.98±0.83^Y	5.32±0.820^x
	Refrigeration temperature	6.5±0.10 ^{bM}	5.9±0.15 ^{aMN}	5.6±0.20 ^{aMN}	4.84±0.11 ^{abMN}	4.65±0.10 ^{aO}	5.31±0.80^X	
PS GREEN	Room temperature	6.4±0.10 ^{bcM}	5.3±0.10 ^{bcMN}	5.1±0.40 ^{aMN}	4.90±0.095 ^{abMN}	4.71±0.124 ^{aN}	5.12±0.68^X	5.14±70^y
	Refrigeration temperature	6.4±0.150 ^{bcM}	5.3±0.15 ^{bcMN}	5.13±0.10 ^{aNO}	4.12±0.11 ^{dNO}	4.00±0.00 ^{bP}	4.82±0.89^Y	
PS RED	Room temperature	6.9±0.10 ^{aM}	5.7±0.20 ^{abMN}	5.7±0.20 ^{aMNO}	4.91±0.140 ^{aNO}	4.68±0.106 ^{aP}	5.32±0.90^Y	5.54±90^w
	Refrigeration temperature	6.9±0.15 ^{aM}	5.8±0.15 ^{aMN}	5.6±0.20 ^{aNO}	4.76±0.12 ^{abNO}	4.66±0.11 ^{aO}	5.33±0.88^X	
	Mean	6.48±0.29^A	5.51±0.32^B	5.38±0.287^C	4.65±0.32^D	4.442±0.32^E		

Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C,...= Overall month; M,N,O,P= Month v/s month.

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4. 26: Effect of storage period, storage condition and chili variety on total phenolics (mg/100ml GAE) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	719.66±0.75 ^{bM}	700.3±10.00 ^{dN}	678.6±1.57 ^{dO}	618.5±2.15 ^{dP}	595±2.64 ^{dQ}	662.59±49.36 ^Y	669.43±44.10 ^y
	Refrigeration temperature	719.66±1.00 ^{bM}	709.1±0.87 ^{bcdN}	686.7±1.00 ^{bO}	640.2±1.0 ^{cP}	625.5±0.85 ^{abQ}	676.28±38.63 ^X	
CH 27 RED	Room temperature	732.1±2.56 ^{aM}	718.7±2.15 ^{abN}	682.3±2.05 ^{cdO}	630.2±0.85 ^{dP}	610.59±1.51 ^{dQ}	674.87±49.35 ^Y	679.46±45.91 ^w
	Refrigeration temperature	732.1±2.01 ^{aM}	721.3±0.96 ^{aN}	695.5±1.15 ^{aO}	645.2±0.80 ^{bP}	625.45±1.00 ^{abcQ}	684.05±43.34 ^X	
PS GREEN	Room temperature	728.4±1.85 ^{aM}	702.2±2.3 ^{cdN}	673.9±1.25 ^{eO}	650.2±0.85 ^{aP}	620.5±2.15 ^{bcQ}	674.97±39.24 ^Y	677.35±38.729 ^x
	Refrigeration temperature	728.4±22.00 ^{aM}	712.3±2.0 ^{abcN}	683.4±1.25 ^{bcO}	647.1±1.00 ^{abP}	624.265±3.05 ^{aQ}	679.79±39.4 ^X	
PS RED	Room temperature	710.1±0.96 ^{cM}	700.1±2.085 ^{dN}	669.3±1.00 ^{fO}	646.1±1.02 ^{Bp}	620.45±1.00 ^{cP}	669.26±34.48 ^Y	669.64±30.017 ^y
	Refrigeration temperature	710.1±1.41 ^{cM}	702±2.05 ^{cdN}	679.9±1.33 ^{cdO}	637.2±1.01 ^{cP}	620.25±1.01 ^{baP}	670.03±36.74 ^X	
	Mean	722.67±8.79 ^A	708.32±8.7 ^B	681.13±7.75 ^C	639.43±10.20 ^D	618.31±10.02 ^E		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; GAE= Gallic acid equivalent; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

27 green (669.43mg/100 gm GAE) and Punjab sindhuri red (669.64mg/100 gm GAE). Monthly, highest total phenolics values was observed in initial stage of storage i.e. 722.67 mg/100 gm GAE followed by 2nd month of storage (708.32 mg/100 gm GAE). As evident from the data of Table 4.19, the individual effect of month, variety and storage condition was significant ($p \leq 0.05$). The refrigeration storage condition was found to have a significant effect on the retention of total phenolics. The results are in accordance with Sakhale *et al* (2015).

4.4.16 Effect of storage period and temperature on β -carotene ($\mu\text{g}/100\text{ gm}$) of honey chili sauce

The β -carotene ($\mu\text{g}/100\text{ gm}$) content of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.27. The β -carotene ($\mu\text{g}/100\text{ gm}$) content of all samples was varied from 400 to 470 $\mu\text{g}/100\text{ gm}$. The β -carotene ($\mu\text{g}/100\text{ gm}$) of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 400, 430, 441-410 and 470 $\mu\text{g}/100\text{ gm}$ respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the β -carotene ($\mu\text{g}/100\text{ gm}$) content of the samples was observed. The maximum beta carotene retention was observed in sample with CH-27 red variety followed by Punjab sindhuri red. According to overall mean value, the maximum β -carotene ($\mu\text{g}/100\text{ gm}$) was for honey chili sauce with CH-27 red (308.00 $\mu\text{g}/100\text{ gm}$), followed by Punjab sindhuri red (296.93 $\mu\text{g}/100\text{ gm}$). The overall mean β -carotene of Punjab sindhuri green and red showed non-significant difference. As shown in Table 4.27, the individual effect of month, storage condition and variety was significant ($p \leq 0.05$). Provitamin A is a powerful antioxidant but it is sensitive towards light and oxygen that might be related with the loss of β -carotene in honey chili sauce during storage (Durrani *et al* 2011).

4.4.17 Effect of storage period and temperature on lycopene ($\mu\text{g}/100\text{ gm}$) of honey chili sauce

The lycopene ($\mu\text{g}/100\text{ gm}$) of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.28. The lycopene content ($\mu\text{g}/100\text{ gm}$) of all samples was varied from 5.0 to 5.4 $\mu\text{g}/100\text{ gm}$. The lycopene content ($\mu\text{g}/100\text{ gm}$) of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 5.0, 5.2, 5.4 and 5.2 $\mu\text{g} / 100\text{ gm}$ respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the lycopene content ($\mu\text{g}/100\text{ gm}$) of the samples was observed. After 8 months of storage, the maximum beta carotene retention was observed in sample with CH-27 red variety followed by Punjab sindhuri red. According to overall mean value, the maximum lycopene content ($\mu\text{g}/100\text{ gm}$) was for honey chili sauce with CH-27 red (5.49 $\mu\text{g}/100\text{ gm}$), followed by Punjab sindhuri red (4.50 $\mu\text{g}/100\text{ gm}$). Monthly, highest and lowest lycopene content 5.21 and 3.75 $\mu\text{g}/100\text{ gm}$ value was observed at initial and 8th month of storage respectively. Table 4.28 depicted that the individual effect

Table 4.27: Effect of storage period, storage condition and chili variety on β -carotene($\mu\text{g}/100 \text{ gm}$) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	400 $\pm$ 15.27 ^{dM}	350 $\pm$ 5.85 ^{deN}	290 $\pm$ 10.06 ^{bcO}	200 $\pm$ 7.67 ^{bcP}	185 $\pm$ 5.00 ^{cP}	286.20 $\pm$ 87.57 ^Y	292.97 $\pm$ 85.46 ^Y
	Refrigeration temperature	400 $\pm$ 7.63 ^{dM}	380 $\pm$ 4.04 ^{abM}	300 $\pm$ 6.42 ^{abN}	220 $\pm$ 10.00 ^{bcO}	195 $\pm$ 15.00 ^{bcO}	299.73 $\pm$ 85.80 ^X	
CH 27 RED	Room temperature	430 $\pm$ 17.55 ^{bcdM}	360 $\pm$ 3.05 ^{cdN}	260 $\pm$ 6.11 ^{deO}	210 $\pm$ 5.00 ^{bcP}	186 $\pm$ 2.00 ^{cQ}	289.00 $\pm$ 95.12 ^Y	308.00 $\pm$ 86.33 ^W
	Refrigeration temperature	430 $\pm$ 3.05 ^{bcM}	390 $\pm$ 3.05 ^{aN}	310 $\pm$ 4.50 ^{aO}	260 $\pm$ 2.51 ^{aP}	245 $\pm$ 5.00 ^{aQ}	327.00 $\pm$ 74.94 ^X	
PS GREEN	Room temperature	441 $\pm$ 8.62 ^{bM}	340 $\pm$ 5.50 ^{efN}	240 $\pm$ 6.65 ^{eO}	200 $\pm$ 5.00 ^{cP}	180 $\pm$ 5.032 ^{cQ}	286.1 $\pm$ 109.661 ^X	295.93 $\pm$ 87.30 ^X
	Refrigeration temperature	410 $\pm$ 4.04 ^{cdM}	370 $\pm$ 3.00 ^{bcN}	300 $\pm$ 8.08 ^{abO}	250 $\pm$ 3.51 ^{aP}	235 $\pm$ 5.00 ^{aQ}	205.53 $\pm$ 100.30 ^Y	
PS RED	Room temperature	470 $\pm$ 5.00 ^{aM}	330 $\pm$ 4.50 ^{fN}	250 $\pm$ 7.09 ^{eO}	200 $\pm$ 12.58 ^{bcP}	178 $\pm$ 3.055 ^{cQ}	280.80 $\pm$ 101.66 ^Y	296.83 $\pm$ 103.73 ^X
	Refrigeration temperature	470 $\pm$ 1.52 ^{aM}	350 $\pm$ 4.16 ^{deN}	280 $\pm$ 6.02 ^{cdO}	220 $\pm$ 5.033 ^{bcP}	205 $\pm$ 1.527 ^{bQ}	313.0 $\pm$ 69.96 ^X	
	Mean	431.96$\pm$27.34^A	359.04$\pm$19.19^B	279.75$\pm$25.19^C	220.42$\pm$22.550^D	201.00$\pm$25.24^E		

PS= Punjab Sindhuri; n = 3; Values are Mean $\pm$ Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4.28: Effect of storage period, storage condition and chili variety on lycopene ($\mu\text{g}/100 \text{ gm}$) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	5.0 $\pm$ 0.30 ^{aM}	4.7 $\pm$ 0.10 ^{aMN}	4.2 $\pm$ 0.15 ^{aNO}	3.9 $\pm$ 0.20 ^{aOP}	3.4 $\pm$ 0.20 ^{aP}	4.26 $\pm$ 0.62 ^Y	4.35 $\pm$ 0.56 ^Y
	Refrigeration temperature	5.0 $\pm$ 0.20 ^{aM}	4.8 $\pm$ 0.15 ^{aM}	4.6 $\pm$ 0.40 ^{aMN}	4.1 $\pm$ 0.251 ^{aNO}	3.9 $\pm$ 0.11 ^{aP}	4.44 $\pm$ 0.493 ^X	
CH 27 RED	Room temperature	5.2 $\pm$ 0.20 ^{aM}	5.0 $\pm$ 0.55 ^{aM}	4.8 $\pm$ 0.10 ^{aMN}	4.5 $\pm$ 0.20 ^{aMN}	4.1 $\pm$ 0.20 ^{aN}	4.72 $\pm$ 0.47 ^X	4.59 $\pm$ 0.53 ^w
	Refrigeration temperature	5.2 $\pm$ 0.15 ^{aM}	4.9 $\pm$ 0.20 ^{aM}	4.4 $\pm$ 0.200 ^{aN}	4.0 $\pm$ 0.251 ^{aNO}	3.8 $\pm$ 0.055 ^{aO}	4.45 $\pm$ 0.56 ^Y	
PS GREEN	Room temperature	5.4 $\pm$ 0.251 ^{aM}	4.8 $\pm$ 0.20 ^{aN}	4.5 $\pm$ 0.15 ^{aNO}	4.0 $\pm$ 0.351 ^{aOP}	3.6 $\pm$ 0.20 ^{aP}	4.44 $\pm$ 0.660 ^X	4.36 $\pm$ 0.66 ^{xy}
	Refrigeration temperature	5.4 $\pm$ 0.351 ^{aM}	4.4 $\pm$ 0.20 ^{aN}	4.1 $\pm$ 0.351 ^{aNO}	3.9 $\pm$ 0.20 ^{aNO}	3.6 $\pm$ 0.200 ^{aP}	4.29 $\pm$ 0.669 ^Y	
PS RED	Room temperature	5.2 $\pm$ 0.351 ^{aM}	4.9 $\pm$ 0.200 ^{aM}	4.6 $\pm$ 0.20 ^{aMN}	4.1 $\pm$ 0.30 ^{aNO}	3.8 $\pm$ 0.10 ^{aO}	4.51 $\pm$ 0.58 ^X	4.503 $\pm$ 0.54 ^{wx}
	Refrigeration temperature	5.2 $\pm$ 0.152 ^{aM}	4.8 $\pm$ 0.10 ^{aMN}	4.5 $\pm$ 0.200 ^{aN}	4.0 $\pm$ 0.251 ^{aO}	3.9 $\pm$ 0.10 ^{aO}	4.49 $\pm$ 0.528 ^Y	
	Mean	5.21 $\pm$ 0.254 ^A	4.77 $\pm$ 0.27 ^B	4.46 $\pm$ 0.28387 ^C	4.05 $\pm$ 0.271 ^D	3.75 $\pm$ 0.24 ^E		
PS= Punjab Sindhuri; n = 3; Values are Mean $\pm$ Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=<.001; Month * Storage condition=NS; Month * Variety=NS; Storage condition* Variety=<.003;
Month * Storage condition* Variety=<.001

of month, and variety was significant ($p \leq 0.05$), while the effect of storage condition was non-significant. Isomerization and oxidation of lycopene due to heat, light and oxygen results in the its loss or reduction during the storage of honey chili sauce as reviewed by Martínez-Hernández *et al* (2016).

4.4.18 Effect of storage period and temperature on per cent inhibition of DPPH (1,1-diphenyl-2-picryl-hydrazyl) of honey chili sauce

The per cent inhibition of DPPH of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.29. The antioxidant activity in terms of DPPH (%) for all samples was varied from 63.56 to 69.56 per cent. The per cent inhibition of DPPH for fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 63.59, 67.59, 63.64 and 69.56 respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the DPPH (%) was observed. After 8 months of storage, the maximum antioxidant activity retention was observed in sample with CH-27 red variety followed by Punjab sindhuri green stored at refrigeration condition. According to overall mean value, the maximum per cent inhibition of DPPH was for honey chili sauce with CH-27 red (52.02), followed by Punjab sindhuri red (50.56). The overall mean ascorbic acid content of green form of both varieties showed non-significant difference. Monthly, highest and lowest per cent inhibition of DPPH i.e. 65.59 and 40.16 was observed at initial and 8th month of storage respectively. As evident from the data of Table 4.29, the effect of month and variety was significant ($p \leq 0.05$), while the effect of storage condition was non-significant. Ascorbic acid, lycopene, phenol components etc. are represents the antioxidant properties of a product. The reduction of antioxidant activity due to light and heat during storage was reported by Del-Toro-Sánchez *et al* (2015). Similar results were observed in the present investigation.

4.4.19 Effect of storage period and temperature on FRAP (Ferric reducing antioxidant power) of honey chili sauce

Table 4.30 depicting the FRAP value (mM/100 gm) of honey chili sauce with dried CH-27 and Punjab sindhuri. The FRAP (mM/100 gm) value of all samples was varied from 4.21 to 4.78. The FRAP (mM/100 gm) of fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 4.48, 4.78, 4.21 and 4.39, respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) decrease in the FRAP (mM/100 gm) was observed. After 8 months of storage, according to overall mean value, the maximum FRAP (mM/100 gm) was for honey chili sauce with CH-27 red (3.43 mM/100 gm), followed by Punjab sindhuri green CH-27 green (3.28 mM/100 gm) that varied non-significantly. Monthly, the highest FRAP value was at initial stage i.e. 4.46 that decreased significantly and showed 2.45 (mM/100 gm) value at month 8th of storage. As shown in Table 4.30, the individual effect of month, storage

Table 4.29: Effect of storage period, storage condition and chili variety on antioxidant activity (DPPH %) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	63.59±6.79 ^a	58.8±1.080 ^a	43.66±1.002 ^{cd}	41.10±0.812 ^{abc}	39.5±0.68 ^b	48.74±9.54 ^Y	48.94±11.98 ^Y
	Refrigeration temperature	63.59±0.94 ^{ab}	55.14±1.11 ^{bc}	44.77±1.19 ^{bc}	41.77±1.30 ^{abc}	40.48±0.81 ^{ab}	49.133±9.27 ^X	
CH 27 RED	Room temperature	67.59±1.08 ^a	58.9±1.005 ^a	49.05±0.866 ^a	43.65±1.00 ^{ab}	40.65±1.10 ^{ab}	51.98±10.35 ^Y	52.025±12.98 ^w
	Refrigeration temperature	67.59±1.10 ^a	58.24±0.94 ^a	46.03±0.82 ^{ab}	44.55±1.24 ^a	42.65±0.48 ^{ab}	52.06±9.91 ^X	
PS GREEN	Room temperature	63.64±1.15 ^{ab}	53.84±1.027 ^{cd}	41.3±1.17 ^{cd}	39.3±0.76 ^c	36.59±1.00 ^c	47.12±10.45 ^X	48.49±9.35 ^y
	Refrigeration temperature	63.64±1.26 ^{ab}	52.38±1.19 ^d	48.27±1.13 ^a	43.21±1.80 ^{ab}	41.35±1.41 ^b	49.87±8.24 ^Y	
PS RED	Room temperature	69.56±1.12 ^a	57.21±1.11 ^{ab}	49.52±0.792 ^a	42.55±1.26 ^{ab}	40.65±0.86 ^a	51.95±10.84 ^X	50.563±11.37 ^x
	Refrigeration temperature	69.56±0.96 ^a	55.01±0.88 ^{bcd}	41.06±0.91 ^d	40.22±1.16 ^{cb}	39.54±0.879	49.16±12.09 ^Y	
	Mean	65.59±3.86 ^A	56.307±2.4 ^B	45.73±3.21 ^C	42.231±1.86 ^D	40.1662±1.93 ^E		
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; DPPH (1,1-diphenyl-2-picryl-hydrazyl);Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.								

CD_(0.05)

Month=<.001; Storage condition=<.NS; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

Table 4.30: Effect of storage period, storage condition and chili variety on antioxidant activity (FRAP mM/100mg) analysis of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	4.48±0.20 ^{bM}	3.45±0.045 ^{dN}	3.00±0.075 ^{abO}	2.48±0.20 ^{cP}	2.15±0.11 ^{bQ}	3.11±0.85^Y	3.28±0.77^y
	Refrigeration temperature	4.48±0.035 ^{bM}	3.85±0.045 ^{cN}	3.18±0.160 ^{abO}	2.99±0.08 ^{aOP}	2.70±0.126 ^{aP}	3.44±0.66^X	
CH 27 RED	Room temperature	4.78±0.04 ^{aM}	3.98±0.0435 ^{abcN}	3.09±0.06 ^{abO}	2.78±0.10 ^{bcP}	2.59±0.137 ^{aP}	3.41±0.85^Y	3.433±0.84^w
	Refrigeration temperature	4.78±0.020 ^{bM}	3.99±0.030 ^{abN}	3.21±0.11 ^{bO}	2.74±0.11 ^{abP}	2.58±0.100 ^{aP}	3.44±0.86^X	
PS GREEN	Room temperature	4.21±0.035 ^{bM}	3.89 ±0.030 ^{abcN}	3.15±0.10 ^{abO}	2.72±0.210 ^{abP}	2.55±0.120 ^{aP}	3.30±0.67^Y	3.280±0.67^x
	Refrigeration temperature	4.21±0.070 ^{bM}	4.00 ±0.015 ^{aM}	3.54±0.100 ^{aN}	2.77±0.09 ^{abO}	2.57±0.100 ^{aO}	3.41±0.68^X	
PS RED	Room temperature	4.39±0.202 ^{bM}	3.04±0.065 ^{eN}	2.95±0.060 ^{cN}	2.39±0.11 ^{abO}	2.19±0.117 ^{bO}	2.97±0.81^Y	3.1433±0.78^z
	Refrigeration temperature	4.39±0.020 ^{bM}	3.87±0.045 ^{bcN}	3.09±0.086 ^{abO}	2.79±0.20 ^{abP}	2.49±0.123 ^{abQ}	3.30±0.74^X	
	Mean	4.46±0.20^A	3.75±0.322^B	3.14±1.87^C	2.69±0.20^D	2.4596±0.227^E		

PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; FRAP (Ferric reducing antioxidant power); Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.

CD_(0.05)

Month=<.001; Storage condition=<.001; Variety=<.001; Month * Storage condition=<.001; Month * Variety=<.001; Storage condition* Variety=<.001; Month * Storage condition* Variety=<.001

condition and variety was significant ($p \leq 0.05$).

4.4.20 Effect of storage period and temperature on mineral content (ppm) of honey chili sauce

The mineral content of honey chili sauce with dried CH-27 and Punjab sindhuri is represented in Table 4.31. The boron content of all samples was varied from range 21.9 to 46.6 ppm that reduced significantly after 8th month of storage. Similarly the calcium content was in the range of 64.9 to 101 ppm with maximum in sample with CH-27 and Punjab sindhuri green. After 8 months storage, the calcium content range was 61.5 to 97.6 ppm. The highest iron content in the fresh honey chili sauce was observed in sample with Punjab sindhuri red (81.6 ppm) followed by green form of both varieties (70.9-71.5 ppm) that reduced significantly after 8 month of storage. The magnesium was highest in sample with CH-27 green (261 ppm). The difference between magnesium content of sample with CH-27 red and Punjab sindhuri green was non-significant. The value for sample with Punjab sindhuri red was 149 ppm). A significant ($p \leq 0.05$) reduction in the magnesium of all samples was observed after 8th months of storage. The phosphorous of all samples were in the range of 121 to 142 ppm that reduced after storage and the final values were in the range of 115 to 132 ppm. In the fresh honey chili sauce, the maximum potassium content was observed sample with CH-27 green (692 ppm) followed by Punjab sindhuri green (660 ppm), Punjab sindhuri red (646 ppm) and CH-27 red (623 ppm). A significant reduction in the potassium content after storage was observed. Similar pattern was observed for the sodium content of the samples. The zinc content was ranged from 15.2 to 42.6 ppm that reduced to 15 to 40.6 ppm.

4.4.21 Effect of storage period and temperature on total plate count (cfu/ml) of honey chili sauce

The Table 4.32 representing the total plate count (cfu/ml) of honey chili sauce with dried CH-27 and Punjab sindhuri. The TPC value of all samples was varied from range 0.02 to 0.03 cfu/ml. The total plate count in the fresh honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 0.02, 0.02, 0.03 and 0.02cfu/ml respectively. During the storage of honey chili sauce at both storage conditions, a significant ($p \leq 0.05$) increase in the total plate count was observed. As observed in the overall mean value, the highest total plate count (0.138 cfu/ml) of honey chili sauce was observed with green form of CH-27 while for red form of CH-27 and green form of Punjab sindhuri varieties showed non-significant difference with value 0.087 and 0.086 cfu/ml respectively. The effect of month, storage was significant ($p \leq 0.05$) but the effect of storage condition and variety was non-significant (Table 4.32). The total plate count of the honey chili sauce was within the safest limit even after 8 months of storage as per reported by Mumtaz *et al* (2018).

Table 4.31: Effect of storage period, storage condition and chili variety on mineral content profile (ppm) of honey chili sauce

	0 MONTH				8 MONTH			
	1	2	3	4	1	2	3	4
Boron	29.7	46.6	31.0	21.9	25.7	42.6	28.0	18.5
Cadmium	1.65	0.52	0.45	0.38	1.35	0.49	0.40	0.35
Calcium	101	88.6	101	64.9	95	82.6	97.6	61.5
Chromium	0.43	0.19	0.30	0.31	0.35	0.17	0.26	0.27
Copper	3.04	2.94	2.42	2.47	2.84	2.74	2.32	2.32
iron	70.9	64.0	71.5	81.6	65.9	60.2	64.5	80.1
Magnesium	261	216	218	149	249	202	206	141
Manganese	2.17	1.91	1.43	1.71	2.00	1.75	1.32	1.65
Nickel	0.86	0.52	0.48	0.68	0.75	0.47	0.30	0.58
Phosphorous	142	121	136	137	132	115	126	125
Potassium	692	623	660	646	650	603	615	625
Sodium	6536	5927	6539	6433	6542	5930	6542	6439
zinc	42.6	26.3	15.2	19.1	40.6	24.3	15.0	18.0
Honey chili sauce containing 1 = CH27 GREEN ; 2= CH 27 RED; 3= PUNJAB SINDHURI GREEN ; 4= PUNJAB SINDHURI RED								

Table 4.32: Effect of storage period, storage condition and chili variety on total plate count (cfu/ml) of honey chili sauce

		Storage period (months)						
Variety	Storage condition	0	2	4	6	8	Mean	
CH 27 GREEN	Room temperature	0.02±0.01 ^{aM}	0.04±0.01 ^{abM}	0.08±0.01 ^{abM}	0.10±0.25 ^{aM}	0.15±0.04 ^{aM}	0.136±0.21^X	0.138±0.223^w
	Refrigeration temperature	0.02±0.01 ^{aM}	0.04±0.01 ^{abM}	0.08±0.01 ^{abM}	0.10±0.01 ^{aM}	0.14±0.04 ^{aM}	0.129±0.23^Y	
CH 27 RED	Room temperature	0.02±0.01 ^{aO}	0.05±0.01 ^{abN}	0.09±0.01 ^{abN}	0.11±0.015 ^{aMN}	0.16±0.04 ^{aM}	0.084±0.05^Y	0.087±0.053^x
	Refrigeration temperature	0.02±0.01 ^{aP}	0.05±0.01 ^{abNO}	0.09±0.01 ^{abMNO}	0.11±0.48 ^{aMN}	0.15±0.045 ^{aM}	0.090±0.57^X	
PS GREEN	Room temperature	0.03±0.01 ^{aO}	0.05±0.01 ^{abNO}	0.09±0.01 ^{abMNO}	0.09±0.01 ^{aMN}	0.15±0.04 ^{aM}	0.080±0.04^Y	0.086±0.050^y
	Refrigeration temperature	0.03±0.01 ^{aN}	0.06±0.0 ^{aMN}	0.08±0.0 ^{aMN}	0.12±0.01 ^{aM}	0.16±0.040 ^{aM}	0.091±0.05^X	
PS RED	Room temperature	0.02±0.01 ^{aN}	0.03±0.01 ^{bN}	0.07±0.01 ^{bMN}	0.12±0.01 ^{aM}	0.16±0.045 ^{aM}	0.081±0.065^X	0.077±0.0514^z
	Refrigeration temperature	0.02±0.01 ^{aO}	0.05±0.01 ^{abNO}	0.09±0.01 ^{abN}	0.09±0.01 ^{aMN}	0.12±0.036 ^{aM}	0.074±0.04^Y	
	Mean	0.0225±0.009^C	0.046±0.12^C	0.085±0.01251^{BC}	0.187±0.234^A	0.145±0.0361^B		

PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly; where w,x,y,z=Overall variety; X,Y= Storage condition; a,b,c,...=Within month; A,B,C...= Overall month; M,N,O,P= Month v/s month.

CD_(0.05)

Month=<.001; Storage condition=NS; Variety=NS; Month * Storage condition=NS; Month * Variety=<.012; Storage condition* Variety=<NS; Month * Storage condition* Variety=<NS

4.4.22 FTIR of honey chili sauce containing CH-27 green

FT-IR spectra, characteristics peaks and functional groups at particular peaks of honey chili sauce with CH-27 green in Figure 4.6 and Table 4.33. The presence of phenolic contents and secondary amines with functional bond OH and N-H at wavelength 3338.5 were observed in honey chili sauce with CH-27 green. CH medium stretching with a band at 2978.8 cm^{-1} attributes the presence of Alkanes in honey chili sauce with CH-27 green. The presence of alkynes and carbodiimide was detected honey chili sauce with CH-27 green with generation of peak with the wavelength range of 2121.3 cm^{-1} . The band 1652.7 cm^{-1} representing the presence of aldehydes, while OH and S=O stretching at 1410.2 cm^{-1} band represents the alcohol and sulfates. The 1257.2 cm^{-1} band range attributes the presence of alkyl aryl ether. C-O and S=O stretch detection at 1056.6 cm^{-1} represents the presence of alcohol and sulfoxide respectively. Aldehyde was detected in honey chili sauce with CH-27 green with band range of 817 cm^{-1} .

Table 4.33 FTIR frequency range, compound class and functional groups of of honey chili sauce containing CH-27 green

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols	Ph-CHR-OH	OH	3338.5	variable	stretching	hydrogen bonded, broad peak
Secondary amines		N-H		medium	stretching	
Alkanes	Cyclobutylated	CH	2978.8	medium	antisymmetric stretching	
Amine salt		N-H		Strong		
Alkynes	R-C=CH	C=C	2121.3	Variable	Stretching mono-substituted	
Carbodiimide		N=C=N		Strong	stretching	
Aldehydes	HO-C=C-CHO	C=O	1652.7	strong	stretching	alpha beta, beta hydroxy aldehyde
Alcohols	HO-R-OH	OH	1410.2	medium	deformation	
Sulfate		S=O		Strong	stretching	
Alkyl aryl ether	Ph-OH	C-O	1257.2	strong	stretching	
Alcohols	HO-R-OH	C-O	1056.6	strong	stretching	
Sulfoxide		S=O			stretching	
Aldehydes	R-CHO	CH	817	medium-weak	deformation	

4.4.23 FTIR of honey chili sauce containing CH-27 red

FT-IR spectra, characteristics peaks and functional groups at particular peaks of honey chili sauce with CH-27 red are represented in Figure 4.6 and Table 4.34. The presence

Table 4.34 FTIR frequency range, compound class and functional groups of honey chili sauce containing CH-27 red

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapour phase	OH	3884.5	medium	stretching	series of sharp peaks
			3841.0			
			3800.8			
			3735.4			
Silicon Compounds	(R) ₃ Si-OH	O-H	3650	medium	stretching	broad peak
Alcohol	Phenol	O-H		Medium, sharp	stretching	
Alcohols	Ph-CHR-OH	OH	3348	variable	stretching	hydrogen bonded, broad peak
Aliphatic primary Amine		N-H		Medium	stretching	
Alkanes	Cyclobutyl	CH	2979.6	medium	antisymmetric stretching	
Amine Salts	NH ₂ ⁺	NH	2077	medium	stretching	Secondary amine salt; often multiple bands
Isothiocyanate		N=C=S			stretching	
Alkenes	CCCH=CHCC	C=C	1637.3	variable	stretching	non-conjugated C=C
Alcohols	HO-R-OH	OH	1342.1	medium	deformation	
Aromatic amine		C-O			stretching	
Alcohols	Ph-OH	C-O	1254.2	strong	stretching	
Alkyl aryl ether		C-O			stretching	
Alcohols	HO-R-OH	C-O	1056.8	strong	stretching	
Alcohols	HO-R-OH	C-O	1128.5	strong	stretching	
Alcohols	R-CH ₂ -OH	C-O		strong	stretching	
Amines	(R) ₃ C-NH ₂	C-N		weak	stretching	
1,4 disubstituted		C-H	815.7	Strong		

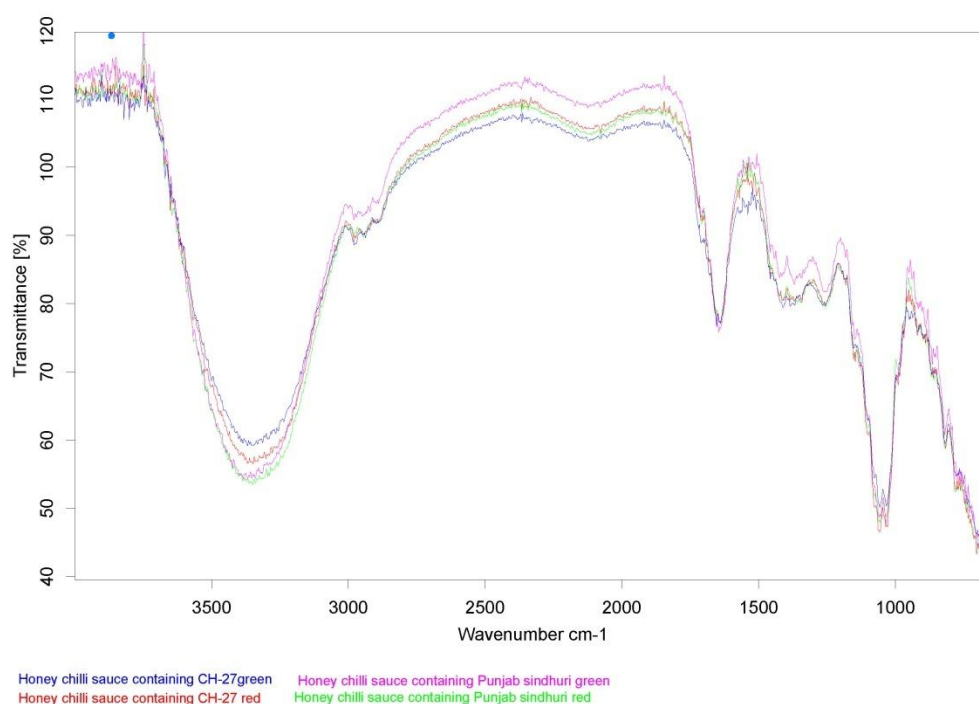


Fig. 4.6 FTIR spectra of honey chili sauce containing CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red

of water vapours and silicon compounds with functional bond OH and N-H at wavelength 3735.4 and 3650 cm^{-1} respectively were observed in honey chili sauce with CH-27 red. The presence of phenolic contents and primary amines with functional bond OH and N-H at wavelength 3348 cm^{-1} were observed in honey chili sauce with CH-27 red. CH medium stretching with a band at 2979.6 cm^{-1} attributes the presence of Alkanes in honey chili sauce with CH-27 red. The presence of amine salts and isothiocyanate was detected honey chili sauce with CH-27 red with generation of peak with the wavelength range of 2077 cm^{-1} . The band 1637.3 cm^{-1} representing the presence of alkanes, while OH and C-O stretching at 1342.1 cm^{-1} band represents the alcohol and aromatic amines respectively. The 1254.2 cm^{-1} band range attributes the presence of alcohols and alkyl arly ether. C-O stretch detection at 1056.8 cm^{-1} also represents the presence of alcohol. Amines and 1,4 disubstituted was detected in honey chili sauce with CH-27 green with band range of 815.7 cm^{-1} .

4.4.24 FTIR of honey chili sauce containing Punjab sindhuri green

Figure 4.6 and Table 4.35 depicts the FT-IR spectra, characteristics peaks and functional groups at particular peaks of honey chili sauce with Punjab sindhuri green chili variety. The presence of water vapours and silicon compounds with functional bond OH and N-H at wavelength 3734.1 and 3650 cm^{-1} respectively were observed in honey chili sauce with Punjab sindhuri green. The presences of aliphatic primary amines with functional bond NH at wavelength 3384.6 cm^{-1} were observed in honey chili sauce with Punjab sindhuri

green. C=C medium stretching with a band at 2124.6 and 1644.6 cm^{-1} attributes the presence of Alkynes and Alkenes in honey chili sauce with Punjab sindhuri green respectively. The presence of alcohol was detected honey chili sauce with Punjab sindhuri green with generation of peak with the wavelength range of 1422.9 cm^{-1} . The band at 1369.7 cm^{-1} represents the presence of phenols, while C-O stretching at 1251.3 cm^{-1} represents the presence of aromatic ester. The 1052.9 cm^{-1} band range attributes the presence of primary alcohols with C-O stretch bond. S=O stretch detection at 1033.78 cm^{-1} represents the presence of sulfoxide. Alkyl halides were detected in honey chili sauce with Punjab sindhuri green with band range of 819.0 cm^{-1} .

Table 4.35: FTIR frequency range, compound class and functional groups of honey chili sauce containing Punjab sindhuri green

Classification	Group	Bond	Range	Intensity	Mode	Notes
			3759.1			
Solvent Impurities	Water vapor phase	OH	3734.1	medium	stretching	series of sharp peaks
Silicon Compounds	(R) ₃ Si-OH	O-H	3650	medium	stretching	broad peak
Aliphatic primary Amines	Ph-NH ₂	NH	3384.6	medium	symmetric stretching	
Alkynes	R-C≡CH	C≡C	2124.6	variable	stretching	mono-substituted
Alkenes	CCCH=CHCC	C=C	1644.6	variable	stretching	non-conjugated C=C
Alcohols	HO-R-OH	OH	1422.9	medium	deformation	
Phenol		OH	1369.7	medium		
Aromatic ester	Ph-OH	C-O	1251.3	strong	stretching	
Primary Alcohols	HO-R-OH	C-O	1052.9	strong	stretching	
Sulfoxide		S=O	1033.7	Strong	stretching	
alkyl halides		C-Cl stretch	819.0	Medium	stretching	

4.4.25 FTIR of honey chili sauce containing Punjab sindhuri red

Figure 4.12 and Table 4.36 depicts the FT-IR spectra, characteristics peaks and functional groups at particular peaks of honey chili sauce with Punjab sindhuri red chili variety. The presence of amine salts and isothiocyanates with functional bond NH at wavelength 3349.7, 2077, and 2800 cm^{-1} respectively were observed in honey chili sauce with

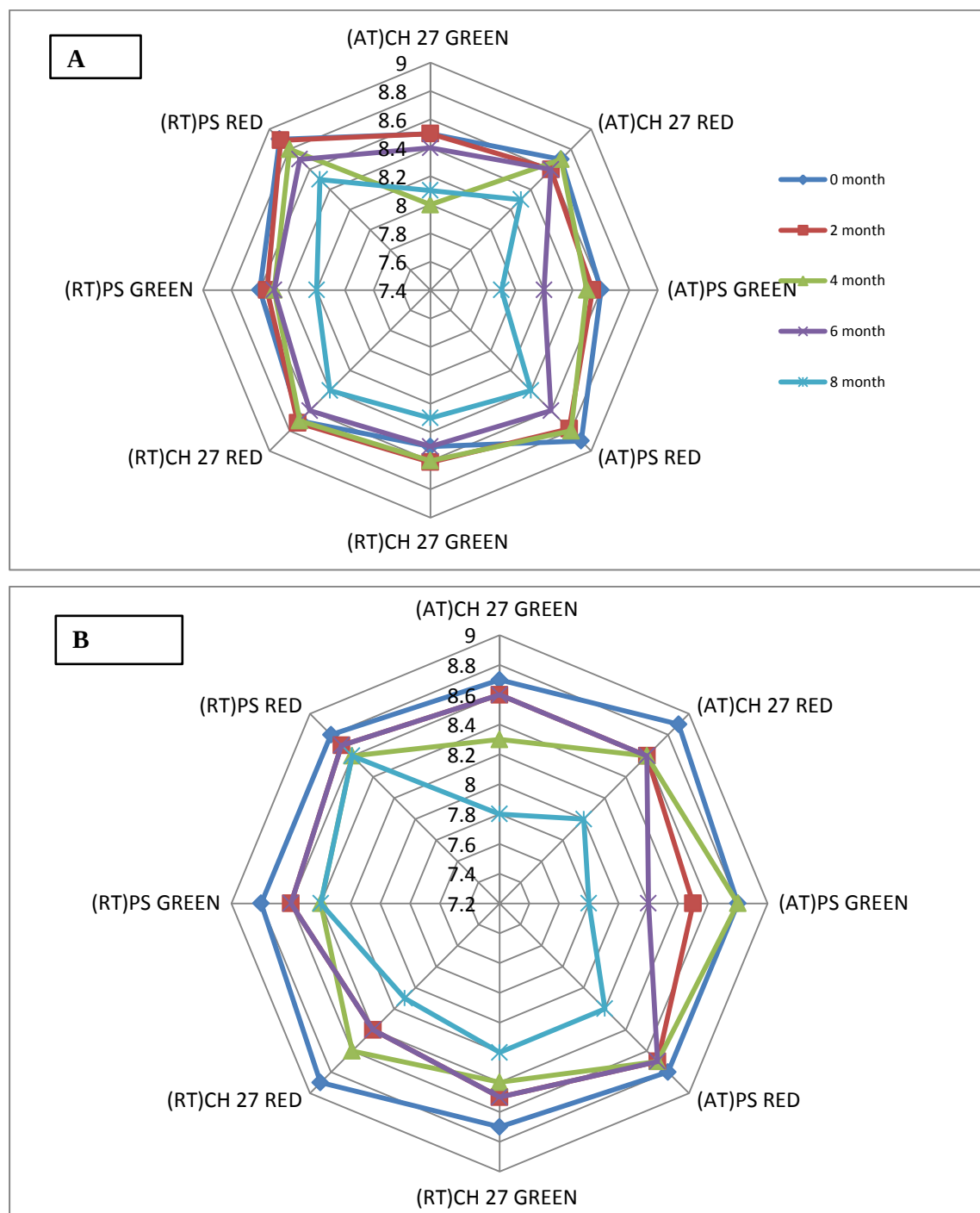
Punjab sindhuri red. The presence of amides with functional bond C=O at wavelength 1642.6 cm^{-1} were observed in honey chili sauce with Punjab sindhuri red. NH, N=N and NO_2 medium stretching with a band at 1539.2 cm^{-1} attributes the presence of amides, azo compounds and nitro compounds in honey chili sauce with Punjab sindhuri red respectively. The presence of amine was detected honey chili sauce with Punjab sindhuri red with generation of peak with the wavelength range of 1357.3 cm^{-1} . The band at 1253.5 cm^{-1} represents the presence of aromatic alcohol, while C-O stretching at 1055.0 cm^{-1} represents the presence of primary alcohol.

Table 4.36 FTIR frequency range, compound class and functional groups of honey chili sauce containing Punjab sindhuri red

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amine Salts	NH_3^+	NH	3349.7	medium	stretching	Primary amine salt; often multiple bands
Amine Salts	NH_2^+	NH	2800-2000	medium	stretching	Secondary amine salt; often multiple bands
Amine Salts	NH_2^+	NH	2077	medium	stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		variable-strong	stretching	
Amides	R-CO-NH-C	C=O	1642.2	strong	stretching	amide I
Amides	R-CO-NH-C	NH	1539.2	strong	combination	amide II, combination of C-N stretching and N-H bending
Azo Compounds	N=N	N=N		medium	stretching	
Nitro Compounds	C- NO_2	NO_2		strong	antisymmetric stretching	
Amines	$(\text{C})_3\text{N}$ Ph-N-(R) ₂	C-N	1357.9	medium-strong	stretching	
aromatic amines	Ph-NH-R	C-N	1253.5	medium-strong	stretching	
Primary Alcohols	HO-R-OH	C-O	1055.0	strong	stretching	

4.4.26 Sensory evaluation

The sensory evaluation scores for colour, consistency, mouth feel and overall acceptability of honey chili sauce is depicted in Figure 4.7. The scores were recorded by semi trained panel on nine point hedonic scale after 2 months for 8 months of storage. The highest scores were recorded for the honey chili sauce with Punjab sindhuri red due to the bright red appealing color of the same.



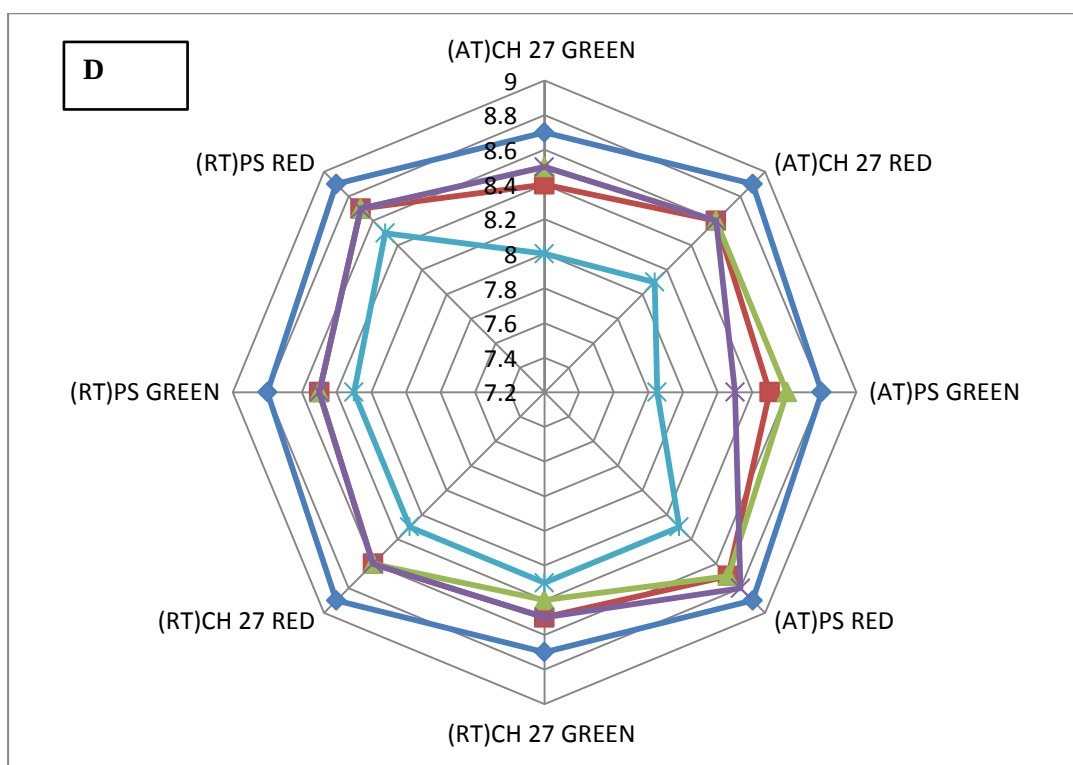
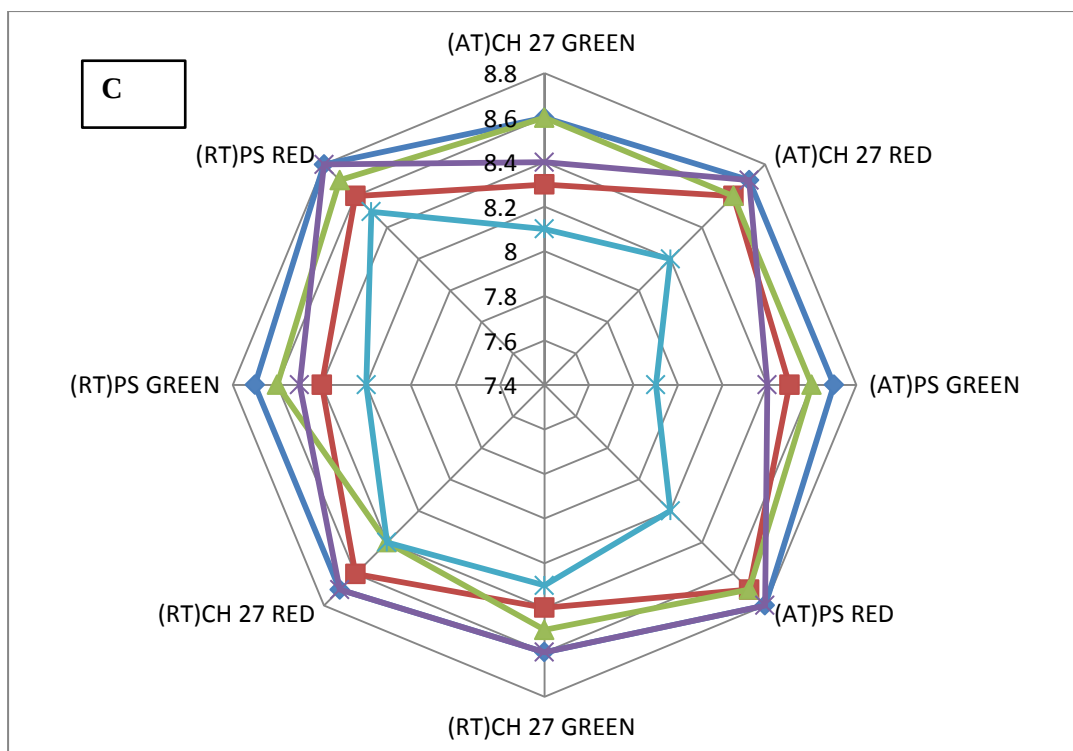


Figure 4.7: Sensory scores of honey chili sauce (A=Colour; B= Consistency; C= Mouth-feel; D= Overall acceptability); {AT= Room temperature, RT= refrigeration temperature}

4.5 Physicochemical, bioactive components, antioxidant activity, colour, mineral analysis of chili paste

4.5.1 Effect of processing on the yield of chili paste

During processing, the chili paste was prepared. The yield of chili paste of CH-27 and Punjab sindhuri are given below.

Table 4.37: Effect of processing on the yield of chili paste

Variety	Yield of paste (%)
CH-27 (Green)	82.67
CH-27 (Red)	90.31
Punjab Sindhuri (Green)	90.50
Punjab Sindhuri (Red)	92.90

The maximum yield was observed in Punajb sindhuri red followed by Punjab sindhuri green, CH-27 red and CH-27 green.

4.5.2 Effect of treatment, storage period and storage condition on the total soluble solids(°Brix)of chili paste

The total soluble solids (°Brix) of stored chilli paste are represented in Table 4.38. During the initial time, the TSS of the samples ranged from 19 to 25°Brix. For the CH-27 green chilli variety, the samples with treatment number 3 and stored at refrigeration temperature has the maximum retention of TSS and the lowest was for the control sample stores at room temperature. The highest mean value of TSS during ten months of storage for the CH-27 red variety was reported for the samples with treatment number 3 and stored at refrigeration with a value of 24⁰Brix. Similar result were observed for the Punjab Sindhuri green and red variety samples with treatment number 3 and stored at refrigeration temperature. Overall, the maximum mean value for TSS of chili paste after 8 months of storage at room and refrigeration temperature was for observed for CH-27 red samples followed by CH-27 green and Punjab sindhuri green. The effect of the month, variety (CH-27 and Punjab sindhuri), storage conditions and treatments was found to have a significant ($p \leq 0.05$) effect on total soluble solids of the chili paste (Table 4.38). Similar results of highest total soluble solids retention with sodium benzoate and KMS was observed by Kumar *et al* (2015) and Jangir *et al* (2017).

4.5.3 Effect of treatment, storage period and storage condition on the total solids (%) of chili paste

The total solids of stored chilli paste are represented in Table 4.39. During the initial time, the total solids of the samples ranged from 74.28 to 87.80 per cent. For the CH-27 green chilli variety, the samples with treatment number 5 and stored at room temperature has the

highest mean value of total solids during the storage period with a value of 84.53 per cent and the lowest was for the control sample stored at room temperature. For the CH-27 red chilli variety, the samples with treatment number 4 and stored at refrigeration temperature has the highest mean value of total solids during the storage period with a value of 79.50 per cent and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of total solids (92.06%) for the storage period. Samples of Punjab Sindhuri red with treatment number 4 and stored at refrigeration conditions had a mean value of 89.33 per cent. Overall, the maximum mean value for acidity (72.53%) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri green samples followed by CH-27 and Punjab sindhuri red variety. All the linear and interaction terms of month, variety, storage condition and treatment were reported to have significant ($p \leq 0.05$) effect on total solids (Table 4.39). A decrease in total solids of beverage preserved with sodium benzoate was reported by Adeola & Aworh (2014).

4.5.4 Effect of treatment, storage period and storage condition on the pH of chili paste

The pH of stored chilli paste is represented in Table 4.40. During the initial time, the pH of the samples ranged from 3.94 to 6.21. For the CH-27 green chilli variety, the samples with treatment number 4 and stored at refrigeration temperature has the highest mean value of pH over the storage period with a value of 4.59 and the lowest was for the control sample stored at room temperature. Similar results were reported for CH-27 red variety, Punjab Sindhuri green and red variety samples with treatment number 3 and stored at refrigeration temperature has highest mean value of pH over the storage period. Similar results of highest pH with sodium benzoate and potassium meta-bisulphite was reported by Kumar *et al* (2015). Overall, the maximum mean value for pH of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 green and red and Punjab Sindhuri red samples followed by Punjab sindhuri green. As evident from the data of Table 4.40, the effect of the month, variety (CH-27 and Punjab sindhuri), treatments and month*treatment interaction was significant ($p \leq 0.05$) on pH except storage conditions.

4.5.5 Effect of treatment, storage period and storage condition on the titratable acidity (%) of chili paste

The acidity of stored chilli paste is represented in Table 4.41. During the initial time, the acidity of the samples ranged from 0.43 to 2.05 per cent. For the CH-27 green chilli variety, the samples with treatment number 3 and stored at room temperature has the highest mean value of acidity during the storage period with a value of 1.43 and the lowest was for the control sample stored at room temperature. For the CH-27 red chilli variety, the samples with treatment number 2 and stored at room temperature has the highest mean value of acidity during the storage period with a value of 1.60 per cent and the lowest was for the control

Table 4.38: Effect of treatment, storage period and storage condition on the TSS (°Brix) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Overall
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	19.00±1.00 ^{aN}	-	-	-	-	-	3.16±0.18 ^B	16.96±1.20 ^x
	Ref	19.00±1.54 ^{aN}	17.00±1.55 ^{bO}	-	-	-	-	6.00±0.30 ^B	
T2	Room	20.00±1.8 ^{aMN}	18.00±1.34 ^{abNO}	18.00±1.8 ^{abN}	17.00±1.5b ^O	17.00±1.98 ^{bO}	16.00±1.78 ^{bO}	20.00±1.2 ^A	
	Ref	20.00±1.2 ^{aMN}	20.00±1.33 ^{aMN}	20.00±1.99 ^{aMN}	19.50±1.52 ^{aMNO}	19.00±1.88 ^{aMNO}	18.50±1.88 ^{aMNO}	19.50±1.0 ^A	
T3	Room	22.00±1.5 ^{aM}	22.00±1.52 ^{aM}	21.00±1.78 ^{abM}	21.00±1.8 ^{abMN}	20.00±1.78 ^{abMN}	19.00±1.33 ^{abMN}	20.83±1.6 ^A	
	Ref	22.00±1.77 ^{aM}	22.00±1.89 ^{aM}	22.00±1.66 ^{aM}	22.00±1.88 ^{aM}	21.00±1.65 ^{aM}	21.00±1.88 ^{aM}	21.66±1.7 ^A	
T4	Room	21.00±1.57 ^{aMN}	20.00±1.67 ^{abMN}	19.50±1.74 ^{abMN}	19.00±1.33 ^{aNO}	19.00±1.52 ^{aMNO}	18.00±1.52 ^{bNO}	19.41±1.2 ^A	
	Ref	21.00±1.79 ^{aMN}	20.50±1.78 ^{aMN}	20.50±1.73 ^{abMN}	20.00±1.32 ^{aMN}	20.00±1.72 ^{aMN}	19.00±1.38 ^{aMN}	20.16±1.8 ^A	
T5	Room	21.00±1.91 ^{aMN}	20.50±1.88 ^{aBMN}	20.00±1.33 ^{abMN}	19.00±1.78 ^{abcNO}	18.00±1.8 ^{bcNO}	17.00±1.88 ^{cNO}	19.25±1.4 ^A	
	Ref	21.00±1.44 ^{aMN}	20.00±1.8 ^{aMN}	19.50±1.65 ^{aMN}	19.50±1.89 ^{aMNO}	19.00±1.33 ^{aMNO}	19.00±1.77 ^{aMN}	19.66±1.5 ^A	
CH-27 red									
T1	Room	20.00±1. 2 ^{aN}	-	-	-	-	-	3.33±0.27 ^C	17.46±2.0 ^w
	Ref	20.00±1.44 ^{aN}	18.00±0.95 ^{bO}	-	-	-	-	6.33±0.30 ^C	
T2	Room	22.00±1.56 ^{aN}	20.00±1.33 ^{abNO}	20.00±0.95 ^{abN}	19.00±1.3 ^{abN}	19.00±1.53 ^{bNO}	18.00±1.77 ^{bN}	20.00±1.2 ^B	
	Ref	22.00±1.87 ^{aN}	21.50±1.74 ^{abNO}	21.50±1.33 ^{abMN}	20.00±1.9 ^{abN}	20.00±1.71 ^{abM}	19.00±1.33 ^{bN}	20.66±1.2 ^{AB}	
T3	Room	25.00±1.11 ^{aM}	25.00±2.25 ^{aM}	24.00±2.00 ^{abM}	24.00±2.4 ^{abM}	23.00±1.36 ^{aM}	22.00±2.00 ^{bM}	23.83±1.5 ^A	
	Ref	25.00±1.23 ^{aM}	24.50±1.25 ^{aM}	24.00±2.25 ^{aMN}	24.00±2.75 ^{aM}	23.50±1.95 ^{aM}	23.00±1.25 ^{aM}	24.00±1.6 ^A	
T4	Room	20.00±1.01 ^{aN}	20.00±2.00 ^{abNO}	19.00±1.4 ^{abN}	18.00±1.25 ^{abN}	17.00±1.24 ^{aO}	17.00±1.4 ^{aN}	18.50±1.4 ^B	
	Ref	20.00±1.65 ^a	19.50±1.20 ^{aNO}	19.00±0.97 ^{aN}	19.00±0.98 ^{aN}	18.00±1.55 ^{aNO}	18.00±1.87 ^{aN}	18.91±1.8 ^B	
T5	Room	21.00±1.3 ^a	20.50±1.40 ^{aNO}	20.00±1.34 ^{aN}	19.50±1.35 ^{aN}	19.00±1.25 ^{aNO}	18.50±1.55 ^{aN}	19.75±2.0 ^B	
	Ref	21.00±1.54 ^a	20.50±1.77 ^{abNO}	19.50±1.78 ^{abN}	19.00±1.79 ^{abN}	18.00±1.74 ^{bNO}	18.00±1.99 ^{bN}	19.33±1 ^B	
Punjab sindhuri green									
T1	Room	20.00±1.36 ^{aN}	-	-	-	-	-	3.33±0.17 ^D	
	Ref	20.00±1.46 ^{aN}	16.00±1.31 ^{bO}	-	-	-	-	6.00±0.12 ^D	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Overall
		0	2	4	6	8	10		
T2	Room	21.00±1.66 ^{aN}	20.00±1.99 ^{abN}	20.00±2.5 ^{abN}	19.00±1.22 ^{abNO}	18.00±1.10 ^{OP}	18.00±1.36 ^{bOP}	20.00±1.0 ^{BC}	17.12±1.2 ^x
	Ref	21.00±1.11 ^{aN}	20.50±2.24 ^{abN}	19.50±2.1 ^{abN}	19.00±3.1 ^{abNO}	18.00±1.00 ^{bOP}	18.00±1.21 ^{bOP}	19.33±1.1 ^C	
T3	Room	25.00±1.75 ^{aM}	24.00±2.25 ^{abM}	23.00±1.64 ^{abcM}	23.00±2.6 ^{abcM}	22.00±2.55 ^{bcMN}	21.00±1.45 ^{cMN}	23.00±1.4 ^A	
	Ref	25.00±2.26 ^{aM}	24.00±2.26 ^{aM}	24.00±1.55 ^{aM}	23.50±0.55 ^{aM}	23.00±1.55 ^{aM}	23.00±0.36 ^{aM}	23.75±1.1 ^A	
T4	Room	21.00±0.95 ^{aN}	20.00±2.99 ^{abN}	20.00±0.97 ^{abN}	19.00±1.65 ^{abNO}	19.00±2.36 ^{abO}	18.00±0.97 ^{bOP}	19.50±1.5 ^C	
	Ref	21.00±0.99 ^{aN}	20.60±1.33 ^{aN}	20.00±0.89 ^{aN}	19.80±1.00 ^{aN}	19.40±2.44 ^{aO}	19.00±1.21 ^{aNO}	19.96±1.3 ^{BC}	
T5	Room	20.00±2.25 ^{aN}	19.00±0.78 ^{abN}	18.00±1.20 ^{abcN}	17.00±2.65 ^{bcO}	16.00±2.12 ^{cP}	15.50±2.1 ^{cP}	17.58±1.5 ^C	
	Ref	20.00±1.25 ^{aN}	19.60±1.11 ^{aN}	19.00±2.50 ^{aN}	18.40±2.11 ^{aNO}	18.00±1.3 ^{aOP}	17.80±2.22 ^{aOP}	18.80±1.2 ^B	
Punjab sindhuri red									
T1	Room	20.00±1.55 ^{aN}	-	-	-	-	-	3.33±0.21 ^B	16.54±0.79 ^y
	Ref	20.00±1.00 ^{aN}	16.00±0.15 ^{bO}	-	-	-	-	6.00±0.30 ^B	
T2	Room	21.00±2.15 ^{aM}	20.00±0.96 ^{abNO}	19.50±1.22 ^{abN}	19.00±1.33 ^{abO}	18.00±1.36 ^{bO}	17.00±1.02 ^{bO}	20.00±1.2 ^A	
	Ref	21.00±2.33 ^{aMN}	20.50±1.00 ^{aMN}	20.40±2.22 ^{abMN}	19.00±1.25 ^{abcMN}	19.00±1.33 ^{bMNO}	18.00±1.00 ^{abMNO}	19.65±1.5 ^A	
T3	Room	21.00±1.22 ^{aM}	21.00±2.00 ^{aM}	20.00±1.95 ^{abcM}	20.00±2.33 ^{abcMN}	20.00±1.00 ^{bcMN}	19.00±2.03 ^{cMN}	20.16±1.6 ^A	
	Ref	21.00±0.97 ^{aM}	20.80±2.52 ^{aM}	20.00±2.45 ^{Ma}	19.50±2.00 ^{aM}	19.50±2.65 ^{aM}	19.00±1.75 ^{aM}	19.96±1.5 ^A	
T4	Room	21.00±0.94 ^{aMN}	21.00±2.36 ^{abMN}	19.00±1.22 ^{abMN}	19.00±1.23 ^{abNO}	18.00±2.41 ^{abMNO}	17.00±1.6 ^{bNO}	19.16±2.1 ^A	
	Ref	21.00±1.22 ^{aMN}	21.00±1.75 ^{aMN}	20.00±1.00 ^{aMN}	20.00±2.36 ^{aMN}	19.00±0.76 ^{aMN}	19.00±1.8 ^{aMN}	20.00±2.1 ^A	
T5	Room	20.00±2.50 ^{aMN}	20.00±2.33 ^{abMN}	19.00±1.00 ^{abcMN}	18.00±3.1 ^{bcNO}	17.00±1.6 ^{cNO}	16.00±2.00 ^{cNO}	18.33±1.8 ^A	
	Ref	20.00±2.36 ^{aMN}	19.00±1.2 ^{aMN}	19.00±2.30 ^{aMN}	18.60±2.6 ^{aMN}	18.50±2.01 ^{aMNO}	18.00±2.65 ^{aMN}	18.85±1.6 ^A	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=NS; Month * Storage condition=<.001; Month * Treatment=<.001;

Variety * Storage condition=NS; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS;

Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment= NS

Table 4.39: Effect of treatment, storage period and storage condition on the total solids (%) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean	
		0	2	4	6	8	10			
CH-27 Green										
T1	Room	86.09±1.00 ^{aM}	-	-	-	-	-	14.34±33.01 ^d	67.22±3.8 ^y	
	Ref	86.09±0.95 ^{aM}	78.29±1.05 ^{bN}	-	-	-	-	27.39±39.93 ^c		
T2	Room	79.14±1.12 ^{aN}	78.53±0.95 ^{aN}	76.80±0.86 ^{abQ}	74.20±1.02 ^{bR}	70.01±1.23 ^{cR}	66.73±1.01 ^{dQ}	74.23±4.73 ^b		
	Ref	79.14±0.94 ^{aN}	78.49±1.03 ^{abN}	78.30±0.91 ^{abPQ}	77.29±1.23 ^{abPQ}	76.32±1.30 ^{bPQ}	76.01±1.40 ^{bOP}	77.59±1.43 ^b		
T3	Room	76.72±0.88 ^{aN}	76.57±0.84 ^{abN}	74.16±0.76 ^{abR}	73.97±1.03 ^{bR}	70.15±1.56 ^{cR}	68.56±1.94 ^{cQ}	73.35±3.25 ^b		
	Ref	76.72±1.5 ^{aN}	76.37±1.10 ^{aN}	75.84±1.00 ^{abQR}	75.44±0.94 ^{abQR}	74.25±1.03 ^{abQ}	73.47±1.04 ^{bP}	75.34±1.44 ^b		
T4	Room	85.11±2.33 ^{aM}	83.92±1.94 ^{aM}	80.51±2.94 ^{bOP}	79.18±3.12 ^{bcOP}	78.56±2.45 ^{bcOP}	76.61±3.56 ^{cO}	80.64±3.18 ^a		
	Ref	85.11±2.01 ^{aM}	83.03±3.04 ^{abM}	81.20±1.78 ^{bcNO}	81.04±1.94 ^{bcNO}	80.01±2.10 ^{cNO}	79.25±2.00 ^{cN}	81.60±2.17 ^a		
T5	Room	85.73 ±1.51 ^{aM}	85.41±1.63 ^{aM}	84.35±1.70 ^{abM}	83.98±1.48 ^{abM}	83.32±1.47 ^{abM}	82.25±1.45 ^{bM}	84.17±1.48 ^a	65.53±4.9 ^z	
	Ref	85.73±1.01 ^{aM}	84.97±1.2 ^{abM}	83.55±0.89 ^{abcMN}	83.19±0.78 ^{abcMN}	82.28±0.78 ^{bcMN}	81.48±1.01 ^{cMN}	83.53±1.72 ^a		
CH-27 red										
T1	Room	79.93±1.20 ^{aM}	-	-	-	-	-	13.32±30.65 ^b		65.53±4.9 ^z
	Ref	79.93±0.90 ^{aM}	78.82±0.50 ^{aM}	-	-	-	-	26.45±38.5 ^b		
T2	Room	78.28±0.91 ^{aM}	77.40±1.70 ^{abM}	76.26±1.68 ^{abc}	75.76±1.78 ^{abcN}	75.42±0.84 ^{bcN}	74.02±1.12 ^{cNO}	76.19±1.64 ^a		
	Ref	74.28±1.03 ^{aM}	73.37±1.23 ^{aN}	73.07±0.94 ^a	72.58±1.26 ^{aO}	72.14±1.40 ^{aO}	71.95±0.87 ^{aN}	72.89±1.16 ^a		
T3	Room	80.54±2.10 ^{aM}	79.14±1.95 ^{abM}	77.43±1.84 ^{bc}	76.87±1.74 ^{bcdN}	75.33±1.94 ^{cdN}	74.25±2.23 ^{dNO}	77.26±1.72 ^a		
	Ref	78.54±2.50 ^{aM}	77.64±2.15 ^{abM}	76.56±2.41 ^{ab}	76.05±2.1 ^{abN}	75.98±2.10 ^{abMN}	75.34±2.45 ^{bN}	76.68±2.34 ^a		
T4	Room	80.31±1.56 ^{aM}	79.14±1.54 ^{abM}	78.74±1.12 ^{abc}	77.25±1.58 ^{bcMN}	77.12±1.45 ^{bcMN}	76.25±1.50 ^{cMN}	78.13±1.39 ^a		
	Ref	80.31±1.80 ^{aM}	80.11±1.78 ^{aM}	80.23±1.74 ^a	79.76±1.74 ^{aM}	78.36±1.78 ^{aM}	78.27±1.78 ^{aM}	79.50±1.65 ^a		
T5	Room	80.00±1.54 ^{aM}	79.89±1.59 ^{aM}	77.43±1.51 ^{ab}	76.25±1.55 ^{bcN}	75.25±1.44 ^{bcN}	74.60±1.30 ^{cN}	77.23±1.22 ^a	30.09±33.67 ^b	
	Ref	78.98±2.53 ^{aM}	78.49±2.67 ^{aM}	78.12±2.45 ^a	77.18±2.21 ^{aMN}	77.01±2.48 ^{aMN}	76.25±2.32 ^{aMN}	77.67±2.32 ^a		
Punjab sindhuri green										
T1	Room	87.80±1.00 ^{aM}	-	-	-	-	-	14.63±33.67 ^b		30.09±33.67 ^b
	Ref	87.80±0.94 ^{aM}	92.77±1.23 ^{bM}	-	-	-	-	30.09±33.67 ^b		

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
T2	Room	83.50±2.50 ^{aN}	81.36±2.10 ^{abO}	80.29±2.00 ^{bP}	79.46±1.94 ^{bcO}	79.15±2.00 ^{bcP}	77.13±2.35 ^{cP}	80.14±2.19 ^a	72.52±3.6 ^w
	Ref	83.50±4.00 ^{bN}	92.28±4.01 ^{aM}	92.26±3.91 ^{aMN}	81.68±2.48 ^{bO}	84.23±4.82 ^{bO}	84.35±4.50 ^{bN}	86.38±4.45	
T3	Room	78.33±1.00 ^{aO}	77.02±0.97 ^{abP}	76.44±1.10 ^{abQ}	76.12±0.94 ^{abP}	75.22±1.54 ^{bQ}	75.12±1.58 ^{bP}	76.37±1.40 ^a	
	Ref	78.33±1.74 ^{bcO}	92.37±1.44 ^{aM}	92.12±1.23 ^{aMN}	76.62±1.11 ^{cP}	78.51±1.89 ^{bcP}	80.54±1.85 ^{bO}	83.08±1.82 ^a	
T4	Room	87.97±1.44 ^{aM[^]}	86.37±1.25 ^{abN}	86.76±1.25 ^{abO}	85.79±1.01 ^{abN}	85.21±1.64 ^{bO}	84.11±1.12 ^{bN}	86.03±1.50 ^a	
	Ref	87.97±1.64 ^{bM}	91.44±1.65 ^{aM}	91.42±1.74 ^{aN}	87.52±1.40 ^{bMN}	88.71±1.95 ^{abN}	89.93±1.75 ^{abM}	89.49±1.80 ^a	
T5	Room	88.62±1.24 ^{aM}	87.67±1.21 ^{abN}	87.15±1.19 ^{abO}	86.52±1.10 ^{abMN}	86.11±1.55 ^{abO}	85.71±1.25 ^{bN}	86.96±1.31 ^a	
	Ref	88.62±2.40 ^{cM}	93.84±2.00 ^{bM}	94.28±2.01 ^{bM}	89.05±1.78 ^{cM}	97.64±3.78 ^{aM}	88.96±3.12 ^{cM}	92.06±3.60 ^a	
Punjab sindhuri red									
T1	Room	87.17±2.11 ^{aM}	-	-	-	-	-	14.52±33.40 ^b	70.64±4.8 ^x
	Ref	87.17±1.94 ^{aM}	95.22±1.54 ^{bM}	-	-	-	-	30.39±44.30 ^b	
T2	Room	78.19±2.50 ^{aO}	77.40±2.36 ^{abP}	76.30±1.36 ^{abcP}	75.25±2.78 ^{bcdPQ}	74.25±2.66 ^{cdO}	73.51±1.11 ^{dQ}	75.81±1.91 ^a	
	Ref	78.19±5.55 ^{cO}	92.62±3.65 ^{aMN}	92.61±2.36 ^{aMN}	82.50±2.56 ^{bN}	91.02±2.33 ^{aM}	90.94±2.36 ^{aM}	87.98±5.80 ^a	
T3	Room	75.95±2.25 ^{aOP}	75.04±2.36 ^{aP}	74.82±3.65 ^{aP}	74.06±2.32 ^{aQ}	73.83±1.56 ^{aO}	73.21±1.22 ^{aQ}	74.48±1.24 ^a	
	Ref	75.15±1.35 ^{dP}	93.84±1.26 ^{aM}	94.03±7.56 ^{aM}	76.73±1.95 ^{dOP}	90.01±2.36 ^{bM}	80.31±1.56 ^{cO}	85.01±8.14 ^a	
T4	Room	83.01±2.32 ^{aN}	82.73±3.33 ^{aO}	81.30±4.56 ^{abP}	79.30±1.88 ^{bcO}	78.25±1.23 ^{cN}	77.79±3.11 ^{cOP}	80.39±2.28 ^a	
	Ref	83.01±1.36 ^{dN}	93.89±2.65 ^{aM}	94.68±2.36 ^{aM}	86.37±1.78 ^{cM}	90.14±1.33 ^{bM}	87.93±2.78 ^{bcN}	89.33±4.29 ^a	
T5	Room	82.89±3.22 ^{aN}	81.27±1.25 ^{abO}	80.12±1.89 ^{bcP}	79.25±1.45 ^{bcO}	78.45±1.56 ^{cN}	77.58±0.36 ^{cP}	79.92±2.00 ^a	
	Ref	82.89±1.45 ^{bN}	90.93±1.36 ^{aN}	90.91±1.75 ^{aN}	88.26±2.66 ^{aM}	89.79±2.36 ^{aM}	88.32±1.78 ^{aN}	88.51±2.93 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

Table 4.40: Effect of treatment, storage period and storage condition on the pH of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	5.80±0.99 ^{aM}	-	-	-	-	-	0.96±2.3 ^b	3.60±0.7 ^w
	Ref	5.32±1.23 ^{aM}	5.22±1.35 ^{aM}	-	-	-	-	1.70±2.7 ^b	
T2	Room	4.19±1.28 ^{aM}	4.10±1.49 ^{aM}	4.01±1.51 ^{aM}	3.92±1.53 ^{aM}	3.86±1.45 ^{aM}	3.82±1.52 ^{aM}	3.98±0.2 ^a	
	Ref	4.19±0.46 ^{aM}	4.15±0.29 ^{aM}	4.10±0.13 ^{aM}	4.02±0.36 ^{aM}	4.06±0.41 ^{aM}	3.92±0.41 ^{aM}	4.07±0.93 ^a	
T3	Room	3.94±0.36 ^{aM}	3.81±0.26 ^{aM}	3.74±1.10 ^{aM}	3.68±1.31 ^{aM}	3.65±1.43 ^{aM}	3.62±0.99 ^{aM}	3.74±1.01 ^a	
	Ref	3.94±0.37 ^{aM}	3.89±0.21 ^{aM}	3.84±1.50 ^{aM}	3.80±1M.70 ^{aM}	3.75±1.80 ^{aM}	3.72±1.00 ^{aM}	3.82±0.68 ^a	
T4	Room	4.73±0.48 ^{aM}	4.65±0.31 ^{aM}	4.59±1.30 ^{aM}	4.48±1.23 ^{aM}	4.40±0.85 ^{aM}	4.35±0.79 ^{aM}	4.53±0.6 ^a	
	Ref	4.73±0.41 ^{aM}	4.69±0.34 ^{aM}	4.62±1.34 ^{aM}	4.58±1.54 ^{aM}	4.51±1.21 ^{aM}	4.46±1.30 ^{aM}	4.59±1.09 ^a	
T5	Room	4.41±0.31 ^{aM}	4.37±0.41 ^{aM}	4.30±1.2 ^{aM}	4.24±1.61 ^{aM}	4.17±1.64 ^{aM}	4.10±1.01 ^{aM}	4.26±0.84 ^a	
	Ref	4.41±0.36 ^{aM}	4.39±0.39 ^{aM}	4.33±1.56 ^{aM}	4.29±1.66 ^{aM}	4.25±1.44 ^{aM}	4.20±1.50 ^{aM}	4.31±1.26 ^a	
CH-27 red									
T1	Room	6.21±0.50 ^{aM}	-	-	-	-	-	1.03±2.38 ^b	3.56±0.6 ^w
	Ref	6.21±1.20 ^{aM}	6.06±1.80 ^{aM}	-	-	-	-	2.04±3.07 ^b	
T2	Room	4.01±1.10 ^{aM}	3.89±1.60 ^{aM}	3.74±1.40 ^{aM}	3.62±1.70 ^{aM}	3.55±1.30 ^{aM}	3.50±1.50 ^a	3.71±1.19 ^a	
	Ref	4.01±0.70 ^{aM}	3.95±0.85 ^{aM}	3.90±0.75 ^{aM}	3.86±0.99 ^{aM}	3.82±1.01 ^{aM}	3.76±0.81 ^{aM}	3.88±0.67 ^a	
T3	Room	3.72±1.10 ^{aM}	3.61±0.95 ^{aM}	3.53±0.99 ^{aM}	3.68±1.01 ^{aM}	3.65±1.20 ^{aM}	3.61±0.90 ^{aM}	3.72±0.84 ^a	
	Ref	3.72±0.40 ^{aM}	3.68±0.34 ^{aM}	3.63±0.45 ^{aM}	3.62±0.31 ^{aM}	3.62±0.47 ^{aM}	3.61±0.40 ^{aM}	3.64±0.33 ^a	
T4	Room	4.64±1.60 ^{aM}	4.59±1.8 ^{aM}	4.51±1.4 ^{aM}	4.46±1.60 ^{aM}	4.40±1.30 ^{aM}	4.35±1.90 ^{aM}	4.49±1.34 ^a	
	Ref	4.64±0.31 ^{aM}	4.59±0.30 ^{aM}	4.55±0.29 ^{aM}	4.49±0.32 ^{aM}	4.45±0.31 ^{aM}	4.41±0.28 ^{aM}	4.52±0.26 ^a	
T5	Room	4.49±1.60 ^{aM}	4.40±1.42 ^{aM}	4.34±1.80 ^{aM}	4.29±1.58 ^{aM}	4.22±1.62 ^{aM}	4.18±1.60 ^{aM}	4.31±1.34 ^a	
	Ref	4.49±1.10 ^{aM}	4.42±1.00 ^{aM}	4.38±0.94 ^{aM}	4.32±1.21 ^{aM}	4.28±1.01 ^{aM}	4.24±1.00 ^{aM}	4.35±0.92 ^a	
Punjab sindhuri green									
T1	Room	5.29±0.90 ^{aM}	-	-	-	-	-	0.88±2.05 ^b	
	Ref	5.29±1.70 ^{aM}	5.17±1.10 ^{aM}	-	-	-	-	0.88±2.10 ^b	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
T2	Room	3.53±0.80 ^{aM}	3.51±0.78 ^{aM}	3.47±0.75 ^{aM}	3.42±0.85 ^{aM}	3.47±0.82 ^{aM}	3.42±0.80 ^{aM}	3.47±0.67 ^a	3.11±0.9 ^x
	Ref	3.53±0.70 ^{aM}	3.51±0.75 ^{am}	3.49±0.79 ^{aM}	3.45±0.70 ^{aM}	3.47±0.67 ^{aM}	3.44±0.62 ^{aM}	3.48±0.58 ^a	
T3	Room	3.51±1.71 ^{aM}	3.49±1.74 ^{aM}	3.42±1.79 ^{aM}	3.40±1.85 ^{aM}	3.35±1.81 ^{aM}	3.28±1.69 ^{aM}	3.40±1.43 ^a	
	Ref	3.51±1.00 ^{aM}	3.49±0.05 ^{aM}	3.45±0.09 ^{aM}	3.42±1.50 ^{aM}	3.39±1.60 ^{aM}	3.32±1.00 ^{aM}	3.42±0.84 ^a	
T4	Room	4.09±1.66 ^{aM}	4.01±1.60 ^{aM}	3.96±1.55 ^{aM}	3.92±1.52 ^{aM}	3.88±1.60 ^{aM}	3.82±1.61 ^{aM}	3.42±1.34 ^a	
	Ref	4.09±1.20 ^{aM}	4.01±1.02 ^{aM}	3.98±0.8 ^{aM}	3.95±0.8 ^{aM}	3.90±1.2 ^{aM}	3.87±1.00 ^{aM}	3.96±1.01 ^a	
T5	Room	3.93±0.40 ^{aM}	3.90±0.9 ^{aM}	3.85±1.1 ^{aM}	3.80±0.00 ^{aM}	3.75±1.00 ^{aM}	3.70±0.14 ^{aM}	3.82±0.34 ^a	
	Ref	3.93±1.40 ^{aM}	3.90±0.94 ^{aM}	3.88±1.48 ^{aM}	3.83±1.00 ^{aM}	3.80±1.02 ^{aM}	3.76±1.20 ^{aM}	3.85±1.17 ^a	
Punjab sindhuri red									
T1	Room	5.54±0.50 ^{aM}	-	-	-	-	-	0.92±0.21 ^b	3.61±0.7 ^w
	Ref	5.54±0.10 ^{aM}	5.42±0.11 ^{aM}	-	-	-	-	0.92±0.22 ^b	
T2	Room	4.46±0.60 ^{aM}	4.41±0.62 ^{aM}	4.37±0.58 ^{aM}	4.33±0.60 ^{aM}	4.28±0.60 ^{aM}	4.23±0.34 ^{aM}	4.46±0.51 ^a	
	Ref	4.46±1.60 ^{aM}	4.42±1.65 ^{aM}	4.39±1.70 ^{aM}	4.35±1.84 ^{aM}	4.29±1.56 ^{aM}	4.25±0.94 ^{aM}	4.361.34 ^a	
T3	Room	4.06±0.70 ^{aM}	3.96±0.75 ^{aM}	3.90±0.77 ^{aM}	3.85±0.91 ^{aM}	3.80±0.56 ^{aM}	3.75±0.44 ^{aM}	3.88±0.59 ^a	
	Refr	4.06±2.10 ^{aM}	3.96±2.50 ^{aM}	3.93±1.80 ^{aM}	3.89±1.10 ^{aM}	3.85±1.40 ^{aM}	3.79±1.40 ^{aM}	3.91±1.77 ^a	
T4	Room	4.69±1.00 ^{aM}	4.60±0.94 ^{aM}	4.54±1.20 ^{aM}	4.50±1.40 ^{aM}	4.48±0.64 ^{aM}	4.42±1.78 ^{aM}	4.53±0.84 ^a	
	Ref	4.69±1.70 ^{aM}	4.63±1.54 ^{aM}	4.59±1.10 ^{aM}	4.55±1.44 ^{aM}	4.51±1.13 ^{aM}	4.49±0.94 ^{aM}	4.57±1.43 ^a	
T5	Room	4.48±0.80 ^{aM}	4.40±0.90 ^{aM}	4.37±1.20 ^{aM}	4.32±1.11 ^{aM}	4.28±0.42 ^{aM}	4.23±0.75 ^{aM}	4.34±0.71 ^a	
	Ref	4.48±1.80 ^{aM}	4.42±1.74 ^{aM}	4.39±1.50 ^{aM}	4.34±1.55 ^{aM}	4.31±1.11 ^{aM}	4.28±1.34 ^{aM}	4.37±1.51 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantlywhere w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=NS; Treatment=<.001; Month * Variety=NS; Month * Storage condition=NS; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=NS; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS; Month * Storage condition * Treatment=NS; Variety * Storage condition * Treatment=NS; Month * Variety * Storage condition * Treatment= NS

Table 4.41: Effect of treatment, storage period and storage condition on titratable acidity (%) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	0.43±1.10 ^{aM}	-	-	-	-	-	0.07±0.38 ^d	0.95±0.05 ^x
	Ref	0.43±1.00 ^{aM}	0.51±0.95 ^{aM}	-	-	-	-	0.15±0.53 ^d	
T2	Room	1.05±1.50 ^{aM}	1.10±1.54 ^{aM}	1.14±1.61 ^{aM}	1.19±1.51 ^{aM}	1.21±1.45 ^{aM}	1.27±1.1.36 ^{aM}	1.15±1.26 ^{abc}	
	Ref	1.05±0.30 ^{aM}	1.07±0.45 ^{aM}	1.10±0.51 ^{aM}	1.13±0.32 ^{aM}	1.16±0.25 ^{aM}	1.20±0.31 ^{aM}	1.11±0.25 ^{abc}	
T3	Room	1.35±1.10 ^{aM}	1.39±1.26 ^{aM}	1.42±1.34 ^{aM}	1.47±1.00 ^{aM}	1.48±0.95 ^{aM}	1.53±1.06 ^{aM}	1.43±1.10 ^a	
	Ref	1.35±1.20 ^{aM}	1.36±1.45 ^{aM}	1.39±1.52 ^{aM}	1.41±1.00 ^{aM}	1.43±0.97 ^{aM}	1.45±1.23 ^{aM}	1.39±1.20 ^a	
T4	Room	0.75±0.80 ^{aM}	0.79±0.95 ^{aM}	0.81±1.10 ^{aM}	0.82±0.82 ^{aM}	0.88±0.65 ^{aM}	0.90±0.74 ^{aM}	0.82±0.80 ^{bc}	
	Ref	0.75±1.30 ^{aM}	0.76±1.45 ^{aM}	0.79±1.53 ^{aM}	0.81±1.34 ^{aM}	0.84±0.74 ^{aM}	0.89±0.96 ^{aM}	0.80±1.30 ^c	
T5	Room	1.20±1.00 ^{aM}	1.26±1.32 ^{aM}	1.29±1.39 ^{aM}	1.32±1.02 ^{aM}	1.35±1.10 ^{aM}	1.39±0.91 ^{aM}	1.30±1.00 ^{ab}	
	Ref	1.20±1.24 ^{aM}	1.26±1.45 ^{aM}	1.29±1.46 ^{aM}	1.32±1.26 ^{aM}	1.34±0.97 ^{aM}	1.35±1.12 ^{aM}	1.29±1.24 ^{ab}	
CH-27 red									
T1	Room	0.46±0.50 ^{aM}	-	-	-	-	-	0.07±0.24 ^e	1.17±0.06 ^{wx}
	Ref	0.46±1.60 ^{aM}	-	-	-	-	-	0.07±0.57 ^e	
T2	Room	1.50±1.40 ^{aM}	1.54±1.10 ^{aM}	1.58±1.12 ^{aM}	1.64±2.84 ^{aM}	1.66±2.21 ^{aM}	1.70±1.41 ^{aM}	1.60±1.17 ^{abc}	
	Ref	1.50±0.80 ^{aM}	1.52±0.60 ^{aM}	1.54±0.11 ^{aM}	1.57±1.65 ^{aM}	1.56±0.40 ^{aM}	1.53±0.75 ^{aM}	1.53±0.67 ^{bc}	
T3	Room	1.21±1.00 ^{aM}	1.25±0.84 ^{aM}	1.30±0.24 ^{aM}	1.33±2.51 ^{aM}	1.36±0.54 ^{aM}	1.40±0.98 ^{aM}	1.30±0.84 ^{cd}	
	Ref	1.21±0.40 ^{aM}	1.22±0.23 ^{aM}	1.25±0.21 ^{aM}	1.27±0.84 ^{aM}	1.29±0.24 ^{aM}	1.30±0.38 ^{aM}	1.25±0.33 ^{cd}	
T4	Room	0.80±1.34 ^{aM}	0.85±1.20 ^{aM}	0.89±0.56 ^{aM}	0.93±2.84 ^{aM}	0.95±0.61 ^{aM}	0.98±1.24 ^{aM}	0.90±1.34 ^d	
	Ref	0.80±0.30 ^{aM}	0.82±0.13 ^{aM}	0.85±0.15 ^{aM}	0.89±2.48 ^{aM}	0.91±0.15 ^{aM}	0.93±0.27 ^{aM}	0.86±0.25 ^d	
T5	Room	2.05±1.60 ^{aM}	2.10±0.54 ^{aM}	2.15±0.84 ^{aM}	2.19±0.69 ^{aM}	2.23±0.84 ^{aM}	1.26±1.40 ^{aM}	1.99±1.38 ^{ab}	
	Ref	2.05±1.10 ^{aM}	2.08±1.00 ^{aM}	2.11±0.55 ^{aM}	2.14±2.28 ^{aM}	2.17±0.55 ^{aM}	2.20±0.89 ^{aM}	2.12±0.92 ^a	
Punjab sindhuri green									
T1	Room	0.46±1.00 ^{aM}	-	-	-	-	-	0.07±0.38 ^e	
	Ref	0.46±0.91 ^{aM}	0.39±1.23 ^{aM}	-	-	-	-	0.14±0.52 ^e	
T2	Room	1.50±1.00 ^{aM}	1.54±1.56 ^{aM}	1.58±1.30 ^{aM}	1.64±1.01 ^{aM}	1.66±1.00 ^{aM}	1.70±0.51 ^{aM}	1.60±0.84 ^{abc}	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	1.50±1.20 ^{aM}	1.52±1.00 ^{aM}	1.54±1.10 ^{aM}	1.57±1.11 ^{aM}	1.56±1.02 ^{aM}	1.53±0.61 ^{aM}	1.53±0.81 ^{bc}	0.91±0.07 ^x
T3	Room	1.21±0.94 ^{aM}	1.25±0.94 ^{aM}	1.30±1.00 ^{aM}	1.33±1.91 ^{aM}	1.36±0.75 ^{aM}	1.40±0.24 ^{aM}	1.30±0.80 ^{cd}	
	Ref	1.21±1.23 ^{aM}	1.22±0.96 ^{aM}	1.25±1.00 ^{aM}	1.27±1.36 ^{aM}	1.29±1.00 ^{aM}	1.30±0.41 ^{aM}	1.25±0.88 ^{cd}	
T4	Room	0.80±0.88 ^{aM}	0.85±1.11 ^{aM}	0.89±0.91 ^{aM}	0.93±1.00 ^{aM}	0.95±0.86 ^{aM}	0.98±0.44 ^{aM}	0.90±0.88 ^d	
	Ref	0.80±1.23 ^{aM}	0.82±0.54 ^{aM}	0.85±0.89 ^{aM}	0.89±0.74 ^{aM}	0.91±1.24 ^{aM}	0.93±0.26 ^{aM}	0.86±0.87 ^d	
T5	Room	2.05±0.94 ^{aM}	2.10±0.57 ^{aM}	2.15±0.91 ^{aM}	2.19±0.91 ^{aM}	2.23±1.35 ^{aM}	1.26±0.11 ^{aM}	1.99±0.92 ^{ab}	
	Ref	2.05±0.94 ^{aM}	2.08±0.94 ^{aM}	2.11±0.99 ^{aM}	2.14±1.12 ^{aM}	2.17±1.02 ^{aM}	2.20±1.00 ^{aM}	2.12±0.90 ^a	
Punjab sindhuri red									
T1	Room	0.28±0.50 ^{aM}	-	-	-	-	-	0.04± 0.20 ^c	1.32±0.06 ^w
	Ref	0.28±0.10 ^{aM}	0.36±0.10 ^{aM}	-	-	-	-	0.10±0.16 ^c	
T2	Room	1.80±0.60 ^{aM}	1.85±0.61 ^{aM}	1.89±0.64 ^{aM}	1.91±0.68 ^{aM}	1.92±0.54 ^{aM}	1.99±0.60 ^{aM}	1.89±0.50 ^a	
	Ref	1.80±1.60 ^{aM}	1.82±1.80 ^{aM}	1.85±1.74 ^{aM}	1.89±1.68 ^{aM}	1.91±1.71 ^{aM}	1.93±1.61 ^{aM}	1.86±1.34 ^a	
T3	Room	1.81±0.70 ^{aM}	1.85±0.80 ^{aM}	1.81±0.78 ^{aM}	1.80±0.68 ^{aM}	1.78±0.71 ^{aM}	1.76±0.74 ^{aM}	1.80±0.58 ^a	
	Ref	1.81±2.10 ^{aM}	1.83±2.20 ^{aM}	1.81±2.10 ^{aM}	1.80±1.98 ^{aM}	1.79±2.01 ^{aM}	1.79±2.19 ^{aM}	1.80±1.76 ^a	
T4	Room	1.01±1.00 ^{aM}	1.07±1.20 ^{aM}	1.10±1.85 ^{aM}	1.12±1.82 ^{aM}	1.14±1.99 ^{aM}	1.18±1.33 ^{aM}	1.10±0.84 ^b	
	Ref	1.01±1.70 ^{aM}	1.02±1.90 ^{aM}	1.06±1.84 ^{aM}	1.09±1.81 ^{aM}	1.11±1.95 ^{aM}	1.14±1.75 ^{aM}	1.07±1.42 ^b	
T5	Room	1.72±0.80 ^{aM}	1.75±0.92 ^{aM}	1.79±0.85 ^{aM}	1.81±0.81 ^{aM}	1.83±0.99 ^{aM}	1.87±0.84 ^{aM}	1.79±0.67 ^a	
	Ref	1.72±1.80 ^{aM}	1.74±1.90 ^{aM}	1.76±1.86 ^{aM}	1.79±1.82 ^{aM}	1.80±1.94 ^{aM}	1.83±1.86 ^{aM}	1.77±1.51 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.									

CD_(0.05)

Month=NS; Variety=<.001; Storage condition=NS; Treatment=<.001; Month * Variety=NS; Month * Storage condition=NS; Month * Treatment=NS; Variety * Storage condition=NS; Variety * Treatment=NS; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS; Month * Storage condition * Treatment=NS; Variety * Storage condition * Treatment=NS; Month * Variety * Storage condition * Treatment=NS

sample stored at room temperature. Highest acidity value for samples treated with sodium benzoate was also reported by Sharmin *et al* (2020). Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of acidity (2.12%) for the storage period. Samples of Punjab Sindhuri red with treatment number 5 and stored at room conditions had a mean value of 1.79 per cent. The maximum mean value for acidity (1.32%) of chili paste after 8 months of storage at room and refrigeration temperature together was observed Punjab Sindhuri red samples followed by CH-27 red. Higher acidity with sodium benzoate than acetic acid was observed that might be related with the fact that the benzoic acid is stronger acid than acetic acid. The chili variety (CH-27 and Punjab sindhuri) and treatments were found to have significant ($p \leq 0.05$) effect on acidity (Table 4.41).

4.5.6 Effect of treatment, storage period and storage condition on the ash content (%) of chili paste

The ash content value of stored chilli paste is represented in Table 4.42. For the CH-27 green chilli variety, the samples with treatment number 5 and stored at room temperature had the highest mean value of ash content value during the storage period with a value of 93.98 per cent and the lowest was for the control sample stored at room temperature. While for the CH-27 red chilli variety, the samples with treatment number 2 and stored at room temperature has the highest mean value of ash content value during the storage period with a value of 94.93 per cent and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 5 and stored at room temperature has highest mean value of ash content value (94.79) for the storage period. Samples of Punjab Sindhuri red with treatment number 2 and stored at refrigeration conditions had a highest mean value of 94.15 per cent. Overall, the maximum mean value for ash content value (79.33%) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri red samples and least (78.39%) was reported for CH-27 green variety samples. Statistically, only the linear terms of month, storage condition and treatment and interaction terms of month * storage condition, month * treatment, storage condition * treatment, month * storage condition * treatment and variety * storage condition * treatment had significant ($p \leq 0.05$) effect on ash content, while other terms were reported as non-significant (Table 4.42). Similar results were reported by Khan *et al* (2016).

4.5.7 Effect of treatment, storage period and storage condition on the colour *L* value of chili paste

The *L* value of stored chilli paste is represented in Table 4.43. During the initial time, the *L* value of the samples ranged from 32.27 to 57.29. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at room temperature has the highest mean value of *L* value during the storage period with a value of 52.58 and the lowest was for the control

Table 4.42: Effect of treatment, storage period and storage condition on the ash content (%) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	96.19±1.23 ^{aM}	-	-	-	-	-	16.03±1.1 ^b	78.39±3.5 ^w
	Ref	96.19±2.31 ^{aM}	93.56±2.36 ^{bM}	-	-	-	-	26.09±1.8 ^b	
T2	Room	93.26±1.36 ^{aN}	93.12±2.45 ^{aM}	89.29±2.65 ^{bN}	88.92±2.79 ^{bcO}	86.49±1.45 ^{cdP}	84.35±3.45 ^{dP}	89.23±4.4 ^a	
	Ref	95.26±2.25 ^{aMN}	94.26±2.65 ^{aM}	93.96±2.36 ^{aM}	92.97±2.78 ^{abM}	90.65±5.45 ^{bcMNO}	89.59±3.65 ^{cNO}	92.78±5.2 ^a	
T3	Room	94.60±2.45 ^{aMN}	94.15±2.36 ^{aM}	93.27±2.45 ^{abM}	92.49±3.54 ^{abM}	92.14±2.65 ^{abMN}	91.25±4.85 ^{bMN}	92.98±5.1 ^a	
	Ref	94.60±2.65 ^{aMN}	93.56±2.75 ^{abM}	92.87±3.12 ^{abcM}	92.71±6.45 ^{abcM}	91.25±3.75 ^{bcMN}	90.59±5.78 ^{cMNO}	92.59±6.2 ^a	
T4	Room	93.90±3.65 ^{aMN}	93.28±3.45 ^{aM}	92.97±3.12 ^{aM}	92.13±2.45 ^{aM}	92.00±4.56 ^{aMN}	91.28±5.69 ^{aMN}	92.59±4.9 ^a	
	Ref	93.90±3.66 ^{aMN}	93.23±3.45 ^{aM}	92.23±4.56 ^{aM}	89.04±3.12 ^{bNO}	88.56±3.45 ^{bOP}	88.02±6.45 ^{bO}	90.83±5.0 ^a	
T5	Room	95.16±3.44 ^{aMN}	95.01±4.56 ^{aM}	94.25±1.78 ^{aM}	93.57±1.78 ^{aM}	93.05±3.58 ^{aM}	92.85±2.36 ^{aM}	93.98±5.2 ^a	
	Ref	95.16±2.35 ^{aMN}	93.25±5.65 ^{abM}	92.58±1.89 ^{abcM}	91.51±1.36 ^{bcdMN}	90.25±6.78 ^{cdNO}	89.56±3.65 ^{dNO}	92.05±5.1 ^a	
CH-27 red									
T1	Room	97.37±3.45 ^{aM}	-	-	-	-	-	16.22±1.1 ^b	79.04±4.2 ^w
	Ref	97.37±3.65 ^{aM}	94.58±3.24 ^{aMNO}	-	-	-	-	32.00±2.0 ^a	
T2	Room	97.76±2.65 ^a	95.68±3.22 ^{abM}	94.29±3.45 ^{bM}	94.88±3.68 ^{bM}	93.86±3.45 ^{bM}	93.11±3.54 ^{bM}	94.93±4.4 ^a	
	Ref	97.76±6.75 ^a	93.59±2.45 ^{bMNO}	92.78±2.36 ^{bMNO}	90.96±3.45 ^{bcOP}	90.89±3.69 ^{bcNOP}	89.59±3.45 ^{cOP}	92.59±5.2 ^a	
T3	Room	93.00±5.36 ^{aN}	92.14±3.15 ^{abO}	91.21±2.95 ^{abNO}	91.46±2.69 ^{abNOP}	91.00±3.74 ^{abNOP}	90.25±3.65 ^{bNO}	91.51±5.0 ^a	
	Ref	94.00±2.36 ^{aN}	93.92±3.66 ^{aMNO}	92.17±1.36 ^{abMNO}	91.58±2.45 ^{abNOP}	90.58±2.45 ^{bNOP}	89.56±2.36 ^{bOP}	91.96±4.6 ^a	
T4	Room	94.89±3.23 ^{aMN}	94.10±3.45 ^{aMNO}	93.74±1.48 ^{aMN}	93.10±2.75 ^{aMNO}	92.95±3.45 ^{aMN}	92.58±3.45 ^{aMN}	93.50±4.2 ^a	
	Ref	94.89±2.45 ^{aMN}	92.75±3.65 ^{abNO}	90.86±2.36 ^{bcO}	89.36±3.45 ^{cdP}	88.59±2.65 ^{cdP}	87.57±3.65 ^{dP}	90.67±4.1 ^a	
T5	Room	96.98±1.23 ^{aM}	95.25±3.65 ^{abMn}	94.40±3.45 ^{abcM}	93.98±2.68 ^{bcMN}	91.88±3.65 ^{cdMNO}	90.34±3.45 ^{dNO}	93.93±3.2 ^a	
	Ref	96.98±2.45 ^{aM}	95.58±3.45 ^{aMNO}	94.58±3.69 ^{abM}	92.58±2.59 ^{bcMNO}	90.25±3.45 ^{cdOP}	89.15±3.66 ^{dOP}	93.1±4.2 ^a	
Punjab sindhuri green									
T1	Room	99.70±3.45 ^{aM}	-	-	-	-	-	16.61±1.2 ^b	78.74±4.6 ^w
	Ref	97.70±3.26 ^{aMN}	96.15±1.36 ^{aM}	-	-	-	-	32.26±2.6 ^b	
T2	Room	94.94±1.23 ^{aN}	92.58±3.45 ^{abO}	91.00±2.64 ^{bcOP}	91.22±3.45 ^{bcNOP}	88.79±1.35 ^{cdOP}	87.28±1.02 ^{dP}	90.96±3.2 ^a	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	94.94±2.45 ^{aN}	94.51±4.56 ^{aMNO}	93.25±2.33 ^{abMNO}	92.54±3.45 ^{abcMNO}	91.28±2.35 ^{bcNO}	90.25±1.00 ^{cNO}	92.79±5.3 ^a	
T3	Room	95.43±3.95 ^{aN}	94.58±3.45 ^{abMNO}	94.26±2.45 ^{abMN}	93.77±2.36 ^{abMN}	92.96±2.34 ^{abMN}	92.48±1.23 ^{bMN}	93.91±5.4 ^a	
	Ref	95.43±2.65 ^{aN}	93.31±2.36 ^{aNO}	90.28±2.95 ^{bP}	88.35±2.33 ^{bcQ}	87.59±3.22 ^{bcP}	86.59±2.10 ^{cP}	90.25±5.6 ^a	
T4	Room	95.14±3.45 ^{aN}	93.26±2.96 ^{abNO}	91.73±2.75 ^{bcNOP}	89.32±2.34 ^{cdPQ}	88.35±3.20 ^{dP}	88.14±2.34 ^{dOP}	90.90±6.0 ^a	
	Ref	95.14±2.33 ^{aN}	94.22±2.85 ^{aMNO}	93.58±2.84 ^{abMNO}	92.80±2.55 ^{abcMNO}	91.25±1.02 ^{cdNO}	90.15±2.95 ^{dNO}	92.85±5.2 ^a	
T5	Room	96.45±4.22 ^{aN}	95.90±2.88 ^{abMN}	95.45±2.95 ^{abM}	94.23±2.35 ^{abM}	94.04±2.11 ^{abM}	93.59±2.75 ^{bM}	94.94±5.0 ^a	
	Ref	96.45±1.35 ^{aN}	93.20±2.36 ^{bNO}	92.15±3.54 ^{bcNOP}	90.81±2.33 ^{bcdOPQ}	89.56±1.02 ^{cdOP}	88.58±2.02 ^{dOP}	91.79±4.6 ^a	
Punjab sindhuri red									
T1	Room	96.06±2.36 ^a	-	-	-	-	-	16.01±1.1 ^c	79.33±5.0 ^w
	Ref	96.06±2.34 ^a	95.71±1.02 ^b	-	-	-	-	37.25±2.0 ^b	
T2	Room	94.25±2.15 ^a	93.25±1.03 ^{ab}	92.72±3.14 ^{abc}	91.79±2.65 ^{abc}	90.54±2.45 ^{cd}	90.00±2.11 ^d	92.09±4.9 ^a	
	Ref	94.25±2.95 ^{bc}	97.63±2.30 ^a	95.58±2.95 ^{ab}	94.61±2.95 ^{bc}	92.58±2.85 ^{cd}	90.25±3.15 ^d	94.15±5.2 ^a	
T3	Room	95.05±2.75 ^a	94.85±2.54 ^{ab}	94.09±2.64 ^{ab}	93.98±2.35 ^{ab}	93.02±2.48 ^{ab}	92.18±2.34 ^b	93.86±5.0 ^a	
	Ref	95.05±2.69 ^a	94.38±3.45 ^a	92.58±2.48 ^a	89.54±2.75 ^a	88.15±2.65 ^a	87.58±1.23 ^b	91.21±5.4 ^a	
T4	Room	94.34±2.41 ^a	92.36±2.46 ^a	91.42±2.65 ^a	90.59±2.75 ^a	90.02±2.36 ^a	89.18±1.02 ^b	91.31±5.0 ^a	
	Ref	94.34±2.36 ^{ab}	93.75±2.15 ^{ab}	92.58±2.51 ^{ab}	91.06±2.45 ^a	90.25±2.45 ^a	89.25±2.34 ^b	91.87±5.6 ^a	
T5	Room	94.78±2.65 ^a	94.00±3.19 ^{bc}	93.18±2.35 ^{abc}	92.38±2.65 ^{ab}	93.14±2.45 ^{ab}	92.36±2.65 ^c	93.30±5.2 ^a	
	Ref	94.78±2.34 ^a	94.04±2.49 ^{ab}	93.58±2.75 ^{abc}	92.80±2.15 ^{abc}	90.25±2.55 ^c	88.25±2.85 ^d	92.28±5.1 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=NS; Storage condition=<.001; Treatment=<.001; Month * Variety=NS; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=.026; Storage condition * Treatment=<.001; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment= NS

Table 4.43: Effect of treatment, storage period and storage condition on the colour (*L* value) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	51.80±0.85 ^{aN}	-	-	-	-	-	8.63±30.4 ^d	39.43±2.3 ^w
	Ref	51.80±1.36 ^{aN}	37.59±1.32 ^{bP}	-	-	-	-	14.89±31.1 ^a	
T2	Room	54.59±1.25 ^{aN}	53.37±1.23 ^{abM}	53.90±1.25 ^{abM}	52.59±1.65 ^{abM}	51.67±2.01 ^{bcM}	49.36±2.65 ^{cMN}	52.58±4.20 ^{bc}	
	Ref	54.59±1.02 ^{aN}	42.33±1.32 ^{bO}	40.41±2.25 ^{bcO}	39.72±1.78 ^{bcO}	39.69±2.11 ^{bcO}	39.54±2.44 ^{cP}	42.71±3.90 ^{ab}	
T3	Room	54.91±0.95 ^{aM}	52.80±1.12 ^{abM}	52.73±1.89 ^{abM}	50.94±2.21 ^{bMN}	51.85±1.65 ^{abM}	50.59±3.45 ^{bM}	52.30±4.50 ^c	
	Ref	54.91±0.85 ^{aM}	41.31±1.00 ^{bO}	39.97±4.33 ^{bcO}	38.24±2.01 ^{bcO}	38.21±1.77 ^{bcO}	38.91±3.55 ^{bcPQ}	41.92±3.22 ^{abc}	
T4	Room	52.27±0.75 ^{aN}	49.88±0.78 ^{abN}	49.83±1.25 ^{abN}	49.65±2.11 ^{abN}	48.24±1.88 ^{bcN}	46.15±2.36 ^{cNO}	49.33±3.26 ^{bc}	
	Ref	52.27±0.96 ^{aN}	40.37±0.68 ^{bO}	39.37±1.26 ^{bO}	39.22±1.89 ^{bO}	38.77±1.78 ^{bO}	38.27±2.33 ^{bPQ}	41.37±2.84 ^{abc}	
T5	Room	53.25±1.02 ^{aN}	49.07±1.36 ^{bN}	49.67±3.24 ^{bN}	48.88±1.75 ^{bN}	48.67±1.98 ^{bN}	47.35±4.55 ^{bO}	49.48±2.41 ^{bc}	
	Ref	53.25±1.03 ^{aN}	39.99±1.25 ^{bOP}	39.43±2.37 ^{bcO}	38.91±1.55 ^{bcO}	38.39±2.01 ^{bcO}	36.91±2.33 ^{cQ}	41.14±2.25 ^e	
CH-27 red									
T1	Room	40.51±0.56 ^{aMN}	-	-	-	-	-	6.75±0.39 ^b	32.06±3.8 ^y
	Ref	40.51±0.66 ^{aMN}	36.87±1.23 ^{bPQ}	-	-	-	-	12.89±1.22 ^b	
T2	Room	40.70±1.23 ^{aMN}	39.97±3.19 ^{abNO}	39.08±4.82 ^{abM}	39.70±1.26 ^{abM}	38.19±1.44 ^{abMN}	37.94±1.56 ^{bM}	39.26±2.45 ^a	
	Ref	40.70±2.36 ^{aMN}	38.69±1.80 ^{abOP}	38.55±3.12 ^{abM}	36.58±1.99 ^{bcNO}	35.95±1.36 ^{bcNO}	35.25±3.45 ^{cNOP}	37.62±2.66 ^a	
T3	Room	43.40±3.11 ^{aM}	40.94±2.94 ^{abNO}	39.27±2.12 ^{bcM}	39.87±2.36 ^{bcM}	38.65±1.44 ^{bcM}	37.41±2.36 ^{cMN}	39.92±3.25 ^a	
	Ref	43.40±4.51 ^{aM}	35.92±1.56 ^{bQ}	34.98±1.23 ^{bN}	34.65±3.45 ^{bOP}	34.01±1.23 ^{bOP}	33.85±1.24 ^{bOP}	36.13±3.62 ^a	
T4	Room	42.29±2.36 ^{aMN}	41.51±3.40 ^{abN}	39.17±2.36 ^{bcM}	37.98±3.45 ^{cdMN}	37.47±2.35 ^{cdMN}	35.78±5.23 ^{dmNO}	39.03±3.28 ^a	
	Ref	39.29±1.85 ^{aN}	35.37±4.65 ^{bQ}	34.53±2.44 ^{bN}	34.34±2.34 ^{bOP}	33.96±1.98 ^{bOP}	33.16±1.22 ^{bP}	35.10±2.87 ^a	
T5	Room	39.25±3.60 ^{bN}	44.45±3.45 ^{aM}	39.20±1.26 ^{bM}	37.34±1.25 ^{bcMN}	37.95±2.45 ^{bMN}	35.06±2.33 ^{cNOP}	38.87±2.89 ^a	
	Ref	39.25±3.45 ^{aN}	36.23±3.89 ^{bPQ}	34.14±3.66 ^{bcN}	33.60±1.44 ^{bcP}	33.01±2.34 ^{cP}	33.90±2.66 ^{bcOP}	35.02±2.47 ^a	
Punjab sindhuri green									
T1	Room	37.92±1.11 ^{aO}	-	-	-	-	-	6.32±0.31 ^c	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	37.92±2.05 ^{aO}	36.85±1.33 ^{aQ}	-	-	-	-	12.46±1.41 ^c	37.27±1.8 ^z
T2	Room	57.29±1.55 ^{aM}	54.02±0.98 ^{bM}	53.55±1.45 ^{bM}	53.57±0.089 ^{bM}	53.37±1.87 ^{bM}	52.19±1.79 ^{bM}	53.94±4.82 ^a	
	Ref	37.29±2.36 ^{bO}	40.25±1.32 ^{aP}	35.49±2.36 ^{bP}	34.90±1.23 ^{bO}	36.35±2.45 ^{bO}	36.17±2.63 ^{bOP}	36.74±2.53 ^b	
T3	Room	53.06±1.54 ^{aN}	52.52±1.23 ^{aMN}	52.90±1.22 ^{aM}	52.24±1.63 ^{aMN}	50.92±3.65 ^{aMN}	52.21±2.64 ^{aM}	52.30±4.44 ^a	
	Ref	37.06±3.23 ^{ab}	38.26±1.33 ^{aPQ}	36.66±1.11 ^{abOP}	35.90±2.31 ^{abO}	35.34±3.65 ^{bO}	35.33±3.12 ^{bP}	36.42±2.85 ^b	
T4	Room	51.89±1.98 ^{aN}	51.03±2.34 ^{aN}	51.83±2.55 ^{aM}	51.20±2.45 ^{aMN}	51.24±1.45 ^{aMN}	48.07±4.31 ^{bN}	50.87±4.86 ^a	
	Ref	38.89±1.25 ^{aO}	38.82±3.64 ^{abPQ}	35.70±3.32 ^{cP}	36.90±1.25 ^{abcO}	36.08±2.55 ^{bcO}	38.00±3.94 ^{abcO}	37.39±2.89 ^b	
T5	Room	37.25±1.44 ^{cO}	52.23±1.36 ^{aMN}	48.36±1.22 ^{bcN}	50.24±1.22 ^{abN}	50.69±1.66 ^{abN}	47.18±2.44 ^{cN}	47.65±3.65 ^a	
	Ref	37.25±2.36 ^{bO}	45.63±0.98 ^{aO}	38.41±1.65 ^{bO}	36.11±1.45 ^{aO}	35.90±1.89 ^{aO}	37.99±1.75 ^{aO}	38.54±2.84 ^b	
Punjab sindhuri red									
T1	Room	32.27±1.22 ^{aQ}	-	-	-	-	-	5.30±0.31 ^a	30.27±2.5 ^z
	Ref	32.27±1.56 ^{aQ}	37.35±1.36 ^{bN}	-	-	-	-	11.60±1.19 ^a	
T2	Room	37.76±1.33 ^{aNO}	37.67±1.34 ^{aN}	36.16±1.87 ^{abM}	36.02±1.66 ^{abM}	35.76±3.45 ^{abM}	33.53±1.65 ^{bM}	36.10±2.84 ^b	
	Ref	35.76±1.12 ^{abOP}	37.23±1.24 ^{aN}	34.02±2.45 ^{bM}	33.68±1.44 ^{bM}	34.13±3.66 ^{bMN}	33.17±2.36 ^{bM}	34.60±1.74 ^b	
T3	Room	41.02±1.36 ^{aM}	40.93±1.11 ^{aM}	35.41±1.70 ^{bM}	34.98±2.55 ^{bM}	34.90±3.42 ^{bMN}	33.42±2.44 ^{bM}	36.77±1.94 ^b	
	Ref	34.00±1.45 ^{bPQ}	38.34±3.42 ^{aMN}	36.11±1.91 ^{abM}	35.47±2.66 ^{bM}	35.57±2.12 ^{bMN}	34.35±2.55 ^{bM}	35.64±2.36 ^b	
T4	Room	41.76±2.22 ^{aM}	41.08±2.89 ^{aM}	36.11±1.78 ^{bM}	34.96±3.44 ^{bcM}	34.20±1.23 ^{bcMN}	33.06±3.44 ^{cM}	36.86±2.44 ^b	
	Ref	36.76±3.21 ^{bOP}	40.99±2.74 ^{aM}	36.39±1.65 ^{bM}	24.82±2.87 ^{dN}	34.15±2.78 ^{bcMN}	32.96±2.44 ^{cM}	34.34±2.48 ^b	
T5	Room	39.87±1.45 ^{aMN}	37.31±2.64 ^{aN}	34.22±1.45 ^{bM}	33.79±2.66 ^{bM}	33.15±1.39 ^{bN}	33.20±1.55 ^{bM}	35.25±2.84 ^b	
	Ref	36.87±3.21 ^{aOP}	37.98±1.78 ^{aN}	36.51±1.21 ^{abM}	33.95±3.44 ^{bM}	35.83±1.22 ^{abM}	35.46±1.55 ^{abM}	36.10±2.85 ^b	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.; L= Darkness (0) to Lightness (100)									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

sample stored at room temperature. For the CH-27 red chilli variety, the samples with treatment number 3 and stored at room temperature has the highest mean value of L value during the storage period with a value of 39.92 and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 2 and stored at room temperature has highest mean value of L value (53.94) for the storage period. Samples of Punjab Sindhuri red with treatment number 4 and stored at room conditions had a mean value of 36.86. Overall, the maximum mean value for L value (39.43) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27green samples and least (32.06) was reported for CH-27 red variety. Statistically, all the linear and interaction terms of month, variety, storage condition and treatment were reported to have significant ($p \leq 0.05$) effect on L value (Table 4.43). Highest L values for all samples were observed for treatment 2 and 3 containing varied quantity of KMS + sodium benzoate + acetic acid. Potassium meta-bisulphite known for their bleaching effect results in the increased brightness of stored chili paste samples (Dar *et al* 2017). Similarly Stivarius *et al* (2002) reported an increased L value for ground beef preserved with 5 per cent acetic acid. The combined effect of potassium metabisulphite and acetic acid results in an increased L value of stored chili paste.

4.5.8 Effect of treatment, storage period and storage condition on the a value of chili paste

The a value of stored chilli paste is represented in Table 4.44. During the initial time, the a value of the samples ranged from -1.27 to 31.61. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at refrigeration temperature had the highest mean value of a value during the storage period with a value of 25.7 and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 2 and stored at room temperature has the highest mean value of a value during the storage period with a value of 30.83 and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of a value (3.11) for the storage period. Samples of Punjab Sindhuri red with treatment number 5 and stored at room conditions had a mean value of 3.11. Overall, the maximum mean value for a value (24.10) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27red samples and least (10.39) was reported for CH-27 green variety samples. Statistically, all the linear and interaction terms of month, variety, storage condition and treatment were reported to have significant ($p \leq 0.05$) effect on a value (Table 4.44).

Table 4.44: Effect of treatment, storage period and storage condition on the colour (*a* value) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	0.37±0.11 ^{aM}	-	-	-	-	-	0.06±0.01 ^b	10.39±0.2 ^y
	Ref	0.37±0.12 ^{bM}	25.17±0.45 ^{aN}	-	-	-	-	4.25±0.20 ^b	
T2	Room	-1.27±0.15 ^{aM}	-0.84±0.22 ^{aQ}	-0.51±0.21 ^{aP}	0.07±0.25 ^{aOP}	0.51±0.75 ^{aPQR}	0.50±0.75 ^{aPQ}	-0.25±0.01 ^b	
	Ref	-1.27±10.84 ^{cM}	25.80±0.36 ^{bN}	31.78±0.33 ^{aM}	32.35±0.31 ^{aM}	33.19±0.85 ^{aM}	32.68±0.26 ^{aM}	25.7±1.71 ^a	
T3	Room	-0.86±0.65 ^{aM}	-0.42±0.21 ^{aPQ}	-0.70±0.36 ^{aP}	-0.67±0.65 ^a	-0.55±0.82 ^a	-0.15±0.95 ^a	-0.55±0.04 ^b	
	Ref	-0.86±0.32 ^{bM}	29.98±0.87 ^{aM}	30.74±0.35 ^{aM}	31.24±0.98 ^{aM}	31.30±0.24 ^{aMN}	29.07±0.34 ^{aN}	25.24±1.73 ^a	
T4	Room	0.60±0.33 ^{aM}	1.31±0.25 ^{aPQ}	2.47±0.35 ^{aO}	2.01±0.92 ^{aO}	2.50±0.83 ^{aPQ}	2.44±0.85 ^{aOP}	1.88±0.11 ^b	
	Ref	0.60±0.45 ^{cM}	21.38±0.66 ^{bO}	27.66±0.45 ^{aN}	28.28±0.92 ^{aN}	27.57±0.75 ^{aO}	28.26±0.41 ^{aN}	22.29±1.53 ^a	
T5	Room	0.79±0.12 ^{aM}	2.08±0.22 ^{aP}	2.14±0.22 ^{aO}	1.92±0.34 ^{aO}	2.79±0.36 ^{aP}	3.34±0.36 ^{aO}	2.17±0.15 ^b	
	Ref	0.79±0.33 ^{cM}	26.56±0.31 ^{bN}	27.45±0.33 ^{abN}	27.22±0.29 ^{abN}	29.48±0.54 ^{aNO}	27.16±0.54 ^{abN}	23.11±1.80 ^a	
CH-27 red									
T1	Room	26.12±1.02 ^{aNO}	-	-	-	-	-	4.35±0.01 ^b	24.10±0.5 ^w
	Ref	26.12±1.22 ^{bNO}	28.03±1.36 ^{aNOP}	-	-	-	-	9.02±0.11 ^b	
T2	Room	28.37±3.2 ^{cN}	31.72±2.31 ^{abM}	32.55±0.78 ^{aM}	29.50±1.34 ^{bcM}	31.24±0.98 ^{abMNO}	31.60±1.78 ^{abM}	30.83±2.40 ^a	
	Ref	28.37±4.32 ^{bcN}	30.34±4.56 ^{abMN}	29.49±1.20 ^{abcNO}	27.54±1.24 ^{cmN}	31.64±1.65 ^{aMN}	27.83±1.36 ^{bcNO}	29.20±2.65 ^a	
T3	Room	23.78±3.29 ^{cO}	27.17±2.36 ^{bOP}	27.52±1.03 ^{bOP}	29.14±1.65 ^{abM}	31.72±2.36 ^{aM}	31.15±3.78 ^{aM}	28.41±2.93 ^a	
	Ref	23.78±3.48 ^{cO}	29.70±0.11 ^{abMNO}	30.15±2.11 ^{abMN}	28.65±3.33 ^{bMN}	32.39±3.45 ^{aM}	29.88±2.91 ^{abMN}	29.09±1.71 ^a	
T4	Room	31.28±0.36 ^{aM}	26.00±0.45 ^{cpQ}	28.80±1.09 ^{abNOP}	27.45±1.36 ^{bcMN}	28.85±1.35 ^{abN}	20.56±3.90 ^{dP}	27.15±1.81 ^a	
	Ref	31.28±1.65 ^{aM}	28.40±2.36 ^{bNOP}	26.67±2.36 ^{bP}	28.40±0.36 ^{bMN}	29.12±2.75 ^{abNO}	26.53±1.80 ^{bO}	28.40±1.83 ^a	
T5	Room	27.41±2.98 ^{abN}	23.74±1.45 ^{cQ}	26.72±2.33 ^{abP}	26.20±0.78 ^{abcN}	28.76±2.85 ^{aN}	25.63±1.50 ^{bcO}	26.41±2.25 ^a	
	Ref	27.41±0.97 ^{bcN}	27.07±2.33 ^{bcOP}	26.73±1.65 ^{cP}	29.54±1.33 ^{abM}	30.77±2.25 ^{aMNO}	27.59±1.44 ^{bcNO}	28.18±2.64 ^a	
Punjab sindhuri green									
T1	Room	29.07±1.11 ^{aMN}	-	-	-	-	-	0.97±0.06 ^b	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	29.07±2.03 ^{aMN}	-	-	-	-	-	0.02±0.01 ^b	1.09±1.05 ^z
T2	Room	28.65±1.36 ^{aN}	29.98±1.22 ^{aM}	29.75±1.36 ^{aM}	29.62±1.36 ^{aM}	29.79±1.72 ^{aM}	28.87±2.33 ^{aM}	-0.27±0.02 ^b	
	Ref	28.65±3.45 ^{aN}	0.42±2.00 ^{bP}	2.08±3.65 ^{bc}	3.19±3.20 ^{bO}	3.10±1.95 ^{bcN}	3.25±2.74 ^{bN}	3.05±0.20 ^a	
T3	Room	31.61±1.26 ^{aM}	20.00±2.13 ^{dN}	27.05±1.32 ^{cN}	28.08±0.98 ^{cN}	30.93±1.84 ^{abM}	28.25±1.26 ^{bcM}	-0.11±0.07 ^b	
	Ref	31.61±3.11 ^{aM}	1.30±3.12 ^{bP}	0.99±1.23 ^{bO}	1.82±1.36 ^{bOP}	2.78±1.83 ^{bN}	2.21±1.98 ^{bNO}	1.21±0.08 ^{ab}	
T4	Room	27.97±1.24 ^{aN}	18.17±3.14 ^{bN}	28.43±1.22 ^{aMN}	26.42±1.98 ^{aN}	28.90±1.60 ^{aM}	27.48±1.65 ^{aM}	1.34±0.09 ^{ab}	
	Ref	27.97±2.55 ^{aN}	6.35±2.21 ^{bO}	2.25±1.34 ^{cO}	3.09±1.32 ^{cO}	3.29±1.36 ^{cN}	3.84±1.75 ^{bcN}	1.06±0.07 ^b	
T5	Room	29.38±2.31 ^{abMN}	19.54±1.32 ^{dN}	26.44±1.24 ^{cN}	26.80±1.75 ^{bcN}	29.72±1.60 ^{aM}	27.90±1.65 ^{abcM}	1.56±0.04 ^{ab}	
	Ref	29.38±1.23 ^{aMN}	7.38±1.44 ^{bO}	2.07±1.21 ^{cO}	3.16±1.72 ^{cO}	3.43±1.22 ^{cN}	2.11±4.33 ^{cNO}	3.11±0.12 ^a	
Punjab sindhuri red									
T1	Room	-0.59±0.04 ^{aM}	-	-	-	-	-	-0.97±0.04 ^b	14.91±1.47 ^x
	Ref	-0.59±0.01 ^{aM}	0.72±1.23 ^{aN}	-	-	-	-	0.02±0.01 ^b	
T2	Room	-0.43±1.12 ^{aM}	-0.46±0.12 ^{aN}	-0.01±0.96 ^{aM}	-0.69±1.01 ^{aN}	-0.30±1.03 ^{aM}	0.26±0.078 ^{aMN}	-0.27±0.01 ^b	
	Ref	-0.43±0.78 ^{bM}	11.66±0.98 ^{aM}	0.80±0.52 ^{bM}	2.05±1.2 ^{bM}	2.22±1.23 ^{bMN}	2.04±0.46 ^{bMN}	3.05±0.12 ^a	
T3	Room	0.27±0.98 ^{aM}	-0.23±0.98 ^{aN}	-0.11±0.98 ^{aM}	-0.11±0.82 ^{aMN}	-0.31±0.78 ^{aM}	-0.21±0.46 ^{aN}	-0.11±0.01 ^b	
	Ref	0.27±0.36 ^{aM}	1.24±0.75 ^{aN}	0.95±0.82 ^{aM}	1.48±0.92 ^{aMN}	1.75±0.36 ^{aMN}	1.58±0.92 ^{aMN}	1.21±0.08 ^{ab}	
T4	Room	0.34±0.78 ^{aM}	0.83±0.46 ^{aN}	1.18±0.91 ^{aM}	1.56±0.91 ^{aMN}	1.58±0.64 ^{aMN}	2.59±0.73 ^{aM}	1.34±0.09 ^{ab}	
	Ref	0.34±0.75 ^{aM}	0.10±0.23 ^{aN}	0.49±0.84 ^{aM}	1.31±1.36 ^{aMN}	2.54±0.81 ^{aM}	1.61±0.81 ^{aMN}	1.06±0.07 ^b	
T5	Room	0.22±0.24 ^{aM}	1.48±0.36 ^{aN}	1.80±0.73 ^{aM}	1.61±1.22 ^{aMN}	2.01±1.11 ^{aMN}	2.29±0.64 ^{aMN}	1.56±0.10 ^{ab}	
	Ref	0.22±0.13 ^{bM}	12.73±0.24 ^{aM}	0.60±0.81 ^{bM}	1.45±1.01 ^{bMN}	2.02±1.00 ^{bMN}	1.67±0.56 ^{bMN}	3.11±0.21 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month; a value= + redness and – greenness									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

4.5.8 Effect of treatment, storage period and storage condition on the *b* value of chili paste

The *b* value of stored chilli paste is represented in Table 4.45. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at room temperature had the highest mean value of *b* value during the storage period with a value of 26.61 and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 2 and stored at room temperature has the highest mean value of *b* value during the storage period with a value of 25.23 and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 3 and stored at room temperature has highest mean value of *b* value (26.60) for the storage period. Samples of Punjab Sindhuri red with treatment number 2 and stored at room conditions had a highest mean value of 19.24. Overall, the maximum mean value for *b* value (21.69) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 green samples and least (11.96) was reported for Punjab Sindhuri red variety samples. All the independent variable i.e. month, variety, storage condition and treatment were observed to have significant ($p \leq 0.05$) effect on color *a* value (Table 4.45). More redness in the plum wine was noted with sodium benzoate (Joshi and Joshi 2014).

4.5.9 Effect of treatment, storage period and storage condition on the ascorbic acid (mg/100 gm) of chili paste

The ascorbic acid of stored chilli paste is represented in Table 4.46. For the CH-27 green chilli variety, the samples with treatment number 3 and stored at refrigeration temperature had the highest mean value of ascorbic acid value during the storage period with a value of 50.01 mg/100 gm and the lowest was for the control sample stored at room temperature. While for the CH-27 red chilli variety, the samples with treatment number 2 and stored at refrigeration temperature has the highest mean value of ascorbic acid value during the storage period with a value of 84.40 mg/100 gm and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 4 and stored at refrigeration temperature has highest mean value of ascorbic acid value (47.13 mg/100 gm) for the storage period. Samples of Punjab Sindhuri red with treatment number 2 and stored at refrigeration conditions had a highest mean value of 73.96 mg/100 gm. Overall, the maximum mean value for ascorbic acid (61.84 mg/100 gm) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 red samples and least (37.73 mg/100 gm) was reported for Punjab Sindhuri green variety samples. Sodium benzoate and Potassium metabisulphite treated tomato pulp was retained highest ascorbic acid content as reported by Sarkar *et al* (2015). Similar results were also reported by Silva *et al* (2016) and Vashista *et al* (2003). Higher retention of ascorbic acid with treatment 2 and 3 might relate with fact of higher retention SO_2 in KMS treated samples (Sra *et al* 2011).

Table 4.45: Effect of treatment, storage period and storage condition on the colour (*b* value) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	27.31±1.47 ^{aM}	-	-	-	-	-	4.55±0.20 ^b	21.69±1.1 ^w
	Ref	27.31±1.23 ^{aM}	26.74±1.27 ^{bMn}	-	-	-	-	9.00±0.49 ^b	
T2	Room	29.17±2.32 ^{aM}	28.02±1.28 ^{abMN}	26.23±1.37 ^{bcdM}	27.19±1.99 ^{abcMN}	25.18±1.55 ^{cdNOP}	23.91±0.78 ^{dNO}	26.61±1.79 ^a	
	Ref	29.17±1.29 ^{abM}	19.74±1.82 ^{dOP}	25.50±1.97 ^{cMN}	28.53±1.65 ^{abM}	29.66±1.45 ^{aM}	26.83±0.99 ^{bcM}	26.57±1.92 ^a	
T3	Room	30.17±1.36 ^{aM}	25.64±1.91 ^{bN}	26.05±1.46 ^{bM}	25.47±1.33 ^{bN}	23.44±1.36 ^{bP}	24.17±1.01 ^{bNO}	25.82±2.12 ^a	
	Ref	30.17±1.24 ^{aM}	29.48±1.00 ^{abM}	24.82±1.43 ^{cMN}	25.89±1.24 ^{cN}	27.32±1.75 ^{bcMN}	21.87±1.11 ^{dO}	26.59±2.02 ^a	
T4	Room	28.00±0.97 ^{aM}	27.06±1.23 ^{abMN}	25.97±0.97 ^{abM}	25.69±1.46 ^{abN}	24.45±1.44 ^{bcOP}	21.71±0.89 ^{bcO}	25.48±2.22 ^a	
	Ref	28.00±0.89 ^{aM}	18.47±1.24 ^{cP}	23.29±0.46 ^{bN}	25.54±1.36 ^{abN}	23.59±1.45 ^{bP}	23.90±1.32 ^{bNO}	23.79±1.93 ^a	
T5	Room	29.59±1.36 ^{aM}	22.25±1.22 ^{cO}	25.77±1.45 ^{bMN}	25.94±1.36 ^{bN}	24.66±1.85 ^{bcOP}	24.91±1.64 ^{bcMN}	25.52±2.11 ^a	
	Ref	29.59±1.24 ^{aM}	19.65±1.00 ^{dOP}	17.25±1.33 ^{dO}	22.45±1.44 ^{cO}	26.56±1.66 ^{bNO}	22.54±1.89 ^{cNO}	23.00±1.71 ^a	
CH-27 red									
T1	Room	25.87±0.098 ^{aN}	-	-	-	-	-	4.31±0.01 ^d	18.49±2.5 ^x
	Ref	25.87±1.23 ^{aN}	18.50±1.65 ^{bOP}	-	-	-	-	7.39±0.31 ^d	
T2	Room	27.66±1.02 ^{aMN}	30.17±1.89 ^{aM}	21.46±1.84 ^{cN}	22.79±1.02 ^{bcMN}	24.74±1.01 ^{bM}	24.56±1.85 ^{bM}	25.23±1.82 ^a	
	Ref	27.66±2.01 ^{aMN}	21.17±1.44 ^{bNO}	18.13±1.62 ^{cO}	17.16±1.03 ^{cP}	21.15±1.00 ^{bO}	16.45±1.65 ^{cO}	20.28±1.56 ^{bc}	
T3	Room	18.05±2.00 ^{dO}	21.31±1.65 ^{cN}	26.54±1.36 ^{aM}	22.19±0.97 ^{cMN}	25.76±1.06 ^{abM}	23.08±1.45 ^{bcMN}	22.82±1.68 ^{abc}	
	Ref	18.05±1.02 ^{bO}	19.91±1.36 ^{abNOP}	17.68±1.89 ^{bO}	17.54±1.36 ^{bP}	21.73±0.93 ^{abNO}	17.69±1.64 ^{bO}	18.76±1.87 ^c	
T4	Room	29.36±1.11 ^{aM}	22.29±1.64 ^{cN}	25.13±1.79 ^{bM}	23.96±2.01 ^{bcM}	24.05±1.94 ^{bcMn}	21.58±1.36 ^{cN}	24.39±2.08 ^{ab}	
	Ref	29.36±1.26 ^{aM}	20.05±1.75 ^{bcNOP}	17.44±1.73 ^{cdO}	19.01±1.01 ^{bcdOP}	20.84±2.01 ^{bO}	16.95±1.64 ^{dO}	20.60±1.88 ^{abc}	
T5	Room	26.63±1.34 ^{aMN}	17.52±1.73 ^{cP}	19.72±1.33 ^{bcNO}	21.01±0.96 ^{bNO}	26.15±1.85 ^{aM}	21.04±1.97 ^{bN}	22.01±1.48 ^{abc}	
	Ref	26.63±1.65 ^{aMn}	18.46±1.48 ^{bOP}	11.86±1.65 ^{cP}	19.50±0.95 ^{bOP}	20.13±1.68 ^{bO}	17.88±1.55 ^{bO}	19.07±1.28 ^c	

Punjab sindhuri green								
T1	Room	14.57±1.03 ^{aN}	-	-	-	-	-	2.42±0.18 ^c
	Ref	14.57±1.22 ^{aN}	0.85±0.89 ^{bOP}	-	-	-	-	2.57±0.24 ^c
T2	Room	14.38±1.36 ^{cN}	28.43±1.20 ^{aM}	20.26±1.08 ^{bO}	27.95±1.65 ^{aM}	29.94±0.98 ^{aM}	28.80±1.56 ^{aM}	24.96±2.44 ^a
	Ref	14.38±0.94 ^{abN}	1.58±1.00 ^{dO}	11.94±1.98 ^{bcP}	14.96±1.65 ^{aNO}	12.86±1.032 ^{abcO}	11.55±1.36 ^{cP}	11.21±1.14 ^b
T3	Room	16.65±0.77 ^{bMN}	28.69±1.33 ^{aM}	28.51±1.56 ^{aM}	28.55±1.45 ^{aM}	28.51±1.23 ^{aM}	28.72±1.25 ^{aM}	26.60±1.84 ^a
	Ref	16.65±1.36 ^{aMN}	1.19±1.46 ^{cO}	14.33±1.75 ^{abP}	14.06±1.36 ^{abN}	14.94±1.58 ^{bNO}	13.00±1.36 ^{bOP}	12.36±0.85 ^b
T4	Room	16.19±1.45 ^{cmN}	28.33±1.95 ^{aM}	25.10±1.65 ^{bN}	27.85±1.89 ^{aM}	28.45±1.69 ^{aM}	23.37±0.95 ^{bN}	24.88±2.85 ^a
	Ref	16.19±1.66 ^{abMn}	-1.89±1.94 ^{cP}	14.36±1.35 ^{abP}	17.05±1.45 ^{aN}	16.19±2.01 ^{abN}	14.00±1.36 ^{bOP}	12.65±1.15 ^b
T5	Room	18.97±1.36 ^{dM}	28.53±1.36 ^{abM}	30.25±1.85 ^{aM}	26.76±1.36 ^{bM}	27.62±1.36 ^{abM}	23.03±1.02 ^{dN}	25.86±2.06 ^a
	Ref	18.97±1.33 ^{aM}	10.84±1.25 ^{cN}	13.92±1.75 ^{bP}	16.33±1.00 ^{abNO}	16.17±1.48 ^{bN}	14.98±1.33 ^{bO}	15.20±1.15 ^b
15.87±1.05 ^y								
Punjab sindhuri red								
T1	Room	3.95±0.95 ^{aN}	-	-	-	-	-	0.65±0.17 ^c
	Ref	3.95±1.34 ^{aN}	1.94±1.33 ^{bO}	-	-	-	-	0.98±0.15 ^c
T2	Room	19.79±0.78 ^{abM}	21.55±1.63 ^{aM}	16.62±1.64 ^{cN}	19.10±1.56 ^{abcM}	20.31±1.78 ^{abM}	18.10±1.36 ^{bcM}	19.24±0.27 ^a
	Ref	19.79±1.44 ^{aM}	-0.80±1.85 ^{cO}	10.70±1.33 ^{bO}	11.78±1.25 ^{bO}	10.10±1.4 ^{bO}	12.30±1.33 ^{bOP}	10.64±0.75 ^b
T3	Room	22.02±1.25 ^{aM}	10.81±1.95 ^{dN}	19.27±1.25 ^{bcM}	17.44±1.89 ^{cNO}	20.79±1.85 ^{abM}	17.03±1.26 ^{cMn}	17.89±1.14 ^a
	Ref	22.02±1.85 ^{aM}	1.44±1.64 ^{dO}	11.21±1.36 ^{cO}	14.54±1.45 ^{bN}	13.05±1.96 ^{bcN}	13.79±1.65 ^{bcO}	12.67±1.04 ^a
T4	Room	19.37±1.95 ^{abM}	9.57±1.36 ^{cN}	17.15±1.33 ^{bMN}	17.66±1.78 ^{aM}	20.57±1.98 ^{aM}	17.73±1.85 ^{bM}	17.00±1.25 ^a
	Ref	19.37±1.28 ^{aM}	0.29±1.85 ^{dO}	11.38±1.25 ^{bcO}	13.88±1.55 ^{bNO}	13.13±1.65 ^{bcN}	10.80±1.64 ^{cP}	11.47±1.26 ^b
T5	Room	20.24±1.65 ^{aM}	12.07±1.42 ^{dN}	15.45±1.65 ^{cN}	17.43±1.36 ^{bcM}	19.80±1.45 ^{abM}	17.19±1.96 ^{bcMN}	17.00±1.55 ^a
	Ref	20.24±1.55 ^{aM}	1.47±1.00 ^{dO}	11.15±1.23 ^{cO}	12.83±1.25 ^{bcNO}	11.72±1.36 ^{bNO}	14.80±1.33 ^{bNO}	12.03±0.80 ^b
11.96 ±1.47 ^z								
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month; b value= + yellowness and - blueness								

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

Table 4.46: Effect of treatment, storage period and storage condition on the ascorbic acid(mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	55.25±1.21 ^{aNO}	-	-	-	-	-	9.20±0.61 ^c	38.55±2.81 ^y
	Ref	55.25±1.02 ^{aO}	52.23±2.03 ^{aNO}	-	-	-	-	17.86±1.12 ^c	
T2	Room	53.88±0.98 ^{aO}	51.53±2.45 ^{abNO}	49.90±1.09 ^{bM}	46.39±1.00 ^{cN}	44.29±2.65 ^{cN}	41.51±1.36 ^{dN}	47.91±2.82 ^a	
	Ref	53.88±1.32 ^{aO}	51.53±2.11 ^{abNO}	50.90±1.25 ^{bM}	49.39±2.36 ^{bcM}	47.29±2.78 ^{cdM}	45.71±2.33 ^{dM}	49.78±3.02 ^a	
T3	Room	54.83±2.36 ^{aO}	52.90±1.02 ^{aMN}	49.28±1.68 ^{bM}	47.30±2.48 ^{bMN}	44.46±2.96 ^{cN}	42.32±2.45 ^{cN}	48.51±2.83 ^a	
	Ref	54.83±2.34 ^{aO}	52.90±1.00 ^{abMN}	50.28±2.36 ^{bcM}	49.30±2.45 ^{cdM}	47.46±2.65 ^{deM}	45.32±2.94 ^{eM}	50.01±3.01 ^a	
T4	Room	60.98±2.56 ^{aM}	50.03±2.33 ^{bP}	40.65±2.85 ^{cO}	31.00±2.65 ^{dP}	20.99±2.45 ^{eR}	10.11±2.91 ^{fQ}	35.62±1.60 ^b	
	Ref	60.98±2.11 ^{aM}	55.03±2.65 ^{bM}	45.65±2.48 ^{cN}	38.00±2.78 ^{dO}	29.99±2.15 ^{eP}	22.11±1.90 ^{fP}	41.96±2.00 ^{ab}	
T5	Room	58.13±1.32 ^{aMN}	49.34±3.21 ^{bP}	40.29±2.48 ^{cO}	32.58±2.88 ^{dP}	25.54±1.02 ^{eQ}	19.82±3.01 ^{fP}	37.61±2.22 ^b	
	Ref	58.13±1.85 ^{aMN}	51.34±2.24 ^{bNO}	46.29±2.65 ^{cN}	40.58±2.55 ^{dO}	36.54±1.06 ^{eO}	30.82±3.2 ^{fO}	43.95±2.32 ^{ab}	
CH-27 red									
T1	Room	87.71±1.52 ^{aM}	-	-	-	-	-	14.61±0.83 ^d	61.84±2.42 ^w
	Ref	87.71±1.22 ^{aM}	85.12±3.45 ^{bM}	-	-	-	-	28.71±1.52 ^d	
T2	Room	86.26±1.39 ^{aM}	84.25±2.46 ^{abM}	82.67±3.01 ^{bMN}	79.10±1.77 ^{cN}	76.90±1.36 ^{cMN}	71.24±1.09 ^{dMN}	80.07±2.54 ^a	
	Ref	86.26±1.92 ^{aM}	85.25±2.11 ^{abM}	84.67±3.22 ^{abM}	83.10±1.65 ^{bcM}	81.90±1.45 ^{cdM}	79.24±2.01 ^{dM}	83.40±3.05 ^a	
T3	Room	84.00±1.74 ^{aM}	79.25±0.98 ^{bN}	75.10±1.26 ^{cMN}	70.65±0.89 ^{dNO}	67.65±1.28 ^{eN}	61.44±2.44 ^{fNO}	73.01±2.73 ^{ab}	
	Ref	84.00±1.35 ^{aM}	81.25±0.77 ^{bN}	78.10±2.45 ^{cMN}	75.65±1.36 ^{cM}	72.65±1.73 ^{dMN}	68.44±2.22 ^{eNO}	76.68±2.86 ^{ab}	
T4	Room	85.38±3.25 ^{aM}	75.25±2.35 ^{bO}	69.38±2.35 ^{cNO}	60.57±1.84 ^{dMN}	52.22±1.91 ^{eO}	42.47±1.04 ^{fP}	64.21±3.09 ^{bc}	
	Ref	85.38±2.45 ^{aM}	80.25±2.85 ^{bN}	76.38±2.94 ^{cMN}	70.57±1.92 ^{dMN}	66.22±2.03 ^{eN}	60.47±1.00 ^{fO}	73.21±2.48 ^{ab}	
T5	Room	88.07±2.65 ^{aM}	75.29±2.91 ^{abO}	68.19±1.93 ^{abcO}	58.48±1.93 ^{bcO}	49.60±2.01 ^{bcO}	40.98±2.88 ^{cP}	55.99±3.28 ^c	
	Ref	88.07±2.84 ^{aM}	81.29±1.45 ^{bN}	76.19±1.97 ^{cMN}	72.48±1.22 ^{dMN}	65.60±2.00 ^{eN}	59.98±2.91 ^{fO}	73.68±3.08 ^{ab}	
Punjab sindhuri green									
T1	Room	55.00±1.23 ^{aMN}	-	-	-	-	-	9.16±0.81 ^b	37.73±3.22 ^y

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	55.00±2.22 ^{aMN}	50.25±1.88 ^{bM}	-	-	-	-	17.51±1.73 ^b	
T2	Room	51.09±2.95 ^{aO}	48.74±1.48 ^{aMN}	45.93±1.65 ^{bN}	41.92±1.07 ^{cNO}	38.79±1.44 ^{dN}	35.26±1.04 ^{eO}	43.61±2.55 ^a	
	Ref	51.09±2.64 ^{aO}	49.74±1.65 ^{abMN}	47.93±1.92 ^{bcMN}	45.92±1.22 ^{cdM}	43.79±1.55 ^{dM}	40.26±3.02 ^{eMN}	46.45±2.65 ^a	
T3	Room	51.52±2.45 ^{aO}	47.23±1.44 ^{bN}	42.37±1.27 ^{cO}	38.59±1.45 ^{dPQ}	35.51±1.23 ^{eOP}	31.48±2.88 ^{fP}	41.11±2.12 ^a	
	Ref	51.52±1.06 ^{aO}	49.23±1.54 ^{aMN}	47.37±1.66 ^{bN}	45.59±1.92 ^{cM}	42.51±1.64 ^{dM}	39.48±2.45 ^{eN}	45.95±2.08 ^a	
T4	Room	52.44±1.35 ^{aNO}	49.78±1.44 ^{bMN}	45.42±1.02 ^{cN}	40.91±1.56 ^{dOP}	35.07±1.75 ^{eP}	30.21±1.09 ^{fP}	42.30±2.27 ^a	
	Ref	52.44±0.95 ^{aNO}	50.78±1.22 ^{bM}	49.42±2.03 ^{cM}	43.91±1.64 ^{dMN}	44.07±2.08 ^{dM}	42.21±2.44 ^{dM}	47.13±2.46 ^a	
T5	Room	55.53±1.55 ^{aM}	48.52±1.75 ^{bMN}	41.43±3.10 ^{cO}	36.93±1.32 ^{dQ}	31.69±2.99 ^{eQ}	27.61±0.98 ^{fQ}	40.28±2.27 ^a	
	Ref	55.53±1.82 ^{aM}	49.52±1.64 ^{bMN}	46.43±3.22 ^{cN}	42.93±1.88 ^{dNO}	37.69±2.85 ^{eNO}	30.61±1.66 ^{fP}	43.78±3.05 ^a	
Punjab sindhuri red									
T1	Room	78.49±1.22 ^{aM}	-	-	-	-	-	13.08±1.01 ^c	55.025±3.21 ^x
	Ref	78.49±1.02 ^{aM}	76.29±1.26 ^{aM}	-	-	-	-	25.65±2.02 ^c	
T2	Room	78.40±3.10 ^{aM}	76.29±2.35 ^{aM}	71.49±1.26 ^{bO}	67.33±1.23 ^{cO}	62.66±1.06 ^{dN}	58.60±1.26 ^{eN}	69.12±2.8 ^a	
	Ref	78.40±2.10 ^{aM}	77.29±1.45 ^{abM}	75.49±2.34 ^{bc}	73.33±3.01 ^{cdM}	70.66±3.2 ^{deM}	68.60±3.45 ^{eM}	73.96±3.06 ^a	
T3	Room	79.71±3.11 ^{aM}	76.89±2.65 ^{bM}	72.45±1.22 ^{cNO}	69.67±2.22 ^{dNO}	63.84±1.02 ^{eN}	59.60±1.22 ^{fN}	70.36±3.29 ^a	
	Ref	79.71±2.45 ^{aM}	77.89±1.48 ^{abM}	75.45±1.36 ^{bMN}	72.67±2.48 ^{cMN}	70.84±1.55 ^{cdM}	68.60±2.66 ^{dM}	74.19±3.67 ^a	
T4	Room	73.08±2.45 ^{aN}	68.78±1.57 ^{bN}	63.88±2.45 ^{cQ}	58.49±2.65 ^{dQ}	53.12±1.89 ^{eP}	48.36±1.55 ^{fP}	52.77±2.55 ^b	
	Ref	73.08±1.02 ^{aN}	70.78±1.22 ^{bN}	67.88±3.24 ^{bP}	62.49±1.05 ^{cP}	58.12±1.92 ^{dO}	51.36±1.54 ^{eO}	63.48±4.21 ^{ab}	
T5	Room	72.53±3.02 ^{aN}	67.87±1.33 ^{bN}	60.03±3.11 ^{cR}	53.34±1.66 ^{cdR}	48.83±2.85 ^{dQ}	42.05±1.44 ^{eQ}	53.35±4.81 ^b	
	Ref	72.53±1.02 ^{aN}	69.87±2.35 ^{bN}	65.03±2.33 ^{cPQ}	59.34±1.34 ^{dQ}	55.83±2.62 ^{eOP}	50.05±1.26 ^{fOP}	61.81±5.4 ^{ab}	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y, z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=NS; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment= 0.01

4.5.10 Effect of treatment, storage period and storage condition on the total phenolics (mg/100 gm GAE) of chili paste

The total phenolics value of stored chilli paste is represented in Table 4.47. For the CH-27 green chilli variety, the samples with treatment number 4 and stored at refrigeration temperature had the highest mean value of total phenolics value during the storage period with a value of 181.71 mg/100 gm GAE and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 4 and stored at room and refrigeration temperature has the highest mean value of total phenolics value during the storage period with a value of 356mg/100 gm GAE and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 4 and stored at room temperature has highest mean value of total phenolics value (290.05mg/100 gm GAE) for the storage period. Samples of Punjab Sindhuri red with treatment number 4 and stored at room conditions had a highest mean value of 269.81 number 4 and stored at room temperature has highest mean value of total phenolics value (290.05mg/100 gm GAE) for the storage. Overall, the maximum mean value for total phenolics value (299.90 number 4 and stored at room temperature has highest mean value of total phenolics value (290.05mg/100 gm GAE) for the storage of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 red samples and least (199.90 number 4 and stored at room temperature has highest mean value of total phenolics value (290.05mg/100 gm GAE) for the storage was reported for Punjab Sindhuri red variety samples. Statistically, all the linear and interaction terms of month, variety, storage conditions and treatment had significant ($p \leq 0.05$) effect on phenols except interaction term of variety * storage condition (Table 4.47). Friedman and Jurgens 2000 reported that various polyphenolics including caeffic acid, catechin, chlorogenic acid, ferulic acid, gallic acid, epigallocatechin etc are unstable to high pH range. Treatment 4 including acetic acid with hot filling process was found to be effective for the retention of polyphenolic components during the storage period.

4.5.11 Effect of treatment, storage period and storage condition on the total chlorophyll (mg/100 gm) of chili paste

The chlorophyll of stored chilli paste is represented in Table 4.48. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at refrigeration temperature had the highest mean value of chlorophyll value during the storage period with a value of 6.72 mg/100 gm and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 2 and stored at refrigeration temperature has highest mean value of chlorophyll value (18.65 mg/100 gm) for the storage period. Overall, the maximum mean value for chlorophyll (15.43 mg/100 gm) of chili paste after 8 months of storage at room and refrigeration temperature together was

Table 4.47: Effect of treatment, storage period and storage condition on the total phenolics (mg/100 gm GAE) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	158.82±10.50 ^{aP}	-	-	-	-	-	26.47±1.50 ^d	142.43±11.9 ^z
	Ref	158.82±13.30 ^{aP}	151.36±12.23 ^{bQ}	-	-	-	-	51.80±3.50 ^d	
T2	Room	160.76±12.00 ^{aP}	156.00±12.36 ^{bP}	150.90±9.56 ^{cQ}	141.89±8.99 ^{dR}	136.31±13.23 ^{eS}	130.55±12.360 ^{fS}	146.08±13.11 ^c	
	Ref	160.76±22.00 ^{aP}	157.50±10.25 ^{bP}	152.00±10.26 ^{cQ}	144.49±12.36 ^{dQ}	139.16±15.36 ^{eR}	135.94±11.36 ^{fR}	148.32±12.41 ^{cd}	
T3	Room	181.99±21.03 ^{aO}	176.48±10.26 ^{bO}	172.36±11.22 ^{cP}	165.98±13.45 ^{dP}	154.14±12.36 ^{eQ}	150.16±12.36 ^{fQ}	166.85±13.22 ^{abc}	
	Ref	181.99±12.32 ^{aO}	178.09±12.36 ^{bO}	175.58±11.26 ^{bO}	170.59±13.45 ^{cO}	168.85±12.01 ^{cO}	158.36±13.27 ^{dP}	172.24±12.46 ^{abc}	
T4	Room	195.21±23.23 ^{aM}	185.28±13.25 ^{bM}	180.00±13.26 ^{cM}	180.30±10.02 ^{cM}	173.25±10.23 ^{dN}	164.67±12.89 ^{eN}	179.79±14.25 ^a	
	Ref	195.21±12.03 ^{aM}	185.96±13.3 ^{bM}	180.80±11.36 ^{cM}	181.30±13.45 ^{cM}	176.23±14.02 ^{dM}	170.78±12.89 ^{eM}	181.71±16.26 ^a	
T5	Room	188.73±23.36 ^{aN}	181.60±10.26 ^{bN}	177.03±16.36 ^{cNO}	171.72±14.56 ^{dO}	165.54±14.23 ^{eP}	160.51±13.78 ^{fOP}	174.19±12.56 ^{ab}	
	Ref	188.73±24.25 ^{aN}	185.43±10.98 ^{bM}	179.13±12.01 ^{cMN}	175.72±13.39 ^{dN}	168.82±12.25 ^{eO}	162.89±10.45 ^{fNO}	176.79±12.76 ^a	
CH-27 red									
T1	Room	331.17±10.89 ^{aP}	-	-	-	-	-	55.19±4.4 ^b	199.90±13.8 ^w
	Ref	331.17±9.56 ^{aP}	325.25±12.36 ^{bP}	-	-	-	-	190.20±18.2 ^b	
T2	Room	345.41±11.23 ^{aN}	338.30±11.36 ^{bN}	330.18±9.08 ^{cP}	326.11±12.33 ^{dR}	331.98±13.45 ^{cR}	324.23±9.45 ^{dR}	332.71±16.55 ^a	
	Ref	345.41±10.56 ^{aN}	339.53±13.48 ^{bN}	333.58±10.2 ^{cO}	329.18±13.45 ^{dQ}	332.35±13.26 ^{cR}	333.27±10.45 ^{cQ}	335.55±14.55 ^a	
T3	Room	349.88±12.36 ^{bM}	349.90±10.89 ^{bM}	359.39±10.98 ^{aM}	350.31±10.23 ^{bP}	341.56±13.00 ^{cQ}	334.07±1.022 ^{dQ}	347.52±17.85 ^a	
	Ref	349.88±10.89 ^{bM}	349.86±10.98 ^{bMO}	355.90±11.78 ^{bN}	351.58±10.98 ^{aP}	350.63±12.09 ^{bP}	344.04±12.39 ^{cP}	350.32±15.65 ^a	
T4	Room	340.05±11.45 ^{dO}	334.57±11.22 ^{eO}	324.22±12.45 ^{fQ}	394.51±10.78 ^{aM}	386.35±11.02 ^{bM}	356.32±12.48 ^{cN}	356.01±15.85 ^a	
	Ref	340.05±10.78 ^{dO}	334.57±13.48 ^{eO}	324.22±12.65 ^{fQ}	394.51±9.01 ^{aM}	386.35±11.01 ^{bM}	356.32±9.12 ^{cN}	356.01±16.55 ^a	
T5	Room	340.61±11.26 ^{eO}	334.53±14.33 ^{fO}	355.32±13.45 ^{cN}	385.65±9.36 ^{aN}	366.13±11.05 ^{bN}	350.26±9.45 ^{dO}	355.42±15.64 ^a	
	Ref	340.61±10.89 ^{dO}	336.83±13.12 ^{eNO}	359.88±11.11 ^{CM}	365.15±10.14 ^{aO}	363.44±11.01 ^{abO}	360.89±9.65 ^{bcM}	354.47±16.55 ^a	
Punjab sindhuri green									
T1	Room	291.74±9.45 ^{aMN}	-	-	-	-	-	48.62±3.30 ^b	
	Ref	291.74±10.65 ^{aMN}	275.6±10.23 ^{aM}	-	-	-	-	97.01±4.84 ^b	
T2	Room	290.67±10.23 ^{aN}	281.35±11.23 ^{bM}	278.84±11.21 ^{bO}	263.90±13.45 ^{cR}	253.78±11.75 ^{dR}	249.25±10.36 ^{eQ}	269.63±18.51 ^a	
	Ref	290.67±12.36 ^{aN}	282.35±10.36 ^{bM}	275.84±10.69 ^{cP}	270.90±13.65 ^{dQ}	265.68±11.45 ^{eQ}	260.58±9.45 ^{fP}	274.34±14.5 ^a	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
T3	Room	293.34±13.45 ^{bMN}	297.80±10.5 ^{aM}	283.41±9.56 ^{cMN}	270.93±11.25 ^{dQ}	267.99±12.36 ^{eQ}	260.25±10.36 ^{fP}	278.96±14.6 ^a	237.67±13.5 ^x
	Ref	293.34±12.37 ^{aMN}	285.73±10.37 ^{bM}	283.81±11.36 ^{bMN}	276.59±10.36 ^{cP}	272.96±10.23 ^{dP}	260.66±10.45 ^{eP}	278.85±16.2 ^a	
T4	Room	293.43±12.91 ^{bMN}	290.25±11.65 ^{cM}	284.92±11.45 ^{dMN}	288.48±10.22 ^{cN}	297.95±10.23 ^{aM}	285.26±10.65 ^{dM}	290.05±14.2 ^a	
	Ref	293.43±12.91 ^{aMN}	290.85±13.45 ^{aM}	285.65±11.65 ^{bcM}	287.18±10.78 ^{bNO}	285.35±9.56 ^{bcN}	283.86±10.44 ^{cM}	287.72±16.3 ^a	
T5	Room	294.02±12.65 ^{bM}	286.96±12.94 ^{cM}	280.00±11.85 ^{dO}	298.86±11.45 ^{aM}	274.58±9.78 ^{eP}	270.25±10.45 ^{fO}	284.11±14.2 ^a	
	Ref	294.02±10.55 ^{aM}	289.51±11.23 ^{bM}	283.00±11.75 ^{cdN}	285.48±11.52 ^{cO}	280.58±10.23 ^{dO}	275.59±10.69 ^{eN}	284.70±12.3 ^a	
Punjab sindhuri red									
T1	Room	236.65±10.45 ^{aN}	-	-	-	-	-	39.44±3.6 ^c	199.90±13.2 ^y
	Ref	236.65±11.36 ^{aN}	225.50±10.33 ^{bN}	-	-	-	-	76.88±4.2 ^c	
T2	Room	227.70±12.24 ^{bO}	220.98±10.36 ^{dO}	228.85±10.23 ^{abQ}	230.67±10.22 ^{aO}	224.67±11.25 ^{cP}	216.78±13.24 ^{ePQ}	224.94±14.2 ^{ab}	
	Ref	227.70±10.36 ^{bO}	220.25±10.33 ^{cO}	226.65±9.056 ^{bQ}	230.67±10.32 ^{aO}	226.17±11.36 ^{bP}	218.56±10.66 ^{cP}	225.00±16.2 ^{ab}	
T3	Room	218.46±12.14 ^{cP}	224.70±10.66 ^{bN}	214.06±9.45 ^{dR}	228.83±10.45 ^{aO}	213.51±10.78 ^{dR}	200.25±13.45 ^{eR}	216.64±4.2 ^c	
	Ref	218.46±12.11 ^{bcP}	224.69±10.33 ^{aN}	216.06±12.03 ^{cR}	220.83±10.98 ^{bP}	216.67±10.95 ^{cQ}	212.58±12.55 ^{dQ}	218.22±18.5 ^c	
T4	Room	261.49±12.45 ^{dM}	265.58±9.05 ^{cM}	279.57±10.36 ^{aM}	269.17±11.23 ^{bM}	277.77±10.65 ^{aM}	265.25±12.04 ^{cM}	269.81±16.2 ^a	
	Ref	261.49±12.36 ^{cM}	262.85±13.00 ^{cM}	270.59±10.48 ^{bN}	269.57±13.12 ^{bM}	274.37±11.23 ^{aN}	262.58±11.25 ^{dN}	266.91±12.3 ^a	
T5	Room	235.18±10.25 ^{bN}	220.58±12.45 ^{dO}	247.94±11.09 ^{aO}	235.72±11.23 ^{bN}	225.11±12.36 ^{cP}	215.25±11.75 ^{eQ}	229.97±11.4 ^{ab}	
	Ref	235.18±10.11 ^{bN}	220.85±12.33 ^{eO}	240.45±12.64 ^{aP}	236.12±11.22 ^{bN}	230.15±12.34 ^{cO}	224.58±11.65 ^{dO}	231.22±12.5 ^{ab}	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; V13.45alues in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month; GAE= Gallic acid equivalent									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

Table 4.48: Effect of treatment, storage period and storage condition on the chlorophyll (mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 green									
T1	Room	4.84±0.12 ^{aM}						0.80±0.06 ^b	3.78±0.16 ^x
	Ref	4.84±0.22 ^{aM}	4.52±0.15 ^{aM}					1.56±0.10 ^b	
T2	Room	5.02±0.13 ^{aM}	4.89±0.13 ^{aM}	4.33±0.12 ^{aM}	4.42±0.12 ^{aM}	4.34±0.21 ^{aM}	4.24±0.22 ^{aM}	4.54±0.20 ^b	
	Ref	5.02±0.18 ^{aM}	4.92±0.14 ^{aM}	4.42±0.24 ^{aM}	4.49±0.14 ^{aM}	4.38±0.24 ^{aM}	4.28±0.21 ^{aM}	4.58±0.23 ^b	
T3	Room	4.89±0.22 ^{aM}	4.73±0.17 ^{aM}	4.60±0.23 ^{aM}	4.48±0.14 ^{aM}	4.34±0.23 ^{aM}	4.25±0.24 ^{aM}	4.54±0.25 ^b	
	Ref	4.89±0.17 ^{aM}	4.75±0.18 ^{aM}	4.63±0.19 ^{aM}	4.51±0.24 ^{aM}	4.38±0.25 ^{aM}	4.28±0.23 ^{aM}	4.57±0.26 ^b	
T4	Room	4.39±0.14 ^{aM}	4.30±0.11 ^{aM}	4.19±0.13 ^{aM}	4.05±0.20 ^{aM}	3.93±0.21 ^{aM}	3.70±0.21 ^{aM}	4.09±0.24 ^b	
	Ref	4.39±0.22 ^{aM}	4.30±0.12 ^{aM}	4.21±0.10 ^{aM}	4.11±0.21 ^{aM}	3.90±0.22 ^{aM}	3.73±0.22 ^{aM}	4.10±0.26 ^b	
T5	Room	4.83±0.14 ^{aM}	4.72±0.11 ^{aM}	4.58±0.13 ^{aM}	4.44±0.23 ^{aM}	4.23±0.24 ^{aM}	4.09±0.21 ^{aM}	4.48±0.20 ^b	
	Ref	4.83±0.14 ^{aM}	4.72±0.22 ^{aM}	4.59±0.17 ^{aM}	4.48±0.22 ^{aM}	4.33±0.23 ^{aM}	4.11±0.24 ^{aM}	4.51±0.20 ^b	
Punjab sindhuri green									
T1	Room	13.23±0.23 ^{aM}	-	-	-	-	-	2.2±0.20 ^a	11.17±0.88 ^w
	Ref	13.23±0.22 ^{aM}	13.05±0.13 ^{aM}	-	-	-	-	4.38±0.16 ^b	
T2	Room	13.93±0.24 ^{aM}	13.82±0.12 ^{aM}	13.69±0.22 ^{aM}	13.54±0.33 ^{aM}	13.44±0.21 ^{aM}	13.28±0.13 ^{aM}	13.61±0.68 ^a	
	Ref	13.93±0.25 ^{aM}	13.85±0.42 ^{aM}	13.72±0.12 ^{aM}	13.60±0.21 ^{aM}	13.52±0.32 ^{aM}	13.34±0.18 ^{aM}	13.66±0.70 ^a	
T3	Room	13.34±0.10 ^{aM}	13.43±0.13 ^{aM}	13.32±0.14 ^{aM}	13.20±0.21 ^{aM}	13.11±0.21 ^{aM}	13.00±0.27 ^{aM}	13.23±0.80 ^a	
	Ref	13.34±0.12 ^{aM}	13.43±0.14 ^{aM}	13.32±0.32 ^{aM}	13.21±0.24 ^{aM}	13.10±0.11 ^{aM}	13.03±0.16 ^{aM}	13.23±0.76 ^a	
T4	Room	13.30±0.25 ^{aM}	13.19±0.22 ^{aM}	13.10±0.11 ^{aM}	12.83±0.12 ^{aM}	12.69±0.22 ^{aM}	12.40±0.24 ^{aM}	12.91±0.82 ^a	
	Ref	13.30±0.22 ^{aM}	13.19±0.22 ^{aM}	13.12±0.14 ^{aM}	12.89±0.11 ^{aM}	12.76±0.13 ^{aM}	12.60±0.12 ^{aM}	12.97±0.60 ^a	
T5	Room	13.12±0.25 ^{aM}	12.93±0.12 ^{aM}	12.82±0.23 ^{aM}	12.65±0.23 ^{aM}	12.50±0.34 ^{aM}	12.33±0.11 ^{aM}	12.72±0.62 ^a	
	Ref	13.12±0.13 ^{aM}	12.93±0.13 ^{aM}	12.82±0.24 ^{aM}	12.69±0.22 ^{aM}	12.54±0.19 ^{aM}	12.43±0.10 ^{aM}	12.75±0.52 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

Table 4.49: Effect of treatment, storage period and storage condition on the chlorophyll *a* content (mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 green									
T1	Room	6.85±0.12 ^{aM}	-	-	-	-	-	1.14±0.08 ^b	5.54±0.25 ^x
	Ref	6.85±0.23 ^{aM}	6.52±0.45 ^{aM}	-	-	-	-	2.22±0.16 ^b	
T2	Room	7.02±0.33 ^{aM}	6.89±0.23 ^{aM}	6.75±0.24 ^{aM}	6.62±0.22 ^{aM}	6.54±0.24 ^{aM}	6.42±0.22 ^{aM}	6.70±0.32 ^a	
	Ref	7.02±0.34 ^{aM}	6.92±0.12 ^{aM}	6.78±0.23 ^{aM}	6.65±0.23 ^{aM}	6.51±0.32 ^{aM}	6.46±0.25 ^{aM}	6.72±0.30 ^a	
T3	Room	6.89±0.28 ^{aM}	6.77±0.32 ^{aM}	6.73±0.24 ^{aM}	6.66±0.24 ^{aM}	6.61±0.32 ^{aM}	6.48±0.32 ^{aM}	6.69±0.36 ^a	
	Ref	6.89±0.18 ^{aM}	6.80±0.33 ^{aM}	6.74±0.34 ^{aM}	6.69±0.12 ^{aM}	6.63±0.22 ^{aM}	6.51±0.27 ^{aM}	6.71±0.34 ^a	
T4	Room	6.79±0.35 ^{aM}	6.60±0.34 ^{aM}	6.39±0.24 ^{aM}	6.20±0.22 ^{aM}	5.95±0.21 ^{aM}	5.70±0.29 ^{aM}	6.27±0.35 ^a	
	Ref	6.79±0.33 ^{aM}	6.65±0.25 ^{aM}	6.46±0.23 ^{aM}	6.31±0.23 ^{aM}	6.08±0.32 ^{aM}	5.86±0.29 ^{aM}	6.35±0.35 ^a	
T5	Room	6.87±0.25 ^{aM}	6.62±0.13 ^{aM}	6.45±0.24 ^{aM}	6.26±0.24 ^{aM}	5.07±0.22 ^{aM}	5.84±0.32 ^{aM}	6.18±0.31 ^a	
	Ref	6.87±0.48 ^{aM}	6.69±0.34 ^{aM}	6.50±0.25 ^{aM}	6.32±0.35 ^{aM}	6.17±0.14 ^{aM}	5.96±0.34 ^{aM}	6.41±0.28 ^a	
Punjab sindhuri green									
T1	Room	18.25±0.23 ^{aM}	-	-	-	-	-	3.0±0.12 ^a	15.43±1.07 ^w
	Ref	18.25±0.22 ^{aM}	18.05±0.22 ^{aM}	-	-	-	-	6.0±0.18 ^a	
T2	Room	18.95±0.31 ^{aM}	18.82±0.13 ^{aM}	18.69±0.12 ^{aM}	18.56±0.11 ^{aM}	18.36±0.23 ^{aM}	18.28±0.22 ^{aM}	18.61±0.91 ^a	
	Ref	18.95±0.22 ^{aM}	18.83±0.23 ^{aM}	18.72±0.22 ^{aM}	18.59±0.12 ^{aM}	18.49±0.22 ^{aM}	18.37±0.21 ^{aM}	18.65±0.62 ^a	
T3	Room	18.54±0.32 ^{aM}	18.45±0.24 ^{aM}	18.32±0.32 ^{aM}	18.20±0.32 ^{aM}	18.11±0.14 ^{aM}	18.00±0.23 ^{aM}	18.27±0.47 ^a	
	Ref	18.54±0.34 ^{aM}	18.45±0.22 ^{aM}	18.36±0.13 ^{aM}	18.27±0.22 ^{aM}	18.18±0.22 ^{aM}	18.06±0.11 ^{aM}	18.27±0.24 ^a	
T4	Room	18.50±0.24 ^{aM}	18.32±0.21 ^{aM}	18.10±0.18 ^{aM}	17.85±0.12 ^{aM}	17.68±0.35 ^{aM}	17.50±0.24 ^{aM}	17.99±0.94 ^a	
	Ref	18.50±0.13 ^{aM}	18.36±0.22 ^{aM}	18.10±0.17 ^{aM}	17.92±0.11 ^{aM}	17.78±0.11 ^{aM}	17.62±0.15 ^{aM}	18.04±0.19 ^a	
T5	Room	18.12±0.24 ^{aM}	17.95±0.23 ^{aM}	17.72±0.19 ^{aM}	17.50±0.24 ^{aM}	17.36±0.22 ^{aM}	17.13±0.26 ^{aM}	17.63±0.25 ^a	
	Ref	18.12±0.15 ^{aM}	17.96±0.31 ^{aM}	17.78±0.32 ^{aM}	17.62±0.11 ^{aM}	17.46±0.21 ^{aM}	17.32±0.13 ^{aM}	17.71±1.65 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

observed for Punjab Sindhuri green samples and lowest (5.54 mg/100 gm) was reported for CH-27 green variety samples. Statistically, all the linear and interaction terms of month, storage condition and treatment showed significant ($p \leq 0.05$) effect on chlorophyll during storage (Table 4.48). Green colour retention of during storage of green chili paste treated with 0.1 per cent KMS was reported by Babu *et al* (2020).

4.5.12 Effect of treatment, storage period and storage condition on the chlorophyll a of chili paste

The chlorophyll a of stored chilli paste is represented in Table 4.49. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at refrigeration temperature had the highest mean value of chlorophyll a value during the storage period with a value of 4.58 and the lowest was for the control sample stored at room temperature. Similarly, Punjab Sindhuri green samples with treatment number 2 and stored at refrigeration temperature has highest mean value of chlorophyll a value (13.66) for the storage period. Overall, the maximum mean value for chlorophyll a (11.17) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri green samples and least (3.78) was reported for CH-27 green variety samples.

4.5.13 Effect of treatment, storage period and storage condition on the chlorophyll b of chili paste

The chlorophyll a of stored chilli paste is represented in Table 4.50. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at room temperature had the highest mean value of chlorophyll b value during the storage period with a value of 2.16 and the lowest was for the control sample stored at room temperature. Similarly, Punjab Sindhuri green samples with treatment number 3 stored at refrigeration temperature and treatment 4 stored at room and refrigeration temperature has highest mean value of chlorophyll b value (5.07) for the storage period. Overall, the maximum mean value for chlorophyll b (4.26) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri green samples and least (1.76) was reported for CH-27 green variety samples.

4.5.14 Effect of treatment, storage period and storage condition on the total carotenoids (mg/100 gm) of chili paste

The total carotenoids value of stored chilli paste is represented in Table 4.51. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at refrigeration temperature had the highest mean value of total carotenoids value during the storage period with a value of 10.57 mg/100 gm and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 2 and stored at refrigeration temperature has the highest mean value of total carotenoids valueduring the storage period with a value of 18.83 mg/100 gm and the lowest was for the

Table 4.50: Effect of treatment, storage period and storage condition on the chlorophyll *b* (mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 green									
T1	Room	2.01±0.12 ^{aM}	-	-	-	-	-	0.33±0.01 ^c	1.76±0.08 ^x
	Ref	2.01±0.11 ^{aM}	2.00±0.14 ^{aM}	-	-	-	-	0.66±0.03 ^c	
T2	Room	2.00±0.10 ^{aM}	2.00±0.14 ^{aM}	2.42±0.14 ^{aM}	2.20±0.11 ^{aM}	2.20±0.15 ^{aM}	2.18±0.12 ^{aM}	2.16±0.10 ^{ab}	
	Ref	2.00±0.13 ^{aM}	2.00±0.15 ^{aM}	2.36±0.12 ^{aM}	2.16±0.12 ^{aM}	2.13±0.16 ^{aM}	2.18±0.13 ^{aM}	2.13±0.12 ^{ab}	
T3	Room	2.00±0.19 ^{aM}	2.04±0.11 ^{aM}	2.13±0.11 ^{aM}	2.18±0.22 ^{aM}	2.27±0.13 ^{aM}	2.24±0.14 ^{aM}	2.14±0.10 ^{ab}	
	Ref	2.00±0.17 ^{aM}	2.05±0.22 ^{aM}	2.11±0.14 ^{aM}	2.18±0.14 ^{aM}	2.26±0.12 ^{aM}	2.23±0.17 ^{aM}	2.13±0.18 ^{ab}	
T4	Room	2.40±0.22 ^{aM}	2.30±0.14 ^{aM}	2.20±0.12 ^{aM}	2.15±0.21 ^{aM}	2.02±0.10 ^{aM}	2.00±0.18 ^{aM}	2.17±0.16 ^{ab}	
	Ref	2.40±0.18 ^{aM}	2.35±0.11 ^{aM}	2.25±0.11 ^{aM}	2.20±0.19 ^{aM}	2.18±0.10 ^{aM}	2.13±0.10 ^{aM}	2.25±0.15 ^a	
T5	Room	2.04±0.11 ^{aM}	1.90±0.11 ^{aM}	1.87±0.14 ^{aM}	1.82±0.17 ^{aM}	0.84±0.11 ^{aM}	1.75±0.19 ^{aM}	1.70±0.12 ^b	
	Ref	2.04±0.14 ^{aM}	1.97±0.14 ^{aM}	1.91±0.21 ^{aM}	1.84±0.10 ^{aM}	1.84±0.14 ^{aM}	1.85±0.19 ^a	1.90±0.12 ^{ab}	
Punjab sindhuri green									
T1	Room	5.02±0.13 ^{aM}	-	-	-	-	-	0.83±0.06 ^b	4.26± ^w
	Ref	5.02±0.12 ^{aM}	5.00±0.14 ^{aM}	-	-	-	-	1.67±0.08 ^b	
T2	Room	5.02±0.17 ^{aM}	5.00±0.15 ^{aM}	5.00±0.15 ^{aM}	5.02±0.19 ^{aM}	4.92±0.15 ^{aM}	5.00±0.12 ^{aM}	4.99±0.24 ^a	
	Ref	5.02±0.13 ^{aM}	4.98±0.16 ^{aM}	5.00±0.12 ^{aM}	4.99±0.12 ^{aM}	4.97±0.12 ^{aM}	5.04±0.13 ^{aM}	4.99±0.28 ^a	
T3	Room	5.20±0.17 ^{aM}	5.02±0.17 ^{aM}	5.00±0.13 ^{aM}	5.00±0.12 ^{aM}	5.00±0.14 ^{aM}	5.00±0.14 ^{aM}	5.03±0.25 ^a	
	Ref	5.20±0.17 ^{aM}	5.02±0.18 ^{aM}	5.04±0.12 ^{aM}	5.06±0.14 ^{aM}	5.08±0.12 ^{aM}	5.04±0.12 ^{aM}	5.07±0.30 ^a	
T4	Room	5.20±0.19 ^{aM}	5.13±0.12 ^{aM}	5.00±0.14 ^{aM}	5.02±0.15 ^{aM}	5.00±0.13 ^{aM}	5.10±0.12 ^{aM}	5.07±0.32 ^a	
	Ref	5.20±0.15 ^{aM}	5.17±0.13 ^{aM}	4.98±0.15 ^{aM}	5.03±0.16 ^{aM}	5.03±0.14 ^{aM}	5.02±0.13 ^{aM}	5.07±0.36 ^a	
T5	Room	5.00±0.16 ^{aM}	5.02±0.14 ^{aM}	4.90±0.12 ^{aM}	4.85±0.14 ^{aM}	4.86±0.14 ^{aM}	4.80±0.14 ^{aM}	4.90±0.16 ^a	
	Ref	5.00±0.14 ^{aM}	5.03±0.16 ^{aM}	4.96±0.18 ^{aM}	4.93±0.15 ^a	4.92±0.12 ^{aM}	4.90±0.17 ^{aM}	4.95±0.25 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=NS; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=NS; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=<.001; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=NS; Variety * Storage condition * Treatment=NS; Month * Variety * Storage condition * Treatment=NS

Table 4.51: Effect of treatment, storage period and storage condition on the total carotenoids (mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	11.25±0.23 ^{aM}	-	-	-	-	-	1.87±0.09 ^d	7.9±0.36 ^y
	Ref	11.25±0.36 ^{aM}	8.58±0.13 ^{bMN}	-	-	-	-	3.30±0.18 ^d	
T2	Room	12.05±0.25 ^{aM}	10.25±0.23 ^{abN}	9.25±0.91 ^{bcM}	7.25±0.92 ^{cdN}	5.58±0.36 ^{dO}	4.58±0.63 ^{dN}	8.16±0.40 ^c	
	Ref	12.05±0.13 ^{aM}	11.52±0.85 ^{aM}	11.11±0.45 ^{abM}	10.58±0.37 ^{abM}	9.58±0.25 ^{abM}	8.58±0.34 ^{bM}	10.57±0.60 ^a	
T3	Room	11.98±0.95 ^{aM}	10.98±0.95 ^{aMN}	9.25±0.47 ^{abM}	8.01±0.19 ^{bMN}	6.58±0.74 ^{bcNO}	5.01±0.26 ^{cN}	8.63±0.64 ^{bc}	
	Ref	11.98±0.65 ^{aM}	10.59±0.69 ^{abMN}	9.40±0.58 ^{bM}	8.58±0.85 ^{bcMN}	7.89±0.25 ^{bcMNO}	6.06±0.19 ^{cMN}	9.08±0.45 ^{abc}	
T4	Room	12.45±0.74 ^{aM}	12.01±0.74 ^{aM}	11.02±0.75 ^{abM}	9.98±0.45 ^{abM}	8.75±0.74 ^{bcMN}	7.12±0.78 ^{cMN}	10.22±0.25 ^{ab}	
	Ref	12.45±0.58 ^{aM}	11.89±0.58 ^{aabM}	10.58±0.45 ^{abcM}	9.48±0.45 ^{bcMN}	8.56±0.66 ^{cMN}	7.89±0.75 ^{cM}	10.14±0.71 ^{ab}	
T5	Room	11.15±0.64 ^{aM}	10.95±0.47 ^{aMN}	8.85±0.62 ^{abM}	7.16±0.92 ^{bcN}	6.45±0.33 ^{bcNO}	6.01±0.43 ^{cMN}	8.42±0.42 ^c	
	Ref	11.15±0.85 ^{aM}	10.28±0.91 ^{aMN}	9.06±0.12 ^{abM}	8.48±0.22 ^{abcMN}	7.18±0.14 ^{bcMNO}	6.09±0.25 ^{cMN}	8.70±0.49 ^{bc}	
CH-27 red									
T1	Room	20.47±0.23 ^{aM}	-	-	-	-	-	3.41±0.21 ^b	15.14±0.64 ^x
	Ref	20.47±0.36 ^{aM}	16.25±0.45 ^{bN}	-	-	-	-	6.12±0.30 ^b	
T2	Room	21.45±0.35 ^{aM}	20.15±0.36 ^{aM}	18.96±0.75 ^{abM}	17.01±0.96 ^{bcM}	15.98±0.36 ^{cdMN}	13.56±0.26 ^{dMN}	17.85±1.3 ^a	
	Ref	21.45±0.36 ^{aM}	20.48±0.85 ^{abM}	19.05±0.45 ^{abM}	18.48±0.68 ^{bM}	17.98±0.78 ^{bcM}	15.58±0.45 ^{cM}	18.83±0.6 ^a	
T3	Room	21.08±0.23 ^{aM}	19.98±0.47 ^{abM}	17.58±0.65 ^{bcM}	16.01±0.56 ^{cM}	14.98±0.58 ^{cdN}	12.98±0.12 ^{dN}	17.10±0.4 ^a	
	Ref	21.08±0.45 ^{aM}	20.00±0.16 ^{aM}	18.59±0.26 ^{abM}	17.10±0.23 ^{bcM}	15.56±0.69 ^{cdMN}	13.45±0.36 ^{dMN}	17.63±0.8 ^a	
T4	Room	22.09±0.16 ^{aM}	20.25±0.36 ^{abM}	18.01±0.91 ^{bcM}	16.45±0.36 ^{cdM}	15.01±0.56 ^{deN}	12.58±0.78 ^{eN}	17.39±1.6 ^a	
	Ref	22.09±0.36 ^{aM}	20.25±0.25 ^{abM}	19.49±0.85 ^{abM}	17.59±0.36 ^{bcM}	15.48±0.36 ^{cdMN}	13.00±0.89 ^{dMN}	17.98±1.4 ^a	
T5	Room	22.87±0.85 ^{aM}	21.01±0.22 ^{aM}	18.21±0.36 ^{bM}	16.13±0.25 ^{bcM}	14.56±0.25 ^{cN}	11.41±0.56 ^{dN}	17.36±0.4 ^a	
	Ref	22.87±0.75 ^{aM}	21.42±0.35 ^{aM}	18.58±0.75 ^{bM}	16.58±0.75 ^{bcM}	14.48±0.25 ^{cdN}	12.46±0.45 ^{dN}	17.73±0.9 ^a	
Punjab sindhuri green									
T1	Room	12.04±0.45 ^{aMN}	-	-	-	-	-	2.00±0.14 ^e	7.25±1.8 ^z
	Ref	12.04±0.12 ^{aMN}	-	-	-	-	-	3.71±0.24 ^d	

Treatment	Storage condition	Storage period (months)							Mean (within variety)	Mean
		0	2	4	6	8	10			
T2	Room	11.28±0.48 ^{aN}	10.25±0.36 ^{aM}	8.59±0.75 ^{AbM}	6.98±1.36 ^{bcMN}	5.58±0.13 ^{cdMN}	3.85±0.36 ^{dM}	7.75±0.49 ^{bc}	18.83±0.38 ^w	
	Ref	11.28±0.96 ^{aN}	10.25±0.36 ^{abM}	9.26±0.25 ^{abcM}	7.55±0.23 ^{bcMN}	6.88±0.45 ^{cdM}	4.56±0.25 ^{dM}	8.29±0.65 ^{abc}		
T3	Room	12.26±0.45 ^{aMN}	11.02±0.25 ^{aM}	9.58±0.336 ^{abM}	7.45±0.56 ^{bcMN}	5.58±0.95 ^{cdMN}	4.58±0.45 ^{dM}	8.41±0.40 ^{abc}		
	Ref	12.26±0.69 ^{aMN}	11.02±0.78 ^{abM}	9.48±0.85 ^{bcM}	7.59±0.75 ^{cdMN}	6.58±0.45 ^{dMN}	5.48±0.26 ^{dM}	8.41±1.38 ^{abc}		
T4	Room	12.32±0.36 ^{aMN}	10.28±0.75 ^{abM}	7.98±0.95 ^{bcM}	5.28±0.95 ^{cdN}	4.01±0.36 ^{dN}	2.98±0.45 ^{dM}	7.14±0.21 ^c		
	Ref	12.32±0.71 ^{aMN}	10.28±0.25 ^{abM}	8.58±0.25 ^{bcM}	6.58±0.25 ^{cdMN}	5.25±0.25 ^{deMN}	3.58±0.63 ^{eM}	7.76±1.23 ^{abc}		
T5	Room	14.71±0.78 ^{aM}	12.02±0.74 ^{abM}	10.03±1.36 ^{bcM}	8.45±0.85 ^{cdM}	6.58±0.95 ^{deMN}	4.25±0.58 ^{eM}	9.34±0.75 ^{ab}		
	Ref	14.71±0.26 ^{aM}	12.18±0.75 ^{abM}	10.48±1.36 ^{bM}	7.48±0.74 ^{cMN}	6.58±0.24 ^{cMN}	5.05±0.75 ^{cM}	9.41±0.80 ^{a0.13}		
Punjab sindhuri red										
T1	Room	26.58±0.36 ^{aM}	-	-	-	-	-	4.43±0.2 ^b	18.83±0.38 ^w	
	Ref	26.58±0.26 ^{aM}	24.96±0.95 ^{bN}	-	-	-	-	8.02±0.6 ^b		
T2	Room	28.28±0.36 ^{aM}	26.58±0.26 ^{abMN}	24.77±0.95 ^{bM}	21.58±0.36 ^{cM}	18.57±0.75 ^{dMN}	15.58±0.54 ^{eMN}	22.56±1.4 ^a		
	Ref	28.28±0.45 ^{aM}	26.58±0.58 ^{abMN}	24.77±0.85 ^{bM}	21.58±0.24 ^{cM}	18.57±0.62 ^{dMN}	15.58±0.61 ^{eMN}	22.56±0.8 ^a		
T3	Room	27.98±0.12 ^{aM}	24.70±0.95 ^{bN}	21.58±0.54 ^{cN}	18.54±0.12 ^{dN}	15.47±0.45 ^{eO}	13.28±0.64 ^{eN}	20.25±0.2 ^a		
	Ref	27.98±0.36 ^{aM}	24.70±0.91 ^{bN}	21.58±0.25 ^{cN}	18.54±0.19 ^{dN}	15.47±0.32 ^{eO}	13.28±0.27 ^{eN}	20.25±0.9 ^a		
T4	Room	29.01±0.14 ^{aM}	27.25±0.73 ^{abMN}	24.56±0.26 ^{bM}	20.45±0.15 ^{cMN}	17.25±0.37 ^{dMNO}	14.25±0.37 ^{eMN}	22.12±1.1 ^a		
	Ref	29.01±0.15 ^{aM}	27.25±0.82 ^{abMN}	25.48±0.22 ^{bM}	22.45±0.16 ^{cM}	19.56±0.29 ^{dM}	16.45±0.91 ^{eM}	23.36±0.3 ^a		
T5	Room	29.45±0.36 ^{aM}	26.98±0.61 ^{aMN}	23.56±0.45 ^{bMN}	20.48±0.75 ^{cMN}	16.45±0.95 ^{dNO}	13.58±0.28 ^{eN}	21.75±0.4 ^a		
	Ref	29.45±0.45 ^{aM}	27.59±0.52 ^{aM}	24.48±0.65 ^{bM}	21.25±0.24 ^{cM}	18.46±0.15 ^{dMn}	16.58±0.64 ^{dM}	22.96±1.0 ^a		
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month										

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=.034; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment= <.001

control sample stored at room temperature. Highest carotenoids retention in dried carrot slice treated with KMS and red guava juice with sodium benzoate was reported by Sra *et al* (2011) and Silva *et al* (2016) respectively. Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of total carotenoids value (9.41 mg/100 gm) for the storage period. Samples of Punjab Sindhuri red with treatment number 4 and stored at refrigeration conditions had a highest mean value of 23.36 mg/100 gm. Overall, the maximum mean value for total phenolics value (18.83 mg/100 gm) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri red samples and least (7.9 mg/100 gm) was reported for CH-27 green variety samples. Statistically, all the linear and interaction terms of month, variety, storage conditions and treatment had significant ($p \leq 0.05$) effect on total carotenoids (Table 4.51). As reported by Bell *et al* (2016), the carotenoids retention of juice was highest at pH range 3, 4, 5 and 6. These pH values also results in an increased carotenoids during storage that might be related with fact of enhanced solubility of crystallized carotenoids present in the vacuoles of plant material. In present investigation, for CH-27 variety, retention of carotenoids was highest for treatment with KMS+sodium benzoate+salt+acetic acid, while for Punjab sidhuri, treatment 4 and 5 containing acetic acid was found to be best.

4.5.15 Effect of treatment, storage period and storage condition on the lycopene (mg/100 gm) of chili paste

The lycopene of stored chilli paste is represented in Table 4.52. For the CH-27 red chilli variety, the samples with treatment number 3 and stored at refrigeration temperature had the highest mean value of lycopene value during the storage period with a value of 3.56 mg/100 gm and the lowest was for the control sample stored at room temperature. While for the of Punjab Sindhuri red chilli variety, the samples with treatment number 3 and stored at refrigeration temperature has the highest mean value of lycopene value during the storage period with a value of 6.58 mg/100 gm and the lowest was for the control sample stored at room temperature.. Overall, the maximum mean value for lycopene (5.25 mg/100 gm) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri red samples. Sarkar *et al* (2015) reported that the sodium benzoate was better for the retention of lycopene content in the tomato pulp comparison to potassium metabisulphite. The higher concentration of preservative was effective for the retention of higher lycopene during storage. Similar results were found in the present investigation. Vashista *et al* (2003) reported 1.2 per cent loss of lycopene in tomato soup preserved with sodium benzoate after 60 days of the storage.

Table 4.52: Effect of treatment, storage period and storage condition on the lycopene content (mg/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 red									
T1	Room	3.60±0.16 ^{aM}	-	-	-	-	-	0.60±0.03 ^d	2.55±0.16 ^x
	Ref	3.60±0.33 ^{aM}	3.05±0.74 ^{aMN}	-	-	-	-	1.06±0.08 ^d	
T2	Room	3.50±0.12 ^{aM}	3.30±0.74 ^{aM}	3.00±0.85 ^{aM}	2.90±0.75 ^{aM}	2.76±0.44 ^{aM}	2.50±0.44 ^{aMN}	2.99±0.16 ^{abc}	
	Ref	3.50±0.23 ^{aM}	3.30±0.22 ^{aM}	3.10±0.45 ^{aM}	2.90±0.45 ^{aM}	2.86±0.54 ^{aM}	2.60±0.22 ^{aM}	3.04±0.15 ^{abc}	
T3	Room	3.90±0.45 ^{aM}	3.70±0.34 ^{aM}	3.50±0.33 ^{aM}	3.20±0.35 ^{aM}	3.00±0.64 ^{aM}	2.79±0.13 ^{aM}	3.34±0.18 ^{ab}	
	Ref	3.90±0.65 ^{aM}	3.70±0.12 ^{aM}	3.60±0.24 ^{aM}	3.50±0.21 ^{aM}	3.40±0.74 ^{aM}	3.28±0.42 ^{aM}	3.56±0.21 ^a	
T4	Room	3.20±0.76 ^{aM}	2.90±0.84 ^{aMN}	2.70±0.21 ^{aM}	2.50±0.74 ^{aM}	2.20±0.85 ^{aMN}	1.96±0.15 ^{aMN}	2.57±0.16 ^c	
	Ref	3.20±0.80 ^{aM}	2.90±0.74 ^{aMN}	2.80±0.29 ^{aM}	2.70±0.55 ^{aM}	2.50±0.29 ^{aMN}	2.20±0.74 ^{aMN}	2.80±0.20 ^{bc}	
T5	Room	3.20±0.71 ^{aM}	3.00±0.44 ^{aMN}	2.90±0.22 ^{aM}	2.60±0.28 ^{aM}	2.40±0.24 ^{aMN}	2.10±0.44 ^{aMN}	2.70±0.21 ^{bc}	
	Ref	3.20±0.74 ^{aM}	3.00±0.12 ^{aMN}	2.90±0.41 ^{aM}	2.70±0.19 ^{aM}	2.64±0.11 ^{aM}	2.41±0.54 ^{aMN}	2.80±0.25 ^{bc}	
Punjab sindhuri red									
T1	Room	6.50±0.42 ^{aM}	-	-	-	-	-	1.08±0.08 ^b	5.25±0.36 ^w
	Ref	6.50±0.44 ^{aM}	6.0±0.22 ^{aM}	-	-	-	-	1.91±0.09 ^b	
T2	Room	6.90±0.43 ^{aM}	6.70±0.41 ^{aM}	6.40±0.54 ^{aM}	6.10±0.55 ^{aM}	5.80±0.54 ^{aM}	5.50±0.46 ^{aM}	6.23±0.30 ^a	
	Ref	6.90±0.31 ^{aM}	6.70±0.48 ^{aM}	6.50±0.52 ^{aM}	6.30±0.54 ^{aM}	6.10±0.54 ^{aM}	5.90±0.54 ^{aM}	6.40±0.44 ^a	
T3	Room	7.00±0.23 ^{aM}	6.90±0.45 ^{aM}	6.50±0.53 ^{aM}	6.20±0.44 ^{aM}	5.90±0.52 ^{aM}	5.70±0.56 ^{aM}	6.36±0.40 ^a	
	Ref	7.00±0.42 ^{aM}	6.90±0.44 ^{aM}	6.70±0.45 ^{aM}	6.50±0.45 ^{aM}	6.30±0.54 ^{aM}	6.10±0.65 ^{aM}	6.58±0.38 ^a	
T4	Room	6.40±0.48 ^{aM}	6.20±0.49 ^{aM}	5.90±0.44 ^{aM}	5.80±0.55 ^{aM}	5.60±0.53 ^{aM}	5.49±0.75 ^{aM}	5.89±0.32 ^a	
	Ref	6.40±0.45 ^{aM}	6.20±0.39 ^{aM}	6.00±0.53 ^{aM}	5.90±0.44 ^{aM}	5.80±0.55 ^{aM}	5.69±0.75 ^{aM}	5.99±0.30 ^a	
T5	Room	6.70±0.44 ^{aM}	6.40±0.33 ^{aM}	6.10±0.46 ^{aM}	5.90±0.65 ^{aM}	5.50±0.44 ^{aM}	5.20±0.55 ^{aM}	5.96±0.29 ^a	
	Ref	6.70±0.42 ^{aM}	6.50±0.34 ^{aM}	6.40±0.56 ^{aM}	6.20±0.44 ^{aM}	6.00±0.46 ^{aM}	5.90±0.74 ^{aM}	6.28±0.42 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=.014; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=<.001; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=.038; Month * Variety * Storage condition * Treatment= NS

4.5.16 Effect of treatment, storage period and storage condition on the extractable color (ASTA) of chili paste

The ASTA of stored chilli paste is represented in Table 4.53. For the CH-27 green chilli variety, the samples with treatment number 5 and stored at refrigeration temperature had the highest mean value of ASTA value during the storage period with a value of 415.37 and the lowest was for the control sample stored at room temperature. While for the CH-27 red chilli variety, the samples with treatment number 5 and stored at refrigeration temperature has the highest mean value of ASTA value during the storage period with a value of 579.41 and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of ASTA value (304.84 ASTA) for the storage period. Samples of Punjab Sindhuri red with treatment number 5 and stored at refrigeration conditions had a highest mean value of 807.74 ASTA. The maximum mean value for ASTA (672.57) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for Punjab Sindhuri red samples and least (316.13 ASTA.) was reported for CH-27 green variety samples. The month duration, storage condition and treatment found to have a significant ($p \leq 0.05$) effect on ASTA (Table 4.53). Acidic pH was found to be the major factor responsible for the degradation of capsanthin in red pepper as reported by Arimboor *et al* (2015). Treatment 5 was less acidic compared to other treatments results in more retention of capsanthin responsible for total extractable color values.

4.5.17 Effect of treatment, storage period and storage condition on capsaicin (%) of chili paste

The capsaicin value of stored chilli paste is represented in Table 4.54. For the CH-27 green chilli variety, the samples with treatment number 5 and stored at refrigeration temperature had the highest mean value of capsaicin value during the storage period with a value of 4.37 per cent and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 5 and stored at refrigeration temperature has the highest mean value of capsaicin value during the storage period with a value of 3.91 per cent and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 5 and stored at refrigeration temperature has highest mean value of capsaicin value (3.40%) for the storage period. Samples of Punjab Sindhuri red with treatment number 5 and stored at room and refrigeration conditions had a highest mean value of 2.42 per cent. The maximum mean value for capsaicin value (4.9%) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 red samples and least (2.09%) was reported for Punjab Sindhuri green variety samples. Statistically, only the interaction terms of month*storage condition and month * storage condition * Treatment were reported to have

Table 4.53: Effect of treatment, storage period and storage condition on the total extractable color (ASTA) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	407.01±3.22 ^{aM}	-	-	-	-	-	61.05±4.8 ^c	316.13±12.91 ^y
	Ref	407.01±1.45 ^{aM}	385.00±1.44 ^{bN}	-	-	-	-	67.83±5.27 ^c	
T2	Room	412.12±2.56 ^{aM}	390.25±1.65 ^{bM}	371.25±7.89 ^{cS}	350.25±4.78 ^S	320.25±5.77 ^{eQ}	295.22±2.56 ^{fR}	356.56±8.46 ^b	
	Ref	412.12±3.45 ^{aM}	392.25±1.44 ^{bM}	373.25±7.56 ^{cS}	356.25±5.45 ^{dR}	330.59±4.88 ^{eQ}	300.22±6.45 ^{fQ}	360.78±8.64 ^{ab}	
T3	Room	419.25±6.45 ^{aM}	400.52±1.54 ^{bM}	380.25±6.75 ^{cR}	355.89±5.65 ^{dR}	322.25±5.98 ^{eP}	300.55±5.78 ^{fQ}	366.30±10.22 ^{ab}	
	Ref	419.25±6.45 ^{aM}	402.52±1.22 ^{bM}	386.25±5.45 ^{cQ}	360.89±5.98 ^{dQ}	328.25±6.78 ^{eP}	300.62±5.92 ^{fQ}	387.19±4.55 ^{ab}	
T4	Room	420.58±7.88 ^{aM}	409.58±1.66 ^{bM}	390.25±5.85 ^{cP}	380.25±5.74 ^{dP}	368.25±5.79 ^{eO}	354.21±5.84 ^{fP}	387.19±3.65 ^{ab}	
	Ref	420.58±5.44 ^{aM}	412.58±1.45 ^{bM}	396.25±4.65 ^{cO}	385.25±4.85 ^{dO}	370.25±6.87 ^{fO}	359.16±6.78 ^{eO}	390.68±4.45 ^{ab}	
T5	Room	445.65±5.66 ^{aM}	430.25±6.74 ^{bM}	415.28±4.36 ^{cN}	397.25±6.78 ^{dN}	389.25±6.88 ^{eN}	375.49±7.82 ^{fN}	408.86±2.55 ^{ab}	
	Ref	445.65±3.22 ^{aM}	433.25±5.85 ^{bM}	419.48±6.78 ^{cM}	409.58±7.89 ^{dM}	398.58±9.78 ^{eM}	385.66±9.42 ^{fM}	415.37±10.20 ^a	
CH-27 red									
T1	Room	598.25±7.45 ^{aM}	-	-	-	-	-	99.70±7.92 ^b	444.70±20.66 ^x
	Ref	598.25±5.68 ^{aM}	579.58±7.45 ^{bO}	-	-	-	-	196.31±5.62 ^b	
T2	Room	600.25±5.94 ^{aMN}	582.25±5.68 ^{bO}	567.38±7.11 ^{cP}	548.25±8.74 ^{dR}	527.06±8.77 ^{eS}	509.42±8.00 ^{fS}	555.77±7.72 ^a	
	Ref	600.25±6.48 ^{aMN}	586.54±5.82 ^{bO}	570.10±7.25 ^{cO}	552.58±8.55 ^{dQR}	530.56±6.74 ^{eR}	519.52±8.74 ^{fQ}	559.93±8.54 ^a	
T3	Room	600.55±5.77 ^{aMN}	580.25±6.71 ^{bN}	562.28±8.45 ^{cQ}	550.25±8.64 ^{dQ}	533.48±5.69 ^{eQ}	510.46±7.56 ^{fS}	556.21±10.21 ^a	
	Ref	600.55±5.22 ^{aMN}	580.25±7.89 ^{bO}	568.28±8.65 ^{cOP}	556.41±8.77 ^{dP}	536.45±6.88 ^{eP}	515.74±6.41 ^{fR}	559.61±4.55 ^a	
T4	Room	595.80±5.98 ^{aN}	585.25±8.79 ^{bN}	570.36±8.44 ^{cO}	558.25±8.41 ^{dP}	545.28±5.78 ^{eO}	532.72±6.55 ^{fP}	564.61±3.55 ^a	
	Ref	595.80±5.68 ^{aN}	587.56±8.22 ^{bN}	576.39±8.77 ^{cN}	563.74±8.65 ^{dO}	558.78±6.8 ^{eN}	548.89±6.78 ^{fO}	571.86±5.85 ^a	
T5	Room	600.45±6.78 ^{aMN}	591.25±8.77 ^{bM}	578.76±8.14 ^{cN}	569.25±8.98 ^{dN}	559.48±8.74 ^{eN}	545.68±8.98 ^{fN}	574.15±4.95 ^a	
	Ref	600.45±4.78 ^{aMN}	591.78±8.98 ^{bM}	588.78±8.44 ^{cM}	573.45±8.45 ^{dM}	565.84±8.21 ^{eM}	556.16±5.88 ^{fM}	579.41±6.45 ^a	
Punjab sindhuri green									
T1	Room	300.25±6.78 ^{aM}	-	-	-	-	-	50.04±3.01 ^b	
	Ref	300.25±5.77 ^{aM}	278.26±9.78 ^{bM}	-	-	-	-	96.41±7.64 ^b	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
T2	Room	312.25±6.78 ^{aM}	295.69±8.65 ^{bM}	278.48±1.55 ^{cM}	257.58±6.78 ^{dM}	232.56±4.56 ^{eN}	210.76±8.77 ^{fN}	264.55±5.87 ^a	241.71±2 5.97 ^z
	Ref	312.25±6.98 ^{aM}	295.49±8.77 ^{bM}	280.86±4.65 ^{cM}	261.75±5.65 ^{dM}	248.64±6.78 ^{eMN}	219.52±8.65 ^{fN}	269.75±6.24 ^a	
T3	Room	305.25±6.81 ^{aM}	280.25±4.56 ^{bM}	271.03±9.77 ^{cM}	250.26±4.56 ^{dM}	232.30±5.88 ^{eN}	210.78±9.44 ^{fN}	258.31±8.6 ^a	
	Ref	305.25±7.63 ^{aM}	281.75±6.81 ^{bM}	272.36±5.64 ^{cM}	255.06±5.44 ^{dM}	241.03±5.77 ^{eN}	225.78±8.77 ^{fN}	263.54±9.56 ^a	
T4	Room	321.30±8.72 ^{aM}	315.25±6.77 ^{bM}	306.61±6.78 ^{cM}	296.58±5.66 ^{dM}	290.66±6.75 ^{eMN}	282.18±5.66 ^{fMN}	302.10±10.27 ^a	
	Ref	321.30±8.88 ^{aM}	315.56±8.98 ^{bM}	306.16±5.52 ^{cM}	299.68±5.64 ^{dM}	292.64±6.4 ^{eMN}	287.88±5.18 ^{fMN}	303.87±2.53 ^a	
T5	Room	320.14±7.88 ^{aM}	313.25±8.88 ^{bM}	308.48±8.64 ^{cM}	300.25±5.34 ^{dM}	294.52±6.78 ^{eMN}	285.16±5.78 ^{fMN}	303.63±5.81 ^a	
	Ref	320.14±8.97 ^{aM}	315.75±6.75 ^{bM}	309.84±8.57 ^{cM}	300.86±7.55 ^{dM}	295.02±8.77 ^{eM}	287.44±5.88 ^{fM}	304.84±6.89 ^a	
Punjab sindhuri red									
T1	Room	809.68±4.56 ^a	-	-	-	-	-	134.95±6.79 ^b	672.57±5 4.77 ^w
	Ref	809.68±5.48 ^a	785.69±6.55 ^{bs}	-	-	-	-	265.90±1.21 ^b	
T2	Room	818.04±5.77 ^{aOP}	800.20±6.35 ^{bR}	780.26±6.77 ^{cR}	760.96±9.78 ^{dR}	742.25±8.78 ^{eS}	721.90±8.77 ^{fS}	770.60±2.83 ^a	
	Ref	818.04±6.48 ^{aOP}	808.56±5.78 ^{bP}	795.96±5.88 ^{cO}	783.65±8.98 ^{dQ}	772.69±5.77 ^{eR}	752.12±9.78 ^{fP}	798.40±3.87 ^a	
T3	Room	820.36±5.74 ^{aO}	802.35±5.88 ^{bQR}	781.29±6.87 ^{cQ}	764.60±7.96 ^{dP}	745.25±9.78 ^{eQ}	728.47±8.88 ^{fR}	773.72±1.88 ^a	
	Ref	820.36±5.99 ^{aO}	803.58±5.98 ^{bQ}	786.86±5.98 ^{cP}	771.66±8.77 ^{dO}	755.85±8.88 ^{eP}	739.52±7.95 ^{fQ}	779.64±8.82 ^a	
T4	Room	816.73±5.64 ^{aP}	811.36±6.75 ^{bO}	802.39±6.78 ^{cN}	795.69±8.77 ^{dN}	784.69±9.78 ^{eO}	779.55±6.78 ^{fO}	798.40±3.86 ^a	
	Ref	816.73±4.68 ^{aP}	811.75±5.87 ^{bO}	804.86±5.78 ^{cN}	795.85±8.65 ^{dN}	788.77±8.65 ^{eN}	780.16±8.97 ^{fO}	799.69±2.84 ^a	
T5	Room	826.07±4.77 ^{aN}	819.69±5.88 ^{bN}	811.25±5.88 ^{cM}	802.36±6.78 ^{dM}	794.69±6.78 ^{eM}	785.29±8.79 ^{fN}	806.56±10.22 ^a	
	Ref	826.07±5.67 ^{aM}	819.75±7.65 ^{bM}	811.74±5.99 ^{cM}	803.85±9.88 ^{dM}	796.78±8.77 ^{eM}	788.24±9.88 ^{fM}	807.74±5.28 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=NS; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=.005

Table 4. 54: Effect of treatment, storage period and storage condition on the capsaicin (%) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	4.19±0.23 ^a	-	-	-	-	-	0.69±0.01 ^b	4.36±0.12 ^{wx}
	Ref	4.19±0.23 ^{aM}	-	-	-	-	-	1.29±0.02 ^b	
T2	Room	4.15±0.36 ^{aM}	4.11±0.12 ^{aM}	4.06±0.17 ^{aM}	4.01±0.09 ^{aM}	3.93±0.01 ^{aM}	3.85±0.09 ^{aM}	4.01±0.24 ^a	
	Ref	4.15±0.25 ^{aM}	4.11±0.16 ^{aM}	4.08±0.17 ^{aM}	4.03±0.01 ^{aM}	3.94±0.11 ^{aM}	3.88±0.08 ^{aM}	4.03±0.28 ^a	
T3	Room	4.18±0.85 ^{aM}	4.13±0.14 ^{aM}	4.09±0.09 ^{aM}	4.02±0.11 ^{aM}	3.95±0.13 ^{aM}	3.88±0.07 ^{aM}	4.04±0.24 ^a	
	Ref	4.18±0.95 ^{aM}	4.15±0.14 ^{aM}	4.11±0.01 ^{aM}	4.01±0.12 ^{aM}	3.97±0.09 ^{aM}	3.91±0.17 ^{aM}	4.05±0.28 ^a	
T4	Room	4.32±0.74 ^{aM}	4.27±0.18 ^{aM}	4.23±0.14 ^{aM}	4.19±0.08 ^{aM}	4.17±0.04 ^{aM}	4.17±0.13 ^{aM}	4.22±0.26 ^a	
	Ref	4.32±0.44 ^{aM}	4.29±0.11 ^{aM}	4.23±0.09 ^{aM}	4.18±0.07 ^{aM}	4.19±0.11 ^{aM}	4.18±0.14 ^{aM}	4.23±0.21 ^a	
T5	Room	4.40±0.55 ^{aM}	4.38±0.12 ^{aM}	4.37±0.11 ^{aM}	4.35±0.12 ^{aM}	4.37±0.17 ^{aM}	4.34±0.14 ^{aM}	4.36±0.30 ^a	
	Ref	4.40±0.12 ^{aM}	4.39±0.13 ^{aM}	4.39±0.10 ^{aM}	4.36±0.01 ^{aM}	4.36±0.11 ^{aM}	4.35±0.16 ^{aM}	4.37±0.21 ^a	
CH-27 red									
T1	Room	3.78±0.09 ^{aM}	-	-	-	-	-	0.63±0.01 ^b	4.9±0.14 ^w
	Ref	3.78±0.04 ^{aM}	3.68±0.09 ^{aM}	-	-	-	-	1.17±0.11 ^b	
T2	Room	3.80±1.20 ^{aM}	3.74±0.03 ^{aM}	3.68±0.12 ^{aM}	3.62±0.07 ^{aM}	3.55±0.21 ^{aM}	3.42±0.23 ^{aM}	3.63±0.17 ^a	
	Ref	3.80±1.30 ^{aM}	3.75±0.07 ^{aM}	3.70±0.18 ^{aM}	3.63±0.14 ^{aM}	3.54±0.21 ^{aM}	3.48±0.12 ^{aM}	3.65±0.19 ^a	
T3	Room	3.79±1.33 ^{aM}	3.71±0.12 ^{aM}	3.64±0.12 ^{aM}	3.54±0.18 ^{aM}	3.47±0.23 ^{aM}	3.36±0.14 ^{aM}	3.58±0.20 ^a	
	Ref	3.79±1.26 ^{aM}	3.72±0.15 ^{aM}	3.65±0.09 ^{aM}	3.55±0.15 ^{aM}	3.48±0.26 ^{aM}	3.41±0.09 ^{aM}	3.60±0.21 ^a	
T4	Room	3.90±0.02 ^{aM}	3.88±0.99 ^{aM}	3.87±0.08 ^{aM}	3.84±0.06 ^{aM}	3.85±0.21 ^{aM}	3.81±0.08 ^{aM}	3.85±0.17 ^a	
	Ref	3.90±0.03 ^{aM}	3.89±0.08 ^{aM}	3.87±0.12 ^{aM}	3.85±0.01 ^{aM}	3.87±0.11 ^{aM}	3.83±0.12 ^{aM}	3.86±0.21 ^a	
T5	Room	3.95±0.09 ^{aM}	3.92±0.12 ^{aM}	3.93±0.15 ^{aM}	3.90±0.11 ^{aM}	3.88±0.20 ^{aM}	3.83±0.11 ^{aM}	3.85±0.14 ^a	
	Ref	3.95±0.12 ^{aM}	3.95±0.14 ^{aM}	3.93±0.17 ^{aM}	3.91±0.12 ^{aM}	3.88±0.28 ^{aM}	3.86±0.10 ^{aM}	3.91±0.21 ^a	
Punjab sindhuri green									
T1	Room	2.44±0.09 ^{aM}	-	-	-	-	-	0.55±0.01 ^b	

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
	Ref	2.44±0.08 ^{aM}	-	-	-	-	-	1.09±0.11 ^b	2.09±0.1w ^x
T2	Room	2.49±0.12 ^{aM}	2.45±0.09 ^{aM}	2.38±0.12 ^{aM}	2.32±0.11 ^{aM}	2.28±0.12 ^{aM}	2.22±0.01 ^{aM}	3.00±0.17 ^a	
	Ref	2.49±0.13 ^{aM}	2.45±0.12 ^{aM}	2.39±0.13 ^{aM}	2.34±0.09 ^{aM}	2.29±0.11 ^{aM}	2.21±0.17 ^{aM}	3.04±0.18 ^a	
T3	Room	2.50±0.21 ^{aM}	2.45±0.13 ^{aM}	2.37±0.12 ^{aM}	2.33±0.12 ^{aM}	2.25±0.09 ^{aM}	2.19±0.13 ^{aM}	3.13±0.15 ^a	
	Ref	2.50±0.08 ^{aM}	2.44±0.21 ^{aM}	2.39±0.11 ^{aM}	2.33±0.21 ^{aM}	2.26±0.04 ^{aM}	2.21±0.15 ^{aM}	3.17±0.21 ^a	
T4	Room	2.40±0.25 ^{aM}	2.38±0.19 ^{aM}	2.40±0.14 ^{aM}	2.37±0.11 ^{aM}	2.39±0.07 ^{aM}	2.43±0.21 ^{aM}	2.96±0.12 ^a	
	Ref	2.40±0.11 ^{aM}	2.40±0.09 ^{aM}	2.41±0.12 ^{aM}	2.39±0.13 ^{aM}	2.39±0.12 ^{aM}	2.41±0.09 ^{aM}	2.98±0.14 ^a	
T5	Room	2.45±0.23 ^{aM}	2.42±0.07 ^{aM}	2.44±0.12 ^{aM}	2.42±0.14 ^{aM}	2.40±0.13 ^{aM}	2.43±0.07 ^{aM}	3.38±0.21 ^a	
	Ref	2.45±0.02 ^{aM}	2.42±0.08 ^{aM}	2.43±0.11 ^{aM}	2.42±0.19 ^{aM}	2.40±0.17 ^{aM}	2.44±0.11 ^{aM}	3.40±0.24 ^a	
Punjab sindhuri red									
T1	Room	3.30±0.13 ^{aM}	-	-	-	-	-	0.40±0.01 ^b	2.67±0.12 ^w
	Ref	3.30±0.12 ^{aM}	3.24±0.01 ^{aM}	-	-	-	-	0.89±0.02 ^b	
T2	Room	3.18±0.09 ^{aM}	3.15±0.03 ^{aM}	3.10±0.09 ^{aM}	3.03±0.09 ^{aM}	2.82±0.09 ^{aM}	2.75±0.14 ^{aM}	2.35±0.12 ^a	
	Ref	3.18±0.08 ^{aM}	3.15±0.09 ^{aM}	3.11±0.01 ^{aM}	3.05±0.06 ^{aM}	2.93±0.18 ^{aM}	2.87±0.15 ^{aM}	2.36±0.14 ^a	
T3	Room	3.32±0.15 ^{aM}	3.25±0.12 ^{aM}	3.18±0.01 ^{aM}	3.11±0.03 ^{aM}	3.06±0.15 ^{aM}	2.91±0.13 ^{aM}	2.34±0.20 ^a	
	Ref	3.32±0.19 ^{aM}	3.25±0.13 ^{aM}	3.21±0.12 ^{aM}	3.16±0.04 ^{aM}	3.10±0.02 ^{aM}	2.99±0.10 ^{aM}	2.35±0.16 ^a	
T4	Room	3.00±0.09 ^{aM}	2.97±0.21 ^{aM}	3.02±0.09 ^{aM}	2.99±0.11 ^{aM}	2.95±0.01 ^{aM}	2.88±0.09 ^{aM}	2.39±0.14 ^a	
	Ref	3.00±0.12 ^{aM}	2.97±0.09 ^{aM}	3.09±0.01 ^{aM}	2.98±0.25 ^{aM}	2.96±0.11 ^{aM}	2.90±0.08 ^{aM}	2.40±0.18 ^a	
T5	Room	3.47±0.13 ^{aM}	3.41±0.19 ^{aM}	3.43±0.11 ^{aM}	3.39±0.12 ^{aM}	3.33±0.12 ^{aM}	3.29±0.12 ^{aM}	2.42±0.14 ^a	
	Ref	3.47±0.18 ^{aM}	3.45±0.01 ^{aM}	3.43±0.12 ^{aM}	3.40±0.13 ^{aM}	3.35±0.09 ^{aM}	3.35±0.13 ^{aM}	2.42±0.12 ^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=NS; Variety=NS; Storage condition=NS; Treatment=NS; Month * Variety=NS; Month * Storage condition=NS; Month * Treatment=<.005; Variety * Storage condition=NS; Variety * Treatment=NS; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS; Month * Storage condition * Treatment=0.03; Variety * Storage condition * Treatment=NS; Month * Variety * Storage condition * Treatment= NS

significant ($p \leq 0.05$) effect on capsaicin (Table 4.54). More acidic condition and less stability of capsaicinoid content were reported by Si *et al* (2014). Treatment 4 and 5 were less acidic than treatment 2 and 3 results in more capsaicin content retention in treatment 5.

4.5.18 Effect of treatment, storage period and storage condition on per cent inhibition of DPPH of chili paste

The antioxidant activity of stored chilli paste is represented in Table 4.55. For the CH-27 green chilli variety, the samples with treatment number 3 and stored at room temperature had the highest mean value of antioxidant activity value during the storage period with a value of 89.78 per cent and the lowest was for the control sample stored at room temperature. While for the CH-27 red chilli variety, the samples with treatment number 2 and stored at room temperature and treatment number 4 and stored at room temperature has the highest mean value of antioxidant activity value during the storage period with a value of 88.99 per cent and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 2 and stored at refrigeration temperature has highest mean value of antioxidant activity value (93.77%) for the storage period. Samples of Punjab Sindhuri red with treatment number 3 and stored at refrigeration conditions had a highest mean value of 88.48 per cent. Overall, the maximum mean value for antioxidant activity (75.42%) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 green samples and least (69.11%) was reported for Punjab Sindhuri green variety samples. As evident from the data of Table 4.55, month, storage condition and treatment found to have a significant ($p \leq 0.05$) effect on antioxidant activity of chili paste. As reported by Settharaksa *et al* (2012), methanolic extract of peanut hull depicted higher DPPH scavenging properties at natural and slight acidic pH range. El-Saadony *et al* (2020) reported the retention of antioxidant activity of cucumber peel preserved with sodium benzoate in terms of DPPH value.

4.5.19 Effect of treatment, storage period and storage condition on the FRAP (mM/100 gm) of chili paste

The FRAP value of stored chilli paste is represented in Table 4.56. For the CH-27 green chilli variety, the samples with treatment number 2 and stored at refrigeration temperature had the highest mean value of FRAP value during the storage period with a value of 2.60 mM/100 gm and the lowest was for the control sample stored at room temperature. Similarly, for the CH-27 red chilli variety, the samples with treatment number 2 and stored at refrigeration temperature has the highest mean value of FRAP value during the storage period with a value of 2.69 mM/100 gm and the lowest was for the control sample stored at room temperature. Punjab Sindhuri green samples with treatment number 2 and stored at refrigeration temperature has highest mean value of FRAP value (1.95) for the storage period. Samples of Punjab Sindhuri red with treatment number 3 and stored at refrigeration

Table 4.55: Effect of treatment, storage period and storage condition on the per cent inhibition of DPPH of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	85.80±1.36 ^{aN}	-	-	-	-	-	14.30±0.53 ^b	75.42±4.21 ^w
	Ref	85.80±1.26 ^{aN}	79.25±0.03 ^{bN}	-	-	-	-	22.68±1.70 ^b	
T2	Room	92.20±1.25 ^{aM}	90.05±1.62 ^{aM}	89.57±1.52 ^{aM}	86.42±2.36 ^{bO}	84.85±1.01 ^{bcO}	83.04±1.36 ^{cP}	87.68±3.22 ^a	
	Ref	92.20±1.62 ^{aM}	91.05±1.53 ^{aM}	90.57±2.36 ^{abM}	90.42±2.36 ^{abM}	89.85±1.65 ^{abM}	88.04±2.36 ^{bM}	85.17±2.65 ^a	
T3	Room	92.60±1.25 ^{aM}	91.81±1.35 ^{abM}	90.97±2.36 ^{abM}	89.58±3.12 ^{bcMN}	87.48±1.39 ^{cdMN}	86.26±3.12 ^{dMN}	89.78±4.84 ^a	
	Ref	92.60±1.6 ^{aM}	91.56±1.36 ^{abM}	90.56±2.48 ^{abcM}	89.66±2.12 ^{bcdMN}	88.16±1.85 ^{cdMN}	87.13±2.34 ^{dMN}	84.53±1.06 ^a	
T4	Room	91.80±1.58 ^{aM}	90.45±1.52 ^{aM}	89.06±2.69 ^{abM}	87.67±1.02 ^{bcNO}	85.93±2.32 ^{cdNO}	83.50±2.75 ^{dOP}	88.06±2.06 ^a	
	Ref	91.80±1.95 ^{aM}	90.45±1.92 ^{abM}	90.06±2.85 ^{abM}	89.86±1.22 ^{abMN}	88.13±2.45 ^{bMN}	87.84±2.85 ^{bM}	84.53±3.99 ^a	
T5	Room	91.10±1.96 ^{aM}	90.57±1.72 ^{abM}	89.28±2.65 ^{abcM}	88.05±1.65 ^{bcMNO}	86.90±2.95 ^{cdNO}	84.66±2.36 ^{dNOP}	88.42±2.18 ^a	
	Ref	91.10±1.59 ^{aM}	90.85±1.52 ^{aM}	89.89±2.94 ^{aM}	88.86±1.33 ^{aMNO}	86.05±2.85 ^{bNO}	85.96±2.95 ^{bMNO}	83.66±4.99 ^a	
CH-27 red									
T1	Room	87.90±3.23 ^{aN}	-	-	-	-	-	14.65±0.76 ^b	73.15±5.25 ^x
	Ref	87.90±1.23 ^{aN}	85.36±2.36 ^{bP}	-	-	-	-	28.87±1.45 ^b	
T2	Room	91.00±2.25 ^{aM}	89.59±2.45 ^{abMN}	87.30±1.02 ^{bcMN}	86.81±3.25 ^{cMN}	85.04±.26 ^{cNO}	84.56±1.01 ^{cMN}	87.38±1.57 ^a	
	Ref	91.00±2.45 ^{aM}	90.59±2.95 ^{aM}	89.30±1.23 ^{abM}	88.81±2.36 ^{abcM}	87.72±3.22 ^{bcM}	86.53±2.00 ^{cM}	88.99±2.55 ^a	
T3	Room	88.80±2.62 ^{aMN}	86.23±2.86 ^{abOP}	85.83±2.36 ^{bNO}	83.61±2.34 ^{bcOP}	82.48±2.12 ^{cOP}	81.23±2.12 ^{cOP}	84.69±3.88 ^a	
	Ref	88.80±2.95 ^{aMN}	87.98±2.73 ^{abMNOP}	86.66±2.35 ^{abcMN}	85.96±2.6 ^{cdNO}	84.69±2.42 ^{deNO}	83.10±2.48 ^{eNO}	86.19±5.27 ^a	
T4	Room	89.00±2.37 ^{aMN}	87.83±2.36 ^{abNOP}	86.91±2.36 ^{abcMN}	85.19±1.26 ^{bcdNO}	84.24±2.35 ^{cdNO}	83.54±3.25 ^{dNO}	88.99±4.08 ^a	
	Ref	89.00±2.81 ^{aMN}	88.83±2.45 ^{aMNO}	87.58±3.25 ^{abMN}	86.29±3.25 ^{abcMN}	85.34±2.14 ^{bcMN}	84.69±3.15 ^{cMN}	86.95±2.89 ^a	
T5	Room	86.30±2.22 ^{aN}	85.49±2.62 ^{abP}	83.40±2.35 ^{bcO}	81.56±1.36 ^{cdP}	80.34±2.33 ^{dP}	79.89±2.19 ^{dP0}	82.83±4.29 ^a	
	Ref	86.30±2.65 ^{aN}	85.49±1.23 ^{aP}	85.86±2.36 ^{abNO}	84.57±2.33 ^{abNO}	83.89±2.24 ^{abNO}	82.85±2.48 ^{bNO}	84.82±3.06 ^a	
Punjab sindhuri green									
T1	Room	86.96±3.45 ^{aNO}	-	-	-	-	-	14.49±0.99 ^b	69.11±3.53 ^y
	Ref	86.96±2.33 ^{aNO}	83.69±2.78 ^{bO}	-	-	-	-	28.44±2.14 ^b	

T2	Room	95.83±2.65 ^{aM}	95.01±2.91 ^{abM}	94.51±2.33 ^{abM}	92.58±3.25 ^{bcM}	91.21±3.56 ^{cM}	90.25±2.01 ^{cM}	93.23±3.82^a	
	Ref	95.83±1.02 ^{aM}	95.00±3.12 ^{abM}	94.55±3.11 ^{abM}	93.49±3.11 ^{abcM}	92.54±2.3 ^{bcM}	91.23±2.11 ^{cM}	93.77±1.25^a	
T3	Room	88.48±2.00 ^{aN}	86.63±2.11 ^{abN}	86.07±2.33 ^{abNO}	85.38±2.33 ^{bNO}	84.20±2.45 ^{bcNO}	82.25±3.02 ^{cNO}	85.50±2.15^a	
	Ref	88.48±2.12 ^{aN}	87.63±2.34 ^{abN}	87.07±2.66 ^{abN}	86.38±2.33 ^{abcN}	85.20±2.85 ^{bcN}	84.25±2.56 ^{cN}	86.50±4.66^a	
T4	Room	86.45±2.11 ^{aNO}	86.25±2.65 ^{aNO}	84.31±2.34 ^{abOP}	83.15±3.45 ^{bcO}	81.98±2.94 ^{bcO}	80.95±2.98 ^{cOP}	83.84±3.24^a	
	Ref	86.45±2.36 ^{aNO}	86.25±2.91 ^{aNO}	84.31±2.34 ^{abOP}	83.89±2.11 ^{abcNO}	82.97±3.12 ^{bcNO}	81.49±1.09 ^{cO}	84.22±2.05^a	
T5	Room	84.64±2.45 ^{aO}	82.17±2.66 ^{abP}	80.05±3.11 ^{bcQ}	79.07±2.33 ^{cP}	78.06±2.12 ^{cdP}	76.15±2.04 ^{dQ}	80.02±3.85^a	
	Ref	84.64±2.78 ^{aO}	83.49±2.98 ^{aP}	82.59±3.22 ^{abPQ}	80.48±2.65 ^{bcP}	79.31±2.01 ^{cP}	78.48±2.68 ^{cPQ}	81.49±1.04^a	
Punjab sindhuri red									
T1	Room	72.60±2.11 ^{aP}	-	-	-	-	-	12.10±0.91^b	73.15±5.80 ^x
	Ref	72.60±2.15 ^{aP}	70.25±1.01 ^{aP}	-	-	-	-	23.80±2.05^b	
T2	Room	84.90±3.45 ^{aN}	83.25±2.00 ^{abN}	82.27±1.25 ^{abN}	80.98±1.35 ^{bcN}	79.32±1.00 ^{cP}	78.89±1.00 ^{cNO}	81.60±4.56^a	
	Ref	84.90±1.05 ^{aN}	83.25±1.21 ^{abN}	82.27±1.00 ^{abcN}	81.99±2.33 ^{bcN}	80.92±1.02 ^{bcP}	80.06±2.36 ^{cN}	82.21±3.25^a	
T3	Room	91.00±3.19 ^{aM}	90.89±2.45 ^{aM}	89.58±2.15 ^{abM}	87.65±3.22 ^{bcM}	85.75±2.35 ^{cdM}	84.69±2.35 ^{dM}	88.26±4.04^a	
	Ref	91.00±2.45 ^{aM}	90.89±3.29 ^{aM}	89.89±2.45 ^{abM}	87.25±1.23 ^{bcM}	86.21±2.44 ^{cM}	85.69±2.44 ^{cM}	88.48±3.24^a	
T4	Room	85.10±.68 ^{aN}	82.36±3.68 ^{abN}	80.19±3.12 ^{bcN}	79.62±1.35 ^{bcN}	78.77±1.26 ^{cdP}	76.36±1.02 ^{dOP}	80.40±2.04^a	
	Ref	85.10±2.48 ^{aN}	82.36±3.78 ^{abN}	80.19±3.65 ^{bcN}	80.00±3.23 ^{bcN}	79.77±1.36 ^{bcP}	78.55±2.36 ^{cNO}	80.90±1.25^a	
T5	Room	79.90±3.48 ^{aNO}	78.25±3.45 ^{abO}	77.02±2.14 ^{bcO}	76.28±3.22 ^{bcO}	75.28±2.35 ^{cdO}	73.25±2.33 ^{dQ}	76.66±1.05^a	
	Ref	79.90±2.52 ^{aO}	78.56±2.15 ^{abO}	76.12±3.95 ^{bcO}	75.28±3.45 ^{cO}	75.05±2.33 ^{cO}	74.46±2.66 ^{cPQ}	76.56±2.05^a	
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month									

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=<.001; Treatment=<.001; Month * Variety=<.001; Month * Storage condition=<.001; Month * Treatment=<.001; Variety * Storage condition=<.001; Variety * Treatment=<.001; Storage condition * Treatment=<.001; Month * Variety * Storage condition=<.001; Month * Variety * Treatment=<.001; Month * Storage condition * Treatment=<.001; Variety * Storage condition * Treatment=<.001; Month * Variety * Storage condition * Treatment=<.001

Table 4.56: Effect of treatment, storage period and storage condition on the antioxidant activity(FRAP mM/100 gm) of chili paste

Treatment	Storage condition	Storage period (months)						Mean (within variety)	Mean
		0	2	4	6	8	10		
CH-27 Green									
T1	Room	2.70±0.12 ^{aM}	-	-	-	-	-	0.45±0.02 ^b	2.11±0.12 ^w
	Ref	2.70±0.36 ^{aM}	2.58±0.98 ^{aMN}	-	-	-	-	0.88±0.04 ^b	
T2	Room	2.85±0.36 ^{aM}	2.75±0.36 ^{aM}	2.59±0.78 ^{aM}	2.48±0.95 ^{aM}	2.40±0.32 ^{aM}	2.28±0.96 ^{aM}	2.55±0.18 ^a	
	Ref	2.85±0.25 ^{aM}	2.78±0.74 ^{aM}	2.65±0.78 ^{aM}	2.52±0.75 ^{aM}	2.47±0.95 ^{aM}	2.35±0.36 ^{aM}	2.60±0.20 ^a	
T3	Room	2.80±0.85 ^{aM}	2.71±0.85 ^{aMN}	2.56±0.85 ^{aMN}	2.38±0.65 ^{aM}	2.30±0.75 ^{aM}	2.22±0.64 ^{aM}	2.49±0.21 ^a	
	Ref	2.80±0.94 ^{aM}	2.73±0.96 ^{aMN}	2.59±0.86 ^{aM}	2.41±0.32 ^{aM}	2.35±0.41 ^{aM}	2.29±0.56 ^{aM}	2.52±0.21 ^a	
T4	Room	2.75±0.16 ^{aM}	2.60±0.75 ^{aMN}	2.49±0.36 ^{aMN}	2.39±0.75 ^{aM}	2.18±0.81 ^{aM}	1.88±0.85 ^{aM}	2.38±0.17 ^a	
	Ref	2.75±0.94 ^{aM}	2.62±0.73 ^{aMN}	2.48±0.28 ^{aMN}	2.36±0.48 ^{aM}	2.22±0.92 ^{aM}	2.05±0.94 ^{aM}	2.41±0.14 ^a	
T5	Room	2.79±0.95 ^{aM}	2.62±0.91 ^{aMN}	2.47±0.25 ^{aMN}	2.32±0.96 ^{aM}	2.13±0.94 ^{aM}	1.83±0.26 ^{aM}	2.36±0.16 ^a	
	Ref	2.79±0.35 ^{aM}	2.66±0.75 ^{aMN}	2.51±0.25 ^{aMN}	2.37±0.24 ^{aM}	2.21±0.76 ^{aM}	2.08±0.35 ^{aM}	2.43±0.12 ^a	
CH-27 red									
T1	Room	2.75±0.12 ^{aM}	-	-	-	-	-	0.45±0.02 ^b	2.18±0.14 ^w
	Ref	2.75±0.13 ^{aM}	2.61±0.45 ^{aMN}	-	-	-	-	0.89±0.05 ^b	
T2	Room	2.90±0.16 ^{aM}	2.79±0.36 ^{aM}	2.70±0.17 ^{aM}	2.61±0.13 ^{aM}	2.50±0.23 ^{aM}	2.39±0.13 ^{aM}	2.64±0.17 ^a	
	Ref	2.90±0.21 ^{aM}	2.81±0.12 ^{aM}	2.74±0.12 ^{aM}	2.65±0.36 ^{aM}	2.58±0.12 ^{aM}	2.50±0.23 ^{aM}	2.69±0.14 ^a	
T3	Room	2.85±0.23 ^{aM}	2.73±0.14 ^{aMN}	2.66±0.36 ^{aM}	2.58±0.32 ^{aMN}	2.45±0.11 ^{aM}	2.37±0.12 ^{aM}	2.60±0.15 ^a	
	Ref	2.85±0.14 ^{aM}	2.78±0.24 ^{aM}	2.70±0.25 ^{aM}	2.62±0.15 ^{aM}	2.53±0.12 ^{aM}	2.48±0.25 ^{aM}	2.66±0.21 ^a	
T4	Room	2.76±0.65 ^{aM}	2.62±0.14 ^{aMN}	2.46±0.34 ^{aMN}	2.29±0.15 ^{aMN}	2.15±0.22 ^{aM}	1.98±0.32 ^{aM}	2.37±0.21 ^a	
	Ref	2.76±0.12 ^{aM}	2.63±0.18 ^{aMN}	2.49±0.25 ^{aMN}	2.35±0.25 ^{aMN}	2.21±0.14 ^{aM}	2.08±0.12 ^{aM}	2.42±0.16 ^a	
T5	Room	2.85±0.14 ^{aM}	2.70±0.19 ^{aMN}	2.58±0.16 ^{aMN}	2.42±0.12 ^{aMN}	2.30±0.15 ^{aM}	2.18±0.11 ^{aM}	2.50±0.14 ^a	
	Ref	2.85±0.15 ^{aM}	2.72±0.17 ^{aMN}	2.60±0.34 ^{aM}	2.48±0.19 ^{aMN}	2.35±0.18 ^{aM}	2.21±0.10 ^{aM}	2.53±0.16 ^a	
Punjab sindhuri green									
T1	Room	2.10±0.01 ^{aM}	-	-	-	-	-	0.35±0.01 ^b	1.15±0.18 ^y

Treatment	Storage condition	Storage period (months)							Mean (within variety)	Mean
		0	2	4	6	8	10			
	Ref	2.10±0.02 ^{aM}	2.04±1.36 ^{aM}	-	-	-	-	0.69±0.02 ^b		
T2	Room	2.19±0.3 ^{aM}	2.08±1.23 ^{aM}	1.93±0.01 ^{aM}	1.85±0.99 ^{aM}	1.76±1.36 ^{aM}	1.65±1.022 ^{aM}	1.91±0.12 ^a		
	Ref	2.19±0.12 ^{aM}	2.10±1.23 ^{aM}	1.99±0.23 ^{aM}	1.89±0.97 ^{aM}	1.80±1.23 ^{aM}	1.73±0.99 ^{aM}	1.95±0.11 ^a		
T3	Room	2.15±0.13 ^{aM}	2.00±2.01 ^{aM}	1.90±0.11 ^{aM}	1.81±1.2 ^{aM}	1.71±1.23 ^{aM}	1.63±0.36 ^{aM}	1.86±0.12 ^a		
	Ref	2.15±0.15 ^{aM}	2.08±2.00 ^{aM}	1.96±0.32 ^{aM}	1.84±1.3 ^{aM}	1.79±1.25 ^{aM}	1.70±0.25 ^{aM}	1.92±0.14 ^a		
T4	Room	2.00±0.21 ^{aM}	1.85±2.11 ^{aM}	1.70±0.22 ^{aM}	1.57±109 ^{aM}	1.43±2.02 ^{aM}	1.35±1.38 ^{aM}	1.65±0.13 ^a		
	Ref	2.00±0.22 ^{aM}	1.88±1.99 ^{aM}	1.72±1.2 ^{aM}	1.59±1.29 ^{aM}	1.47±1.00 ^{aM}	1.38±1.22 ^{aM}	1.67±0.15 ^a		
T5	Room	2.06±0.33 ^{aM}	1.89±1.32 ^{aM}	1.75±1.3 ^{aM}	1.60±1.24 ^{aM}	1.43±1.22 ^{aM}	1.23±1.23 ^{aM}	1.66±0.16 ^a		
	Ref	2.06±0.34 ^{aM}	1.90±1.36 ^{aM}	1.78±1.6 ^{aM}	1.62±1.36 ^{aM}	1.46±1.00 ^{aM}	1.28±1.00 ^{aM}	1.68±0.14 ^a		
Punjab sindhuri red										
T1	Room	2.40±0.21 ^{aM}	-	-	-	-	-	0.40±0.01 ^b	1.87±0.12 ^x	
	Ref	2.40±1.2 ^{aM}	2.38±2.01 ^{aM}	-	-	-	-	0.79±0.02 ^b		
T2	Room	2.45±1.3 ^{aM}	2.29±2.11 ^{aM}	2.19±1.32 ^{aM}	2.09±2.36 ^{aM}	1.95±2.44 ^{aM}	1.90±0.02 ^{aM}	2.14±0.21 ^a		
	Ref	2.45±0.99 ^{aM}	2.38±0.39 ^{aM}	2.25±3.21 ^{aM}	2.19±2.33 ^{aM}	2.13±2.11 ^{aM}	2.09±1.03 ^{aM}	2.24±0.18 ^a		
T3	Room	2.50±1.56 ^{aM}	2.36±2.10 ^{aM}	2.25±1.25 ^{aM}	2.19±2.11 ^{aM}	2.11±2.45 ^{aM}	2.08±1.3 ^{aM}	2.24±0.14 ^a		
	Ref	2.50±2.36 ^{aM}	2.39±1.03 ^{aM}	2.27±1.22 ^{aM}	2.21±2.15 ^{aM}	2.17±2.32 ^{aM}	2.12±0.32 ^{aM}	2.27±0.16 ^a		
T4	Room	2.54±2.33 ^{aM}	2.28±1.33 ^{aM}	2.16±1.11 ^{aM}	2.05±2.15 ^{aM}	1.88±1.21 ^{aM}	1.75±0.52 ^{aM}	2.11±0.12 ^a		
	Ref	2.54±2.41 ^{aM}	2.33±1.36 ^{aM}	2.19±1.20 ^{aM}	2.10±2.00 ^{aM}	1.95±1.02 ^{aM}	1.86±0.22 ^{aM}	2.16±0.14 ^a		
T5	Room	2.59±2.11 ^{aM}	2.33±1.34 ^{aM}	2.17±1.23 ^{aM}	2.05±2.44 ^{aM}	1.93±0.96 ^{aM}	1.83±0.22 ^{aM}	2.15±0.12 ^a		
	Ref	2.59±2.02 ^{aM}	2.37±1.23 ^{aM}	2.21±1.36 ^{aM}	2.11±2.11 ^{aM}	2.02±0.88 ^{aM}	1.83±0.22 ^{aM}	2.18±0.18 ^a		
Ref= refrigeration; n=3, Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly where w,x,y,z=Mean variety; a,b,c,...=Within month; A,B,C...= Mean month; M,N,O,P= Month v/s month.										

CD_(0.05)

Month=<.001; Variety=<.001; Storage condition=NS; Treatment=<.001; Month * Variety=NS; Month * Storage condition=NS; Month * Treatment=<.001; Variety * Storage condition=NS; Variety * Treatment=NS; Storage condition * Treatment=NS; Month * Variety * Storage condition=NS; Month * Variety * Treatment=NS; Month * Storage condition * Treatment=NS; Variety * Storage condition * Treatment=NS; Month * Variety * Storage condition * Treatment= NS

conditions had a highest mean value of 2.27 mM/100 gm. Overall, the maximum mean value for FRAP value (2.18 mM/100 gm) of chili paste after 8 months of storage at room and refrigeration temperature together was observed for CH-27 red samples and least (1.15 mM/100 gm) was reported for Punjab Sindhuri green variety samples. The linear terms of month, variety, and treatment and interaction terms of month and treatment were reported to have significant ($p \leq 0.05$) effect on FRAP (Table 4.56). Treatment 2 (KMS+Sodium benzoate+ acetic acid+salt) found to be best for the higher antioxidant activity of chili paste in terms of FRAP. This might be related with the fact that the benzoic acid along with acetic acid results in the reduction of pH value and the iron is more soluble at low pH owing for the formation of Ferric hydroxide results in higher FRAP value (Paiva-Martins & Gordon 2002).

4.6 Effect of extraction method, temperature, solvent, solvent concentration and chili variety on oleoresin extraction yield, colour and FTIR spectra

The oleoresins were extracted with refluxing and ultrasonication process. Two solvents i.e. acetone and ethanol with varied concentration were used in the mentioned process. The extracted oleoresins were analyzed for the yield per cent, colour value and functional components using FTIR process.

4.6.1 Oleoresin extraction using refluxing method and combination of refluxing and ultrasonication process

As depicted in Table 4.57, the oleoresins extracted with refluxing method coded from R1 to R32. In extraction process, acetone and ethanol with 50 and 90 per cent concentration were used. Refluxing was done at 2 temperature range i.e. 25 and 60°C. As shown in Table 4.57, the oleoresins from freeze dried samples of both varieties were extracted with the combination of refluxing and ultrasonication process. Two solvents i.e. acetone and ethanol with 90 per cent concentration was used. Following refluxing for 3 hours, the ultrasonication was carried out for an hour at 20-25 KHz frequency.

4.6.2 Oleoresin extraction using ultrasonication method

As evident from the data of Table 4.58, codes from S1 to S16 were used in the ultrasonication extraction process. 50 and 90 per cent concentration of both ethanol and acetone were used in this process. Ultrasonication was conducted at 60°C at 25 KHz. The process was carried out for an hour followed by filtration and vacuum concentration.

4.6.3 Effect of extraction method, temperature, solvent, solvent concentration and chili variety on oleoresin extraction yield and colour value

As depicted in Table 4.59, a significant effect of extraction method, temperature solvent and solvent concentration were observed on the yield and colour value of oleoresins. The ultrasonication technique was resulted in the highest extraction yield i.e. 7.1 per cent from Punjab sindhuri red using 90 per cent acetone. Punjab sindhuri dried at 65°C with 90 per cent acetone represented 6.8 per cent yield in the ultrasonication process extraction. In the

refluxing process 6.6 and 6.5 per cent yield was observed for Punjab sindhuri with 50 per cent acetone and Punjab sindhuri with 90 per cent acetone at 60°C extraction temperature respectively. As reported by Rafajlovska *et al* (2007), acetone is more effective in oleoresin

Table 4.57: Oleoresin extraction with refluxing method

Group no.	Sample coding	Variety	Drying temp. (°C)	Solvent	Solvent concentration (%)	Extraction temp(°C)
1	R9	CH-27	65	Acetone	50	25
	R7				90	
	R10				50	60
	R8				90	
2	R17			Ethanol	50	25
	R19				90	
	R18				50	60
	R20				90	
3	R3	PS		Acetone	50	25
	R1				90	
	R4				50	60
	R2				90	
4	R27			Ethanol	50	25
	R5				90	
	R28				50	60
	R6				90	
5	R13	CH-27	85	Acetone	50	25
	R11				90	
	R14				50	60
	R12				90	
6	R31			Ethanol	50	25
	R15				90	
	R32				50	60
	R16				90	
7	R23	PS		Acetone	50	25
	R21				90	
	R24				50	60
	R22				90	
8	R29			Ethanol	50	25
	R25				90	
	R30				50	60
	R26				90	
9	R33	PS	Freeze dried	Acetone	90	60+ 20-25 KHz+99 watt
	R34	CH-27		Ethanol	90	
	R35			Acetone	90	
	R36			Ethanol	90	

Table 4.58: Oleoresin extraction using ultrasonication method

Group no.	Sample coding	Variety	Drying temp. (°C)	Solvent	Solvent concentration (%)	Extraction temp(°C)	Extraction method	
10	S9	CH-27	65	Acetone	50	60	Ultrasonication 20-25 KHz+99 watt	
	S8				90			
	S6			Ethanol	50			
	S5				90			
11	S3	PS		Acetone	50			
	S1				90			
	S4			Ethanol	50			
	S2				90			
12	S14	CH-27	85	Acetone	50			
	S7				90			
	S16			Ethanol	50			
	S15				90			
13	S13	PS		Acetone	50			
	S12				90			
	S10			Ethanol	50			
	S11				90			

extraction than ethanol due to its low boiling point and smaller dynamical viscosity. Lopez-Cervantes *et al* 2014 found sonication and acetone combination best for the extraction of oleoresins. Sofyana *et al* (2013) found higher extraction yield (6.2%) of oleoresins with ultrasonication assisted technique than maceration.

In colour analysis (Table 4.59), the highest *L* value was observed for CH-27 (46.85) with 50 per cent ethanol at 25°C refluxing temperature followed by CH-27 (45.78) and Punjab sindhuri (45.49) with 90 per cent acetone and CH-27 (45.85) with 90 per cent acetone ethanol at 60°C refluxing temperature. The color *a* value (redness) was significantly higher CH-27 using 50 and 90 per cent ethanol (34.77 and 34.37) in ultrasonication process. In refluxing process, Punjab sindhuri with 90 per cent ethanol (33.25) followed by CH-27 with 50 per cent acetone (32.78) and ethanol (32.46) showed higher *a* value. The colour in term of *b* value, the highest values were for freeze dried samples using combination of refluxing and ultrasonication process (45.61-48.59). In refluxing process, Punjab sindhuri treated with 90 per cent ethanol at 25 and 60°C extraction temperature showed 40.25 and 39.58 *b* value respectively. Krithika *et al* (2014) previously reported *L*, *a* and *b* value of encapsulated oleoresins in the range of 36.02-24.63, 36.11-24.56 and 36.15-24.36 respectively.

Table 4.59: Effect of extraction method, temperature, solvent, solvent concentration and chili variety on oleoresin extraction yield and colour

Treatment	Sr. No	Sample code	Oleoresin yield (%)	<i>L</i>	<i>a</i>	<i>b</i>
Refluxing	1.	R1	4.8	45.56±2.0 ^{ab}	30.25±1.7 ^{abcde}	35.26±2.5 ^{fg hijklm}
	2.	R2	6.5	42.95±2.9 ^{bcdefg}	29.56±1.9 ^{bcdef}	34.12±2.6 ^{ijklmn}
	3.	R3	3.9	41.58±2.1 ^{defghij}	28.56±2.7 ^{defgh}	36.28±2.9 ^{cdefghijk}
	4.	R4	4.5	42.75±1.8 ^{bcdefg}	30.26±2.0 ^{abcde}	33.69±2.5 ^{ijklmn}
	5.	R5	4.9	40.86±3.0 ^{efghij}	31.29±2.6 ^{abcde}	39.58±3.1 ^{bc}
	6.	R6	6.2	39.86±2.5 ^{fg hij}	32.89±1.6 ^{ab}	40.25±3.2 ^b
	7.	R7	6.0	39.82±2.6 ^{fg hij}	28.98±1.3 ^{cdefg}	37.89±3.6 ^{bcdef}
	8.	R8	6.3	40.89±3.6 ^{efghij}	30.77±1.7 ^{abcde}	34.25±3.6 ^{hijklmn}
	9.	R9	5.6	42.89±3.6 ^{bcdefg}	31.89±2.9 ^{abcd}	33.48±2.9 ^{klmno}
	10.	R10	5.9	39.78±2.5 ^{fg hij}	29.98±2.1 ^{abcde}	32.87±4.0 ^{klmno}
	11.	R11	5.0	44.89±3.8 ^{abcd}	31.26±2.0 ^{abcde}	33.69±1.9 ^{ijklmn}
	12.	R12	6.2	45.78±4.2 ^{ab}	30.24±1.8 ^{abcde}	34.15±5.6 ^{ijklmn}
	13.	R13	4.5	42.79±4.0 ^{bcdefg}	32.78±2.0 ^{ab}	38.78±2.6 ^{bcde}
	14.	R14	4.8	41.86±3.9 ^{defghi}	31.79±1.9 ^{abcde}	37.45±2.6 ^{bcdefghi}
	15.	R15	6.1	42.99±4.3 ^{bcdefg}	30.25±2.6 ^{abcde}	33.69±2.5 ^{ijklmn}
	16.	R16	5.4	42.85±4.2 ^{bcdefg}	31.78±2.4 ^{abcde}	37.45±3.2 ^{bcdefgh}
	17.	R17	5.1	46.85±4.4 ^a	32.46±2.1 ^{ab}	36.58±3.1 ^{cdefghijk}
	18.	R18	5.6	41.85±3.6 ^{defghi}	30.89±3.2 ^{abcde}	36.98±3.0 ^b
	19.	R19	5.9	43.86±4.0 ^{abcde}	31.89±1.9 ^{abcd}	32.25±3.6 ^{mno}
	20.	R20	6.2	45.85±4.3 ^{ab}	30.78±1.6 ^{abcde}	31.48±3.1 ^{no}
	21.	R21	6.0	43.76±4.0 ^{abcde}	31.42±2.5 ^{abcde}	30.27±3.2 ^o
	22.	R22	6.2	45.49±4.2 ^{ab}	30.36±2.6 ^{abcde}	35.25±2.9 ^{fg hijklm}
	23.	R23	5.4	44.85±4.0 ^{abcd}	31.78±2.1 ^{abcde}	36.85±2.1 ^{bcdefghij}
	24.	R24	6.6	41.56±3.9 ^{defghij}	30.15±1.6 ^{abcde}	35.12±2.6 ^{ghijklm}
	25.	R25	6.4	39.58±3.5 ^{ghij}	29.98±1.9 ^{abcde}	33.69±2.5 ^{ijklmn}
	26.	R26	6.1	38.85±3.6 ^{hijk}	28.49±2.3 ^{efgh}	31.29±2.6 ^{no}
	27.	R27	4.2	41.85±3.4 ^{defghi}	31.23±2.1 ^{abcde}	37.89±1.9 ^{bcdef}
	28.	R28	4.6	39.75±2.5 ^{fg hij}	32.58±2.6 ^{ab}	36.58±2.6 ^{cdefghijk}
	29.	R29	5.5	38.45±2.9 ^{jk}	33.25±1.9 ^a	36.98±2.8 ^{bcdefghij}
	30.	R30	5.9	41.75±4.1 ^{defghij}	31.58±3.5 ^{abcde}	35.45±3.0 ^{efghijklm}
	31.	R31	4.5	42.87±3.5 ^{bcdefg}	30.78±3.0 ^{abcde}	36.78±3.1 ^{cdefghijk}
	32.	R32	4.8	42.15±3.6 ^{cdefgh}	32.28±3.1 ^{abc}	36.59±2.5 ^{cdefghijk}
Refluxing + Ultrasonication	33.	R33	3.5	33.69±3.5 ^l	25.78±2.5 ^{ghi}	48.59±4.1 ^a
	34.	R34	3.6	34.26±2.5 ^l	26.26±1.5 ^{fghi}	46.58±4.1 ^a
	35.	R35	3.3	34.56±2.1 ^l	25.47±1.7 ^{hi}	47.59±4.2 ^a
	36.	R36	3.2	35.69±2.9 ^{kl}	24.23±2.6 ^l	45.61±4.1 ^a
Ultrasonication	37.	S1	6.8	43.74±4.2 ^{abcde}	30.45±2.7 ^{abcde}	36.58±3.5 ^{cdefghijk}
	38.	S2	6.9	39.96±3.5 ^{fg hij}	31.69±2.6 ^{abcde}	35.69±2.6 ^{defghijkl}
	39.	S3	6.4	41.74±3.6 ^{defghij}	29.98±1.9 ^{abcde}	34.59±3.2 ^{ghijklmn}
	40.	S4	5.0	39.74±3.1 ^{fg hij}	30.48±2.9 ^{abcde}	38.95±4.1 ^{bcd}
	41.	S5	6.7	42.78±3.5 ^{bcdefg}	30.98±3.5 ^{abcde}	37.52±2.5 ^{bcdefg}
	42.	S6	6.3	39.58±2.8 ^{ghij}	32.01±3.6 ^{abc}	35.36±2.8 ^{fg hijklm}
	43.	S7	6.7	38.56±2.6 ^{ijk}	29.58±2.9 ^{bcdef}	35.69±2.4 ^{defghijkl}
	44.	S8	6.6	41.25±2.9 ^{efghij}	31.24±1.9 ^{abcde}	36.98±3.1 ^{bcdefghij}
	45.	S9	5.9	40.29±2.9 ^{fg hij}	31.29±2.5 ^{abcde}	34.59±3.2 ^{ghijklmn}
	46.	S10	6.6	39.58±3.1 ^{ghij}	32.58±3.1 ^{ab}	35.69±3.7 ^{defghijkl}
	47.	S11	6.1	41.26±4.1 ^{efghij}	31.58±2.7 ^{abcde}	38.59±2.9 ^{bcdef}
	48.	S12	7.1	45.28±3.5 ^{abc}	30.89±2.4 ^{abcde}	36.25±3.1 ^{cdefghijk}
	49.	S13	6.3	41.25±3.5 ^{efghij}	30.25±2.6 ^{abcde}	34.59±4.0 ^{ghijklmn}
	50.	S14	5.1	39.58±2.5 ^{ghij}	32.05±3.1 ^{abc}	35.78±3.1 ^{defghijkl}
	51.	S15	6.5	41.23±4.5 ^{efghij}	34.77±2.9 ^a	34.59±2.9 ^{ghijklmn}
	52.	S16	6.1	42.28±4.0 ^{efghij}	34.37±2.9 ^a	38.59±2.5 ^{bcdef}

4.6.4 Effect of extraction method, temperature, solvent, solvent concentration and chili variety on FT-IR spectra, characteristics peaks and functional groups at particular peaks of extracted oleoresin

4.6.4.1 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 1

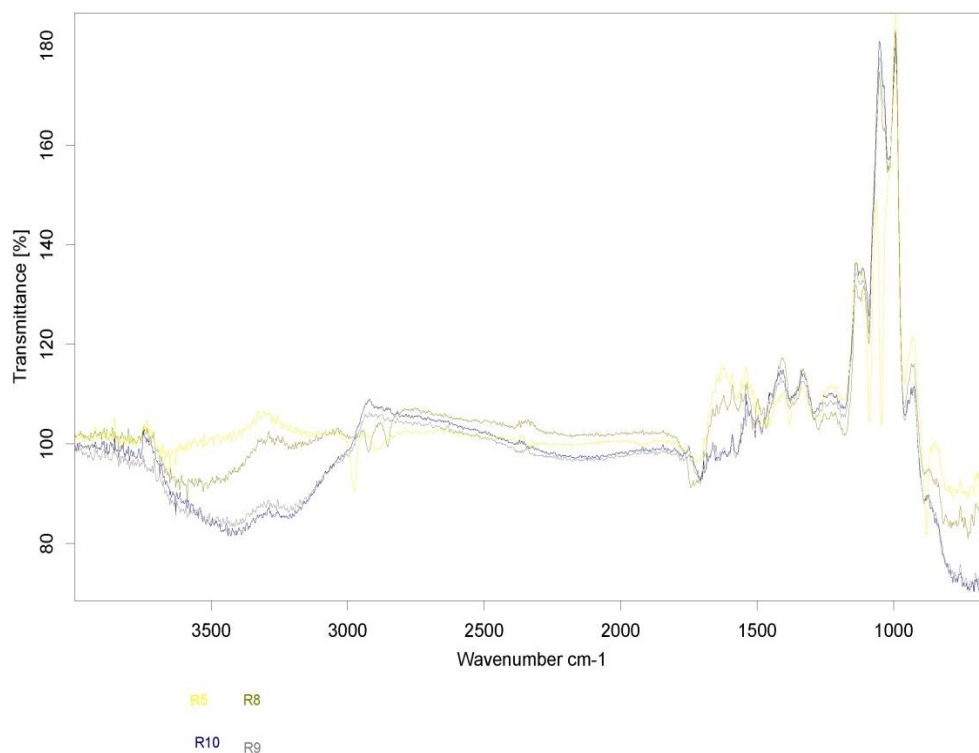


Figure 4.8: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R7, R8, R9 and R10 (group 1) oleoresin

4.6.4.1.1 Fourier transform infrared (FT-IR) spectroscopy of R8 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R8 oleoresin are represented in Figure 4.8 and Table 4.60. The silicon compounds presence was determined by the presence of band in the range of 3687.3 cm^{-1} in R8 oleoresin sample. The alkane presence was determined by the presence of band in the range of 2923.4 cm^{-1} in R8 oleoresin sample. The presence of aldehydes and amides were revealed in R8 oleoresin sample due to the presence of band with the range of $2853.4\text{--}1727.7$ and 1569.7 cm^{-1} respectively. N-O strong asymmetric stretch with a band at 1507.1 attributes the presence of nitro compounds in R8 oleoresin sample. The presence of alkanes and alcohol was detected in R8 oleoresin with generation of peak with the wavelength range of 1481.4 and $1377.4\text{--}1016.8\text{ cm}^{-1}$ respectively. In R8 oleoresin 958.2 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H and C=C-H and strong bending with a band at 788.9 , 727.0 and 674.4 cm^{-1} attributes the presence of 1,3 disubstituted, monosubstituted and alkynes in R8

oleoresin sample respectively.

Table 4.60: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R8 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3587.3	Medium	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2923.4	Medium	Symmetric stretching	
Aldehydes	C=CC=C-CHO	CH	2853.4	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	CH=CH-CHO	C=O	1742.8	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1507.1	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1481.4	Variable	Deformation	
aromatics		C-C	1467.1	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1377.4	Medium	Deformation	
Alcohols	Ph-CHR-OH	OH	1273.5	Strong	Deformation	
Alcohols	(R) ₃ C-OH	C-O	1173.5	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.0	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1016.8	Strong	Stretching	
Aldehydes	R-CHO	CH	958.2	Medium-weak	Deformation	
1,2,3 disubstituted		C-H	788.9	Strong	Bending	
monosubstituted		C-H	727.0	Strong	Bending	
alkynes		-C≡C- H: C-H	674.4	Strong	Bending	

4.6.4.1.2 Fourier transform infrared (FT-IR) spectroscopy of R9 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R8 oleoresin are represented in Figure 4.8 and Table 4.61. The amines presence was determined by the presence of band in the range of 3420.7 cm⁻¹ in R9 oleoresin sample. The alkane presence was determined by the presence of band in the range of 2923.4 cm⁻¹ in R9 oleoresin sample. The presence of aldehydes was revealed in R9 oleoresin sample due to the presence

of band with the range of 1577.5 cm^{-1} respectively. N-O strong asymmetric stretch with a band at 1506.5 cm^{-1} attributes the presence of nitro compounds in R9 oleoresin sample. The presence of alkanes, alcohol, nitro compounds, and secondary alcohol was detected in R9 oleoresin with generation of peak with the wavelength range of 1484.4, 1378.5, 1292.4, 1090.0 and 1021.9 cm^{-1} respectively. In R9 oleoresin 959.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-O and C-H strong stretching and medium deformation with a band at 1173.5, 1089.0-1016.8 and 958.2 cm^{-1} attributes the presence of alcohol, secondary alcohol and aldehydes in R9 oleoresin sample respectively.

Table 4.61: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R9 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amines	CH ₂ -NH-CH ₂	NH	3420.7	Weak	Stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1708.1	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkanes	Cyclohexyl	CH	2923.4	Medium	Symmetric stretching	
Amides	R-CO-NH-C	NH	1577.5	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.5	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Alkanes	Cyclohexyl	CH	1484.4	Variable	Deformation	Amide II, combination of C-N stretching and N-H bending
Alcohols	HO-R-OH	OH	1378.5	Medium	Deformation	
nitro compounds		N-O	1292.4	Medium	Symmetric stretch	
Secondary Alcohols	HO-R-OH	C-O	1090.0	Strong	Stretching	In ring
Secondary Alcohols	HO-R-OH	C-O	1021.9	Strong	Stretching	
Aldehydes	R-CHO	CH	959.6	Medium-weak	Deformation	
Alcohols	(R) ₃ C-OH	C-O	1173.5	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.0	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1016.8	Strong	Stretching	
Aldehydes	R-CHO	CH	958.2	Medium-weak	Deformation	

4.6.4.1.3 Fourier transform infrared (FT-IR) spectroscopy of R10 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R10 oleoresin are represented in Figure 4.8 and Table 4.62. The amines presence was determined by the presence of band in the range of 3427.5 cm^{-1} in R10 oleoresin sample. The aldehyde presence was determined by the presence of band in the range of 1707.1 cm^{-1} in R10 oleoresin sample. The presence of nitro compound was revealed in R10 oleoresin sample due to the presence of band with the range of 1506.7 and 1290.0 cm^{-1} . C-O and C-H strong stretching and medium weak deformation with a band at 1090.0 - 1017.9 and 958.6 cm^{-1} attributes the presence of secondary alcohol and aldehydes in R10 oleoresin sample respectively.

Table 4.62: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R10 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amines	$\text{CH}_2\text{-NH-CH}_2$	NH	3427.5	Weak	Stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1707.1	Strong	Stretching	Alpha beta unsaturated aldehyde
nitro compounds		N-O	1506.7	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Alcohols	HO-R-OH	OH	1379.5	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1290.0	Medium	Symmetric stretch	Alpha beta unsaturated aldehyde
Secondary Alcohols	HO-R-OH	C-O	1090.4	Strong	Stretching	In ring
Secondary Alcohols	HO-R-OH	C-O	1017.9	Strong	Stretching	
Aldehydes	R-CHO	CH	958.6	Medium-weak	Deformation	

4.6.4.2 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 2 oleoresin

4.6.4.2.1 Fourier transform infrared (FT-IR) spectroscopy of R17 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R17 oleoresin are represented in Figure 4.9 and Table 4.63. The alcohol, alkanes and aldehyde presence was determined by the presence of band in the range of 3629.6, 2923.1 and 2853.1 cm^{-1} in R17 oleoresin sample respectively. The presence of esters and amides was revealed in R17 oleoresin sample due to the presence of band with the range of 1743.4 and 1569.5 cm^{-1} respectively. N-O and C-C strong and medium stretching with a band at 1506.6 and 1466.1 cm^{-1} attributes the presence of nitro compounds and aromatics respectively in R17 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R17 oleoresin with generation of peak with the wavelength range of 1364.3 and 1170.3-1022.3 cm^{-1} respectively. In R17 oleoresin 961.4 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 887.5 and 727.2 cm^{-1} attributes the presence of 1, 3 disubstituted and monosubstituted in R17 oleoresin sample respectively, while 816.2 cm^{-1} band attributes the presence of amine salts.

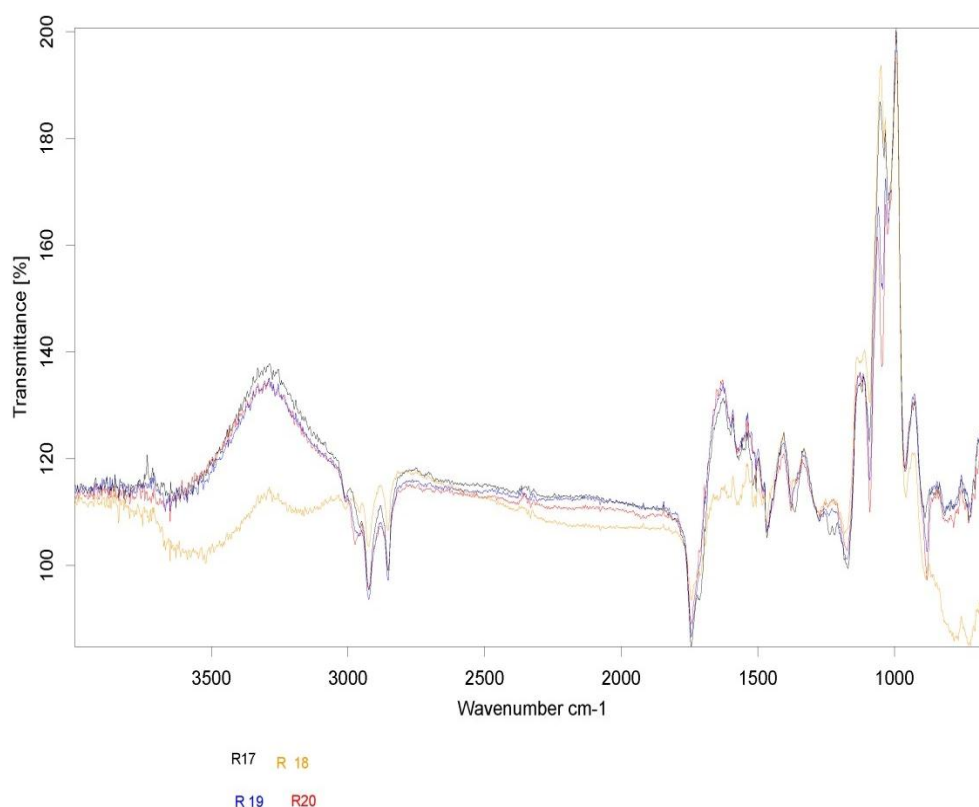


Figure 4.9: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R17, R18, R19 and R20 (group 2) oleoresin

Table 4.63: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R17 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3629.6	Medium, sharp	stretching	Broad peak
Alkanes	Cyclohexyl	CH	2923.1	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.1	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.4	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.5	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics		C-C	1466.1	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1364.3	Medium	Deformation	amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1170.3	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1091.3	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.7	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1022.3	Strong	Stretching	
Aldehydes	R-CHO	CH	961.4	Medium-weak	Deformation	
1,3 disubstituted		C-H	887.5	Strong	Bending	
Amine Salts	NH ₂ ⁺	NH ₂	816.2	Strong	Rocking	Secondary amine salt; broad peak
monosubstituted		C-H	727.2	Strong	Bending	

4.6.4.2.2 Fourier transform infrared (FT-IR) spectroscopy of R18 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R18 oleoresin are represented in Figure 4.9 and Table 4.64. The alcohol, amide, alkanes and

Table 4.64: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R18 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3520.7	Medium, sharp	Stretching	Broad peak
Amides	R-CO-NH-C	NH	3161.5	Medium	Stretching	C=O and NH are in a cis configuration
Alkanes	Cyclohexyl	CH	2924.2	Medium	Symmetric stretching	secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1742.9	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.4	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Aromatics		C-C	1466.5	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1377.2	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1182.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.8	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1021.6	Strong	Stretching	
Aldehydes	R-CHO	CH	957.3	Medium-weak	Deformation	
1,2,3 disubstituted		C-H	781.4	Strong	Bending	
monosubstituted		C-H	721.7	Strong	Bending	
alkynes		–C≡C– H: C–H	680.2	Strong	Bending	

aldehyde presence was determined by the presence of band in the range of 3520.7, 3161.5, 2924.2 and 2853.7 cm^{-1} in R18 oleoresin sample respectively. The presence of esters and amides was revealed in R18 oleoresin sample due to the presence of band with the range of 1742.9 and 1569.4 cm^{-1} respectively. C-C medium stretching with a band at 1466.5 cm^{-1} attributes the presence of aromatics in R18 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R18 oleoresin with generation of peak with the wavelength range of 1377.2 and 1182.4-1021.6 cm^{-1} respectively. In R18 oleoresin 657.3 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 781.4 and 721.7 cm^{-1} attributes the presence of 1, ,2, 3 disubstituted and monosubstituted in R18 oleoresin sample respectively, while 680.2 cm^{-1} band attributes the presence of alkynes.

4.6.4.2.3 Fourier transform infrared (FT-IR) spectroscopy of R19 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R19 oleoresin are represented in Figure 4.9 and Table 4.65. The alcohol, alkanes and aldehyde presence was determined by the presence of band in the range of 3650.2, 2923.5 and 2853.7 cm^{-1} in R19 oleoresin sample respectively. The presence of esters and amides was revealed in R19 oleoresin sample due to the presence of band with the range of 1743.6 and 1569.7 cm^{-1} respectively. N-O and C-C medium stretching with a band at 1506.4 and 1466.6 cm^{-1} attributes the presence of nitro compounds and aromatics in R19 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R19 oleoresin with generation of peak with the wavelength range of 1377.4 and 1172.4-1022.7 cm^{-1} respectively. In R19 oleoresin 962.3 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 880.5 and 721.7 cm^{-1} attributes the presence of 1, ,3 disubstituted and monosubstituted in R19 oleoresin sample respectively, while 815.7 cm^{-1} band attributes the presence of amine salts.

4.6.4.2.4 Fourier transform infrared (FT-IR) spectroscopy of R20 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R20 oleoresin are represented in Figure 4.9 and Table 4.66. The alcohol, alkanes and aldehyde presence was determined by the presence of band in the range of 3650.2, 2923.9 and 2853.3 cm^{-1} in R20 oleoresin sample respectively. The presence of esters and amides was revealed in R20 oleoresin sample due to the presence of band with the range of 1743.1 and 1575.8 cm^{-1} respectively. N-O and C-C medium stretching with a band at 1506.4 and 1466.3 cm^{-1} attributes the presence of nitro compounds and aromatics in R20 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R20 oleoresin with generation of peak with the wavelength range of 1378.4 and 1172.6-1025.1 cm^{-1} respectively. In R20 oleoresin 960.0 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 880.3, 782.8 and 728.1 cm^{-1} attributes the presence of 1, 3

disubstituted, 1, 2, 3 disubstituted and monosubstituted in R20 oleoresin sample respectively.

Table 4.65: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R19 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3650.2	Medium, sharp	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2923.5	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.6	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	
Aromatics		C-C	1466.6	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1377.4	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1172.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.7	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1043.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1022.7	Strong	Stretching	
Aldehydes	R-CHO	CH	962.3	Medium-weak	Deformation	
1,3 disubstituted		C-H	880.5	Strong	Bending	
Amine Salts	NH ₂ ⁺	NH ₂	815.7	Strong	Rocking	Secondary amine salt; broad peak
monosubstituted		C-H	721.7	Strong	Bending	

Table 4.66: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R20 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3650.5	Medium, sharp	Stretching	broad peak
Alkanes	Cyclohexyl	CH	2923.9	Medium	Symmetric stretching	secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.1	Strong	Stretching	
Amides	R-CO-NH-C	NH	1575.8	Strong	Combination	amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	
Aromatics		C-C	1466.3	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1378.4	Medium	Deformation	amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1172.6	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.5	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1045.0	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1025.1	Strong	Stretching	
Aldehydes	R-CHO	CH	960.0	Medium-weak	Deformation	
1,3 disubstituted		C-H	880.3	Strong	Bending	
1,2,3 disubstituted		C-H	782.8	Strong	Bending	Secondary amine salt; broad peak
monosubstituted		C-H	728.1	Strong	Bending	

4.6.4.3 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 3 oleoresin

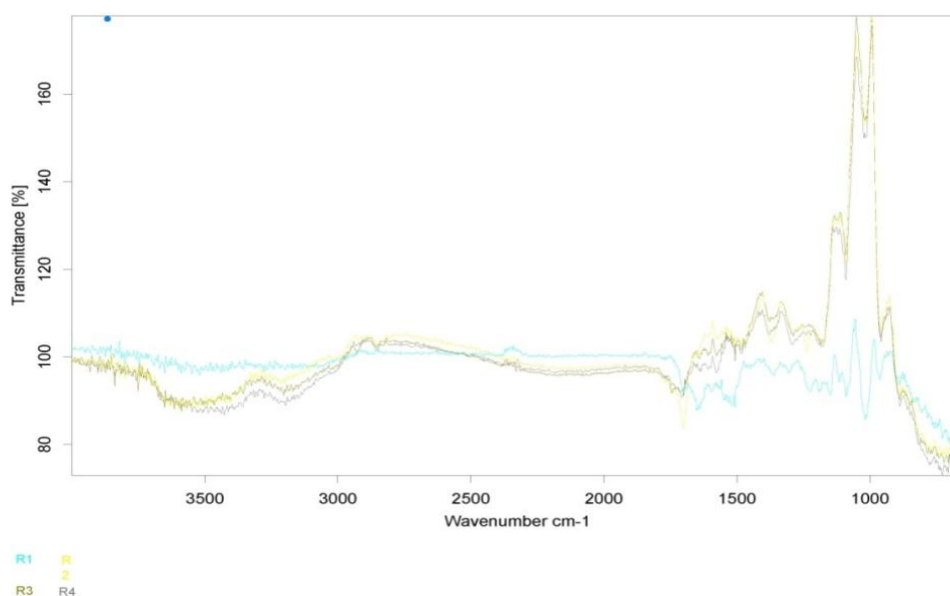


Figure 4.10: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R1, R2, R3 and R4(group 3) oleoresin

4.6.4.3.1 Fourier transform infrared (FT-IR) spectroscopy of R1 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R1 oleoresin are represented in Figure 4.10 and Table 4.67. The water vapours presence was determined by the presence of band in the range of 3747 cm^{-1} in R1 oleoresin sample. The phenols presence was determined by the presence of band in the range of $3691.0\text{--}3420.1\text{ cm}^{-1}$ in R1 oleoresin sample. The presence of amino acids and alcohol was revealed in R1 oleoresin sample due to the presence of band with the range of 3489.5 cm^{-1} . NH and OH medium stretching with a band at 3462.9 , 3439.0 , 3427.2 , 3411.6 , 3388.5 and 3355.5 cm^{-1} attributes the presence of amines and alcohols in R1 oleoresin sample. The presence of alkynes was detected in R1 oleoresin with generation of peak with the wavelength range of 3277.6 cm^{-1} . The band at 3266.1 cm^{-1} represents the amides, while OH stretching at 3241.4 , 3196.7 , 3168.9 and 3133.9 cm^{-1} band represents the presence of alcohols, amides and sulphur compounds. In R1 oleoresin, 2873.3 cm^{-1} band range attributes the presence of aldehydes. NH stretching with the range of peak wavelength from 2455.1 cm^{-1} represents the amine salts. Alkynes presence was detected in R1 oleoresin with the band range of 2196.2 cm^{-1} . C=O and C-H stretch detection in R1 oleoresin results in the presence of aldehydes and aromatic compounds. C=C stretch with band 1650.6 cm^{-1} R1 oleoresin attributes the presence of alkenes. N-H and NH bend with the peak range of 1595.9 and 1563.6 cm^{-1} in R1 oleoresin

reveals the presence of Amines and amides. Nitro and aromatic compounds were detected in R1 oleoresin with band range of 1543-1518.1 and 1507.3 cm^{-1} respectively. The presence of alcohol, alkane, phenol, vinyl ether, tertiary alcohol and aliphatic ester was detected in R1 oleoresin with generation of peak with the wavelength range of 1450.2, 1362.0, 1305.3, 1223.8, 1191.0 and 1149.6 cm^{-1} respectively. The secondary alcohol with C-O stretch was detected at band range 1161.1 and 1089.6 cm^{-1} . CC and C=C bend with the peak range of 1017.7 and 963.0 cm^{-1} in R1 oleoresin reveals the presence of Alkanes and alkene respectively. 1,3 disubstituted, 1,4 disubstituted, 1,2,3 disubstituted and monosubstituted compounds with C-H bending were detected in R1 oleoresin with band range of 887.8-873.3, 805.7, 783.0, and 748-728 cm^{-1} respectively. Alkynes were detected with band range 681-657 cm^{-1} .

Table 4.67: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R1 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3747.0	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3691.09	Medium, sharp	Stretching	Broad peak
			3669.0			
			3651.0			
			3639.1			
			3620.6			
			3598.6			
			3588.9			
			3575.4			
			3547.5			
			3520.1			
Amines	CH ₂ -NH-CH ₂	NH	3489.5	Weak	Stretching	Secondary amine
Alcohol		O-H		Strong, Broad	Stretching	Intermolecular bond
Amines	CH ₂ -NH-CH ₂	NH	3462.9	Weak	Stretching	Secondary amine
			3439.0			
			3427.2			
			3411.6			
Alcohols	Ph-CHR-OH	OH	3388.5	Variable	Stretching	Hydrogen bonded, broad peak
Amines	CH ₂ -NH-CH ₂	NH		Weak	Stretching	Secondary amine

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols	Ph-CHR-OH	OH	3355.5	Variable	Stretching	Hydrogen bonded, broad peak
Amines	CH ₂ -NH-CH ₂	NH		Weak	Stretching	Secondary amine
alkynes (terminal)	-C≡C-H: C-H stretch		3277.6	Strong		
Amides	R-CO-NH-CO-NHR	NH	3266.1	Medium	Stretching	Hydantoin
Alcohols	R-CH ₂ -OH	OH	3241.4	Variable	Stretching	Hydrogen bonded, broad peak
Amides	R-CO-NH-CO-NHR	NH		Medium	Stretching	Hydantoin
Amides	R-CO-NH ₂	NH	3196.7	Medium	Antisymmetric stretching	Primary amide
Amides	R-CO-NH-C	NH	3168.9	Medium	Stretching	C=O and NH are in a cis configuration
Amides	R-CO-NH-CO-NHR	NH	3133.9	Medium	Stretching	Hydantoin
Sulfur Compounds	R-(C=S)-NH ₂	NH		Medium	Stretching	Thioamide
Sulfur Compounds	R-NH-(C=S)-NH ₂	NH		Medium	Stretching	Thiourea
Aldehydes	C=CC=C-CHO	CH	2873.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ⁺	NH	2455.1	Medium-strong	Stretching	Tertiary amine salt; often multiple bands
Alkynes	R-C≡C-R	C≡C	2196.2	Variable	Stretching	di-substituted
Aldehydes	CH=CH-CHO	C=O	1699.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Aromatic compound		C-H		Weak	Bending	
alkenes		-C=C-	1650.6	Medium	Stretch	
Amine		N-H	1595.9	Medium-strong	Bend	
Amides	R-CO-NH-C	NH	1563.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending

Classification	Group	Bond	Range	Intensity	Mode	Notes
nitro compounds		N–O	1543.3	Strong	Asymmetric stretch	
nitro compounds		N–O	1518.1	Strong	Asymmetric stretch	
Aromatics	1,2,3,4,5,6-substituted	Ring	1507.3	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1450.2	Medium-weak	Deformation	
Alkane		C-H		Medium	Bending	Methyl group
Alcohols	HO-R-OH	OH	1362.0	Medium	Deformation	
Phenol		O-H	1305.3	Medium	Bending	
Vinyl ether		C-O	1223.8	Strong	Stretching	
Tertiary alcohol		C-O	1191.0	Strong	Stretching	
Aliphatic ester	(R) ₃ C-OH	C-O	1149.6	Strong	Stretching	
Secondary Alcohols	(R) ₂ CH-OH	C-O	1161.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.6	Strong	Stretching	
Alkanes	Cyclopropyl	CC	1017.7	Medium	Ring deformation	
Alkene		C=C	963.0	Strong	Bending	
1,3 disubstituted		C-H	887.8	Strong	Bending	
1,3 disubstituted		C-H	873.3	Strong	Bending	
1,4 disubstituted		C-H	805.7	Strong	Bending	
1,2,3 disubstituted		C-H	783	Strong	Bending	
monosubstituted		C-H	748-728	Strong	Bending	
alkynes		–C≡C– H: C– H	681-657	Strong	Bending	

4.6.4.3 .2 Fourier transform infrared (FT-IR) spectroscopy of R2 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R2 oleoresin are represented in Figure 4.10 and Table 4.68. The silicon compound presence was determined by the presence of band in the range of 3563.4 cm⁻¹ in R2 oleoresin sample. The phenols presence was determined by the presence of band in the range of 3205.1 cm⁻¹ in R2 oleoresin sample. The presence of aldehyde was revealed in R2 oleoresin sample due to the presence of band with the range of 1705-1680 cm⁻¹. CC medium stretching with a band at 750-720cm⁻¹ attributes the presence of alkanes in R2 oleoresin sample.

Table 4.68: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R2 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3563.4	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3205.1	Variable	Stretching	Hydrogen bonded, broad peak
Aldehydes	CH=CH-CHO	C=O	1705-1680	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkanes	R(CH ₂) ₄ -C	CC	750-720	Medium	Skeletal vibration	

4.6.4.3.3 Fourier transform infrared (FT-IR) spectroscopy of R3 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R3 oleoresin are represented in Figure 4.10 and Table 4.69. The silicon presence was determined

Table 4.69: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R3 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3837.6	Medium	Stretching	broad peak
			3750.7			
			3651.3			
Alcohol		O-H	3587.4	Medium sharp	Stretching	
Alcohols	Ph-CHR-OH	OH	3203.6	Variable	Stretching	Hydrogen Bonded, Broad Peak
Ester		C=O	1743.9	Strong	Stretching	6-membered lactone
Amine Salts	NH ₂ ⁺	NH ₂	1576.2	Medium	Deformation	Secondary amine salt
nitro compounds		N-O	1506.1	Strong	Asymmetric stretch	
Alcohols	HO-R-OH	OH	1377.0	Medium	Deformation	
Alcohols	Ph-OH	C-O	1184.0	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1091.0	Strong	Stretching	
Alkyl Halide		C-F	1018.0	Strong	Stretch	
Aldehydes	R-CHO	CH	958.5	Medium-weak	Deformation	
Alkenes	RCH=CHR cis	CH	690.0	Medium	Deformation	CH out-of-plane deformation

by the presence of band in the range of 3651.3 cm^{-1} in R3 oleoresin sample. The phenols presence was determined by the presence of band in the range of 3587.4 and 3203.6 cm^{-1} in R3 oleoresin sample. The presence of ester was revealed in R3 oleoresin sample due to the presence of band with the range of 1743.9 cm^{-1} . NH_2 medium deformation with a band at 1576.2 cm^{-1} attributes the presence of amines salts in R3 oleoresin sample. The presence of nitro compound was detected in R3 oleoresin with generation of peak with the wavelength range of 1506.1 cm^{-1} . OH medium deformation and C-O strong stretching at 1377.0 and $1184.0\text{-}1091.0\text{ cm}^{-1}$ band represents the presence of alcohols respectively. In R3 oleoresin, 1018 cm^{-1} band range attributes the presence of alkyl halides. CH stretching with the range of peak wavelength from 958.5 cm^{-1} represents the aldehyde. Alkenes presence was detected in R3 oleoresin with the band range of 690.0 cm^{-1} .

4.6.4.3.4 Fourier transform infrared (FT-IR) spectroscopy of R4 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R4 oleoresin are represented in Figure 4.10 and Table 4.70. The amine presence was determined by the presence of band in the range of 3426.9 cm^{-1} in R4 oleoresin sample. The amide presence was determined by the presence of band in the range of 3196.4 cm^{-1} in R4 oleoresin

Table 4.70: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R4 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amines	$\text{CH}_2\text{-NH-CH}_2$	NH	3426.9	Weak	Stretching	secondary amine
Amides	R-CO-NH_2	NH	3196.4	Medium	Symmetric stretching	
α , β -unsaturated aldehydes, ketones		C=O	1706.6	Strong	Stretching	
Ester		C=O	1743.9	Strong	Stretching	
Amine Salts	NH_2^+	NH_2	1576.9	Medium	Deformation	
nitro compounds		N-O	1507.1	Strong	Asymmetric stretch	
Alcohols	HO-R-OH	OH	1379.0	Medium	Deformation	
Alcohols	Ph-OH	C-O	1182.0	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1090.0	Strong	Stretching	
Alkyl Halide		C-F	1016.0	Strong	Stretch	
Aldehydes	R-CHO	CH	958.5	Medium-weak	Deformation	
Alkane		C=C	655.7	Medium	Bending	

sample. The presence of α , β -unsaturated aldehydes, ketones and ester was revealed in R4 oleoresin sample due to the presence of band with the range of 1706.6-1743.9 cm^{-1} . NH_2 medium deformation with a band at 1576.9 attributes the presence of amine salts in R4 oleoresin sample. The presence of alcohol was detected in R4 oleoresin with generation of peak with the wavelength range of 1379-1090.0 cm^{-1} . The band at 1016.0 cm^{-1} represents the alkyl halide, while CH stretching at 958.5 cm^{-1} band represents the presence of aldehydes. In R4 oleoresin, 655.7 cm^{-1} band range attributes the presence of alkanes.

4.6.4.4 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 4 oleoresin

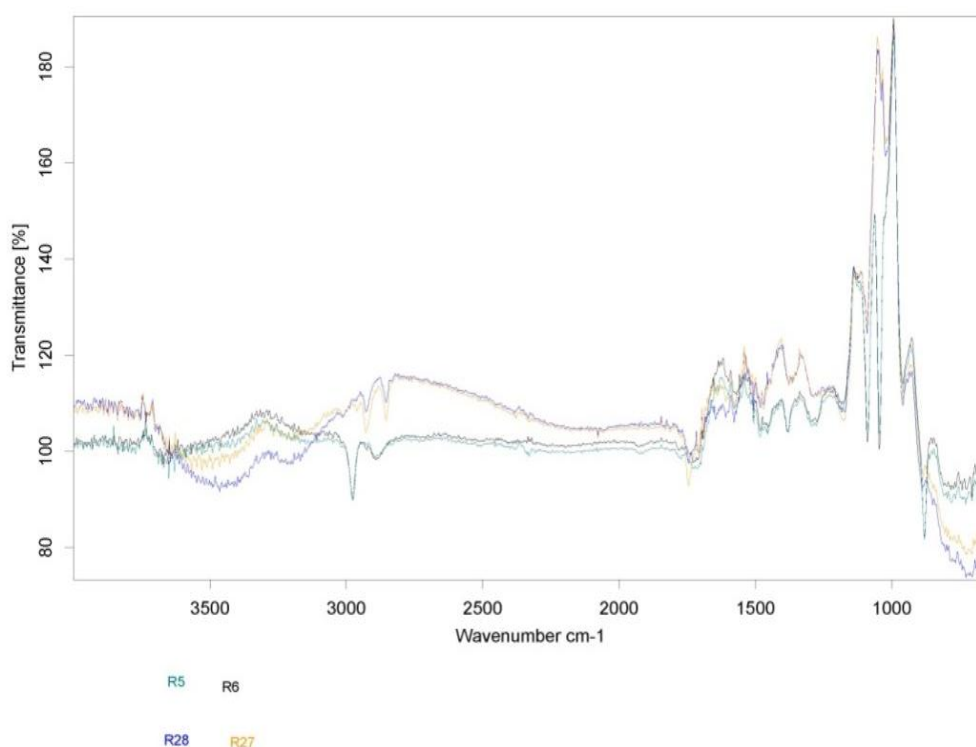


Figure 4.11: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R5, R6, R27 and R28 (group 4) oleoresin

4.6.4.4.1 Fourier transform infrared (FT-IR) spectroscopy of R5 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R5 oleoresin are represented in Figure 4.11 and Table 4.71. The phenols presence was determined by the presence of band in the range of 3650.3 cm^{-1} in R5 oleoresin sample. The alkane presence was determined by the presence of band in the range of 2975.5 cm^{-1} in R5 oleoresin sample. The presence of aldehydes and amine salts were revealed in R5 oleoresin sample due to the presence of band with the range of 1712.7 and 1576.5 cm^{-1} respectively. CH variable deformation with a band at 1481.7 attributes the presence of alkanes in R5 oleoresin sample. The presence of alcohol was detected in R5 oleoresin with generation of peak with the wavelength range of 1379 cm^{-1} . The band at 1507.1 and 1292.5 cm^{-1} represents

the nitro compounds, while CH stretching at 958.5cm^{-1} band represents the presence of aldehydes. In R5 oleoresin, 1088.6 and 1044.1cm^{-1} band range attributes the presence of secondary alcohols, while 879.3 and 728.4cm^{-1} strong bending represents the presence of 1,3 disubstituted and monosubstituted respectively. C=C-H strong bending with a band at 684.4cm^{-1} attributes the presence of alkynes in R5 oleoresin sample.

Table 4.71: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R5 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols, Phenols		O-H	3650.3		Stretching	Free hydroxyl
Alkanes	Cyclohexyl	CH	2975.5	Medium	Symmetric stretching	
Aldehydes	Ph-CHO	C=O	1712.7	Strong	Stretching	Aryl aldehyde
Amine Salts	NH_2^+	NH_2	1576.5	Medium	Deformation	Secondary amine salt
Alkanes	Cyclohexyl	CH	1481.7	Variable	Deformation	
Alcohols	HO-R-OH	OH	1379.0	Medium	Deformation	
nitro compounds		N-O	1507.1	Strong	Asymmetric stretch	
Alcohols	HO-R-OH	OH	1379.4	Medium	Deformation	
nitro compounds		N-O	1292.2	Medium	Symmetric stretch	
Secondary Alcohols	HO-R-OH	C-O	1088.6	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1044.1	Strong	Stretching	
Aldehydes	R-CHO	CH	958.2	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.3	Strong	Bending	
monosubstituted		C-H	728.4	Strong	Bending	
alkynes		$\text{—C}\equiv\text{C—}$ H: C— H	684.4	Strong	Bending	

4.6.4.4.2 Fourier transform infrared (FT-IR) spectroscopy of R6 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R6 oleoresin are represented in Figure 4.11 and Table 4.72. The silicon compounds presence was determined by the presence of band in the range of 3675.6 cm^{-1} in R6 oleoresin sample. The alkane presence was determined by the presence of band in the range of 2976.5 cm^{-1} in R6 oleoresin sample. The presence of aldehydes and amides were revealed in R6 oleoresin sample due to the presence of band with the range of 1727.7 and 1569.9 cm^{-1} respectively. N-

O strong asymmetric stretch with a band at 1506.1 attributes the presence of nitro compounds in R6 oleoresin sample. The presence of alkanes and alcohol was detected in R6 oleoresin with generation of peak with the wavelength range of 1481.4 and 1380 cm^{-1} respectively. The band at 1506.1 and 1292.5 cm^{-1} represents the nitro compounds, while CH deformation at 1481.4 cm^{-1} band represents the presence of alkanes. In R6 oleoresin, 1294.5 and 1089.0-1045.3 cm^{-1} band range attributes the presence of nitro compounds and secondary alcohols respectively, while 958.2 and 879.3 cm^{-1} strong bending represents the presence of aldehyde and 1,3 disubstituted respectively. C-H and C=C-H medium deformation and strong bending with a band at 705.7 and 656.6 cm^{-1} attributes the presence of and alkenes alkynes in R6 oleoresin sample respectively.

Table 4.72: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R6 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3675.6	Medium	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2976.5	Medium	Symmetric stretching	Alkanes
Aldehydes	CH=CH-CHO	C=O	1727.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1569.9	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.1	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1481.4	Variable	Deformation	
Alcohols	HO-R-OH	OH	1380.1	Medium	Deformation	
nitro compounds		N-O	1294.5	Medium	Symmetric stretch	
Secondary Alcohols	HO-R-OH	C-O	1089.0	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1045.3	Strong	Stretching	
Aldehydes	R-CHO	CH	958.2	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.9	Strong	Bending	
Alkenes	RCH=CHR cis	CH	705.7	Medium	Deformation	CH out-of-plane deformation
alkynes		-C≡C-H: C-H	656.6	Strong	Bending	

4.6.4.4.3 Fourier transform infrared (FT-IR) spectroscopy of R27 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R27 oleoresin are represented in Figure 4.11 and Table 4.73. The alcohol presence was determined by the presence of band in the range of 3645.2 and 3205.1 cm^{-1} in R27 oleoresin sample respectively. The presence of alkanes, aldehyde and ester was revealed in R27 oleoresin sample due to the presence of band with the range of 2928.9, 2854.1 and 1744.4 cm^{-1}

Table 4.73: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R27 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3650.9	Medium, sharp	Stretching	Broad peak
Alcohol			3645.2	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.5	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3205.1	Variable	Stretching	Hydrogen bonded, broad peak
Alkanes	Cyclohexyl	CH	2928.8	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2854.1	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1744.4	Strong	Stretching	
Aldehydes	CH=CH-CHO	C=O	1691.5	Strong	Stretching	alpha beta unsaturated aldehyde
Amidines	N=CH-N	C=N	1608.8	Medium-strong	Stretching	
Amides	R-CO-NH-C	NH	1577.6	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Alkanes	Cyclohexyl	CH	1468.8	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1376.9	Medium	Deformation	In ring
Secondary Alcohols	(R) ₂ CH-OH	C-O	1173.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.7	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1037.7	Strong	Stretching	
Aldehydes	R-CHO	CH	958.6	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.7	Strong	Bending	
Alkenes	RCH=CHR cis	CH	706.4	Medium	Deformation	
Alkenes	RCH=CHR cis	CH	673.6	Medium	Deformation	CH out-of-plane deformation
Alkenes	RCH=CHR cis	CH	654.9	Medium	Deformation	CH out-of-plane deformation

respectively. C=O, C=N and NH strong stretching with a band at 1691.5, 1608.8 and 1577.5 cm^{-1} attributes the presence of aldehydes, amidines and amides in R27 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R27 oleoresin with generation of peak with the wavelength range of 1376.9-1037.7 cm^{-1} respectively. In R27 oleoresin 958.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band 879.7 and 706.4- 654.9 cm^{-1} attributes the presence of 1,3 disubstituted and alkenes respectively.

4.6.4.4.4 Fourier transform infrared (FT-IR) spectroscopy of R28 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R28 oleoresin are represented in Figure 4.11 and Table 4.74. The alcohol and amines presence was

Table 4.74: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R28 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3734.0	Medium	Stretching	Series of sharp peaks
Alcohol			3650.9	Medium, sharp	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3463.8	Weak	Stretching	Secondary amine
Alkanes	Cyclohexyl	CH	2927.4	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2854.0	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1744.0	Strong	Stretching	
Aldehydes	CH=CH-CHO	C=O	1707.4	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1691.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1577.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Aromatics	1,2,3,4,5,6-substituted	Ring	1506.2	Variable	Stretching	
bAlkanes	Cyclohexyl	CH	1481.5	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1375.9	Medium	Deformation	In ring
Secondary Alcohols	(R) ₂ CH-OH	C-O	1183.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.1	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1023.1	Strong	Stretching	
Alkenes	RCH=CHR cis	CH	658.9	Medium	Deformation	CH out-of-plane deformation

determined by the presence of band in the range of 3650.9 and 3463.8 cm^{-1} in R28 oleoresin sample respectively. The presence of alkanes, aldehyde and ester was revealed in R28 oleoresin sample due to the presence of band with the range of 2927.4, 2854.0 and 1744.0 cm^{-1} respectively. C=O, and NH strong stretching with a band at 1707.4-1691.2 and 1577.6 cm^{-1} attributes the presence of aldehydes and amides in R28 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R28 oleoresin with generation of peak with the wavelength range of 1375.9-1023.1 cm^{-1} respectively. In R28 oleoresin 958.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H medium deformation with a band 658.9 cm^{-1} attributes the presence of alkenes.

4.6.4.5 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 5 oleoresin

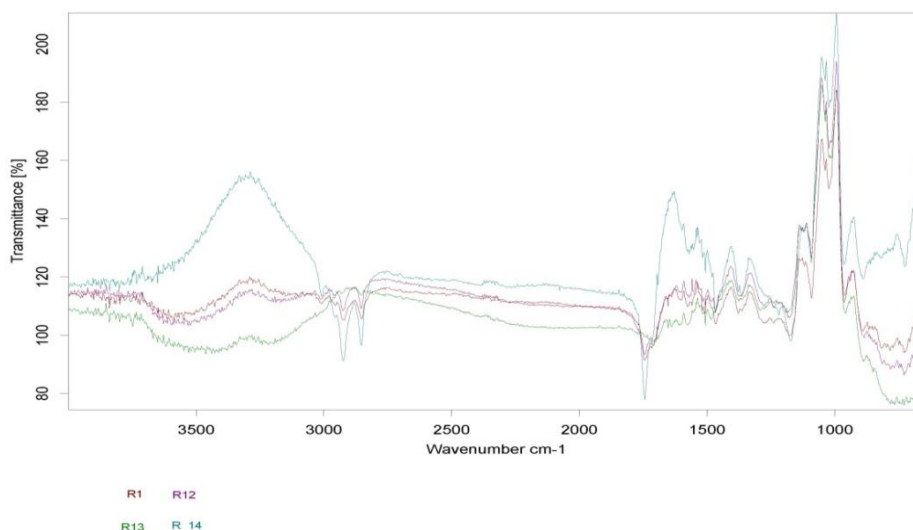


Figure 4.12: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R11, R12, R13 and R14 (group 5) oleoresin

4.6.4.5.1 Fourier transform infrared (FT-IR) spectroscopy of R11 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R11 oleoresin are represented in Figure 4.12 and Table 4.75. The alcohol and alkanes presence was determined by the presence of band in the range of 3719.8 and 3613.6 cm^{-1} in R11 oleoresin sample respectively. The aldehyde presence was determined by the presence of band in the range of 2851.6 cm^{-1} in R11 oleoresin sample. The presence of esters and amine salts was revealed in R11 oleoresin sample due to the presence of band with the range of 1743.9 and 1575.7 cm^{-1} respectively. N-O strong asymmetric stretch with a band at 1507.6 cm^{-1} attributes the presence of nitro compounds in R11 oleoresin sample. The presence of aromatics, alcohol and secondary alcohol was detected in R11 oleoresin with generation of peak with the wavelength range of 1465.7, 1377.1, 1175.9-1023.0 cm^{-1} respectively. In R11

oleoresin 962.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 782.8 and 727.3 cm^{-1} attributes the presence of 1, 2, 3 disubstituted and monosubstituted in R11 oleoresin sample respectively. 680.9 cm^{-1} band wavelength attributes the presence of alkynes.

Table 4.75: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R11 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
			3839.1			
Solvent Impurities	Water vapor phase	OH	3719.8	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3613.6	Medium, sharp	Stretching	Broad peak
			3587.3			
Alkanes	Cyclohexyl	CH	2920.8	Medium	Symmetric stretching	
Aldehydes	C=CC=C-CHO	CH	2851.6	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.9	Strong	Stretching	
Amine Salts	NH_2^+	NH_2	1575.7	Medium	Deformation	Secondary amine salt
nitro compounds		N-O	1507.6	Strong	Asymmetric stretch	Alpha Beta Unsaturated Aldehyde
aromatics		C-C	1465.7	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1377.1	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	$(\text{R})_2\text{CH-OH}$	C-O	1175.9	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.7	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.6	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1023.0	Strong	Stretching	
Aldehydes	R-CHO	CH	962.6	Medium-weak	Deformation	
1,2,3 disubstituted		C-H	782.8	Strong	Bending	
monosubstituted		C-H	727.3	Strong	Bending	
alkynes		$\text{C}\equiv\text{C-H}$	680.9	Strong	Bending	

4.6.4.5.2 Fourier transform infrared (FT-IR) spectroscopy of R12 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R12 oleoresin are represented in Figure 4.12 and Table 4.76. The alcohol and amides presence was determined by the presence of band in the range of 3531.2 and 3169.0 cm^{-1} in R12 oleoresin sample respectively. The alkanes and aldehyde presence was determined by the presence of band in the range of 2925.8 and 2853.5 cm^{-1} in R12 oleoresin sample respectively. The presence of esters and amine salts was revealed in R12 oleoresin sample due to the presence

Table 4.76: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R12 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3531.2	Medium, sharp	Stretching	Broad Peak
Amides	R-CO-NH-C	NH	3169.0	Medium	Stretching	C=O and NH are in a cis configuration
Alkanes	Cyclohexyl	CH	2925.8	Medium	Symmetric stretching	
Aldehydes	C=CC=C-CHO	CH	2853.5	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.9	Strong	Stretching	
Amine Salts	NH ₂ ⁺	NH ₂	1569.1	Medium	Deformation	Secondary amine salt
nitro compounds		N-O	1507.2	Strong	Asymmetric stretch	Alpha Beta Unsaturated Aldehyde
aromatics		C-C	1466.7	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1364.2	Medium	Deformation	amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1176.6	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.4	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1038.3	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1022.4	Strong	Stretching	
Aldehydes	R-CHO	CH	929.8	Medium-weak	Deformation	
monosubstituted		C-H	728.4	Strong	Bending	

1506.1 cm^{-1} respectively. OH medium deformation with a band at 1375.2 cm^{-1} attributes the of band with the range of 1743.9 and 1569.1 cm^{-1} respectively. N-O strong asymmetric stretch with a band at 1507.2 cm^{-1} attributes the presence of nitro compounds in R12 oleoresin sample. The presence of aromatics, alcohol and secondary alcohol was detected in R12 oleoresin with generation of peak with the wavelength range of 1466.7, 1364.2, 1176.9-1022.4 cm^{-1} respectively. In R12 oleoresin 929.8 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 728.4 cm^{-1} attributes the presence of monosubstituted in R12 oleoresin sample.

4.6.4.5.3 Fourier transform infrared (FT-IR) spectroscopy of R13 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R13 oleoresin are represented in Figure 4.12 and Table 4.77. The amines and aldehyde presence was determined by the presence of band in the range of 3462.2 and 1708.6 cm^{-1} in R13 oleoresin sample respectively. The presence of amine salts and nitro compounds was revealed in R13 oleoresin sample due to the presence of band with the range of 1576.3 and

Table 4.77: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R13 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3747.6	Medium	Stretching	Series of sharp peaks
Amines	$\text{CH}_2\text{-NH-CH}_2$	NH	3462.2	Weak	Stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1708.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Amine Salts	NH_2^+	NH_2	1576.3	Medium	Deformation	Secondary amine salt
nitro compounds		N-O	1506.1	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Alcohols	HO-R-OH	OH	1375.2	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	$(\text{R})_2\text{CH-OH}$	C-O	1183.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.9	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.3	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1016.0	Strong	Stretching	
Aldehydes	R-CHO	CH	957.4	Medium-weak	Deformation	

presence of alcohol in R13 oleoresin sample. The presence of secondary alcohol was detected in R13 oleoresin with generation of peak with the wavelength range of 1183.4-1016.0 cm^{-1} . In R13 oleoresin 957.4 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 880 and 725.5 cm^{-1} attributes the presence of 1,3 disubstituted and monosubstituted in R14 oleoresin sample respectively.

4.6.4.5.4 Fourier transform infrared (FT-IR) spectroscopy of R14 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R14 oleoresin are represented in Figure 4.12 and Table 4.78. The alkanes and aldehyde presence

Table 4.78: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R14 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3651.0	Medium, sharp	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2924.2	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.5	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.4	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1466.4	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1363.6	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1171.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1091.5	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.8	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1023.0	Strong	Stretching	
Aldehydes	R-CHO	CH	962.7	Medium-weak	Deformation	
1,3 disubstituted		C-H	880.0	Strong	Bending	
Monosubstituted		C-H	725.5	Strong	Bending	

was determined by the presence of band in the range of 2924.2 and 2853.5 cm^{-1} in R14 oleoresin sample respectively. The presence of esters and amide was revealed in R14 oleoresin sample due to the presence of band with the range of 1743.4 and 1569.7 cm^{-1} respectively. N-O strong asymmetric stretch with a band at 1506.4 cm^{-1} attributes the presence of nitro compounds in R14 oleoresin sample. The presence of alcohol secondary alcohol was detected in R14 oleoresin with generation of peak with the wavelength range of 1363.6 and 1171.1-1023.0 cm^{-1} respectively. In R14 oleoresin 962.7 cm^{-1} medium weak deformation represents the presence of aldehyde.

4.6.4.6 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 6 oleoresin

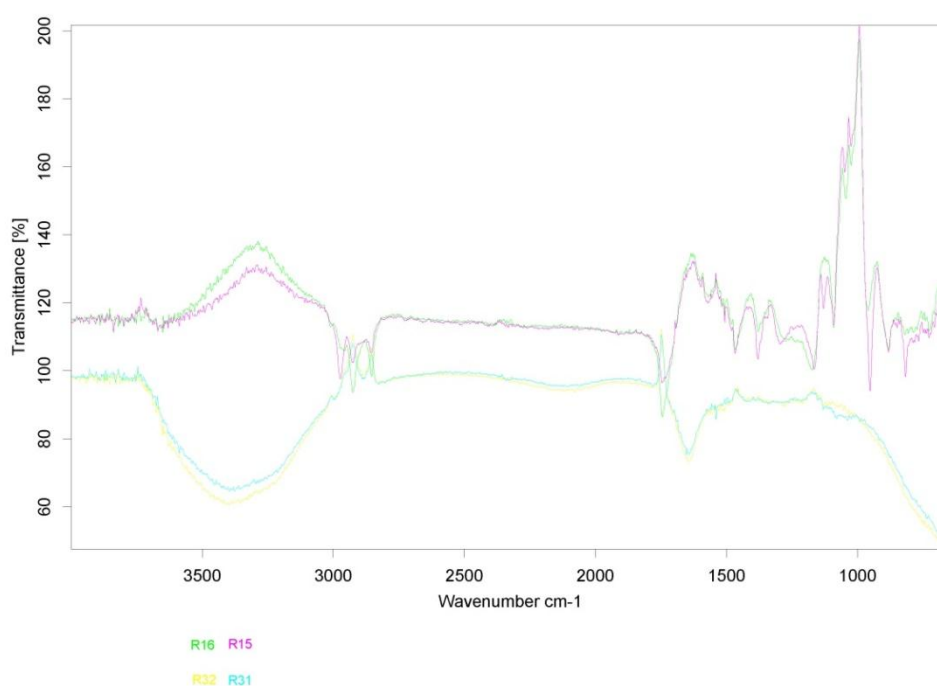


Figure 4.13: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R15, R16, R31 and R32 (group 6) oleoresin

4.6.4.6.1 Fourier transform infrared (FT-IR) spectroscopy of R15 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R15 oleoresin are represented in Figure 4.13 and Table 4.79. The alkanes and aldehyde presence was determined by the presence of band in the range of 2972.8-2924.4 and 2854.6 cm^{-1} in R15 oleoresin sample respectively. The presence of esters and amides was revealed in R15 oleoresin sample due to the presence of band with the range of 1745 and 1569.6 cm^{-1} respectively. C-C medium stretching with a band at 1466.7 cm^{-1} attributes the presence of aromatics in R15 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R15 oleoresin with generation of peak with the wavelength range of 1379.8 and 1165.4-1024.4 cm^{-1} . In R13 oleoresin 951.7 cm^{-1} medium weak deformation represents the

presence of aldehyde. C-H strong bending with a band at 881 and 726.6 cm^{-1} attributes the presence of 1,3 disubstituted and monosubstituted in R15 oleoresin sample respectively, while 816.5 cm^{-1} band attributes the presence of amine salts.

Table 4.79: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R15 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3669.5	Medium	Stretching	broad peak
Alkanes	Cyclohexyl	CH	2972.8	Medium	Symmetric stretching	Alkanes
Alkanes	Cyclohexyl	CH	2924.4	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2854.6	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1745.0	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Aromatics		C-C	1466.7	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1379.8	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1295.5	Medium	Symmetric stretch	
Secondary Alcohols	(R) ₂ CH-OH	C-O	1165.7	Strong	Stretching	
Tertiary alcohol	C-O		1129.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.6	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1048.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1024.4	Strong	Stretching	
Aldehydes	R-CHO	CH	951.7	Medium-weak	Deformation	
1,3 disubstituted		C-H	881.0	Strong	Bending	
Amine Salts	NH ₂ ⁺	NH ₂	816.5	Strong	Rocking	Secondary amine salt; broad peak
monosubstituted		C-H	726.6	Strong	Bending	
Alkenes	RCH=CHR cis	CH	657.6	Medium	Deformation	CH out-of-plane deformation

4.6.4.6.2 Fourier transform infrared (FT-IR) spectroscopy of R16 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R16 oleoresin are represented in Figure 4.13 and Table 4.80. The alkanes and aldehyde presence was determined by the presence of band in the range of 2924.9 and 2853.9 cm^{-1} in R16 oleoresin sample respectively. The presence of esters and amides was revealed in R16

Table 4.80: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R16 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R) ₃ Si-OH	O-H	3651.1	Medium	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2924.9	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.9	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1744.1	Strong	Stretching	
Amides	R-CO-NH-C	NH	1568.8	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics		C-C	1465.7	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1378.5	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1172.7	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.5	Strong	Stretching	In ring
Secondary Alcohols	HO-R-OH	C-O	1025.2	Strong	Stretching	
Aldehydes	R-CHO	CH	959.3	Medium-weak	Deformation	
1,3 disubstituted		C-H	881.0	Strong	Bending	
Amine Salts	NH ₂ ⁺	NH ₂	818.7	Strong	Rocking	Secondary amine salt; broad peak
Monosubstituted		C-H	726.9	Strong	Bending	

oleoresin sample due to the presence of band with the range of 1744 and 1568.8 cm^{-1} respectively. N-O and C-C strong and medium stretching with a band at 1506.6 and 1465.7 cm^{-1} attributes the presence of nitro compounds and aromatics respectively in R16 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R16 oleoresin with generation of peak with the wavelength range of 1378.5 and 1172.7-1025.2 cm^{-1} . In R16 oleoresin 959.3 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 881 and 726.9 cm^{-1} attributes the presence of 1,3 disubstituted and monosubstituted in R16 oleoresin sample respectively, while 818.7 cm^{-1} band attributes the presence of amine salts.

4.6.4.6.3 Fourier transform infrared (FT-IR) spectroscopy of R31 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R31 oleoresin are represented in Figure 4.13 and Table 4.81. The phenols presence was determined by the presence of band in the range of 3674.3 cm^{-1} in R31 oleoresin sample. The presence of aldehyde and alkynes was revealed in R31 oleoresin sample due to the presence of band with the range of 2889-2824.8, and 2104.0 cm^{-1} respectively. The presence of alkenes, ketones and amides was detected in R31 oleoresin with generation of peak with the wavelength range of 1781.1 and 1642.9 cm^{-1} respectively. In R31 oleoresin 1539.9 cm^{-1} strong asymmetric stretch represents the presence of nitro compounds. OH medium deformation with a band 1440.8 cm^{-1} attributes the presence of alcohol.

Table 4.81: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R31 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols, Phenols		O-H	3674.3		Stretching	Free hydroxyl
Aldehydes	C=CC=C-CHO	CH	2889.0 2824.8	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Alkynes	R-C $\equiv$ CH	C $\equiv$ C	2104.0	Variable	Stretching	mono-substituted
Alkenes	(R) ₂ C=CH ₂	CH	1781.1	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Amides	R-C(O)-NH-R	C=O	1642.9	Weak-medium	Stretching	
Nitro Compounds		N-O	1539.9	Strong	Asymmetric stretch	Nitro Compounds
Alcohols	HO-R-OH	OH	1440.8	Medium	Deformation	

4.6.4.6.4 Fourier transform infrared (FT-IR) spectroscopy of R32 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R32 oleoresin are represented in Figure 4.13 and Table 4.82. The phenols presence was determined by the presence of band in the range of 3650.8cm^{-1} in R32 oleoresin sample. The presence of aldehyde and alkynes was revealed in R32 oleoresin sample due to the presence of band with the range of $2882.9\text{--}2824.9$, and 2104.0 cm^{-1} respectively. The presence of amine salts, isothiocyanates was detected in R32 oleoresin with generation of peak with the wavelength range of 2077.2 cm^{-1} . In R32 oleoresin 1644.8 cm^{-1} weak medium stretch represents the presence of amides. N-O and C-O with band 1539.2 and 1275.5 cm^{-1} attributes the presence of nitro compounds and alkyl ethyl ether respectively.

Table 4.82: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R33 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols, Phenols		O-H	3650.8		Stretching	Free hydroxyl
Aliphatic primary amines		N-H	3398.2	Medium	Stretching	
Aldehydes	C=CC=C-CHO	CH	2882.9 2824.9	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Alkynes	R-C $\equiv$ CH	C $\equiv$ C	2104.0	Variable	Stretching	mono-substituted
Amine Salts	NH ₂ ⁺	NH	2077.2	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Amides	R-C(O)-NH-R	C=O		Weak-medium	Stretching	
Nitro Compounds		N-O	1539.2	Strong	Asymmetric stretch	Nitro Compounds
Alkyl ethyl ether		C-O	1275.5	Strong	Stretching	

4.6.4.7 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 7 oleoresin

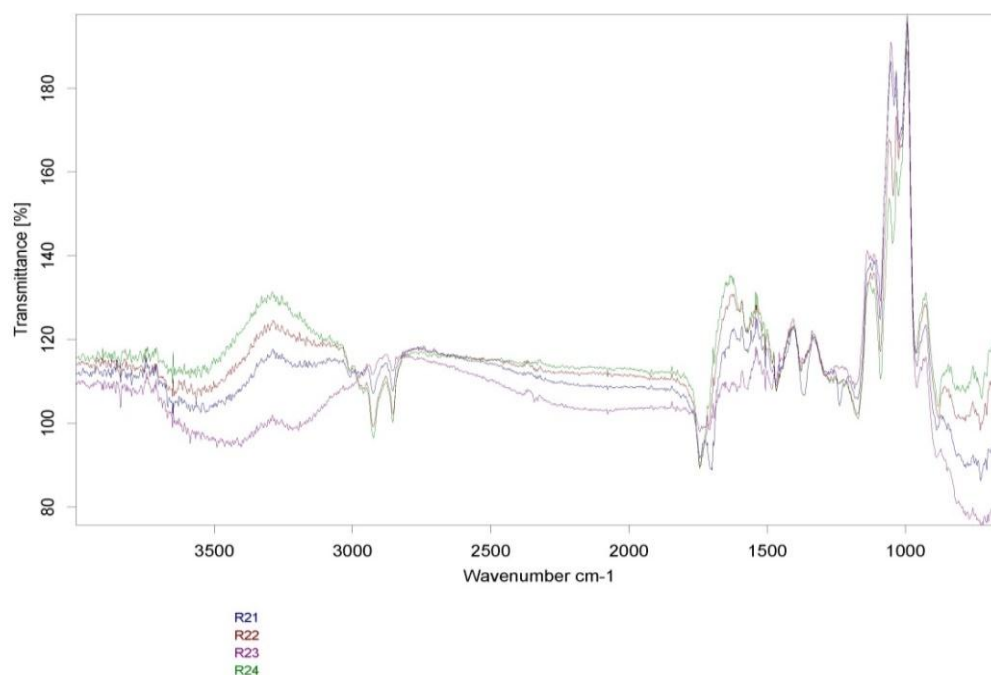


Figure 4.14: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R21, R22, R23 and R24 (group 7) oleoresin

4.6.4.7.1 Fourier transform infrared (FT-IR) spectroscopy of R21 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R21 oleoresin are represented in Figure 4.14 and Table 4.83. The alcohol, alkanes and aldehyde presence was determined by the presence of band in the range of 3650.6-3548.8, 2924.3 and 2854.0 cm^{-1} in R21 oleoresin sample respectively. The presence of esters and amides was revealed in R21 oleoresin sample due to the presence of band with the range of 1743.0 and 1699.7 cm^{-1} respectively. N-O and C-C medium stretching with a band at 1506.5 and 1467.4 cm^{-1} attributes the presence of nitro compounds and aromatics in R21 oleoresin sample. The presence of aromatics, alcohol and secondary alcohol was detected in R21 oleoresin with generation of peak with the wavelength range of 1467.4, 1238.1-1022.6 cm^{-1} respectively. In R21 oleoresin 957.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 72.2 cm^{-1} attributes the presence of monosubstituted in R21 oleoresin sample.

Table 4.83: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R21 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3650.6	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3548.8	Medium, sharp	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2924.3	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2854.0	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1743.0	Strong	Stretching	
Aldehydes	CH=CH-CHO	C=O	1699.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1569.4	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1506.5	Strong	Asymmetric stretch	
Aromatics		C-C	1467.4	Medium	Stretching	In ring
Alcohols	Ph-OH	C-O	1238.1	Strong	Stretching	
Secondary Alcohols	(R) ₂ CH-OH	C-O	1172.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1091.1	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1040.9	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1022.6	Strong	Stretching	
Aldehydes	R-CHO	CH	957.6	Medium-weak	Deformation	
Monosubstituted		C-H	727.2	Strong	Bending	

4.6.4.7.2 Fourier transform infrared (FT-IR) spectroscopy of R22 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R22 oleoresin are represented in Figure 4.14 and Table 4.84. The alcohol, alkanes and aldehyde presence was determined by the presence of band in the range of 3651.0-3645.1, 2924.9 and 2853.0 cm⁻¹ in R22 oleoresin sample respectively. The presence of esters and amides was revealed in R22 oleoresin sample due to the presence of band with the range of 1742.2 and

Table 4.84: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R22 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3651.0	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3645.1	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3565.4	Medium	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2924.9	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.0	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1742.2	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-o	1506.4	Strong	Asymmetric stretch	
Aromatics		C-C	1466.4	Medium	Stretching	In ring
Alcohols	HO-R-OH	OH	1377.0	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1176.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.7	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1044.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1024.2	Strong	Stretching	
Aldehydes	R-CHO	CH	961.6	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.0	Strong	Bending	
1,2,3 disubstituted		C-H	782.3	Strong	Bending	
Monosubstituted		C-H	728.8	Strong	Bending	

1569.7 cm^{-1} respectively. N-O and C-C medium stretching with a band at 1506.4 and 1466.4 cm^{-1} attributes the presence of nitro compounds and aromatics in R22 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R22 oleoresin with generation of peak with the wavelength range of 1377-1024.2 cm^{-1} respectively. In R22 oleoresin 961.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 879.0, 782.3 and 728.8 cm^{-1} attributes the presence of 1,3 disubstituted, 1,2,3 disubstituted and monosubstituted in R22 oleoresin sample respectively.

4.6.4.7.3 Fourier transform infrared (FT-IR) spectroscopy of R23 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R23 oleoresin are represented in Figure 4.14 and Table 4.85. The alcohol and amines presence was determined by the presence of band in the range of 3651.0 and 3490.3 cm^{-1} in R23 oleoresin sample respectively. The presence of esters and amides was revealed in R23 oleoresin sample due to the presence of band with the range of 1743.7 and 1570.2 cm^{-1} respectively. N-O and C-C medium stretching with a band at 1506.4 and 1482.0 cm^{-1} attributes the presence of nitro compounds and aromatics in R23 oleoresin sample. The presence of alkanes, alcohol and secondary alcohol was detected in R23 oleoresin with generation of peak with the wavelength range of 1482.0 and 1377.6-1037.9 cm^{-1} respectively. In R23 oleoresin 959.3 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H, NH that are medium deformation and strong wagging with a band at 718.9 cm^{-1} attributes the presence of alkanes and amines in R23 oleoresin sample respectively.

4.6.4.7.4 Fourier transform infrared (FT-IR) spectroscopy of R24 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R24 oleoresin are represented in Figure 4.14 and Table 4.86. The alcohol presence was determined by the presence of band in the range of 3651.0 -3645.1 cm^{-1} in R24 oleoresin sample respectively. The presence of alkanes and aldehyde was revealed in R24 oleoresin sample due to the presence of band with the range of 2924.9 and 2853.8 cm^{-1} respectively. The presence of esters and amides was revealed in R24 oleoresin sample due to the presence of band with the range of 1742.2 and 1569.7 cm^{-1} respectively. N-O and CH strong stretching and variable deformation with a band at 1506.4 and 1466.4 cm^{-1} attributes the presence of nitro compounds and alkanes in R24 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R24 oleoresin with generation of peak with the wavelength range of 1377.0-1024.2 cm^{-1} respectively. In R24 oleoresin 961.6 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H strong bending with a band at 879.0, 782.3 and 728.8 cm^{-1} attributes the presence of 1,3 disubstituted, 1,2,3 disubstituted and monosubstituted in R24 oleoresin sample respectively.

Table 4.85: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R23 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3651.0	Medium, sharp	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3490.3	Weak	Stretching	Secondary amine
Alcohol		O-H		Strong, Broad	Stretching	Intermolecular bond
Esters		C=O	1743.7	Strong	Stretching	
Amides	R-CO-NH-C	NH	1570.2	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1482.0	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1377.6	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1183.9	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.6	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.9	Strong	Stretching	
Aldehydes	R-CHO	CH	959.3	Medium-weak	Deformation	
Benzene derivatives			718.9			
Alkenes	RCH=CHR cis	CH		Medium	Deformation	CH out-of-plane deformation
Amines	CH ₂ -NH-CH ₂					
		NH		Strong	Wagging	Broad peak

Table 4.86: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R24 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3651.0	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3645.1	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3565.8	Medium	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2924.9	Medium	Symmetric stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2853.8	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Esters		C=O	1742.2	Strong	Stretching	
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1466.4	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1377.0	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1176.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.6	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1044.1	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1024.2	Strong	Stretching	
Aldehydes	R-CHO	CH	961.6	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.0	Strong	Bending	
1,2,3 disubstituted		C-H	782.3	Strong	Bending	Secondary amine salt; broad peak
Monosubstituted		C-H	728.8	Strong	Bending	

4.6.4.8 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 8 oleoresin

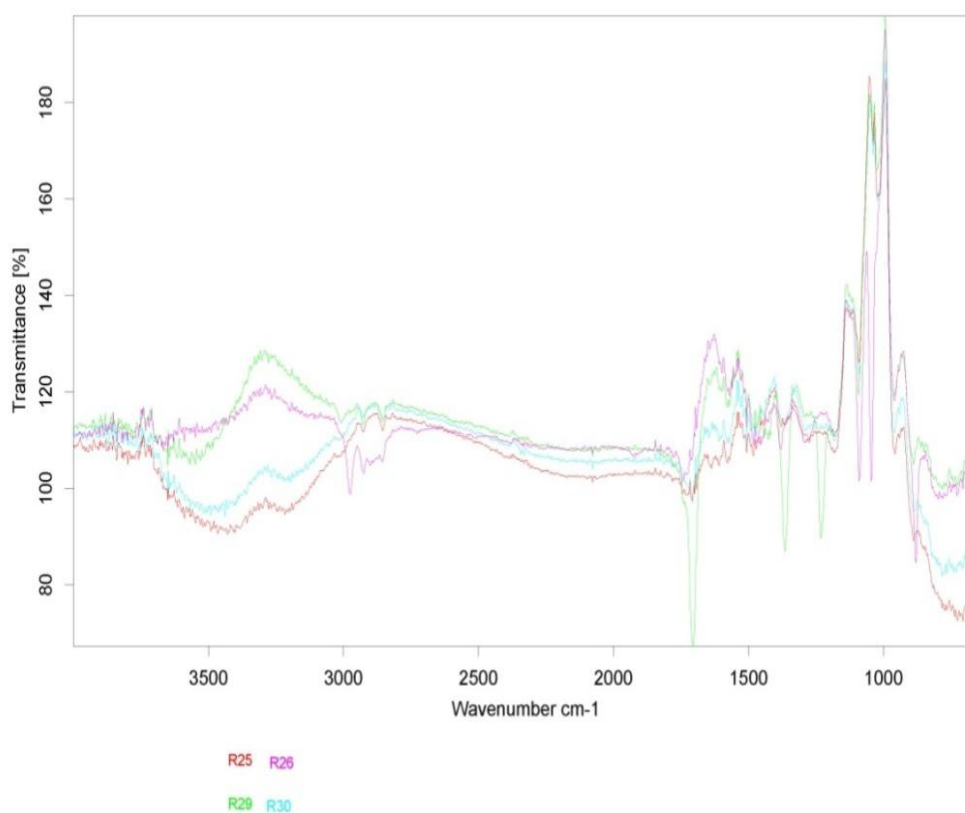


Figure 4.11: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R25, R26, R29 and R30 (group 8) oleoresin

4.6.4.8.1 Fourier transform infrared (FT-IR) spectroscopy of R25 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R25 oleoresin are represented in Figure 4.15 and Table 4.87. The amine presence was determined by the presence of band in the range of 3428.6 cm^{-1} in R25 oleoresin sample respectively. The presence of aldehyde and amides was revealed in R25 oleoresin sample due to the presence of band with the range of 1708.6 and 1577.7 cm^{-1} respectively. N-O and CH strong stretching and variable deformation with a band at 1506.6 and 1481.4 cm^{-1} attributes the presence of nitro compounds and alkanes in R25 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R25 oleoresin with generation of peak with the wavelength range of 1377.9 - 1021.9 cm^{-1} respectively. In R25 oleoresin 956.8 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H medium deformation with a band 706.1 cm^{-1} attributes the presence of alkenes.

Table 4.87: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R25 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amines	CH ₂ -NH-CH ₂	NH	3428.6	Weak	Stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1708.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1577.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	
Alkanes	Cyclohexyl	CH	1481.4	Variable	Deformation	
Alcohols	HO-R-OH	OH	1377.9	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Secondary Alcohols	(R) ₂ CH-OH	C-O	1183.8	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1090.3	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1021.9	Strong	Stretching	
Aldehydes	R-CHO	CH	956.8	Medium-weak	Deformation	
Alkenes	RCH=CHR cis	CH	706.1	Medium	Deformation	CH out-of-plane deformation

4.6.4.8.2 Fourier transform infrared (FT-IR) spectroscopy of R26 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R26 oleoresin are represented in Figure 4.15 and Table 4.88. The alcohol presence was determined by the presence of band in the range of 3650.8-3589.9 cm⁻¹ in R26 oleoresin sample respectively. The presence of alkanes and ester was revealed in R26 oleoresin sample due to the presence of band with the range of 2974.8-2924.9 and 1743.6 cm⁻¹ respectively. C=O and NH strong stretching and variable deformation with a band at 1691.6 and 1569.5 cm⁻¹ attributes the presence of aldehydes and amides in R26 oleoresin sample. The presence of alcohol and secondary alcohol was detected in R26 oleoresin with generation of peak with the wavelength range of 1379.9-1044.7 cm⁻¹ respectively. In R26 oleoresin 959.7 cm⁻¹ medium weak deformation represents the presence of aldehyde. C-H strong bending with a band 879.7 and 796.9 cm⁻¹ attributes the presence of 1,3 disubstituted and monosubstituted respectively.

Table 4.88: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R26 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3732.6	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3589.9	Medium, sharp	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2974.8	Medium	Symmetric stretching	
Alkanes	Cyclohexyl	CH	2924.9	Medium	Symmetric stretching	Secondary amine
Esters		C=O	1743.6	Strong	Stretching	
Aldehydes	CH=CH-CHO	C=O	1691.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1569.5	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Alkanes	Cyclohexyl	CH	1481.4	Variable	Deformation	In ring
Alcohols	HO-R-OH	OH	1379.7	Medium	Deformation	
Alcohols	HO-R-OH	OH	1363.6	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Alcohols	Ph-CHR-OH	OH	1274.3	Strong	Deformation	
Secondary Alcohols	(R) ₂ CH-OH	C-O	1181.7	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.4	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1044.7	Strong	Stretching	
Aldehydes	R-CHO	CH	959.7	Medium-weak	Deformation	
1,3 disubstituted		C-H	879.7	Strong	Bending	
Monosubstituted		C-H	796.9	Strong	Bending	

4.6.4.8.3 Fourier transform infrared (FT-IR) spectroscopy of R29 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R29 oleoresin are represented in Figure 4.15 and Table 4.89. The alcohol and alkanes presence was determined by the presence of band in the range of 3651.9 and 2928.0 cm⁻¹ in R29

oleoresin sample respectively. The presence of alkanes, aldehyde and amides was revealed in R29 oleoresin sample due to the presence of band with the range of 2928.0, 1706.1 and 1578.0 cm^{-1} respectively. The presence of alcohol, nitro and secondary alcohol was detected in R29 oleoresin with generation of peak with the wavelength range of 1470.7-1021.8 cm^{-1} respectively. In R29 oleoresin 959.0 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H medium deformation with a band 887.5 and 781.1 cm^{-1} attributes the presence of 1,3 disubstituted and 1,2,3 disubstituted respectively.

Table 4.89: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R29 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol			3651.9	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3548.6	Medium, sharp	Stretching	Broad peak
Alkanes	Cyclohexyl	CH	2928.0	Medium	Symmetric stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1706.1	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-CO-NH-C	NH	1578.0	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Alcohols	R-CH ₂ -OH	OH	1470.7	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1425.7	Medium	Deformation	
Nitro		N-O	1364.2	Strong	Stretching	
Alcohols	Ph-OH	C-O	1231.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1091.1	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1038.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1021.8	Strong	Stretching	
Aldehydes	R-CHO	CH	959.0	Medium-weak	Deformation	
1,3 disubstituted		C-H	887.5	Strong	Bending	
1,2,3 disubstituted		C-H	781.1	Strong	Bending	1,2,3 disubstituted

4.6.4.8.4 Fourier transform infrared (FT-IR) spectroscopy of R30 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R30 oleoresin are represented in Figure 4.15 and Table 4.90. The amines and aldehydes presence

was determined by the presence of band in the range of 3438.4 and 1707.4-1691.5 cm^{-1} in R30 oleoresin sample respectively. The presence of amidines and amides was revealed in R30 oleoresin sample due to the presence of band with the range of 1608.9 and 1577.9 cm^{-1} respectively. The presence of alkanes, nitro and secondary alcohol was detected in R30

Table 4.90: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R30 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Silicon Compounds	(R)3Si-OH	O-H	3650.9	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3438.4	Weak	Stretching	Secondary amine
Aldehydes	CH=CH-CHO	C=O	1707.4	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1691.5	Strong	Stretching	Alpha beta unsaturated aldehyde
Amidines	N=CH-N	C=N	1608.9	Medium-strong	Stretching	Amidines
Amides	R-CO-NH-C	NH	1577.9	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1538.9	Strong	Asymmetric stretch	Nitro compounds
nitro compounds		N-O	1506.3	Strong	Asymmetric stretch	Nitro compounds
Alkanes	Cyclohexyl	CH	1482.0	Variable	Deformation	In ring
Nitro		N-O	1364.8	Strong	Stretching	
Secondary Alcohols	(R) ₂ CH-OH	C-O	1176.2	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1089.5	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1037.9	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1022.5	Strong	Stretching	
Aldehydes	R-CHO	CH	960.2	Medium-weak	Deformation	
1,2,3 disubstituted		C-H	781.9	Strong	Bending	1,2,3 disubstituted
alkynes		-C≡C- H: C-H	684.4	Strong	Bending	
Alkenes	RCH=CHR cis	CH	657.3	Medium	Deformation	CH out-of-plane deformation

oleoresin with generation of peak with the wavelength range of 1482.0-1022.5 cm^{-1} respectively. In R30 oleoresin 960.2 cm^{-1} medium weak deformation represents the presence of aldehyde. C-H medium deformation with a band 781.1, 684.4 and 657.3 cm^{-1} attributes the presence of 1, 2, 3 disubstituted, alkynes and alkenes respectively.

4.6.4.9 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 9 oleoresin

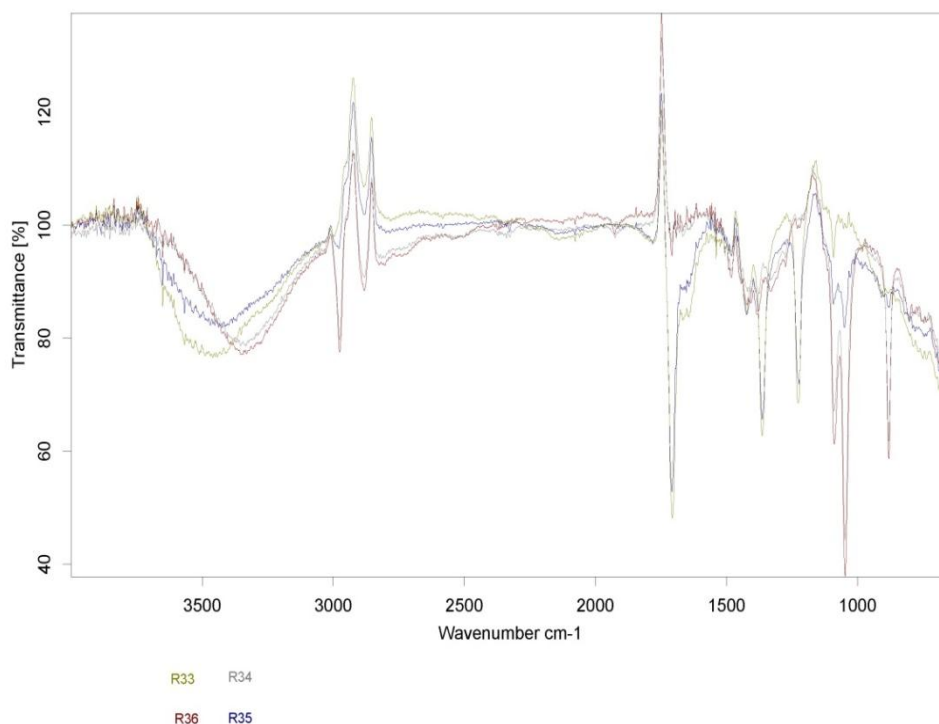


Figure 4.16: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R33, R34, R35 and R36 (group 9) oleoresin

4.6.4.9.1 Fourier transform infrared (FT-IR) spectroscopy of R33 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R33 oleoresin are represented in Figure 4.16 and Table 4.91. The phenols presence was determined by the presence of band in the range of 3650.2 cm^{-1} in R33 oleoresin sample. The presence of amines and aldehyde was revealed in R33 oleoresin sample due to the presence of band with the range of 3459.5 and 2883.5 cm^{-1} respectively. The presence of amine salts, isothiocyanates was detected in R33 oleoresin with generation of peak with the wavelength range of 2077.2 cm^{-1} . In R33 oleoresin 1781.6 cm^{-1} medium overtone represents the presence of alkenes and ketones. C=O and N-O with band 1706.2 and 1538.7 cm^{-1} attributes the presence of aldehydes and nitro compounds respectively. Alcohols and secondary alcohols were detected at the band range 1422.6-1091.3 cm^{-1} .

Table 4.91: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R33 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
alcohols, phenols		O–H	3650.2		Stretching	Free hydroxyl
Amines	CH ₂ -NH-CH ₂	NH	3459.5	Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2883.5	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.2	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.6	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	CH=CH-CHO	C=O	1706.2	Strong	Stretching	Alpha beta unsaturated aldehyde
nitro compounds		N–O	1538.7	Strong	Asymmetric stretch	Nitro compounds
Aromatics	1,2,3,4,5,6-substituted	Ring	1490.5	Variable	Stretching	
Alcohols	HO-R-OH	OH	1422.6	Medium	Deformation	
Alcohols	HO-R-OH	OH	1363.5	Medium	Deformation	
Vinyl ether		C-O	1226.8	Strong	Stretching	
Alcohols	Ph-OH	C-O		Strong	Stretching	
Alkanes	C-(CH ₃) ₃	CC		Medium	Skeletal vibration	
Secondary Alcohols	HO-R-OH	C-O	1091.3	Strong	Stretching	In ring

4.6.4.9.2 Fourier transform infrared (FT-IR) spectroscopy of R34 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R34 oleoresin are represented in Figure 4.16 and Table 92. The presence of amines, alkanes and

aldehyde was revealed in R34 oleoresin sample due to the presence of band with the range of 3332.5, 2975.8 and 2880.4-1691.0 cm^{-1} respectively. The presence of ketones and nitro compounds was detected in R34 oleoresin with generation of peak with the wavelength range of 1667.3 and 1545.5-1538.9 cm^{-1} . In R34 oleoresin 1482.5 and 1382.9 cm^{-1} medium overtone represents the presence of aromatics and phenols respectively. Alcohols and secondary alcohols were detected at the band range 1363.5-1047.3 cm^{-1} .

Table 4.92: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R34 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amines	$\text{CH}_2\text{-NH-CH}_2$	NH	3332.5	Weak	Stretching	Secondary amine
Alkanes	Cyclohexyl	CH	2975.8	Medium	Symmetric stretching	Alkanes
Aldehydes	C=CC=C-CHO	CH	2880.4	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-CHO	CH	2814.4	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	CH=CH-CHO	C=O	1708.1	Strong	Stretching	alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1691.0	Strong	Stretching	alpha beta unsaturated aldehyde
Ketones	C=C-C(O)-R	C=O	1667.3		Stretch	
nitro compounds		N-O	1545.5	Strong	Asymmetric stretch	Nitro compounds
nitro compounds		N-O	1538.9	Strong	Asymmetric stretch	Nitro compounds
Aromatics	1,2,3,4,5,6-substituted	Ring	1482.5	Variable	Stretching	
Phenols		O-H	1382.9		Bending	
Alcohols	HO-R-OH	OH	1363.5	Medium	Deformation	
Secondary Alcohols	HO-R-OH	C-O	1089.2	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1047.3	Strong	Stretching	
1,3 disubstituted		C-H	880.2	Strong	Bending	

4.6.4.9.3 Fourier transform infrared (FT-IR) spectroscopy of R35 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R35 oleoresin are represented in Figure 4.16 and Table 4.93. The presence of alcohol, amines and

aldehyde was revealed in R35 oleoresin sample due to the presence of band with the range of 3650.3, 3424.9 and 2882.8 cm^{-1} respectively. The presence of alkenes, ketones and aldehydes was detected in R35 oleoresin with generation of peak with the wavelength range of 1781.6 and 1707.4 cm^{-1} respectively. In R35 oleoresin 1545.7 and 1539.0 cm^{-1} asymmetric stretch represents the presence of nitro compounds. Aromatics, alcohols and secondary alcohols were detected at the band range 1480.6, 1363.4-1049.6 cm^{-1} respectively. The presence of 1,3 disubstituted revealed in R35 sample due the presence of band with a range of 879.1 cm^{-1} .

Table 4.93: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R35 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohol		O-H	3650.3	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.2	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3424.9	Weak	Stretching	Secondary amine
Alkanes	Cyclohexyl	CH	2978.4	Medium	Symmetric stretching	Alkanes
Aldehydes	C=CC=C-CHO	CH	2882.8	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Alkenes	(R) ₂ C=CH ₂	CH	1781.6	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	CH=CH-CHO	C=O	1707.4	Strong	Stretching	Alpha beta unsaturated aldehyde
nitro compounds		N-O	1545.7	Strong	Asymmetric stretch	Nitro compounds
nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.6	Variable	Stretching	
Alcohols	HO-R-OH	OH	1423.0	Medium	Deformation	
Alcohols	HO-R-OH	OH	1363.4	Medium	Deformation	
Vinyl ether		C-O	1222.8	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1091.7	Strong	Stretching	In ring
Alcohols	HO-R-OH	C-O	1049.6	Strong	Stretching	
1,3 disubstituted		C-H	879.1	Strong	Bending	

4.6.4.9.4 Fourier transform infrared (FT-IR) spectroscopy of R36 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of R36 oleoresin are represented in Figure 4.16 and Table 4.94. The presence of alcohol, amines, alkanes and aldehyde was revealed in R36 oleoresin sample due to the presence of band with the range of 3650.5, 3552.1 2975.5 and 2882.3-2802.9 cm^{-1} respectively. The presence of alkenes and aldehydes was detected in R36 oleoresin with generation of peak with the wavelength range of 1925.1 and 1707.4-1690.9 cm^{-1} respectively. In R36 oleoresin 1538.9 cm^{-1} strong asymmetric stretch represents the presence of nitro compounds. Aromatics,

Table 4.94: FT-IR spectra, characteristics peaks and functional groups at particular peaks of R36 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.8	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3650.5	Medium, sharp	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3352.1	Variable	Stretching	Hydrogen bonded, broad peak
Amines	CH ₂ -NH-CH ₂	NH		Weak	Stretching	Secondary amine
Alkanes	Cyclohexyl	CH	2975.5	Medium	Symmetric stretching	Alkanes
Aldehydes	C=CC=C-CHO	CH	2881.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehyde		C-H	2802.9	Medium	Stretching	Doublet
Allenes	C=C=C	C=C=C	1925.1	strong	stretching	
Aldehydes	CH=CH-CHO	C=O	1707.4	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Nitro Compounds		N-O	1538.9	Strong	Asymmetric stretch	Nitro compounds
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.8	Variable	Stretching	
Alcohols	HO-R-OH	OH	1423.0	Medium	Deformation	
Phenols		O-H	1383.7		Bending	
Secondary Alcohols	HO-R-OH	C-O	1088.4	Strong	Stretching	
1,3 disubstituted		C-H	880.2	Strong	Bending	

alcohols, phenols and secondary alcohols were detected at the band range 1480.8, 1423.0, 1383.7 and 1088.4 cm^{-1} respectively. The presence of 1,3 disubstituted revealed in R36 sample due the presence of band with a range of 880.2 cm^{-1} .

4.6.4.10 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 10 oleoresin

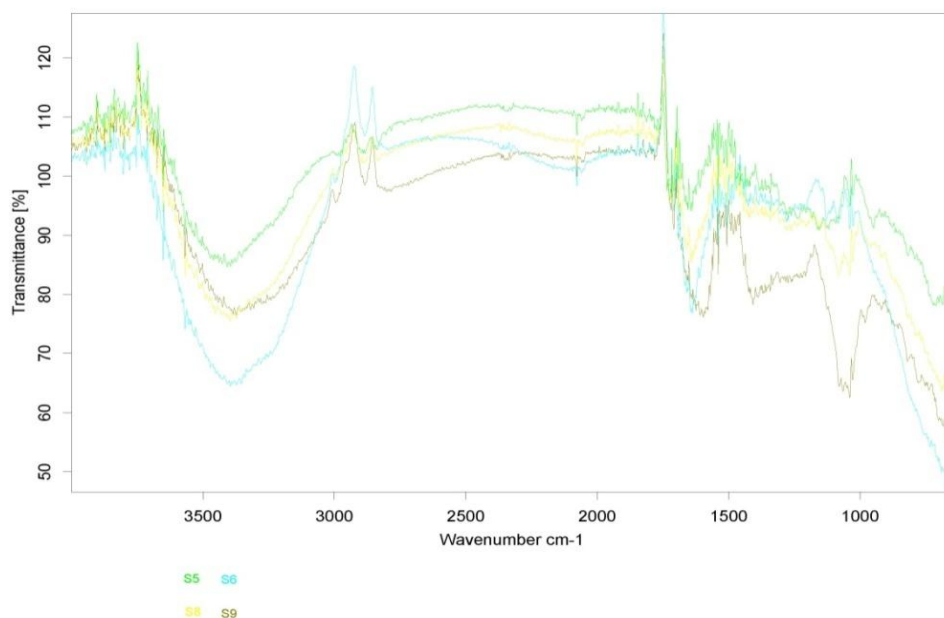


Figure 4.17: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S5, S6, S8 and S9 (group 10) oleoresin

4.6.4.10.1 Fourier transform infrared (FT-IR) spectroscopy of S5 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S5 oleoresin are represented in Figure 4.17 and Table 4.95. The water vapours presence was determined by the presence of band in the range of 3720.3 cm^{-1} in S5 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of 3699.4-3505.6 cm^{-1} in S5 oleoresin sample. The presence of amines and aldehyde was revealed in S5 oleoresin sample due to the presence of band with the range of 3425.3-3407.3 and 2837.9 cm^{-1} respectively. NH and N=C=S medium and strong stretching with a band at 2077.4 cm^{-1} attributes the presence of amines salts and isothocyanatess in S5 oleoresin sample. The presence of allenes, alkenes and anhydrides was detected in S5 oleoresin with generation of peak with the wavelength range of 1924.7, 1850.8 and 1830.1 cm^{-1} respectively. The band at 1812.5 cm^{-1} represents the acyl chlorides, while stretching at 1774.0 cm^{-1} band represents the presence of alkenes and ketones. In S5 oleoresin, 1763.7-1733.7 and 1724.6-1690.5 cm^{-1} band range attributes the presence of amides and aldehydes respectively. Amides and amidines

with the range of peak wavelength $1643.5\text{--}1552.8\text{ cm}^{-1}$ was observed. Nitro compounds and amides presence was detected in S5 oleoresin with the band range of $1545.3\text{--}1506.6\text{ cm}^{-1}$. Aromatics, phenols and alcohol presence were detected in S5 oleoresin with the band range of $1458.8\text{--}1303.5\text{ cm}^{-1}$. The presence of alkyl ethyl ether, alcohols and anhydrides was detected in S5 oleoresin with generation of peak with the wavelength range of $1274.2\text{--}1038.6\text{ cm}^{-1}$. The presence of aromatic and amine salts was detected in S5 oleoresin with generation of peak with the wavelength range of 948.7 and 816.6 cm^{-1} respectively. At 718.9 cm^{-1} , components benzene derivatives, alkenes and amines were detected, while at 672.4 cm^{-1} presence of alkenes were revealed.

Table 4.995: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S5 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3720.3	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3699.4	Medium, sharp	Stretching	Broad peak
Alcohols, phenols		O-H	3687.5		Stretching	Free hydroxyl
Alcohols, phenols		O-H	3673.9		Stretching	Free hydroxyl
Alcohol		O-H	3650.7	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3614.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.5	Medium	Stretching	Broad peak
Alcohol		O-H	3531.6	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3505.6	Medium, sharp	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3425.4	Weak	Stretching	Secondary amine
Amines	CH ₂ -NH-CH ₂	NH	3407.3	Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2837.9	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.2	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	

Classification	Group	Bond	Range	Intensity	Mode	Notes
Allenes	C=C=C	C=C=C	1924.7	Strong	Stretching	
Alkenes	RCH=CH ₂	CH	1850.8	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Anhydrides		C=O	1830.1		Stretching	Two band
Acyl chlorides	R-C(O)-Cl	C=O	1812.5	Strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1774.0	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Amides	R-CO-NH-CO-NHR	C=O	1763.7	Strong	Antisymmetric stretching	Noncyclic conjugated
Amides	R-CO-NH-CO-NHR	C=O	1733.7	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1724.6	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1708.0	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1699.1	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.5	Strong	Stretching	Alpha beta unsaturated aldehyde
alkenes		-C=C-	1654.8	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.5	Weak-medium	Stretching	
Amidines	N=CH-N	C=N	1609.3	Medium-strong	Stretching	Amidines
Amides	R-CO-NH-C	NH	1569.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Amides	R-CO-NH-C	NH	1559.6 1552.8	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
nitro compounds		N-O	1545.3	Strong	Asymmetric stretch	Nitro compounds
nitro compounds		N-O	1538.9	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.3	Strong	Combination	Amide II, combination of C-N stretching and

Classification	Group	Bond	Range	Intensity	Mode	Notes
						N-H bending
nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.1	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.3	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1458.8	Medium-weak	Deformation	
Alkane		C-H		Medium	Bending	Methyl group
Alcohols	HO-R-OH	OH	1442.5	Medium	Deformation	
Alcohols	HO-R-OH	OH	1419.5	Medium	Deformation	
Phenols		O-H	1383.1		Bending	
Alcohols	HO-R-OH	OH	1369.0	Medium	Deformation	Amide II, combination of C-N stretching and N-H bending
Amine		C-N	1342.1	Medium weak	Stretching	
Phenols		O-H	1303.5		Bending	
Alkyl ethyl ether		C-O	1274.2	Strong	Stretching	
Alcohols	Ph-OH	C-O	1237.6	Strong	Stretching	
Anhydrides	C=C-COOCOR	C-O-C	1155.2	Strong	Stretching	Absence of strong band is good negative information
Alcohols	HO-R-OH	C-O	1038.6	Strong	Stretching	
Aromatics	1,3,5-trisubstituted	CH	948.7	Weak	Deformation	1 adjacent H out-of-plane deformation
Amine Salts	NH ₂ ⁺	NH ₂	816.6	Strong	Rocking	Secondary amine salt; broad peak
Benzene derivatives			718.9			
Alkenes	RCH=CHR cis	CH		Medium	Deformation	CH out-of-plane deformation
Amines	CH ₂ -NH-CH ₂	NH		Strong	Wagging	broad peak
Alkenes	RCH=CHR cis	CH	672.4	Medium	Deformation	CH out-of-plane deformation

4.6.4.10.2 Fourier transform infrared (FT-IR) spectroscopy of S6 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S6 oleoresin are represented in Figure 4.17 and Table 4.96. The water vapours presence was determined by the presence of band in the range of 3720.3cm^{-1} in S6 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3699.4\text{--}3505.9\text{ cm}^{-1}$ in S6 oleoresin sample. The presence of aliphatic primary amines and aldehyde was revealed in S6 oleoresin sample due to the presence of band with the range of 3395.6 and 2883.7cm^{-1} respectively. NH and N=C=S medium and strong stretching with a band at 2077.4 cm^{-1} attributes the presence of amines salts and isothiocyanates in S6 oleoresin sample. The presence of acyl chlorides and aldehyde was detected in S6 oleoresin with generation of peak with the wavelength range of $1813.0\text{--}1690.4\text{ cm}^{-1}$ respectively. The band at 1637.5 cm^{-1} represents the amides, while asymmetric stretching at $1545.5\text{--}1506.7\text{ cm}^{-1}$ band represents the presence of nitro compounds. In S6 oleoresin, $1471.5\text{--}1425.1\text{ cm}^{-1}$ band range attributes the presence of alcohols. Alkyl ethyl ether and tertiary alcohol with the range of peak wavelength 1275.9 and 1129.3 cm^{-1} respectively was observed. secondary alcohol and alcohols presence was detected in S6 oleoresin with the band range of 1083.3 and 1038.6 cm^{-1} respectively.

Table 4.96: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S6 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.8	Medium	Stretching	Series of sharp peaks
Alcohol		O-H	3699.4	Medium, sharp	Stretching	Broad peak
Alcohols, phenols		O-H	3687.8		Stretching	Free hydroxyl
Alcohols, phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.9	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3566.9	Medium	Stretching	Broad peak
Aliphatic primary amines		N-H	3395.6	Medium	Stretching	
Aldehydes	C=CC=C-CHO	CH	2883.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH		Medium	Stretching	Secondary

Classification	Group	Bond	Range	Intensity	Mode	Notes
			2077.2			amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable- strong	Stretching	
Acyl chlorides	R-C(O)-Cl	C=O	1813.0	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH- CHO	C=O	1707.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH- CHO	C=O	1698.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH- CHO	C=O	1690.4	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-C(O)- NH-R	C=O	1637.5	Weak- medium	Stretching	
Nitro compounds		N-O	1545.5	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1506.7	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6- substituted	Ring	1491.1	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1471.5	Medium- weak	Deformation	
Alcohols	HO-R-OH	OH	1442.5	Medium	Deformation	
Alcohols	HO-R-OH	OH	1425.1	Medium	Deformation	
Alkyl ethyl ether		C-O	1275.9	Strong	Stretching	
Tertiary alcohol	C-O		1129.3	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1083.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.6	Strong	Stretching	

4.6.4.10.3 Fourier transform infrared (FT-IR) spectroscopy of S8 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S8 oleoresin are represented in Figure 4.17 and Table 4.97. The water vapours presence was determined by the presence of band in the range of 3712.7cm^{-1} in S8 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of 3687.4cm^{-1} .

3614.9 cm^{-1} in S8 oleoresin sample. The presence of amines and aldehyde was revealed in S8 oleoresin sample due to the presence of band with the range of 3427.6-2978.2 and 2889.1-2839.2 cm^{-1} respectively. NH and N=C=S medium and strong stretching with a band at 2077.3 cm^{-1} attributes the presence of amines salts and isothiocyanates in S8 oleoresin sample. The presence of allenes, alkenes, anhydrides and acyl chlorides was detected in S8 oleoresin with generation of peak with the wavelength range of 1924.7-1812.8 cm^{-1} respectively. The anti-symmetric stretching at 1763.7 and 1724.6-1679.8 cm^{-1} band represents the presence of amides and aldehydes respectively. In S8 oleoresin, 1654.4 cm^{-1} band range attributes the presence of alkenes. Amides and amidines with the range of peak wavelength 1643.4-1631.3 and 1609.8 cm^{-1} respectively was observed. Amides and amidines with the range of peak wavelength 1643.4-1631.3 and 1609.8 cm^{-1} respectively was observed. Aromatics and alcohols with the range of peak wavelength 1491-1480.9 and 1470.9-1425.0 cm^{-1} respectively was observed. Amine, alkyl ethyl ether, alcohols and alkynes were observed in the range of 1275.1-689.0 cm^{-1} .

Table 4.97: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S 8 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.7	Medium	Stretching	Series of sharp peaks
Silicon Compounds	(R) ₃ Si-OH	O-H	3700.2	Medium	Stretching	Broad peak
Alcohols		O-H	3687.4	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.7		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3614.9	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.6	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3427.6	Weak	Stretching	Secondary amine
Amines	CH ₂ -NH-CH ₂	NH	2978.2	Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2889.1	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-	CH	2839.2	Weak	Stretching	CH stretching in Fermi

Classification	Group	Bond	Range	Intensity	Mode	Notes
	CHO					resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ \+	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Allenes	C=C=C	C=C=C	1924.7	Strong	Stretching	
Alkenes	RCH=CH ₂	CH	1850.8	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Anhydrides		C=O	1838.7		Stretching	Two band
Acyl chlorides	R-C(O)-Cl	C=O	1812.8	Strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.5	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Amides	R-CO-NH-CO-NHR	C=O	1763.7	Strong	Antisymmetric stretching	Noncyclic conjugated
Aldehydes	Ph-CHO	C=O	1724.6	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1699.0	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1679.8	Strong	Stretching	Alpha beta unsaturated aldehyde
alkenes		-C=C-	1654.4	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.4	Weak-medium	Stretching	
Amides	R-C(O)-NH-R	C=O	1631.3	Weak-medium	Stretching	
Amidines	N=CH-N	C=N	1609.8	Medium-strong	Stretching	Amidines

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amides	R-CO-NH-C	NH	1569.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Amides	R-CO-NH-C	NH	1559.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1545.5	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.2	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1517.7	Strong	Asymmetric stretch	
Nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.0	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.9	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1470.9	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1442.4	Medium	Deformation	
Alcohols	HO-R-OH	OH	1425.0	Medium	Deformation	
Amine		C-N	1342.1	Medium weak	Stretching	
Alkyl ethyl ether		C-O	1275.1	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1079.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.8	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1027.4	Strong	Stretching	
alkynes		-C≡C- H: C-H	689.0	Strong	Bending	

4.6.4.10.4 Fourier transform infrared (FT-IR) spectroscopy of S9 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S9 oleoresin are represented in Figure 4.17 and Table 4.98. The water vapours presence was determined by the presence of band in the range of 3712.7cm^{-1} in S9 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3687.4\text{--}3373.4\text{ cm}^{-1}$ in S9 oleoresin sample. The presence of aldehyde, amine salts and isothiocyanates was revealed in S9 oleoresin sample due to the presence of band with the range of 2883.3 and 2783.0 and 2077.3cm^{-1} respectively with NH and N=C=S medium and strong stretching. The presence of anhydrides, acyl chlorides and alkenes & ketones was detected in S9 oleoresin with generation of peak with the wavelength range of 1839.0 , 1812.5 and 1781.4 cm^{-1} respectively. The strong stretching at $1719.0\text{--}1690.7\text{ cm}^{-1}$ band represents the presence of aldehydes respectively. In S9 oleoresin, 1654.4 cm^{-1} band range attributes the presence of alkenes. Amine and nitro compounds with the range of peak wavelength 1595.9 and $1545.5\text{--}1506.6\text{cm}^{-1}$ respectively was observed. Amides with the range of peak wavelength 1529.6 cm^{-1} was observed. Aromatics and alcohols with the range of peak wavelength $1491\text{--}1480.5$ and $1471.5\text{--}1028.2\text{ cm}^{-1}$ respectively were observed.

Table 4.98: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S9 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.7	Medium	Stretching	Series of sharp peaks
Alcohols		O-H	3687.4	Medium, sharp	Stretching	Free
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.6	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3373.4	Variable	Stretching	Hydrogen bonded, broad peak
Aldehydes	C=CC=C-CHO	CH	2883.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2783.0	Medium	Stretching	Secondary amine salt; often multiple bands
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-	Stretching	

				strong		
Anhydrides		C=O	1839.0		Stretching	Two band
Acyl chlorides	R-C(O)-Cl	C=O	1812.5	Strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.4	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1699.0	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1654.6	Medium	Stretch	
Amine		N-H	1595.9	Medium-strong	Bend	
Nitro compounds		N-O	1545.5	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.0	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.5	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1471.5	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1406.8	Medium	Deformation	
Alcohols	HO-R-OH	C-O	1038.7	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1028.2	Strong	Stretching	

4.6.4.11 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 11 oleoresin

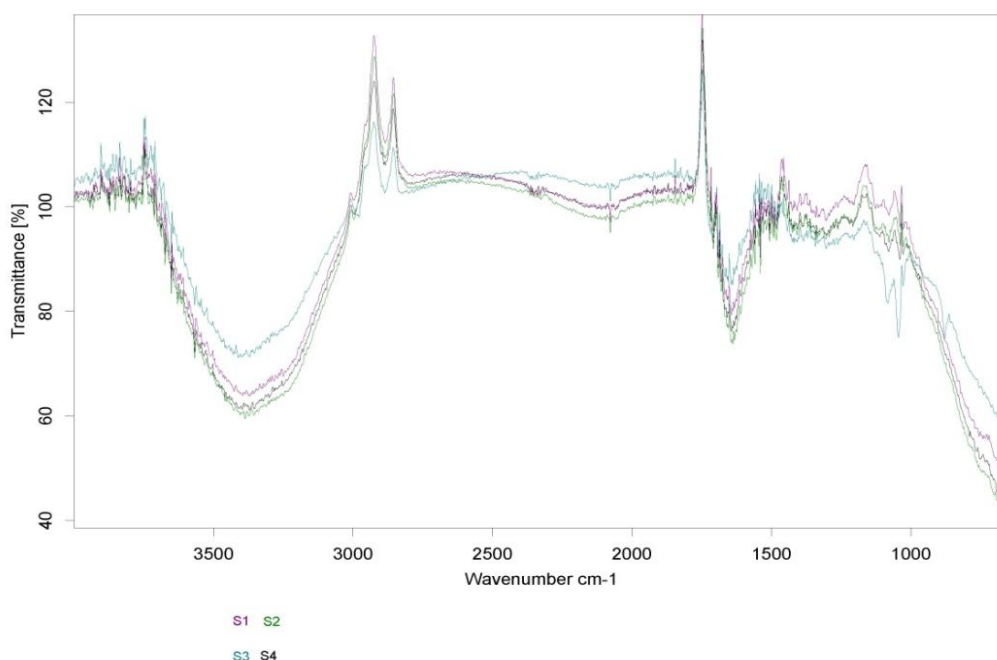


Figure 4.18: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S1, S2, S3 and S4 (group 10) oleoresin

4.6.4.11.1 Fourier transform infrared (FT-IR) spectroscopy of S1 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S1 oleoresin are represented in Figure 4.18 and Table 4.99. The phenols (alcohol) and amines presence was determined by the presence of band in the range of $3688.5\text{--}3369.5\text{ cm}^{-1}$ in S1 oleoresin sample. The presence of aldehyde was revealed in S1 oleoresin sample due to the presence of band with the range of 2884.5 cm^{-1} . NH and N=C=S medium and strong stretching with a band at 2077.3 cm^{-1} attributes the presence of amines salts and isothiocyanates in S1 oleoresin sample. The presence of acyl chlorides was detected in S1 oleoresin with generation of peak with the wavelength range of 1813.0 cm^{-1} . The band at $1718.9\text{--}1690.2\text{ cm}^{-1}$ represents the aldehydes, while C=O stretching at 1643.19 cm^{-1} band represents the presence of amides. In S1 oleoresin, $1545.3\text{--}1539.1\text{ cm}^{-1}$ band range attributes the presence of nitro compounds. Ring stretching with the range of peak wavelength from $1491.1\text{--}1480.8\text{ cm}^{-1}$ represents the aromatics. Alcohol, phenols, secondary alcohol presence was detected in S1 oleoresin with the band range of $1442.7\text{--}1038.8\text{ cm}^{-1}$.

Table 4.99: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S1 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Alcohols		O-H	3688.5	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.8	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3369.5	Variable	Stretching	Hydrogen bonded, broad peak
Amines	CH ₂ -NH-CH ₂	NH		Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2884.5	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Acyl chlorides	R-C(O)-Cl	C=O	1813.0	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1718.9	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.5	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1698.8 1690.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-C(O)-NH-R	C=O	1643.1	Weak-medium	Stretching	
Nitro compounds		N-O	1545.3	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.3	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.5	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.1	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.8	Variable	Stretching	
Alcohols	HO-R-OH	OH	1442.7	Medium	Deformation	
Alcohols	HO-R-OH	OH	1424.8	Medium	Deformation	
Phenols		O-H	1303.9		Bending	
Secondary Alcohols	HO-R-OH	C-O	1078.2	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.8	Strong	Stretching	

4.6.4.11.2 Fourier transform infrared (FT-IR) spectroscopy of S2 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S2 oleoresin are represented in Figure 4.18 and Table 4.100. The water vapours presence was determined by the presence of band in the range of 3712.9 cm^{-1} in S2 oleoresin sample. The phenols (alcohol) and amines presence was determined by the presence of band in the range of $3673.5\text{--}3386.5\text{ cm}^{-1}$ in S2 oleoresin sample. The presence of aldehyde was revealed in S2 oleoresin sample due to the presence of band with the range of 2884.3 cm^{-1} . NH and N=C=S medium and strong stretching with a band at 2077.2 cm^{-1} attributes the presence of amines salts and isothiocyanates in S2 oleoresin sample. The presence of acyl chlorides was detected in S2 oleoresin with generation of peak with the wavelength range of 1812.8 cm^{-1} . The band at $1718.9\text{--}1690.2\text{ cm}^{-1}$ represents the aldehydes, while C=O stretching at 1637.7 cm^{-1} band represents the presence of amides. In S2 oleoresin, $1545.3\text{--}1506.4\text{ cm}^{-1}$ band range attributes the presence of nitro compounds. Ring stretching with the range of peak wavelength from 1481.4 cm^{-1} represents the aromatics. Alcohol, phenols, secondary alcohol presence was detected in S1 oleoresin with the band range of $1442.7\text{--}1038.2\text{ cm}^{-1}$.

Table 4.100: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S2 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.9	Medium	Stretching	Series of sharp peaks
Alcohols, Phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.9	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.3	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3386.5	Variable	Stretching	Hydrogen bonded, broad peak
Amines	CH ₂ -NH-CH ₂	NH		Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2884.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.2	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Acyl chlorides	R-C(O)-Cl	C=O	1812.8	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1718.9	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-	C=O	1707.5	Strong	Stretching	Alpha beta

	CHO					unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Amides	R-C(O)-NH-R	C=O	1637.7	Weak-medium	Stretching	
Nitro compounds		N-O	1545.3	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1481.4	Variable	Stretching	
Alcohols	HO-R-OH	OH	1442.7	Medium	Deformation	
Alcohols	HO-R-OH	OH	1424.8 1406.9	Medium	Deformation	
Amine		C-N	1341.4	Medium weak	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1078.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.2	Strong	Stretching	

4.6.4.11.3 Fourier transform infrared (FT-IR) spectroscopy of S3 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S3 oleoresin are represented in Figure 4.18 and Table 4.101. The water vapours presence was determined by the presence of band in the range of 3712.9 cm^{-1} in S3 oleoresin sample. The phenols (alcohol) and amines presence was determined by the presence of band in the range of $3687.3\text{--}3411.2\text{ cm}^{-1}$ in S3 oleoresin sample. The presence of alkanes and aldehyde was revealed in S3 oleoresin sample due to the presence of band with the range of 2978.2 and $2885.2\text{--}2823.6\text{ cm}^{-1}$ respectively. NH and N=C=S medium and strong stretching with a band at 2077.4 cm^{-1} attributes the presence of amines salts and isothiocyanates in S3 oleoresin sample. The presence of alkenes and ketones was detected in S3 oleoresin with generation of peak with the wavelength range of 1781.6 cm^{-1} . The band at $1718.9\text{--}1690.6\text{ cm}^{-1}$ represents the aldehydes, while C=C and C=O stretching at 1654.4 and 1637.8 cm^{-1} band represents the presence of alkenes and amides respectively. In S3 oleoresin, $1545.3\text{--}1539.0\text{ cm}^{-1}$ band range attributes the presence of nitro compounds. Ring stretching with the range of peak wavelength $1480.8\text{--}1419.4\text{ cm}^{-1}$ represents the aromatics. Alcohol, amine, phenols, secondary alcohol presence was detected in S3 oleoresin with the band range of $1419.4\text{--}1027.6\text{ cm}^{-1}$.

Table 4.101: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S3

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.9	Medium	Stretching	Series of sharp peaks
Alcohols		O-H	3687.3	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.6	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3411.2	Weak	Stretching	Secondary amine
Alkanes	Cyclohexyl	CH	2978.2	Medium	Symmetric stretching	Alkanes
Aldehydes	C=CC=C-CHO	CH	2885.2	Weak	Stretching	CH stretching in fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-CHO	CH	2823.6	Weak	Stretching	
Amine Salts	NH ₂ \+	NH	2077.4	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.6	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1718.9	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1698.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
alkenes		-C=C-	1654.9	Medium	Stretch	

Classification	Group	Bond	Range	Intensity	Mode	Notes
Amides	R-C(O)-NH-R	C=O	1637.8	Weak-medium	Stretching	
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.4	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.5	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.0	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.8	Variable	Stretching	
Alcohols	HO-R-OH	OH	1419.4	Medium	Deformation	
Amine		C-N	1341.9	Medium weak	Stretching	
Phenols		O-H	1303.5		Bending	
Secondary Alcohols	HO-R-OH	C-O	1082.5	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1044.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1027.6	Strong	Stretching	
1,3 disubstituted		C-H	878.2	Strong	Bending	

4.6.4.11.4 Fourier transform infrared (FT-IR) spectroscopy of S4 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S4 oleoresin are represented in Figure 4.18 and Table 4.102. The water vapours presence was determined by the presence of band in the range of 3712.8 cm^{-1} in S4 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3673.3\text{--}3650.7\text{ cm}^{-1}$ in S4 oleoresin sample. The presence of aldehyde was revealed in S4 oleoresin sample due to the presence of band with the range of 2883.7 cm^{-1} respectively. NH and N=C=S medium and strong stretching with a band at 2077.4 cm^{-1} attributes the presence of amines salts and isothocyanatess in S4 oleoresin sample. The presence of alkenes and ketones was detected in S4 oleoresin with generation of peak with the wavelength range of 1781.6 cm^{-1} . The band at $1718.9\text{--}1690.6\text{ cm}^{-1}$ represents the aldehydes, while C=C and C=O stretching at 1659.9 and $1642.9\text{--}1559.6\text{ cm}^{-1}$ band represents the presence of alkenes and

amides respectively. In S4 oleoresin, 1545.5-1506.3 cm^{-1} band range attributes the presence of nitro compounds. Ring stretching with the range of peak wavelength 1491.1 cm^{-1} represents the aromatics. Alcohol, amine, phenols, secondary alcohol presence was detected in S4 oleoresin with the band range of 1419.4-1039.3 cm^{-1} .

Table 4.102: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S4 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.8	Medium	Stretching	Series of sharp peaks
Alcohols, Phenols		O-H	3673.7		Stretching	Free hydroxyl
Alcohol		O-H	3650.7	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3571.5	Medium	Stretching	Broad peak
Aldehydes	C=CC=C-CHO	CH	2883.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.4	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
			1812..8			
Alkenes	(R) ₂ C=CH ₂	CH	1781.6	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1718.9	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1698.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1658.9	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1642.9	Weak-medium	Stretching	
Amides	R-CO-NH-C	NH	1559.6	Strong	Combination	Amide II, combination of C-

Classification	Group	Bond	Range	Intensity	Mode	Notes
						N stretching and N-H bending
Nitro compounds		N–O	1545.5	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N–O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.4	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N–O	1506.3	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.1	Variable	Stretching	
Alcohols	HO-R-OH	OH	1419.4	Medium	Deformation	
Amine		C-N	1341.9	Medium weak	Stretching	
Phenols		O-H	1303.5		Bending	
Secondary Alcohols	HO-R-OH	C-O	1079.6	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1039.3	Strong	Stretching	

4.6.4.12 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 12 oleoresin

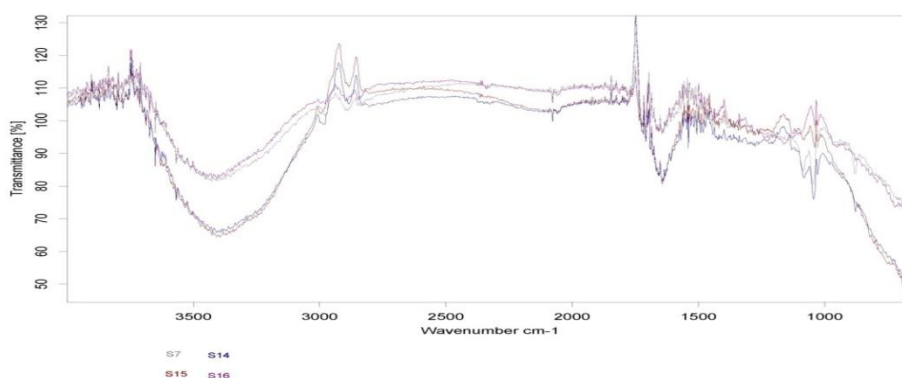


Figure 4.19: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S7, S14, S15 and S16 (group 12) oleoresin

4.6.4.12.1 Fourier transform infrared (FT-IR) spectroscopy of S7 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S7 oleoresin are represented in Figure 4.19 and Table 4.103. The water vapours presence was determined by the presence of band in the range of 3712.7cm^{-1} in S7 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of 3687.4cm^{-1} .

3614.9 cm^{-1} in S7 oleoresin sample. The presence of amines and aldehyde was revealed in S7 oleoresin sample due to the presence of band with the range of 3427.6-2978.2 and 2889.1-2839.2 cm^{-1} respectively. NH and N=C=S medium and strong stretching with a band at 2077.3 cm^{-1} attributes the presence of amines salts and isothiocyanates in S7 oleoresin sample. The presence of allenes, alkenes, anhydrides and acyl chlorides was detected in S7 oleoresin with generation of peak with the wavelength range of 1924.7-1812.8 cm^{-1} respectively. The band at 1781.5 cm^{-1} represents the alkenes and ketones, while anti-symmetric stretching at 1763.7 and 1724.6-1679.8 cm^{-1} band represents the presence of amides and aldehydes respectively. In S7 oleoresin, 1654.4 cm^{-1} band range attributes the presence of alkenes. Amides and amidines with the range of peak wavelength 1643.4-1631.3 and 1609.8 cm^{-1} respectively was observed.

Table 4.103: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S7 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.7	Medium	Stretching	Series of sharp peaks
Silicon Compounds	(R) ₃ Si-OH	O-H	3700.2	Medium	Stretching	Broad peak
Alcohols		O-H	3687.4	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.7		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3614.9	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.6	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3427.6	Weak	Stretching	Secondary amine
Amines	CH ₂ -NH-CH ₂	NH	2978.2	Weak	Stretching	Secondary amine
Aldehydes	C=CC=C-CHO	CH	2889.1	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-CHO	CH	2839.2	Weak	Stretching	CH stretching in Fermi resonance with overtone of

Classification	Group	Bond	Range	Intensity	Mode	Notes
						1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Allenes	C=C=C	C=C=C	1924.7	Strong	Stretching	
Alkenes	RCH=CH ₂	CH	1850.8	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Anhydrides		C=O	1838.7		Stretching	Two band
Acyl chlorides	R-C(O)-Cl	C=O	1812.8	Strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.5	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Amides	R-CO-NH-CO-NHR	C=O	1763.7	Strong	Antisymmetric stretching	noncyclic conjugated
Aldehydes	Ph-CHO	C=O	1724.6	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1699.0	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1679.8	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1654.4	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.4	Weak-medium	Stretching	
Amides	R-C(O)-NH-R	C=O	1631.3	Weak-medium	Stretching	
Amidines	N=CH-N	C=N	1609.8	Medium-strong	Stretching	Amidines
Amides	R-CO-NH-C	NH	1569.6	Strong	Combination	Amide II, combination of C-N

Classification	Group	Bond	Range	Intensity	Mode	Notes
						stretching and N-H bending
Amides	R-CO-NH-C	NH	1559.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1545.5	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.2	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1517.7	Strong	Asymmetric stretch	
Nitro compounds		N-O	1506.6	Strong	Asymmetric stretch	Alpha Beta Unsaturated Aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.0	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.9	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1470.9	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1442.2	Medium	Deformation	
Alcohols	HO-R-OH	OH	1419.2	Medium	Deformation	
Phenols		O-H	1384.0		Bending	
Amine		C-N	1342.8	Medium weak	Stretching	
Anhydrides	C=C-COOCOR	C-O-C	1146.3	Strong	Stretching	Absence of strong band is good negative information
Secondary Alcohols	HO-R-OH	C-O	1083.8	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1045.1	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.6	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1027.6	Strong	Stretching	
1,3 disubstituted		C-H	879.2	Strong	Bending	

4.6.4.12.2 Fourier transform infrared (FT-IR) spectroscopy of S14 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S14 oleoresin are represented in Figure 4.19 and Table 4.104. The water vapours presence was determined by the presence of band in the range of $3712.9\text{--}3733.5\text{ cm}^{-1}$ in S14 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3687.8\text{--}3650.7\text{ cm}^{-1}$ in S14 oleoresin sample. The presence of amine, aldehyde, amine salts and isothiocyanates was revealed in S14 oleoresin sample due to the presence of band with the range of $3428.6\text{--}2077.3\text{ cm}^{-1}$. The presence of alkenes and ketones was detected in S14 oleoresin with generation of peak with the wavelength range of 1781.1 cm^{-1} . The strong stretching at $1719.0\text{--}1690.4\text{ cm}^{-1}$ band represents the presence of aldehydes. The presence of alkenes, nitro compounds, alkanes and amides was detected in S14 oleoresin with generation of peak with the wavelength range of $1654.7\text{--}1480.9\text{ cm}^{-1}$. In S14 oleoresin, $1658.6\text{--}1506.3\text{ cm}^{-1}$ band range attributes the presence of aromatic, amides and nitro compounds. Alkyl ethyl ether and alcohols with the range of peak wavelength $1275.5\text{--}1025.2\text{ cm}^{-1}$ were observed.

Table 4.104: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S14 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.9	Medium	Stretching	Series of sharp peaks
Solvent Impurities	Water vapor phase	OH	3747.0	Medium	Stretching	Series of sharp peaks
Solvent Impurities	Water vapor phase	OH	3733.5	Medium	Stretching	Series of sharp peaks
Alcohols		O-H	3687.8	Medium, sharp	Stretching	Free
alcohols, phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.7	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.3	Medium	Stretching	Broad peak
Amines	CH ₂ -NH-CH ₂	NH	3428.6	Weak	Stretching	Secondary amine
Aldehyde		C-H	2802.9	Medium	Stretching	Doublet
Aldehydes	C=CC=C-CHO	CH	2883.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH		Medium	Stretching	Secondary amine salt; often multiple bands

Isothiocyanates	R-N=C=S	N=C=S	2077.3	variable-strong	stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.1	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1698.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.4	Strong	Stretching	Alpha beta unsaturated aldehyde
alkenes		-C=C-	1654.7	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.1	Weak-medium	Stretching	
Amides	R-CO-NH-C	NH	1569.6	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1545.2	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.2	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1517.4	Strong	Asymmetric stretch	
Nitro compounds		N-O	1506.4	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Alkanes	Cyclohexyl	CH	1480.9	Variable	Deformation	
Alcohols	HO-R-OH	OH	1424.3	Medium	Deformation	
Alkyl ethyl ether		C-O	1275.5	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1081.7	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1043.4	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1025.2	Strong	Stretching	

4.6.4.12.3 Fourier transform infrared (FT-IR) spectroscopy of S15 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S15 oleoresin are represented in Figure 4.19 and Table 4.105. The water vapours presence was determined by the presence of band in the range of 3712.9 cm^{-1} in S15 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3687.7\text{--}3650.6\text{ cm}^{-1}$ in S15 oleoresin sample. The presence of aliphatic primary amine, aldehyde, amine salts and isothiocyanates was revealed in S15 oleoresin sample due to the presence of band with the range of $3498.6\text{--}2077.3\text{ cm}^{-1}$. The presence of acyl chlorides was detected in S15 oleoresin with generation of peak with the wavelength range of 1813.0 cm^{-1} . The strong stretching at $1719.0\text{--}1690.4\text{ cm}^{-1}$ band represents the presence of aldehydes. The presence of alkenes, nitro compounds, alkanes and amides was detected in S15 oleoresin with generation of peak with the wavelength range of $1643.1\text{--}1506.5\text{ cm}^{-1}$. In S15 oleoresin, $1491.2\text{--}1419.5\text{ cm}^{-1}$ band range attributes the presence of aromatic, alkanes and alcohols. Alkyl ethyl ether and alcohols with the range of peak wavelength $1275.5\text{--}1038.9\text{ cm}^{-1}$ were observed.

Table 4.105: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S15 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.7	Medium	Stretching	Series of sharp peaks
Alcohols		O-H	3687.7	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.6		Stretching	Free hydroxyl
Alcohol		O-H	3650.6	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.8	Medium	Stretching	Broad peak
Aliphatic primary amines		N-H	3398.2	Medium	Stretching	
Aldehydes	C=CC=C-CHO	CH	2883.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Acyl chlorides	R-C(O)-Cl	C=O	1813.0	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde

Aldehydes	CH=CH-CHO	C=O	1707.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1698.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1658.7	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.1	Weak-medium	Stretching	
Amides	R-CO-NH-C	NH	1569.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Amides	R-CO-NH-C	NH	1559.1	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.2	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.5	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.2	Variable	Stretching	
Alkanes	Cyclohexyl	CH	1481.0	Variable	Deformation	
Alcohols	HO-R-OH	OH	1442.3	Medium	Deformation	
Alcohols	HO-R-OH	OH	1419.5	Medium	Deformation	
Alkyl ethyl ether		C-O	1275.5	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1081.5	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.9	Strong	Stretching	

4.6.4.12.4 Fourier transform infrared (FT-IR) spectroscopy of S16 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S16 oleoresin are represented in Figure 4.19 and Table 4.106. The water vapours presence was determined by the presence of band in the range of 3747-3712.9 cm^{-1} in S16 oleoresin sample. The phenols presence was determined by the presence of band in the range of 3687.7-3532.9 cm^{-1} in S16 oleoresin sample. The presence of amine and aldehydes was revealed in S16 oleoresin sample due to the presence of band with the range of 3451.7 and 2898.0-2848.3 cm^{-1} respectively. NH and N=C=S medium stretching with a band at 2077.3 cm^{-1} attributes the presence of amines salts and isothiocyanates in S16 oleoresin sample. The presence of allenes, alkenes, anhydrides and acyl chlorides was detected in S16 oleoresin with generation of peak with the wavelength range of 1924.7, 1850.8, 1838.2 and 1812.7 cm^{-1} respectively. The band at 1871.6 cm^{-1} represents the alkenes and ketones while C=H stretching at 1727.7-1679.6 cm^{-1} band represents the presence of aldehydes. In S16 oleoresin, 1658.9-1559.0 cm^{-1} band range attributes the presence of alkenes, amidines and amides. N-O stretching with the range of peak wavelength from 1545.4- 1506.7 cm^{-1} represents the nitro compounds. Alkane's presence was detected in S16 oleoresin with the band range of 1481.0 cm^{-1} OH stretch detection in S16 oleoresin results in the presence of alcohols. The presence of alkynes and alkane was detected in S16 oleoresin with generation of peak with the wavelength range of 689.2 and 672.7 cm^{-1} respectively.

Table 4.106: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S16 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3747.0	Medium	Stretching	Series of sharp peaks
Solvent Impurities	Water vapor phase	OH	3734.3	Medium	Stretching	Series of sharp peaks
Solvent Impurities	Water vapor phase	OH	3712.9	Medium	Stretching	Series of sharp peaks
			3700.3			
Alcohols		O-H	3687.7	Medium, sharp	Stretching	Free
alcohols, phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.7	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.5	Medium	Stretching	Broad peak
Alcohol		O-H	3532.9	Medium,	Stretching	Broad peak

				sharp		
			3506.0			
Amines	CH ₂ -NH-CH ₂	NH	3451.7	Weak	Stretching	Secondary Amine
Aldehydes	C=CC=C-CHO	CH	2898.0	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-CHO	CH	2848.3	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
			23339.9			
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Allenes	C=C=C	C=C=C	1924.7	Strong	Stretching	
Alkenes	RCH=CH ₂	CH	1850.8	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Anhydrides		C=O	1838.2		Stretching	Two band
Acyl chlorides	R-C(O)-Cl	C=O	1812.7	Strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.6	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	CH=CH-CHO	C=O	1727.7	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1708.0	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1699.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.8	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1679.6	Strong	Stretching	Alpha beta unsaturated aldehyde

Alkenes		--C=C--	1658.9	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.1	Weak-medium	Stretching	
Amidines	N=CH-N	C=N	1609.5	Medium-strong	Stretching	
Amides	R-CO-NH-C	NH	1563.6	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Amides	R-CO-NH-C	NH	1559.0	Strong	Combination	amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.2	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.7	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Alkanes	Cyclohexyl	CH	1481.0	Variable	Deformation	
Alcohols	$\text{R-CH}_2\text{-OH}$	OH	1470.7	Medium-weak	Deformation	
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.2	Variable	Stretching	
Alcohols	$\text{R-CH}_2\text{-OH}$	OH	1458.8	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1442.7	Medium	Deformation	
Alcohols	HO-R-OH	OH	1432.1	Medium	Deformation	
Alcohols	Ph-CHR-OH	OH	1357.2	Strong	Deformation	
Secondary Alcohols	$\text{(R)}_2\text{CH-OH}$	C-O	1161.1	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.0	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1027.5	Strong	Stretching	
alkynes		$\text{--C}\equiv\text{C--}$ H: C-H	689.2	Strong	Bending	
Alkenes	RCH=CHR cis	CH	672.7	Medium	Deformation	CH out-of-plane deformation

4.6.4.13 FT-IR spectra, characteristics peaks and functional groups at particular peaks of group 13 oleoresin

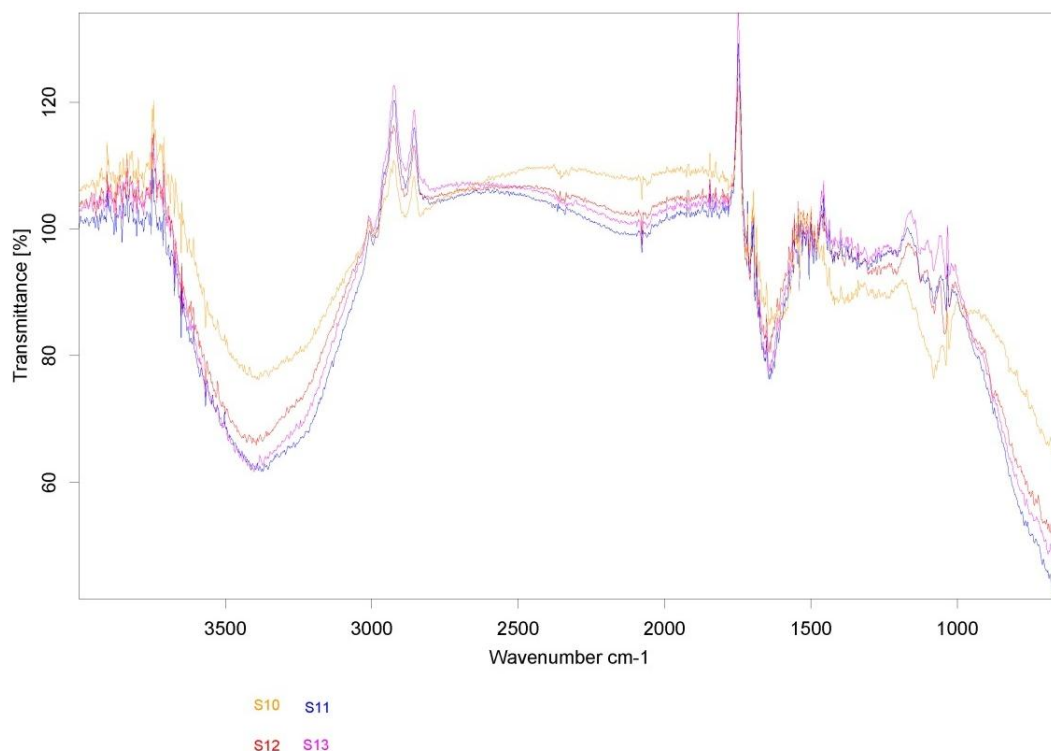


Figure 4.20: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S10, S11, S12 and S13(group 13) oleoresin

4.6.4.13.1 Fourier transform infrared (FT-IR) spectroscopy of S10 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S10 oleoresin are represented in Figure 4.20 and Table 4.107. The water vapours presence was determined by the presence of band in the range of 3712.7cm^{-1} in S10 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3687.8\text{--}3387.0\text{ cm}^{-1}$ in S10 oleoresin sample. The presence of aldehyde, amine salts and isothiocyanates was revealed in S10 oleoresin sample due to the presence of band with the range of $2883.3\text{--}2834.7$ and 2077.3cm^{-1} respectively with NH and N=C=S medium and strong stretching. The presence of anhydrides, alkenes & ketones was detected in S10 oleoresin with generation of peak with the wavelength range of 1838.5 , and 1781.3 cm^{-1} respectively. The strong stretching at $1718.9\text{--}1690.6\text{ cm}^{-1}$ band represents the presence of aldehydes. In S10 oleoresin, 1658.6 cm^{-1} band range attributes the presence of alkenes. Amides, amidines and amine with the range of peak wavelength $1643.1\text{--}1624.2$, 1609.6 and 1559.6 cm^{-1} respectively were observed. Nitro compounds and Amides with the range of peak wavelength $1545\text{--}1539.1$ and 1529.5 cm^{-1} respectively was observed. Aromatics, alkanes and alcohols with the range of peak wavelength $1480.5\text{--}1027.5\text{ cm}^{-1}$ were observed.

Table 4.107: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S10 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.8	Medium	Stretching	Series of sharp peaks
Alcohols		O-H	3687.8	Medium, sharp	Stretching	Free
Alcohols, Phenols		O-H	3673.7		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3629.5	Medium, sharp	Stretching	Broad peak
Alcohol		O-H	3615.3	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.2	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3387.0	Variable	Stretching	Hydrogen bonded, broad peak
Aldehydes	C=CC=C-CHO	CH	2883.8	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Aldehydes	C=CC=C-CHO	CH	2834.7	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Anhydrides		C=O	1838.5		Stretching	Two band
Alkenes	(R) ₂ C=CH ₂	CH	1781.3	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1718.9	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1708.0	Strong	Stretching	Alpha beta unsaturated aldehyde

Aldehydes	CH=CH-CHO	C=O	1699.1	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1658.6	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.1	Weak-medium	Stretching	
Amides	R-C(O)-NH-R	C=O	1624.2	Weak-medium	Stretching	
Amidines	N=CH-N	C=N	1609.6	Medium-strong	Stretching	Amidines
Amine		N-H	1559.6	Medium-strong	Bend	
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.1	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.5	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1506.3	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.0	Variable	Stretching	
Aromatics	1,2,3,4,5,6-substituted	Ring	1480.5	Variable	Stretching	
Alcohols	R-CH ₂ -OH	OH	1471.0	Medium-weak	Deformation	
Alcohols	HO-R-OH	OH	1406.8	Medium	Deformation	
Alcohols	R-CH ₂ -OH	OH	1459.0	Medium-weak	Deformation	
Alkane		C-H		Medium	Bending	Methyl group
Alcohols	HO-R-OH	OH	1442.2	Medium	Deformation	
Alcohols	HO-R-OH	OH	1419.2	Medium	Deformation	
Phenols		O-H	1384.3		Bending	
Secondary Alcohols	HO-R-OH	C-O	1080.3	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.7	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1027.5	Strong	Stretching	

4.6.4.13.2 Fourier transform infrared (FT-IR) spectroscopy of S11 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S11 oleoresin are represented in Figure 4.20 and Table 4.108. The water vapours presence was determined by the presence of band in the range of 3712.7cm^{-1} in S11 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3673.5\text{--}3377.0\text{ cm}^{-1}$ in S11 oleoresin sample. The presence of aldehyde, amine salts and isothiocyanates was revealed in S11 oleoresin sample due to the presence of band with the range of 2884.5 and 2077.3cm^{-1} respectively with NH and $\text{N}=\text{C}=\text{S}$ medium and strong stretching. The presence of acyl chlorides, aromatics and aldehydes was detected in S11 oleoresin with generation of peak with the wavelength range of $1812.9\text{--}1698.8\text{cm}^{-1}$. The medium stretching at 1654.8 and 1529.4 cm^{-1} band represents the presence of amides. In S11 oleoresin, $1545.6\text{--}1539.0$ and 1506.3 cm^{-1} band range attributes the presence of nitro compounds. Aromatics, alkanes and alcohols with the range of peak wavelength $1491.2\text{--}1079.0\text{ cm}^{-1}$ were observed.

Table 4.108: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S11 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.7	Medium	Stretching	Series of sharp peaks
Alcohols, Phenols		O–H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	$(\text{R})_3\text{Si-OH}$	O-H	3567.3	Medium	Stretching	Broad peak
Alcohols	Ph-CHR-OH	OH	3377.0	Variable	Stretching	Hydrogen bonded, broad peak
Aldehydes	$\text{C}=\text{CC}=\text{C}-\text{CHO}$	CH	2884.5	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH_2^+	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	$\text{R-N}=\text{C}=\text{S}$	$\text{N}=\text{C}=\text{S}$		Variable-strong	Stretching	
Acyl chlorides	R-C(O)-Cl	$\text{C}=\text{O}$	1812.9	Strong	Stretching	
Aldehydes	Ph-CHO	$\text{C}=\text{O}$	1718.0	Strong	Stretching	Aryl aldehyde
Aldehydes	$\text{CH}=\text{CH}-\text{CHO}$	$\text{C}=\text{O}$	1707.6	Strong	Stretching	Alpha beta unsaturated

						aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.5	Strong	Stretching	Alpha beta unsaturated aldehyde
Aromatic compound		C-H		Weak	Bending	
Aldehydes	CH=CH-CHO	C=O	1698.8	Strong	Stretching	Alpha beta unsaturated aldehyde
Aromatic compound		C-H		Weak	Bending	
Alkenes		-C=C-	1654.8	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.2	Weak-medium	Stretching	
Nitro compounds		N-O	1545.6	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.4	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.3	Strong	Asymmetric stretch	Alpha Beta Unsaturated Aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.2	Variable	Stretching	
Alkanes	Cyclohexyl	CH	1481.2	Variable	Deformation	
Alcohols	HO-R-OH	OH	1442.5	Medium	Deformation	
Alcohols	HO-R-OH	OH	1425.0	Medium	Deformation	
Phenols		O-H	1303.4		Bending	
Secondary Alcohols	HO-R-OH	C-O	1079.0	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.2	Strong	Stretching	

4.6.4.13.3 Fourier transform infrared (FT-IR) spectroscopy of S12 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S12 oleoresin are represented in Figure 4.20 and Table 4.109. The water vapours presence was determined by the presence of band in the range of 3712.9 cm^{-1} in S12 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3673.5\text{--}3650.8\text{ cm}^{-1}$ in S12 oleoresin sample. The presence of aliphatic primary amines, aldehyde, amine salts and isothiocyanates was revealed in S12 oleoresin sample due to the presence of

band with the range of 3394.2, 2884.2 and 2077.2 cm^{-1} respectively with NH and N=C=S medium and strong stretching. The presence of acyl chlorides, aromatics and aldehydes was detected in S12 oleoresin with generation of peak with the wavelength range of 1812.9-1690.5 cm^{-1} . The medium stretching at 1658.4 and 1643.7 cm^{-1} band represents the presence of alkenes and amides respectively. In S12 oleoresin, 1517.2 1506.7 cm^{-1} band range attributes the presence of nitro compounds. Aromatics, alkanes and alcohols with the range of peak wavelength 1481.3-1026.8 cm^{-1} were observed.

Table 4.109: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S12 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.9	Medium	Stretching	Series of sharp peaks
Alcohols, Phenols		O-H	3673.5		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Silicon Compounds	(R) ₃ Si-OH	O-H	3567.5	Medium	Stretching	Broad peak
Aliphatic primary amines		N-H	3394.2	Medium	Stretching	
Aldehydes	C=CC=C-CHO	CH	2884.2	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.2	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Acyl chlorides	R-C(O)-Cl	C=O	1812.9	Strong	Stretching	
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.9	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.5	Strong	Stretching	Alpha beta unsaturated aldehyde
Aromatic compound		C-H		Weak	Bending	
Aldehydes	CH=CH-CHO	C=O	1699.2	Strong	Stretching	Alpha beta unsaturated aldehyde
Aromatic compound		C-H		weak	Bending	

Alkenes		-C=C-	1658.4	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.7	Weak-medium	Stretching	
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.7	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro compounds		N-O	1517.2	Strong	Asymmetric stretch	
Nitro compounds		N-O	1506.7	Strong	Asymmetric stretch	Alpha Beta Unsaturated Aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.1	Variable	Stretching	
Alkanes	Cyclohexyl	CH	1481.3	Variable	Deformation	
Alcohols	HO-R-OH	OH	1442.7	Medium	Deformation	
Alcohols	HO-R-OH	OH	1419.4	Medium	Deformation	
Phenols		O-H	1384.7		Bending	Phenols
Secondary Alcohols	HO-R-OH	C-O	1077.9	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1042.9	Strong	Stretching	
Secondary Alcohols	HO-R-OH	C-O	1026.8	Strong	Stretching	

4.6.4.13.4 Fourier transform infrared (FT-IR) spectroscopy of S13 oleoresin

FT-IR spectra, characteristics peaks and functional groups at particular peaks of S13 oleoresin are represented in Figure 4.20 and Table 4.110. The water vapours presence was determined by the presence of band in the range of 3712.8 cm^{-1} in S13 oleoresin sample. The phenols (alcohol) presence was determined by the presence of band in the range of $3673.6\text{--}3650.8\text{ cm}^{-1}$ in S13 oleoresin sample. The presence of aldehyde, amine salts and isothiocyanates was revealed in S13 oleoresin sample due to the presence of band with the range of 2554.2 and 2077.3 cm^{-1} respectively with NH and N=C=S medium and strong stretching. The presence of alkenes and ketones was detected in S13 oleoresin with generation of peak with the wavelength range of 1781.7 cm^{-1} . The strong stretching at $1719.0\text{--}1690.4\text{ cm}^{-1}$ band represents the presence of aldehydes. In S13 oleoresin, $1658.6\text{--}1506.3\text{ cm}^{-1}$ band range attributes the presence of aromatic, amides and nitro compounds. Aromatics, alkanes and alcohols with the range of peak wavelength $1491.1\text{--}1038.3\text{ cm}^{-1}$ were observed.

Table 4.110: FT-IR spectra, characteristics peaks and functional groups at particular peaks of S13 oleoresin

Classification	Group	Bond	Range	Intensity	Mode	Notes
Solvent Impurities	Water vapor phase	OH	3712.8	Medium	Stretching	Series of sharp peaks
Alcohols, Phenols		O-H	3673.6		Stretching	Free hydroxyl
Alcohol		O-H	3650.8	Medium, sharp	Stretching	Broad peak
Aldehydes	C=CC=C-CHO	CH	2884.2	Weak	Stretching	CH stretching in Fermi resonance with overtone of 1390 CH rocking
Amine Salts	NH ₂ ⁺	NH	2077.3	Medium	Stretching	Secondary amine salt; often multiple bands
Isothiocyanates	R-N=C=S	N=C=S		Variable-strong	Stretching	
Alkenes	(R) ₂ C=CH ₂	CH	1781.7	Medium	Overtone	2 x CH ₂ out-of-plane deformation
Ketones	4C ring Ketones	C=O		Strong	Stretching	4 membered ring ketones
Aldehydes	Ph-CHO	C=O	1719.0	Strong	Stretching	Aryl aldehyde
Aldehydes	CH=CH-CHO	C=O	1707.6	Strong	Stretching	Alpha beta unsaturated aldehyde
Aldehydes	CH=CH-CHO	C=O	1690.4	Strong	Stretching	Alpha beta unsaturated aldehyde
Alkenes		-C=C-	1658.6	Medium	Stretch	
Amides	R-C(O)-NH-R	C=O	1643.0	Weak-medium	Stretching	
Nitro compounds		N-O	1545.4	Strong	Asymmetric stretch	Nitro compounds
Nitro compounds		N-O	1539.0	Strong	Asymmetric stretch	Nitro compounds
Amides	R-CO-NH-C	NH	1529.5	Strong	Combination	Amide II, combination of C-N stretching and N-H bending
Nitro Compounds		N-O	1506.3	Strong	Asymmetric stretch	Alpha beta unsaturated aldehyde
Aromatics	1,2,3,4,5,6-substituted	Ring	1491.1	Variable	Stretching	
Alcohols	HO-R-OH	OH	1425.0	Medium	Deformation	
Phenol		O-H	1305.3	Medium	Bending	
Secondary Alcohols	HO-R-OH	C-O	1080.7	Strong	Stretching	
Alcohols	HO-R-OH	C-O	1038.3	Strong	Stretching	

CHAPTER-V

SUMMARY

In the fresh green form of chillies, size (9.2 cm), acidity (0.47%), ash content (0.96%), total sugars (2.3gm/100 gm), total phenolics (181.89 mg/100ml GAE) and total chlorophyll content (1.04 mg/gm.) were observed highest for Punjab sindhuri variety while total solids (17.1%) ascorbic acid (99.5 mg/100 gm), total extractable colour (241 ASTA), crude fibre (6.65%) and capsaicin content (1.27) were notified highest for CH-27 variety. For fresh red form of chillies, crude fibre (9.81%), total phenolics (276.06 mg/ 100ml GAE), ascorbic acid (132.6 mg/ 100 gm) and capsaicin content (1.27%) were observed highest for CH-27 variety, while total extractable colour (429 ASTA), total carotenoids (12.05 mg/100 gm), beta carotene (5.85 mg/100 gm) and lycopene (3.2 µg/100 gm) were found to be highest for Punjab sindhuri variety.

For the mineral analysis, calcium (30.31 ppm), copper (0.154 ppm), magnesium (33.86 ppm) manganese (0.224 ppm) and sodium (5.766 ppm) were observed highest for CH-27 variety. In Punjab sindhuri red, iron content (1.46 ppm) was found to be highest. For antioxidant activity analysis, the per cent inhibition of DPPH (89.91%) and FRAP (2.29 mM/100 gm) was highest for CH-27 green variety. The highest peak intensities for phenolic components were observed for green form of CH-27 and Punjab sindhuri.

Both forms of CH-27 and Punjab sindhuri varieties were dried at 65°C and 85°C in tray drier and at -40°C in a freeze drier followed by packing in HDPE packs for further analysis. During the drying process, it was observed that the drying time for CH-27 variety (28 hours) was less compared to Punjab sindhuri (32-34 hours). The Punjab sindhuri chili was thick skinned chili variety that took more time for the drying. In CH-27 chilli variety, highest TSS (9.5°Brix) and total solids (95.21%) were at 65°C, while ash content (5.61%) was highly retained at 85°C. In case of Punjab sindhuri, highest TSS (9.1°Brix) was at 65°C while total solids (93.84%) and ash content (5.80%) were highly retained during freeze drying. For bioactive component analysis, the capsaicin content (5.66%), total phenolics (689.3 mg/100ml GAE) and total chlorophyll content (18.37) including chlorophyll *a* (10.55) and chlorophyll *b* (7.82) were highest for freeze dried green form of CH-27 and Punjab sindhuri chili variety. Other bioactive compounds including, ascorbic acid (660.16 mg/100 gm), total extractable colour (495 ASTA), total carotenoids (20 mg/100 gm), β-carotene (9.80 mg/100 gm) and lycopene (5.44 µg/100 gm) were highest for freeze dried Punjab sindhuri red variety. Freeze drying was found to be effective in retaining green and red colour of both varieties.

For mineral analysis, it was found that the calcium (22.2 ppm), iron (3.62 ppm), phosphorous (229.89 ppm) retention were highest in chillies dried at 85°C. The per cent inhibition of DPPH (92.51%) and FRAP (12.58 mM/100ml) were found to be highest for

freeze dried samples followed by samples dried at temperature 85°C. Antioxidant activity (per cent inhibition of DPPH) of CH-27 variety showed non-significant difference among each drying temperature.

The honey chili sauce was packed into glass containers (50gm). The samples were stored at room as well as refrigeration temperature. The physicochemical, phytochemical analysis, colour, antioxidant activity, mineral, microbiological, sensory evaluation and FTIR spectra were carried out of interval of 2 months. The processed product was found to be safe for consumption up to 8 months of storage with its nutrients intact. Total soluble solids (69.43°Brix), total solids (84.49%), ash content (2.86%), ascorbic acid (5.54mg/100 gm) and redness (*a* value) (4.84) were better retained in honey chili sauce containing Punjab sindhuri red variety. During storage, it was found that the total phenolics (679.46 mg/100ml GAE), β -carotene (308 μ g/100 gm), lycopene (4.59 μ g/100 gm), per cent inhibition of DPPH (52%), FRAP (3.43 mM/100ml) were highest for honey chili sauce containing CH-27 red. During storage, electrical conductivity (3.36 μ S/cm), total sugars (63.56 mg/100 gm) and reducing sugars (55.20 mg/100 gm) content were retained maximum in honey chili sauce containing Punjab sindhuri green variety.

The highest FTIR peak intensities of phenolic component were observed in honey chili sauce containing CH-27 green and Punjab sindhuri green. The total plate count (cfu/ml) was within the safest limit for all the samples till 8 months of storage. In the sensory evaluation, the highest sensory scores were recorded for honey chili sauce with Punjab sindhuri red during storage.

Chilies were processed into the chili paste, preserved with Class I and II preservative using hurdle technology and packed in retort pouches. During processing of chili into paste, highest yield was observed for Punjab sindhuri red (92.90%) followed by Punjab sindhuri green (90.50%).

Chili paste samples were treated with different treatments such as T2= 0.2 gm KMS + 0.2gm Sodium benzoate + 1ml acetic acid + 5gm NaCl, per 100 gm; T3= 0.3gm KMS + 0.3gm sodium benzoate + 1.5ml acetic acid + 10gm NaCl per 100 gm; T4= 0.5ml acetic acid per 100 gm + hot filling and T5= 1ml acetic acid per 100 gm + hot filling with one sample (T1) without any treatment as a control and stored at room as well as refrigeration temperature. During storage, it was observed that the chili paste samples treated with T2= 0.2gm KMS + 0.2gm Sodium benzoate + 1ml acetic acid + 5gm NaCl, per 100 gm were found to be best for retaining physicochemical, phytochemical and antioxidant activity. Overall total soluble solids (17.46°Brix), ash content (79.04%), FRAP (2.18mM/100ml), capsaicin (4.9%), ascorbic acid (61.84 mg/100 gm) were highly retained in CH-27 red while per cent inhibition of DPPH (75.42%) was highest for CH-27 green. Overall total solids (72.52%) , total phenolics (237.67 mg/100 gm GAE) were maximum in Punjab sindhuri green

while total carotenoids (18.83mg/100 gm), total colouring matter (672.57 ASTA), lycopene (5.25 mg/100 gm) and total chlorophyll (15.43 mg/100 gm) were highest in Punjab sindhuri red. The chili paste was found to be safe for consumption up to 10 months.

The red form of both dried chilies varieties were used for the extraction of oleoresins using refluxing and ultrasonication method. Two solvent i.e. acetone (50 and 90%) and ethanol (50 and 90%) were used in the present investigation. In the oleoresins extraction, the highest 7.1 per cent yield was observed for Punjab sindhuri treated with ultrasonication using 90 per cent acetone. In the colour analysis, the *a* value was found to be highest for oleoresins extracted from CH-27 using 90 per cent ethanol with ultrasonication followed by CH-27 using 50 per cent ethanol with ultrasonication and Punjab sindhuri with 90 per cent ethanol with refluxing at 25°C. The highest FTIR peak intensities for the phenolic group were observed for the oleoresins extracted with ultrasonication treatment.

Outcomes of the study

- The physicochemical and phytochemical analysis of green chili showed significantly highest total phenolics and total chlorophyll content in Punjab sindhuri while ascorbic acid, total extractable colour (capsanthin), crude fibre, antioxidant activity and capsaicin content were highest for CH-27 variety.
- The total phenolics, ascorbic acid and capsaicin content were significantly highest in CH-27 red variety, while total extractable colour (capsanthin), crude fibre, total carotenoids, beta carotene and lycopene content were higher in Punjab sindhuri red variety.
- In the mineral analysis, calcium, copper, manganese, magnesium and sodium were observed highest for CH-27 red variety while the iron was highest for Punjab sindhuri red.
- The highest peak intensities for phenolic component were observed for CH-27 green and Punjab sindhuri green.
- During drying process, the freeze drying method was found to be better for retention of capsaicin content, total phenolics and total chlorophyll content including chlorophyll *a* and chlorophyll *b* in both CH-27 and Punjab sindhuri green variety while ascorbic acid, total extractable colour, total carotenoids, β -carotene and lycopene content were highest in Punjab sindhuri red variety. The minerals and antioxidant activity were highly retained in tray drying at 85°C.
- The prepared honey chili sauce was found to be safe for consumption up to 8 months of storage. Higher retention of total phenolics, β -carotene, lycopene content, DPPH, FRAP, redness (color *a* value) were observed for honey chili sauce containing CH-27 red while total sugars and reducing sugars content were highly retained in honey chili sauce

containing Punjab sindhuri green. Total soluble solids, total solids, ash content and ascorbic acid were highly retained in honey chili sauce containing Punjab sindhuri red.

- The highest FTIR peak intensities of the phenolic component were observed in honey chili sauce containing CH-27 green and Punjab sindhuri green. During the sensory evaluation, highest sensory scores were recorded for honey chili sauce containing Punjab sindhuri red due to its bright red color.
- During the processing of chili into paste, highest yield was observed for Punjab sindhuri variety. The treatment containing 0.2 gm KMS + 0.2 gm Sodium benzoate + 1 ml acetic acid + 5 gm NaCl/100 gm of chili paste was found to be effective in retaining physicochemical, phytochemical characteristics and antioxidant activity of the chili paste during 10 months storage duration.
- During the oleoresins extraction, ultrasonication technique resulted in the highest extraction yield (7.1%) from Punjab sindhuri red with 90 per cent acetone.
- During the colour analysis, the highest color *a* value (redness) was observed for Punjab sindhuri with 90 per cent ethanol followed by CH-27 with 90 per cent acetone, Punjab sindhuri with 50 per cent ethanol and CH-27 with 90 per cent ethanol.
- The qualitative assessment of the effect of both oleoresin extraction method (refluxing and ultrasonication) illustrated by Fourier transmission infrared spectroscopy (FTIR) revealed higher FTIR peak intensities of the phenolic group in oleoresin samples extracted with ultrasonication method

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ANNEXURE-I

Cost of honey chilli sauce	
Raw material	Cost (Rs.)/100gm
Ingredients	
Honey	50
Garlic	0.7
Salt	0.06
Acetic acid	11
Chilli flakes	5
Xanthan gum	2
Glass container (50gm)	5
Labeling cost	2
Processing cost	5
Total cost	80.76

LIST OF PUBLISHED/ACCEPTED/SUBMITTED RESEARCH ARTICLES

Sr. no.	Publication	Journal	NAAS rating	Status
1.	Comparative evaluation of chilli varieties: effect of harvesting stages on physicochemical and phytochemical compounds"	Israel Journal of Plant Sciences	6.91	Under review
2.	"Effect of chili varieties and storage conditions on quality attributes of honey chili sauce: a preservation study	Journal of Food Processing and Preservation	7.29	Under revision



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Comparative evaluation of chilli varieties: effect of harvesting stages on physicochemical and phytochemical compounds

Running head: Comparative Evaluation of CH-27 and Punjab sindhuri

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ABSTRACT

An attempt has been made for the comparative evaluation of CH-27 and Punjab sindhuri chilli varieties on the basis of physico-chemical and phytochemical potential. While comparing the nutritional profile of both chilli varieties, the green form of Punjab sindhuri exhibited highest total phenolics (181.89 mg/100ml GAE), total chlorophyll (10.43) and CH-27 exhibited highest ascorbic acid (99.5 mg/100 gm), crude fibre (6.65%), total extractable color (241 ASTA) and capsaicin content (1.27%). Considering red form of both chilli varieties, CH-27 was highest in total phenolics (276.06 mg/100ml GAE), ascorbic acid (132.6 mg/100 gm), crude fibre (9.81%) and capsaicin content (1.17%) while Punjab sindhuri exhibited high total extractable color (429 ASTA), total carotenoids (12.05 mg/100 gm), β -carotene (5.85 mg/100 gm) and lycopene content (3.2 μ g/100 gm). The results support that the antioxidant activity in terms of DPPH (89.91 %) and FRAP (2.29 mM/100 gm) was highest for CH-27 green. Calcium, copper, manganese and sodium was effectively highest for CH-27 red, while iron was highest in Punjab sindhuri red. This study shows the comparative nutritional profiling of CH-27 and Punjab sindhuri chilli varieties at green and after maturation red stage.

Key words

CH-27, Punjab Sindhuri, Capsaicin, Fourier transmission infrared spectroscopy

Introduction

Throughout the world, spices are used as esoteric food adjuncts for food flavours. The adverse climate conditions in India are well situated for the cultivation of all kind of spices (Krithika *et al* 2014). Chilli belongs to genus *Capsicum* under *Solanaceae* family. *Capsicum annuum* and *Capsicum frutescens* are well known in India with *Capsicum annuum* most cultivated species. Fresh chilli is an important commercial crop that has been known for its importance as a part of human diet in the form of spice, condiment and vegetable since the commencing of civilization (Swapan *et al* 2017).

Chillies are considered as a good source of Vitamin A, B5, B6, ascorbic acid, amino acids, minerals, phytochemicals (Saleh *et al* 2018). Chilli is also considered as functional food due to the presence of capsaicin. Capsaicin is an alkaloid responsible for the pungency of chillies, antioxidant, anti-cancer, antiarthritic and analgesic properties and has miscellaneous prophylactic and therapeutic uses (Swapan *et al* 2017). Some studies evaluated the antiobesity properties of capsaicin, as it increases the thermogenesis and energy expenditure results in inhibition of fat accumulation. Apart from the spicy character, the color of chilli is also an important character that attracts the consumer. The red color of chilli is due the presence of carotenoids. The major carotenoids present in red chilli are capsanthin and capsorubin and represents its antioxidant activity (Arumingtyas *et al* 2019). Capsanthin and its natural fatty esters proved as better free radical scavengers than beta carotene. Capsanthin component of chilli decompose more slowly as compare to other carotenoids that results in last longer free radical scavenging property (Eggersdorfer and Wyss, 2018).

The CH-27 hybrid chilli variety is resistant to fruit rot, leaf curl virus, root knot nematode and tolerant to thrip and mite. This variety is also suitable for processing. The Punjab sindhuri is a highly yielding variety that is moderately resistant to leaf curl, die-back and tolerant to aphids, yellow mites (Dhaliwal *et al* 2013 and Dhaliwal *et al* 2015). Harvesting of crop at proper stage of maturity is important to maintain the nutritional as well as storage quality of crop for longer period of time. CH-27 and Punjab sindhuri chilli varieties were recommended for commercial cultivation by Punjab Agricultural University, Ludhiana, but the complete nutritional composition before and after maturation of these both varieties are not available currently. Therefore, an attempt has been made in the present study to perform the comparative analysis of these chilli varieties at green and red stage so that they could attract the researchers and industrialists for their value addition in coming future.

Materials and method

Chilli (*Capsicum frutescens*) varieties CH-27 and Punjab sindhuri were obtained from Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India. Green form of CH-27 and Punjab sindhuri were harvested after 20 days of flowering while the red form of CH-27 and Punjab sindhuri harvesting duration was 40-45 days after flowering. The harvested chilli were collected into mesh plastic bags and stored in to cold stores (7±2°C) till the further analysis. The raw material was selected on the basis of uniform size and color.

Physicochemical properties

A known quantity of sample (10 gm) was blended with 3-4 ml of distilled water and analysed directly with hand refractrometer (Erma, Japan) and pH meter (Mettler Toledo) to obtain total soluble solids (°Brix) and pH value respectively. The size in each respective group of chilli was obtained using measuring scale. The titratable acidity and ash content (%) were determined with standard AOAC methods. The titratable acidity results were expressed in terms of % citric acid. The total sugar was determined using colorimetric phenol-sulfuric acid method (Ranganna, 1986). Crude fibre was determined using fibertec (Foss instrument, Sweden) by acid-base digestion with H₂SO₄ (1.25%) and NaOH (1.25%) respectively.

Color analysis

The color of the samples was measured using Hunter Color Lab (Ultra Scan, Hunter Lab, USA). The results were expressed in terms of *L* , *a** and *b** values as described by Buve *et al* (2018). The total color change (ΔE) was calculated with means values using following equation

$$\Delta E = \sqrt{(L_0 - L_1)^2 + (a_0 - a_1)^2 + (b_0 - b_1)^2} \quad \text{Equ. 1}$$

Antioxidant activity

Antioxidant activity of chilli varieties were determined in terms of 2,2 Diphenyl 1 picrylhydrazyl (DPPH) and Feric reducing antioxidant power (FRAP) assay. A known quantity (5gm) was refluxed at 30°C for 2 hours using 80 per cent methanol. After 2 hours, the refluxed sample was filtered in 100ml volumetric flask using Whatman no. 4 filter paper. The remaining residue was again refluxed for 1 hour using 80 per cent methanol followed by filtration in same volumetric flask. The final volume made up to mark using 80 per cent methanol. The collected filtrate was used in standard methods described by Goraya and Bajwa, 2015 and Stratil *et al* 2008 used for DPPH and FRAP estimation respectively. The Trolox and Ferrous sulphate were used as standards for DPPH and FRAP respectively.

Bioactive compound analysis

The total phenolic content of samples was determined using Folin-Ciocalteu reagent according to method described by Singleton *et al* 1965. Standard titrimetric method described by AOAC (2000) was used for the estimation of ascorbic acid. 2,6 Dichlorophenol Indophenol dye solution was used that gets reduced by the ascorbic acid. Total chlorophyll, α , β carotene and lycopene were determined following the methods described by Ranganna, 1986 using a spectrophotometer. A colorimetric method described by Bajaj and Kaur, 1979 was used for the estimation of Capsaicin content using Folin-Ciocalteu. Total extractable colour (ASTA) was estimated using American Spice Trade Association sample. The known quantity (1gm) of crushed sample was taken into 100ml volumetric flask and filled with pure acetone up to the mark. The samples were incubated under dark conditions at room temperature ($34\pm 3^\circ\text{C}$) for 14 hours. The absorbance of the extract was noted at 460nm against acetone as blank. The ASTA unit calculated using following equation

$$\text{ASTA} = \frac{\text{OD at } 460\text{nm} \times 16.4}{\text{Weight of sample}}$$

Fourier transmission infrared (FT-IR) spectroscopy

FT-IR spectroscopy was employed to further characterize the presence of different components in terms of functional groups. The structural components of the fresh samples were accessed with Fourier transform infrared spectrometer (Thermo Scientific Nicolet 6700 spectrometer) using an attenuated total reflection (ATR) accessory and deuterated triglycine sulphate detector. FTIR spectra was carried out at Electron Microscopy and Nano science Laboratory, Punjab Agricultural University, Ludhiana. Fresh chilli samples were crushed into fine paste for FTIR spectroscopy. A small quantity of sample was placed on ATR for the measurement of peak intensity. The spectra were collected in the range of $4000\text{--}400\text{ cm}^{-1}$, with a 4 cm^{-1} resolution accumulating 32 scans at room temperature ($28\pm 2^\circ\text{C}$). After the first spectrum, the ATR was cleaned with Iso-propyl alcohol before the analysis of next sample.

Mineral analysis

The inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Thermo ICAP 6000 series, England) was used for the estimation of mineral content. A known quantity (1gm) of sample was dissolved into 10ml of nitric acid:perchloric acid (3:1) and incubated at room temperature ($30\pm 3^\circ\text{C}$) for overnight. The digestion of samples was conducted at hot plate (150°C) till the complete decomposition of material occurs. In the left over crystal clear drops, double distilled water was added and volume made up to 25ml with the same and analysed with ICP-AES that provides the list of present mineral profile with quantity on the

computer screen.

Statistical analysis

ANOVA was carried out on the data applying the function of Post hoc, Tukey and Duncan using SPSS 16 software. Homogeneity of variance was adapted and results were expressed as means $\pm$ standard deviation.

Results and discussion

The physicochemical properties of fresh CH-27 and Punjab sindhuri cultivars are depicted in Table 1. There was a significant difference in the size of both cultivars. The maximum fruit length was observed in Punjab sindhuri red with minimum in CH-27 green. Similar results were observed by Dhaliwal *et al* 2013 and Dhaliwal *et al* 2015. Similar trend was observed in total soluble solids (TSS). The TSS was less in green cultivar whereas after maturation, the TSS was increased up to 33-50% as observed in red cultivars. These results agreed those reported by Bernardo *et al* 2008. A significant increase of 17-22, 16-32 and 70-88.65% in total solids, acidity and ash content was observed after maturation respectively. A significant difference of crude fibre content was observed in CH-27 green and red, while in Punjab sindhuri, the difference was non-significant.

The bioactive components of CH-27 and Punjab sindhuri chilli varieties are depicted in Table 2. The 80% radical scavenging activity was represented by the presence of phenolic components. The red form of CH-27 (276.06 mg/100ml GAE) and Punjab sindhuri (233.56 mg/100ml GAE) contains the highest amount of total phenolics followed by Punjab sindhuri green and CH-27 green. The results of the present study are in agreement of Kumar *et al* 2010 who reported total phenolics increase during ripening of chilli pepper. The results showed that there were significant differences ($p \leq 0.05$) for the ascorbic acid content for all the samples. Highest ascorbic acid content was observed for red form of CH-27 (132.6 mg/100 gm) and Punjab sindhuri (107.63 mg/100 gm). A range of 76.3-161.3 mg/100 gm of fresh weight of ascorbic acid in various varieties of green chilli was reported by Litoriya *et al* 2014. CH-27 green (1.27%) and red (1.17%) recorded the highest capsaicin content followed by Punjab sindhuri green (1.05%) and Punjab sindhuri red (0.84%). The results are in close agreement with Dhaliwal *et al* 2013 who reported 1 per cent capsaicin content Punjab sindhuri while 0.42 and 0.68 per cent capsaicin content in CH-27 green and red contain respectively. Significant difference ($p \leq 0.05$) was observed for total extractable color of both chilli varieties with highest value for Punjab sindhuri red (429 ASTA) followed by CH-27 red (328 ASTA), CH-27 green (241 ASTA) and Punjab sindhuri green (178 ASTA). Similar

results were reported by Dhaliwal *et al* 2013 and Dhaliwal *et al* 2015. Total carotenoids, β -carotene and lycopene content were highest for Punjab sindhuri red. The results are in agreement of Hornero-Mendez *et al* 2000; Pritwani and Mathur 2017; Ozgur *et al* 2011.

The antioxidant activity in terms of DPPH and FRAP is represented in Table 2. In this study, the highest DPPH scavenging activity was shown by extract of CH-27 chilli variety (88-89%) followed by Punjab sindhuri red (80.6%) and green (76.5%). Similar results were observed for FRAP values with highest antioxidant activity for CH-27 (2.29 mM/100 gm). Similar results were reported by Sim and Sil 2008; Keles *et al* 2016.

In this study, we measured the colour value in terms of L^* , a^* and b^* as depicted in Figure 1, where L^* indicate lightness of the samples; 100 = white, 0 = black; a^* designate redness when positive; greenness when negative; b^* represent yellowness when positive, blueness when negative. The mentioned results indicating bright red vivid colour was observed for CH-27 red (-11.32) compared to Punjab sindhuri red (-2.37). Similar trend for greenness of CH-27 (21.56) and Punjab sindhuri (16.48) was observed. Ergunes and Tarhan, 2006 reported that the fresh red pepper had L^* a^* b^* values of 33.66, 37.79 and 15.71 respectively.

The mineral composition of CH-27 and Punjab sindhuri is represented in Table 3. There was a significant difference ($p \leq 0.05$) in calcium content of CH-27 and Punjab sindhuri. Highest calcium was observed for red form of CH-27 (30.31) and Punjab sindhuri (26.79). The iron content significantly found higher for Punjab sindhuri red (1.46) followed by CH-27 green (1.28), Punjab sindhuri green (1.25) and CH-27 red (1.20). The phosphorus was highest for Punjab sindhuri green (73.37) followed by CH-27 red (58.77), CH-27 green (61.95) and Punjab sindhuri red (50.39). Sulphur and zinc content was found highest for the Punjab sindhuri green (46.42 and 0.79) and red form (38.86 and 0.55).

FT-IR spectra, characteristics peaks and functional groups at particular peaks of CH-27 green, red and Punjab sindhuri green and red form chilli varieties are represented in Figure 2 and Table 4. The phenols presence was determined by the presence of band in the range of $3430-3674\text{ cm}^{-1}$ in CH-27 and Punjab sindhuri chilli varieties. The presence of amino acids was revealed in CH-27 green and red due to the presence of band with the range of 3430 and 3453 cm^{-1} respectively. C-H medium stretching with a band at 2918.5 and 2851.4 cm^{-1} attributes the presence of Alkanes in Punjab sindhuri red variety. The presence of isothiocyanates was detected in both forms of CH-27 and Punjab sindhuri with generation of peak with the wavelength range of 2077 cm^{-1} . The band at 1728 cm^{-1} in case of CH-27 green and Punjab sindhuri red representing the α , β unsaturated ester, while C=O stretching at

1706.9 cm^{-1} band in CH-27 red represents the conjugated aldehydes. In Punjab sindhuri red, 1691.3 cm^{-1} band range attributes the presence of primary amides. N-O stretching with the range of peak wavelength from 1506.4 to 1544.8 cm^{-1} in both forms of CH-27 and Punjab sindhuri chilli varieties represents the nitro compounds. Alkyl aryl ether presence was detected in CH-27 green, red and Punjab sindhuri green with the band range of 1236.8, 1242.4 and 1239.9 cm^{-1} respectively. C-O stretch detection in both chilli varieties results in the presence of alcohol. C-F stretch with band 1013.3 cm^{-1} in CH-27 green attributes the presence of Alkyl halides. =C-H bend with the peak range of 961.8 to 962.7 cm^{-1} in both forms of CH-27 and Punjab sindhuri reveals the presence of Alkenes. Benzene derivatives and alkyl halide were detected in Punjab sindhuri red with band range of 720.5 and 661.8 cm^{-1} respectively. Similar results were reported by Linhegowda *et al* 2012; El Kaaby *et al* 2016.

Conclusions

Green form of CH-27 contains more ascorbic acid, total colouring matter, crude fibre and capsaicin content, while green form of Punjab sindhuri represents more total phenolics and chlorophyll content. The red form of CH-27 was rich in total phenolics, ascorbic acid and capsaicin content while total extractable colour, crude fibre, total carotenoids, beta carotene and lycopene was highest for Punjab sindhuri. In mineral profiling, it was observed that CH-27 red contains highest calcium, copper, Maganese and sodium while Iron was higher in Punjab sindhuri red. Antioxidant activity was highest for CH-27 green. FTIR spectra showed highest peak intensities of phenolic components for green form of CH-27 and Punjab sindhuri. The results of the present investigation expand the knowledge regarding variation in physicochemical, phytochemical, colour, mineral and FT-IR profiling of CH-27 and Punjab sindhuri at different stage of harvesting.

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Disclosure statement

The authors declare that they have no conflict of interest.

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Table 1.Physicochemical analysis of CH-27 (green and red) and Punjab sindhuri (Green and red) chilli varieties

Parameters	CH 27 GREEN	CH 27 RED	PS GREEN	PS RED
Size (cm)	6.3±0.10 ^b	6.1±0.10 ^b	9.2±0.05 ^a	9.4±0.15 ^a
TSS (°B)	3±0.76 ^c	6±0.55 ^a	3±0.15 ^c	4.5±0.30 ^b
Total Solids (%)	17.1±0.10 ^c	20.7±0.20 ^a	14±0.12 ^d	18.1±0.10 ^b
Acidity (%)	0.17±0.01 ^d	0.25±0.01 ^c	0.47±0.01 ^b	0.56±0.04 ^a
Ash content (%)	1.94±0.10 ^c	6.47±0.20 ^b	0.96±0.03 ^d	8.44±0.08 ^a
Total sugars (gm/100 gm)	8.2±0.10 ^a	7.4±0.11 ^b	2.3±0.05 ^c	7.4±0.10 ^b
Crude fibre (%)	29.65±0.75 ^c	46.81±0.53 ^a	32.36±2.50 ^{bc}	35.18±0.72 ^b
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; °B*= Degree Brix;; Values in a column and row of table with different superscripts differ significantly				

Table 2.Bioactive component and antioxidant activity of CH-27 (green and red) and Punjab sindhuri (Green and red) chilli varieties

Parameters	CH 27 GREEN	CH 27 RED	PS GREEN	PS RED
Total phenolics (mg/100ml GAE)	143.47±2.50 ^d	276.06±16.02 ^a	181.89±12.70 ^c	233.56±14.00 ^b
Ascorbic acid (mg/100 gm)	99.5±0.52 ^c	132.6±1.29 ^a	73.8±0.72 ^d	107.63±0.50 ^b
Capsaicin (%)	1.27±0.04 ^a	1.17±0.07 ^{ab}	1.05±0.04 ^b	0.84±0.02 ^c
Total extractable color (ASTA)	2.41±0.01 ^c	3.28±0.01 ^b	1.78±0.02 ^d	4.29±0.02 ^a
Total chlorophyll	4.41±0.25 ^b	-	10.43±0.40 ^a	-
Chlorophyll a	3.25±0.25 ^b	-	7.18±0.52 ^a	-
Chlorophyll b	1.16±0.03 ^b	-	3.24±0.25 ^a	-
Total chlorophyll (mg/gm)	0.44±0.03 ^b	-	1.04±0.02 ^a	-
Total carotenoids (mg/100 gm)	6.43±0.24 ^d	9.7±0.15 ^b	6.82±0.03 ^c	12.05±0.01 ^a
β carotene (mg/100 gm)	1.99±0.03 ^d	3.06±0.02 ^b	2.17±0.02 ^c	5.85±0.04 ^a
Lycopene (µg/100 gm)	-	1.7±0.15 ^b	-	3.2±0.25 ^a
DPPH (%)	89.91±4.49 ^a	88.96±4.44 ^b	76.5±6.12 ^d	80.6±7.21 ^c
FRAP (mM/100 gm)	2.29±0.18 ^a	2.28±0.10 ^a	1.62±0.12 ^c	2.10±0.17 ^b
PS= Punjab Sindhuri; n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly (p≤0.05) ; GAE= Gallic acid equivalent; ASTA= American Spice Trade Association; DPPH= 2,2-diphenyl-1-picrylhydrazyl; FRAP= Ferric reducing antioxidant power				

Table 3.Mineral content (ppm)of CH-27 and Punjab sindhuri chilli varieties

Mineral	CH-27 (green)	CH-27 (red)	Punjab Sindhuri (green)	Punjab Sindhuri (red)
Calcium	23.44±0.73 ^c	30.31±0.42 ^a	21.48±0.01 ^d	26.79±1.10 ^b
Chromium	0.012±0.0005 ^a	0.013±0.002 ^a	0.005±0.001 ^b	0.006±0.001 ^b
Copper	0.154±0.004 ^a	0.147±0.0036 ^a	0.18±0.026 ^a	0.096±0.004 ^b
Iron	1.28±0.009 ^b	1.20±0.005 ^d	1.25±0.004 ^c	1.46±0.002 ^a
Magnesium	33.86±0.31 ^a	32.08±0.03 ^b	27.43±0.04 ^c	20.3±0.67 ^d
Manganese	0.19±0.003 ^b	0.22±0.003 ^a	0.16±0.002 ^d	0.18±0.004 ^c
Sodium	3.64±0.003 ^d	5.77±0.003 ^a	5.21±0.003 ^b	4.62±0.005 ^c
Phosphorus	61.95±0.04 ^c	58.77±0.04 ^b	73.37±0.53 ^a	50.39±0.05 ^d
Sulphur	38.25 ^b ±0.27	33.74 ^c ±0.04	46.42±0.45 ^a	38.86±0.07 ^b
Zinc	0.43±0.019 ^d	0.49±0.001 ^{bc}	0.79±0.058 ^a	0.55±0.005 ^b
n = 3; Values are Mean ± Standard Deviation; Values in a column and row of table with different superscripts differ significantly				

Table 4.FTIR frequency range, compound class and functional groups of CH-27 and Punjab sindhuri chilli varieties

Compound class	Functional groups	Frequency range (cm ⁻¹)			
		CH-27 Green)	CH-27 (Red)	PS (Green)	PS (Red)
Alcohol, phenols	O-H stretching vibration	3815.5	-	3815.4	3803.0
		3779.2	-	3779.5	-
		3720.8	-	3733.2	3734.0
Alcohol, phenols	O-H stretching (medium sharp)	3645.9	3674.2	3674.1	3674.2
Alcohol , phenols	O-H stretching (medium sharp)	3568.2	3661.3	3661.2	-
Amine	N-H (Medium)	3430.3	3453.1	-	-
Alkanes	C-H stretching (medium)				2918.5
Alkanes	C-H stretching (medium)	-	-	-	2851.4
Isothiocynates	N=C=S stretching (strong)	2077.1	2077.2	2077.4	2077.1
α,β unsaturated ester	C=O stretching (strong)	1728.4	-	-	1728.0
Conjugated aldehydes	C=O stretching (strong)		1706.9		

Primary amide	C=O stretching (strong)	-	-	-	1691.3
Alkene	C=C stretching (weak)	-	-	-	1664.2
Alkene	C=C stretching (strong)	1643.4		1638.1	-
Nitro compound	N-O stretching (strong)	1544.8	-	-	-
Nitro compound	N-O stretching (strong)	1519.9	-	1521.8	1520.8
Nitro compound	N-O stretching (strong)	1506.4	1506.0	-	-
Alkanes	C-H bend	1443.6	1442.2	1442.8	1467.5
Alkyl aryl ether	C-O stretching (Strong)	1236.8	1242.4	1239.9	
Alcohol RR'R''C-OH (3°)	C-O stretch	1165.8	-	-	1170.7
Alcohol RR'CH-OH (2°) or C=C-CRR'-OH	C-O stretch (Medium to strong)	1104.8	1104.9	1104.9	-
Alkyl halide R-F	C-F stretch (Very strong)	1013.3	-	-	-
Alkenes <i>trans</i> RCH=CHR'	=C-H bend	962.7	961.8	962.3	962.2
1,2,3 trisubstituted	C-H bending (Strong)	882.5	-	-	
Benzene derivative		-	-	-	720.5
Alkyl halide	C-Cl (Strong)	-	-	-	661.8
*PS= Punjab sindhuri					

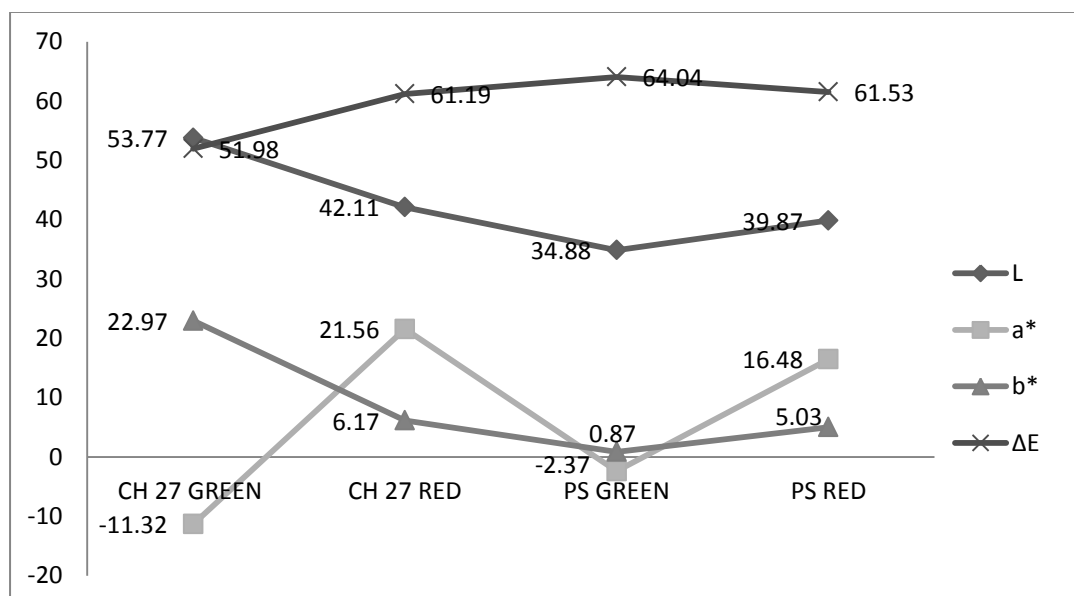
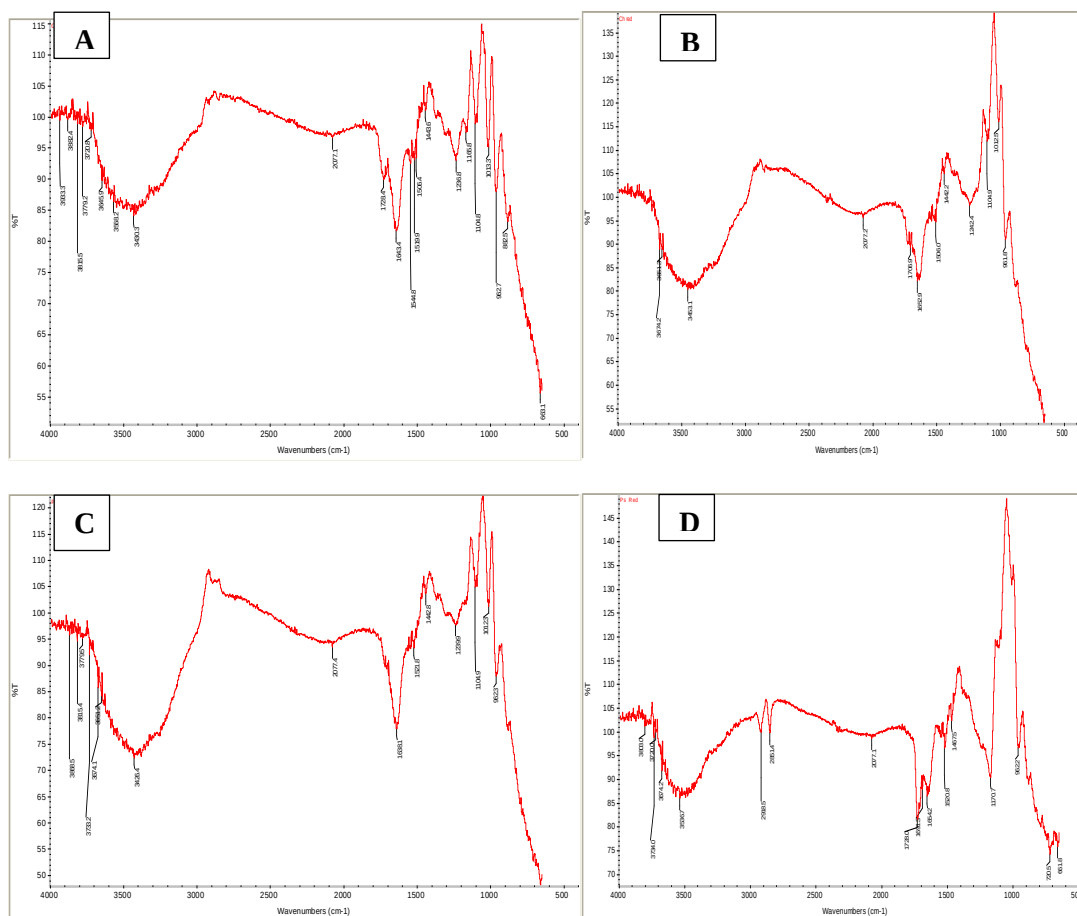


Figure 1. Colour values for CH-27 and Punjab sindhuri chilli varieties



A= CH-27 green; B= CH-27 red; C= Punjab sindhuri green; D= Punjab sindhuri red

Figure 2. FT-IR spectra of CH-27 and Punjab sindhuri chilli varieties

3 of many

Hangouts

 Manpreet ▾

 **2 Invites**
Subhash Birwal, Meet Kokri

Inbox x

Tue, Dec 1, 2020, 10:22 AM

Dear Dr. Aggarwal:

Your manuscript entitled "Effect of chili varieties and storage conditions on quality attributes of honey chili sauce: a preservation study" by Kaur, Manpreet; Aggarwal, Poonam; Kumar, Vikas, has been successfully submitted online and is presently being given full consideration for publication in the *Journal of Food Processing and Preservation*.

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Manpreet Kaur

Effect of chili varieties and storage conditions on quality attributes of honey chili sauce: a preservation study

Short title: Preservation of honey chili sauce

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Abstract

Honey chili sauce was standardized using green and red CH-27 and Punjab sindhuri chili varieties. The samples were stored at ambient ($25\pm 2^{\circ}\text{C}$) as well as refrigeration ($4\pm 2^{\circ}\text{C}$) temperature and analysed up to 8 months with 2 months interval. Honey chili sauce with CH-27 red was found to be significantly ($p\leq 0.05$) highest in total phenolic components, beta carotene, lycopene and antioxidant activities while total solids, ash content and ascorbic acid content were highly retained in samples containing Punjab sindhuri red chili variety. All the samples were acceptable even after 8 months of storage on the basis of their sensory scores with intact nutrients.

Key words

Honey, Chili, Chili sauce, FT-IR

Novelty Impact Statement

Honey chili sauce containing Punjab sindhuri red chili scored highest sensory scores due to its bright red colour. Honey chili sauce may add spice and flavour to cuisine and can be used as a wonderful dip aside a dish. Value addition of chili with honey can add flavour as well as health promoting properties of both to the food.

1. INTRODUCTION

One of the nature's wonder and remarkable gift, honey is an organic, viscous and natural sweet substance. From the centuries, it has been used in various food products as a sweetener.

The moisture absorbing capacity of honey helps in the preservation of bakery products. It is used as an energy product that directly absorbed into blood without any digestion. Honey is also known for its various properties including wound healing, antidiabetic, antioxidants, immune boosting, anti-inflammatory, antimicrobial, anticarcinogenic, antihelminthic, cardio protective, neuromodulatory action etc. (Abeshu and Geleta, 2016; Liyanage and Hordugoda, 2017; De Oliveria, 2018). The major nutritional and health relevant component of honey is carbohydrate (fructose and glucose) with a smaller amount of proteins, enzymes, amino acids, minerals, polyphenols and aroma compounds (Bogdanov et al. 2008).

Capsicum annuum L is an important commercial crop widely cultivated worldwide. Colour, taste, pungency characteristics of chili is responsible for its popularity. Chili is a good source of vitamins, minerals, phytochemicals including flavonoids, carotenoids, phenolics, saponins, cyanogenic glycosides, stilbenes, tannins, alkaloids, amines, betalains capsaicin, homocapsaicin, dihydrocapsaicin, nordihydrocapsaicin, homodihydrocapsaicin. Anti tumor, analgesic, anti-inflammatory, anticancer represents the pharmaceutical properties of chilies. CH-27 and Punjab Sindhuri chili varieties are developed by Punjab Agricultural University, Ludhiana. CH-27 hybrid variety is pungent, high in dry matter and capsanthin, while Punjab sindhuri is tall, thick and dark green in color (Dhaliwal et al. 2013; Dhaliwal et al. 2015; Swapan et al. 2017; Reyes-Escogido et al. 2011). Garlic (*Allium Sativum L.*) is the most important crop used for its culinary, therapeutic and medicinal properties. Distinct flavour of garlic is due to complex biochemical reactions. Garlic contains 33 sulfur compounds, 17 amino acids, vitamin A, B1, C, mineral like calcium, copper, iron, potassium, magnesium, selenium, zinc; fiber etc. Higher concentration of sulphur compounds represents the pungent odour and medicinal properties of *Allium* species (Martin et al. 2016; Gebreyohannes and Gebreyohannes, 2013).

Consumers use various kinds of sauces in their daily life. Sauces are considered as crowning glory to any dish that are capable imparting color and flavour simultaneously improving the representation of any food product (Sikora et al. 2008). As per the literature availability, no study was conducted on the honey chili sauce and its preservation. Therefore, the objective of the present study was to develop the honey chili sauce along with checking its shelf stability.

2. MATERIAL AND METHODS

2.1 Selection of raw material

The CH-27 (green and red) and Punjab sindhuri (green and red) chili varieties were procured from the College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana,

Punjab, India. The samples were collected in perforated gunny bags and stored in cold store (0°C) at Food Industry Business Incubation Centre, Department of Food Science and Technology, Punjab Agricultural University Ludhiana for further processing after sorting. Honey, fresh garlic, xanthan gum, acetic acid and salt (Tata) were procured from local market.

2.2 Preparation of honey chili sauce

The washing of chili was done thoroughly under running tap water. After pat drying and pedicle removal, chilies were dried in cabinet dryer at 65° for 8-10 hours and processed into flakes. The xanthan gum was dissolved into warm followed by mixing all ingredients together. The composition of the standardized recipe of honey chili sauce is honey (59%), water (25%), xanthan gum (0.83%), fresh garlic crushed (9%), salt (2.5%), acetic acid (2.1%) and chili flakes (1.25%). The sauce (Figure S1) was packed into 100gm glass containers, stored for 8 months at room (25±2°C) and refrigeration (4°C).

2.3 Physicochemical analysis

Samples were analysed in triplicates for each parameter. The analyses were conducted for 8 months of storage with 2 months interval.

The total soluble solids (TSS)

Hand refractometer (Erma, Japan) was used for the estimation of total soluble solids of sample. The prism surface was cleaned with cotton and a homogenous drop of the sample was placed on it. Results were checked through eyepiece of refractometer in the direction of light. Where the base of the blue colour sit on the scale was taken as reading and results were recorded in °Brix.

pH

pH meter (Mettler Toledo) was used for the estimation pH of the samples. The pH meter was calibrated with buffer solution of pH 4.0 and 7.0 before analysis.

Titratable acidity

The standard procedure Ranganna (2017) was followed for the determination of titratable acidity by titrating a known quantity (5gm) of homogenous sample against 0.1N NaOH solution using phenolphthalein as an indicator. The results were expressed as per cent titratable acidity.

Total solids

A known quantity of sample was taken into pre weighed aluminium dish and kept in hot air oven at $90\pm 5^{\circ}\text{C}$ to achieve persistent weight. After cooling it in desiccator, weight along with aluminium dish was recorded. Total solids (%) was calculated using following formula

$$\text{Total solids (\%)} = \frac{(\text{Wt. of dish + dried sample}) - (\text{Wt. of dish + fresh sample})}{(\text{Wt. of dish + fresh sample}) - \text{Wt. of empty dish}} \times 100$$

Ash content

Known quantity of sample was weighed into silica crucible and charred over direct flame followed by ashing in muffle furnace at $550\text{-}600^{\circ}\text{C}$ for 5-6 hours. Samples were cooled at ambient temperature and difference in weight was used for the calculation of ash content. The results were calculated in per cent.

Total sugars

Total sugars were estimated as per method developed by Dubois et al. 1956. Sugars were extracted with 80 per cent isopropyl alcohol and estimated on the basis of formation of hydroxymethyl furfural by the dehydration of glucose. The absorption of developed yellow-brown complex with phenol was analysed at 490nm. Glucose was used as standard and results were expressed as per cent total sugar.

Reducing sugar

Standard method of Nelson and Somogyi, 1952 were used for the estimation of reducing sugars which were extracted with 80 per cent isopropyl alcohol. It was estimated on the basis of their reaction with alkaline tartrate results in reduction of cupric to cuprous oxide. Blue complex developed by the reaction of cuprous oxide with arsenomolybdic acid and molybdenum blue form due to molybdic acid reduction noted at 520nm. Standard glucose of known concentration was used as standard and results were expressed as per cent reducing sugar.

Water activity

Water activity was measured using Aqua lab water activity meter. The temperature of the sample was not to exceed 4°C than the chamber temperature and reading was displayed within the 40 seconds.

Electrical conductivity

Electrical conductivity of the sample was measured using conductivity meter ranging from 0 to 100ms. The instrument was calibrated using standard KCl solution. The sample was placed in the glass beaker and the instrument probe was dipped into the sample that results in reading on instrument display.

Colour analysis

Colour of the samples was measured using Hunter Color Lab (Ultra Scan, Hunter Lab, USA) in terms of L, a and b values as described by Buve et al. 2018.

Viscosity

The Brookfield viscometer (Model LVT 98534) was used for the estimation of viscosity and results were expressed in centipoise (cP).

$$\text{Viscosity (cP)} = \text{Dial reading} \times \text{factor}$$

2.6 Phytochemical analysis

Ascorbic acid

The ascorbic acid content was determined by titrimetric method described by Ranganna, 2017. 2,6-dichlorophenol-indophenol dye reduced to bluish complex by present ascorbic acid. Standard ascorbic acid was used for the calculation of dye factor and results were expressed as mg ascorbic acid/ 100gm of sample (fresh weight).

$$\text{Dye factor} = \frac{\text{mg of ascorbic acid in solution}}{\text{ml of dye used}}$$

$$\text{Ascorbic acid (mg/100gm)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made} \times 100}{\text{Aliquot taken} \times \text{weight of sample}}$$

Total carotenoids content

The standard method described in Ranganna, 2017 was used for the estimation of total carotenoids content of samples. A known amount of sample was ground with 80 per cent acetone (20-40 ml). The extract was centrifuged@2000 rpm for 10 minutes followed by supernatant separation. The residue again ground with 80 per cent acetone until colourless residue was not obtained. The absorbance of the supernatant read at 480, 645 and 663nm against 80 per cent acetone as blank. The total carotenoid content results were expressed as mg/gm of sample.

$$\text{Total carotenoids} \left(\frac{\text{mg}}{\text{gm}} \right) = \frac{(A_{480} + 0.144 A_{663}) - (0.638 A_{645}) \times \text{volume made}}{1000 \times \text{weight of sample}}$$

A₄₈₀ = Absorbance at wavelength of 480nm

A₆₄₅ = Absorbance at wavelength of 645nm

A₆₆₃ = Absorbance at wavelength of 663nm

Carotene content

The beta carotene of the samples was determined by standard method given in Ranganna, 2017. A known quantity of sample with pinch of sodium sulphate was taken and macerated with 10-15 ml of acetone until colourless residue was not obtained. Centrifugation was done

@2000 rpm for 5 minutes to obtain clear supernatant. The supernatant was transferred into separating funnel followed by addition 5-10 petroleum ether. Distilled water added and kept undisturbed for few minutes to obtain two separate layers. The lower layer discarded and same procedure was repeated. After 2-3 washing, the upper layer taken into volumetric flask and volume made up to 100ml with petroleum ether. The absorbance was noted at 452 nm against blank and total β -carotene was calculated with following formula

$$\beta - Carotene \left(\frac{\mu g}{100gm} \right) = \frac{optical\ density\ at\ 452\ X\ 10^4\ X\ 100}{weight\ of\ sample\ X\ 560\ X\ 1000}$$

Lycopene

The lycopene content of samples were determined by standard method given in Raganna, 2017. The known quantity of the sample was extracted with acetone in pestle motor to colourless residue. The extract was taken into separating funnel along with 10-15ml petroleum ether. Carotenoids pigments were separated into petroleum ether phase by diluting acetone (lower phase) with water. Lower phase was transferred into another separating funnel and petroleum ether extract was collected into amber bottle. Acetone phase extraction was repeated until it became colourless. Acetone phase was discarded. To the petroleum ether extract, small quantity of sodium sulphate was added and transferred to 50ml volumetric flask. Dilution was done up to mark with petroleum ether. From this 5ml sample was taken and further diluted to 50ml. The optical density was noted at 503nm and lycopene content was calculated using following formula

$$Lycopene \left(\frac{mg}{100gm} \right) = \frac{3.1206\ X\ optical\ density\ X\ volume\ made\ X\ dilution\ X\ 100}{1\ X\ weight\ of\ sample\ X\ 1000}$$

Total phenolics

The total phenolics/phenols were determined with Folin-Ciocalteu method described by Singleton and Rossi, 1999. The total phenolics were extracted using 80 per cent methanol and estimated on the basis of their reaction with phosphomolybdate (oxidizing agent) in Folin-Ciocalteu reagent under alkaline condition. The total phenolics of samples were calculated from linear equation obtained from the calibration curve between concentrations of gallic acid and results were expressed as mg/100gm of Gallic acid equivalent.

2.7Antioxidant activity evaluation

Antioxidant assays used for the estimation of free radical scavenging activity of the samples were DPPH (1,1-diphenyl-2-picryl-hydrazyl) and FRAP (Ferric reducing antioxidant power).

DPPH (1,1-diphenyl-2-picryl-hydrazyl)

Antioxidants from the samples were extracted with 80 per cent methanol and reduction in violet bluish color by the scavenging of 1,1-diphenyl-2-picryl-hydrazyl (free radicals) with antioxidant components of sample noted at 517nm against control sample. The results were expressed as per cent antioxidant activity (Goraya and Bajwa)2015.

FRAP (Ferric reducing antioxidant power)

Procedure described by Stratil et al. 2006 was used for the estimation of extract ability to reduce FeCl_3 . Antioxidants reduced the Fe^{3+} to Fe^{2+} at low pH and developed coloured Ferrous probe complex was analysed at 593nm. Fresh FeSO_4 solution was used as standard and results were expressed as mM/ml.

2.8 Fourier Transform Infrared Spectroscopy

The structural components of the fresh honey chili sauce samples were accessed with Fourier transform infrared spectrometer (Thermo Scientific Nicolet 6700 spectrometer) using an attenuated total reflection accessory and deuterated triglycine sulphate detector. FTIR was carried out at Electron Microscopy and Nano science Laboratory, Punjab Agricultural University, Ludhiana. The honey chili sauce was ground into viscous homogenous mass prior to spectroscopy. The spectra were collected in the $4000\text{--}400\text{ cm}^{-1}$, with a 4 cm^{-1} and 32 scans at room temperature.

2.9 Microbial analysis

For the quantitative determination of total plate count, pour plate method was performed (Mailoa et al. 2017). Sample dilution of 10^{-2} and 10^{-4} were used and results were expressed as colony forming unit (cfu)/ml of sample.

2.10 Sensory Evaluation

For checking the consumer acceptance of the developed product, the organoleptic attributes were evaluated in terms of colour, flavour, consistency and overall acceptability during 8 months storage with 2 months interval. The coded samples were given to the semi-trained panels along with white bread slices. The results were recorded on the basis of nine-point hedonic scale score.

2.11 Statistical analysis

The results of the present study were expressed as the means of three independent determinations in the form of pooled data of 8 months storage. Univariate Analysis of variance was performed for the statistical estimation using SPSS16. $p \leq 0.05$ performed to

check the significance effect of storage period, storage condition and chili varieties on the properties of honey chili sauce. Post-Doc Tukey's used for checking the effect of over-all effect of 3 dependent variables i.e. storage period, storage condition and chili varieties, while to evaluate the individual effect of storage period, storage condition and chili varieties, two-way analysis of variance was used.

3. Results and discussion

3.1 Total soluble solids

The effect of storage period on the TSS oh honey chili sauce with CH-27 and Punjab sindhuri chili varieties are presented in Table 1. At the initial stage, the total soluble solid content was in the range of 68-68.08° Brix. A slight increase in the TSS of samples was observed that might be related to the solubilisation of insoluble constituents of honey due to the presence of acid (Singh et al. 2006). In addition, during storage transpirational and respirational losses occurs that are also responsible for an increased total soluble solid concentration in the honey chili sauce. During storage, it was found that the room as well as refrigeration condition have a non-significant effect on the TSS of the product.

3.2 pH

The pH values of all the samples were in the range of 3.80 to 3.98 (Table 1). A significant decrease in the pH values of all samples were observed during 8 months of storage. As earlier reviewed, the reduction in pH of samples might be related with the fact that glucose and fructose converted to carbon dioxide and alcohol that further hydrolysed to oxygen and acetic acid results in dropped pH of stored samples (Evahelda et al. 2017). As reported by Monggudal et al. (2018), the drop in pH during storage might be due to the reaction of various components and ions concentration present in honey.

3.3 Titratable acidity

Acidity of the honey is related to the presence of organic acid in it. A significant ($p \leq 0.05$) increase in the titratable acidity of honey chili sauce during storage was observed (Table 1). The initial acidity values were in the range of 0.82 to 2.32 per cent while at the end of storage the mean values were in the range of 1.35 to 3.00 per cent. The increase in the acidity of samples was related to the same fact as pH decreased during storage. Other than that during storage, some solids reduce that become salts and bases results in titratable acidity variation than the original value.

3.4 Total solids

The comparison of total solids of honey chili sauce with CH-27 and Punjab sindhuri chili variety showed significant ($p \leq 0.05$) difference as shown in Table 1. The total solids of stored samples were in the range of 81.67 to 87.57 per cent. A significant increase followed by decrease in total solids of stored honey chili sauce was observed. During storage, transpirational losses results in the increased total solid concentration in the honey chili sauce. Decrease in total solids during storage was due to the degradation of protein present in the samples as reported by Abdalla et al. (2009).

3.5 Total sugars

At the initial stage of storage, the total sugar content of all honey chili sauce samples were in the range of 58.50 to 63.27 gm/100gm as depicted in Table 1. During storage, an increase in the total sugar of samples up to 4 months of storage was observed. After 4th month, there was a decrease in the total sugar content of all samples. An increase in total sugars of stored samples might be related either to the moisture loss of product during storage results in more concentration of total sugars or the conversion of complex carbohydrates to simpler sugars (Islam et al. 2013). The effect of month and variety was found to be significant, while the effect of storage condition was non-significant (Table S1). As suggested by Sharma et al. (2019), chemical and maillard's reaction of sugar with acid during the storage duration leads to the reduction of total sugar content

3.6 Reducing sugars

In honey, mainly fructose and glucose sugars are present. In the honey chili sauce, the reducing sugar content was in the range of 46.37 to 54.29 gm/100gm for all the samples (Table 1). Similar trend of total sugars was observed for reducing sugar as a significant ($p \leq 0.05$) increase followed by a significant decrease in the reducing sugars of all samples was observed. The conversion of non-reducing sugar to reducing results in an escalation of reducing sugars of the sample. As reported by Bishnoi et al. (2015), the sucrose content present in sample converted to glucose and fructose during storage results in the change of reducing sugar content.

3.7 Viscosity

A significant ($p \leq 0.05$) increase in the viscosity of stored samples of honey chili sauce was observed (Table 2). Initially, the viscosity (cP) of samples was in the range 12500 to 12750 but it increased to 18254 to 19965 during eight months of storage. According to Sharma et al. (2014), the viscosity of product related to intermolecular forces between molecule and water solutes including sugars and acids interaction, results from hydrogen bond strength and inter-

molecular spacing that strongly dependant on concentration and temperature. Increase in total solids results in increase in hydrated molecule and H-bonding with OH groups of solutes results in enhanced flow resistance and increase in viscosity.

3.8 Total phenolics

The phenolics secondary metabolites are known for their antioxidant activity. As depicted in Table 2, the total phenolics content of samples were in the range of 710.1 to 732.1 mg/100gm GAE. There was a significant ($p \leq 0.05$) decline of 5 to 8 per cent in the total phenolics during storage of 8 months. The retention of total phenolics was more on the refrigeration storage condition compare to room temperature. The higher water loss and enzyme activity at room temperature might be related with oxidation and hydrolysis of phenolics (Deng et al. 2018; Ali et al. 2018). The findings of the present investigation are in line with those reported by Sakhale et al. (2015). As reported by Kumar and Thakur (2019), the decline in the phenolics irrespective of storage period and conditions can be attributed to the activity of polyphenol oxidase.

3.9 Water activity

For the food stability by preventing or restraining growth of micro-organism, water activity plays an important role. In the present investigation, water activity of stored honey chili sauce was found in the range of 0.781 to 0.797. The water activity content of samples was significantly ($p \leq 0.05$) effected by the storage period and storage condition. As reported by Chirife et al. (2006), the water activity of honey is greatly influenced by concentration of glucose and fructose in the water of honey. In present investigation, an elevation in total sugar as well as reducing sugars during storage was observed that might be the results of varied water activity of honey chili sauce during storage.

3.10 Electrical conductivity

Electrical conductivity of samples may be depicted by presence of ash and acid content that reveals the existence of ions and organic acid. The electrical conductivity of sample is directly proportional to the presence of ions and organic acid (Rebaia and Lanez, 2014). In the present investigation, the electrical conductivity of samples was in the range of 2.20-2.95 $\mu\text{S}/\text{cm}$. A significant 23.3 to 25.6 per cent increase in the electrical conductivity of honey chili sauce was observed. Similar trend of increased electrical conductivity due to ageing was observed by Qamar et al. (2013). The individual effect of month and variety and was significant ($p \leq 0.05$), while the effect of storage condition was non-significant (Table S1).

3.11 Ash content

Ash content is influenced by the chemical composition of samples that estimates the mineral content of the same. As depicted in Table 3, the initial ash content (%) of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red was 2.41-2.45, 2.26-2.35, 2.33-2.24 and 2.41-2.45 respectively. A 40 to 45 per cent significant increase in the ash content of stored honey chili sauce was observed during 8 months of storage that might be related with the moisture loss during storage results in higher ash content concentration left behind in the samples. Similar results were reported by Abdalla et al. (2009).

3.12 β -carotene

Beta carotene is a provitamin A and known for its powerful antioxidant properties. In the present investigation, the β -carotene content was 400, 430, 441-410 and 470 $\mu\text{g}/100\text{gm}$ in honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red respectively. A slight decrease in the beta carotene content was observed during the storage (Table 2). The maximum retention was observed for the samples with CH-27 red followed by Punjab sindhuri red. The loss of beta carotene during storage might be related with the fact of its sensitivity towards light and oxygen (Durrani et al. 2011). Similar finding were reported by Anjum et al. (2008).

3.13 Lycopene content

The bright red carotenoid lycopene is a plant nutrient with higher antioxidant properties. The lycopene content of the honey chili sauce was in the range of 5.0 to 5.4 $\mu\text{g}/100\text{gm}$ (Table 3). A significant ($p \leq 0.05$) reduction was observed during 8 months storage with maximum retention of lycopene in samples stored at refrigeration temperature. The effect of month, and variety was found to be significant ($p \leq 0.05$), while the effect of storage condition was non-significant. Heat, light and oxygen factors are related with the isomerization and oxidation of lycopene during the storage (Martinez-hernandez et al. 2016). The isomerization of lycopene to mono or cis-trans form occurs in presence of heat or light and reisomerization during storage notified. After oxidation, lycopene molecule split results in loss of colour (Xianquan et al. 2005).

3.14 Ascorbic acid

The water soluble ascorbic acid is well known for its potent reducing and antioxidant properties. The ascorbic acid content of honey chili sauce was found to be in the range of 6.1-6.9 $\text{mg}/100\text{gm}$ of the sample (Table 3). A significant reduction in ascorbic acid irrespective of both storage temperature and chili varieties were observed during storage of honey chili

sauce. Factors like light, oxygen, temperature, metal ions catalyst, pH etc. influenced the degradation of ascorbic acid. The results are in agreement with Kaur et al. (2019). The reduction in ascorbic acid might be due to enzymatic oxidation of L-ascorbic acid to dehydroascorbic acid (Kumar and Thakur 2020).

3.15 Antioxidant activity

In the present investigation, the antioxidant activity in terms of DPPH and FRAP was conducted. At initial stage of storage, the DPPH and FRAP values were in the range of 63.56-69.56 per cent and 4.21-4.78 mM respectively (Table 3). A significant ($p \leq 0.05$) reduction in DPPH and FRAP values of stored samples were observed irrespective of storage condition, chili varieties and storage duration. As reported by Del-Toro-Sánchez et al. (2015), the high temperature and light are the main factors for the reduction of antioxidant activity. It was reviewed that the polyphenols are directly correlates with the antioxidant activity of sample. Oxidation of polyphenols and carotenoids during storage results in declined antioxidant activity (Michalczyk and Macura 2010).

3.16 Colour analysis

Colour values of honey chili sauce was determined in terms of L , a and b values that depicts the lightness to darkness, greenness to redness and yellowness to blueness respectively. At initial stage of storage, the L , a and b value of all samples was varied from range 24.79 to 31.83, 1.67 to 4.1 and -0.26 to 7.74 respectively. A significant increase in the L value up to 6 month followed by a decrease in 8 month was observed. Similar trend was observed for a and b value. The individual effect of month, storage condition, variety, interaction part, the month * variety, storage condition * variety, month * storage condition and overall month * storage condition * variety showed significant ($p \leq 0.05$) effect on the * L value of the stored honey chili sauce. Similarly, in a value, the individual effect of month, storage condition, variety, interaction part, the month * variety, storage condition * variety and month * storage condition showed significant ($p \leq 0.05$) effect. But the overall month * storage condition * variety showed non-significant effect on the * a value of the stored honey chili sauce. For b value, the individual effect of month and variety was significant ($p \leq 0.05$) but the effect of storage condition was non-significant. Similarly in the interaction part, the month * variety, storage condition * variety, month * storage condition and overall month * storage condition * variety showed significant ($p \leq 0.05$) effect on the * b value of the stored honey chili sauce (Table 4 and Table S1).

3.17 Total plate count

To evaluate the micro-organisms in the prepared honey chili sauce, total plate count method was adopted. The colony forming unit/ml of honey chili sauce was in the range of 0.02 to 0.03 at the initial stage of storage (Table 4). A significant ($p \leq 0.05$) increase in the total plate count was observed during 8 months of storage but it was within the desirable limit (Mumtaz et al. 2018).

3.18 Sensory evaluation

The results of sensory evaluation of honey chili sauce in terms of colour, consistency, mouth feel and overall acceptability is presented in Figure 1. The sensory attributes of honey chili sauce reveals that the product has an excellent sensory quality and overall acceptability. Though the product was found to have bright colour (7.9-8.9), consistency (7.8-8.8), mouth feel (7.9-8.8) and overall acceptability (7.85-8.9). With maximum sensory scores, honey chili sauce with Punjab sindhuri red was graded as best out of all samples might be due to the bright red colour of dried Punjab sindhuri chili that makes it appealing. Even after 8 months of storage, the product was acceptable with intact nutrients.

3.19 FT-IR characterization of honey chili sauce

FT-IR spectra, characteristics peaks and functional groups at particular peaks of honey chili sauce with CH-27 green, CH-27 red, Punjab sindhuri green and Punjab sindhuri red depicted in Figure 2 and Table S2. The presence of silicon mineral that functions as vitamin D and calcium was confirmed in honey chili sauce with CH-27 red with peak 3650. The presence of phenolic contents and secondary amines with functional bond OH and N-H at wavelength 3484.6, 3349.7, 3348 and 3338.5 cm^{-1} were observed in all samples of honey chili sauce. Flavouring components amine salts presence was observed in honey chili sauce with CH-27 red and Punjab sindhuri red with generation of peak with the wavelength range of 2077 cm^{-1} . The band at 1369.7 cm^{-1} represents the presence of phenols, while C-O stretching at 1251.3 cm^{-1} represents the presence of aromatic ester in honey chili sauce with Punjab sindhuri green. The presence of amine was detected honey chili sauce with Punjab sindhuri red with generation of peak with the wavelength range of 1357.3 cm^{-1} . The band at 1253.5 cm^{-1} represents the presence of aromatic alcohol, while C-O stretching at 1055.0-1056 cm^{-1} represents the presence of primary alcohol in sauce with all honey chili sauce samples. .

4. Conclusions

In conclusion, it was observed that honey chili sauce was safe for consumption up to 8 months of storage. Honey chili sauce samples prepared with CH-27 red chili variety retained

maximum total phenolics, beta carotene, lycopene content, DPPH, FRAP and redness (a*) value during the storage. Other component including total soluble solids, total solids, ash content and ascorbic acid was observed maximum in sample with Punjab sindhuri red chili variety. With Fourier transmission infrared spectroscopy, it was observed that the highest peaks for phenolic components were for honey chili sauce with green form of both CH-27 and Punjab sindhuri. On the nine-point hedonic scale, maximum scores were recorded for samples with Punjab sindhuri red variety during storage.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in the publication.

DATA AVAILABILITY STATEMENT

Data will be available on request from the authors. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1 Effect of storage condition, storage period and chili varieties on the physicochemical properties of honey chili sauce

Variety		Storage period (months)							Storage period (months)						
		0	2	4	6	8	Total	Overall mean	0	2	4	6	8	Total	Overall mean
		Total soluble solids (°Brix)							pH						
CH 27 GREEN	A	68±3.4 ^{aM}	69±1.00 ^{aM}	69.5±1.36 ^{aM}	70±1.00 ^{aM}	68.9± 0.64 ^{aM}	69.42±1.16 ^X	69.09±4.1 ^{wx}	3.83±0.03 ^{aM}	2.54±0.08 ^{aN}	2.51±0.05 ^{bCN}	2.49±0.01 ^{bCN}	2.46±0.04 ^{bCN}	2.76±0.55 ^X	2.74±0.16 ^y
	R	68±3.4 ^{aN}	68.8±1.1 ^{aMN}	69±0.75 ^{aMN}	70±0.87 ^{aM}	69±1.00 ^{aMN}	68.77±1.38 ^Y		3.83±0.06 ^{aM}	2.63±0.07 ^{cdN}	2.5±0.10 ^{cNP}	2.37±0.05 ^{dP}	2.35±0.041 ^{cP}	2.73±0.58 ^Y	
CH 27 RED	A	68±4.08 ^{aM}	68.3±0.55 ^{aM}	69±1.36 ^{aM}	69.5±0.61 ^{aM}	68.6±1.050 ^{aM}	68.83±1.07 ^X	68.81±4.1 ^y	3.96±0.2 ^{aM}	2.76±0.07 ^{bCN}	2.74±0.065 ^{aN}	2.59±0.02 ^{bN}	2.55±0.035 ^{bN}	2.87±0.479 ^Y	2.89±0.17 ^x
	R	68±0.5 ^{aM}	68.1±1.0 ^{bN}	69±0.288 ^{aMN}	70.5±1.1 ^{aM}	68.5±0.95 ^{aMN}	68.78±1.23 ^Y		3.96±0.05 ^{aM}	2.87±0.056 ^{abN}	2.69±0.052 ^{abcO}	2.59±0.10 ^{abO}	2.57±0.045 ^{abO}	2.94±0.54 ^X	
PS GREEN	A	68±0.76 ^{aM}	68.3±.50 ^{aM}	68.8±0.84 ^{aM}	69±0.87 ^{aM}	68.5±2.6 ^{aM}	68.49±0.83 ^Y	68.71±5.4 [*]	3.8±0.07 ^{aM}	2.73±0.065 ^{bCN}	2.70±0.10 ^{abcNP}	2.56±0.04 ^{bp}	2.53±0.05 ^{bp}	2.86±0.499 ^Y	2.90±0.23 ^x
	R	68±0.7 ^{aM}	68.3±0.65 ^{aM}	68.8±0.83 ^{aM}	69.5±0.55 ^{aM}	68.5±0.96 ^{aM}	68.93±0.93 ^X		3.8±0.10 ^{aM}	2.92±0.65 ^{abN}	2.73±0.070 ^{abP}	2.63±0.06 ^{abP}	2.61±0.05 ^{abP}	2.93±0.463 ^X	
PS RED	A	68±1.52 ^{aM}	69±0.70 ^{aM}	69.5±1.05 ^{aM}	70.5±0.70 ^{aM}	69.2±1.30 ^{aM}	69.28±1.3 ^Y	69.43±4.2 ^w	3.98±0.0435 ^{aM}	2.81±0.056 ^{bN}		2.60±0.06 ^{abP}	2.57±0.03 ^{bp}	2.93±0.463 ^Y	2.98±0.24 ^w
	R	68±0.3 ^{aM}	69±1.05 ^{aM}	69.4±0.60 ^{aM}	70.6±0.62 ^{aM}	69.1±0.85 ^{aM}	69.58±0.89 ^X		3.98±0.118 ^{aM}	2.97±0.041 ^{aN}	2.77±0.032 ^{ap}	2.76±0.05 ^{ap}	2.73±0.06 ^{ap}	3.01±0.476 ^X	
Total		68.08±1.10 ^C	68.84±1.04 ^B	69.16±0.92 ^B	70.07±0.79 ^A	68.90±0.93 ^B			3.85±0.127 ^A	2.77±0.148 ^B	2.66±0.11 ^C	2.57±0.11 ^B	2.55±0.114 ^B		
		Titratable acidity (%)							Total solids (%)						
CH 27 GREEN	A	2.30±0.10 ^{aM}	2.0±0.90 ^{abM}	2.73±0.09 ^{aM}	2.94±0.06 ^{aM}	3.00±0.70 ^{aM}	2.63±0.60 ^X	2.60±0.437 ^w	81.67±1.05 ^{bNO}	83.79±1.02 ^{bMN}	85±1.00 ^{aM}	81.56±1.02 ^{aNO}	80.25±0.65 ^{aO}	82.42±1.92 ^Y	82.70±2.76 ^x
	R	1.79±0.04 ^{bN}	1.85±0.1 ^{abcN}	2.3±0.10 ^{bCN}	2.54±0.05 ^{CM}	2.60±0.40 ^{CM}	2.57±0.17 ^Y		81.67±1.18 ^{bNO}	89.13±0.99 ^{aM}	80.09±0.80 ^{JO}	83.1±1.24 ^{aN}	81±1.0 ^{abO}	83.00±3.45 ^X	
CH 27 RED	A	0.82±0.01 ^{CO}	1.1±0.11 ^{bCN}	1.5±0.10 ^{aMN}	1.75±0.04 ^{aM}	1.79±0.047 ^{cdM}	2.19±0.37 ^X	2.18±0.19 ^x	82.85±1.03 ^{bMN}	80.75±0.47 ^{bMN}	83.31±1.00 ^{abCM}	81.96±0.95 ^{aMN}	80.25±0.64 ^{aMN}	81.30±1.24 ^Y	81.72±1.33 ^y
	R	0.92±0.01 ^{CO}	0.99±0.14 ^{CO}	1.3±0.10 ^{deN}	1.32±0.1 ^{HN}	1.35±0.045 ^{aM}	2.16±0.27 ^Y		82.85±1.00 ^{BM}	80.17±0.051 ^{bN}	81.18±1.10 ^{bcdMN}	83.08±0.98 ^{aM}	80.95±1.01 ^{aMN}	81.61±1.43 ^X	
PS GREEN	A	2.3±0.1 ^a	2.43±0.06 ^{aO}	2.5±0.10 ^{bN}	2.75±0.04 ^{BM}	2.79±0.036 ^{BM}	1.39±0.39 ^X	1.26±0.39 ^y	82.48±1.02 ^{bN}	80.18±0.59 ^{BM}	84.4±1.05 ^{aMN}	82.79±1.34 ^{aN}	81.05±0.99 ^{abN}	81.78±1.78 ^Y	82.41±1.64 ^z
	R	1.79±0.02 ^{BO}	1.94±0.06 ^{abN}	2.26±0.09 ^{CN}	2.40±0.10 ^{CM}	2.45±0.045 ^{bcM}	1.14±0.20 ^Y		82.85±1.00 ^{BM}	80.17±0.051 ^{BM}	81.18±1.10 ^{cdM}	83.08±0.98 ^{aM}	80.95±1.01 ^{aM}	82.38±1.49 ^X	
PS RED	A	0.82±0.03 ^{CN}	1.13±0.10 ^{bCN}	1.16±0.05 ^{aM}	1.31±0.03 ^{BM}	1.35±0.040 ^{aM}	1.17±0.290 ^X	1.22±0.23 ^y	87.57±0.966 ^{aM}	88.06±4.71 ^{abM}	80.34±0.67 ^{cdM}	84.39±0.97 ^{aM}	81.75±0.96 ^{aM}	82.46±2.78 ^Y	84.49±5.06 ^w
	R	0.92±0.025 ^{CP}	1.06±0.22 ^{bCN}	1.32±0.03 ^{deN}	1.52±0.03 ^{CM}	1.57±0.030 ^{aM}	1.12±0.25 ^Y		87.57±1.04 ^{abMN}	85.22±1.11 ^{abM}	85.62±0.95 ^{aMN}	84.38±1.1 ^{aNO}	82.68±0.99 ^{aO}	83.73±2.02 ^X	
		1.47±0.66 ^C	1.56±0.59 ^C	1.87±0.60 ^B	2.06±0.635 ^A	2.11±0.70 ^A			83.50±2.64 ^A	83.49±3.29 ^A	83.07±2.1 ^A	82.93±1.34 ^A	81.17±1.03 ^B		
		Total sugar (gm/100gm)							Reducing sugars (gm/100gm)						
CH 27 GREEN	A	60.48±1.0 ^{bN}	62.72±1.0 ^{abcN}	66.47±1.0 ^{aM}	62.93±2.12 ^{abN}	60.26±1.04 ^{abN}	62.62±2.34 ^Y	62.90±2.47 ^x	51.93±1.01 ^{bN}	52.04±0.055 ^{aN}	59.37±1.42 ^{abM}	53.46±0.02 ^{dN}	52.56±0.035 ^{aN}	53.91±3.04 ^Y	54.03±4.3 ^x
	R	60.48±1.0 ^{bN}	63.22±1.1 ^{abcMN}	68.59±1.69 ^{aM}	65.68±2.8 ^{abMN}	63.24±0.95 ^{abN}	63.18±2.64 ^X		54.29±0.065 ^{ap}	54.53±0.005 ^{aO}	57.88±0.11 ^{1¹bcM}	42.4±0.02 ^{bN}	40.55±0.030 ^{RO}	54.15±3.11 ^X	
CH 27 RED	A	63.27±1.0 ^{aM}	63.34±0.95 ^{abM}	64.50±0.94 ^{aM}	58.31±1.27 ^{bN}	55.24±1.002 ^{bO}	60.98±3.69 ^Y	61.74±3.81 ^x	52.88±0.58 ^{bN}	53.02±0.056 ^{bN}	59.56±0.10 ^{abM}	57.9±0.80 ^{aO}	55.65±0.027 ^{ap}	49.92±7.29 ^Y	52.87±3.7 ^y
	R	63.27±1.0 ^{aM}	63.85±1.00 ^{aM}	68.77±2.69 ^{aM}	66.05±4.48 ^{abM}	65.54±5.90 ^{abM}	62.51±3.907 ^X		46.37±0.045 ^{CN}	46.39±0.085 ^{IN}	59.29±0.065 ^{bcM}	54.98±0.01 ^{bcM}	52.65±0.04 ^{aN}	55.83±1.48 ^X	
PS GREEN	A	60.05±0.9 ^{BO}	59.70±1.01 ^{CO}	66.62±1.06 ^{aMN}	68.53±1.006 ^{aM}	65.55±1.00 ^{aN}	64.02±3.75 ^X	63.56±3.8 ^w	51.93±0.0755 ^{bp}	52.28±0.075 ^{dp}	59.9±0.15 ^{aM}	54.29±0.03 ^{cdN}	52.34±0.03 ^{IO}	55.8±2.74 ^X	55.20±3.3 ^w
	R	60.0±0.9 ^{abMN}	59.78±1.02 ^{bCN}	64.14±1.67 ^{aMN}	62.06±3.76 ^{abM}	60.55±3.06 ^{abMN}	63.10±3.49 ^Y		54.29±0.045 ^{aO}	54.59±0.075 ^{aO}	57.9±1.09 ^{cdM}	57.55±0.020 ^{abN}	55.34±0.035 ^{bN}	54.61±1.84 ^Y	
PS RED	A	58.50±0.9 ^{CO}	56.66±2.01 ^{abO}	65.83±3.01 ^{aM}	61.11±1.0 ^{abMN}	59.45±0.99 ^{abN}	58.41±1.36 ^Y	58.88±4.70 ^y	52.88±0.035 ^{bp}	52.73±0.06 ^{bp}	57.75±0.81 ^{cdM}	55.43±0.025 ^{bN}	54.59±0.036 ^{IO}	51.93±5.18 ^X	50.29±4.0 ^z
	R	58.5±0.9 ^{cNO}	57.17±2.06 ^{abO}	63.36±3.21 ^{aM}	69.07±4.56 ^{abN}	67.54±4.82 ^{abMN}	59.35±6.15 ^X		46.37±0.050 ^{CP}	46.18±0.050 ^{abO}	56.89±0.01 ^{IM}	47.24±0.020 ^{bN}	46.65±0.040 ^{IO}	48.66±4.27 ^Y	
		59.37±3.7 ^D	59.47±4.49 ^D	65.74±1.944 ^A	69.19±3.87 ^B	61.09±3.94 ^C			51.37±3.084 ^C	51.45±3.18 ^C	58.49±1.297 ^A	52.90 ±5.137 ^B	51.29±4.94 ^C		

Note: PS= Punjab Sindhuri; *B*= Degree Brix; A= Room temperature (25±2° C); R= refrigeration temperature (4° C); n = 3;

Data present in the table are average values aa Mean ± Standard Deviation; Values in a column and rows with different upper and lower case superscripts differ significantly; lower case w,x,y,z= effect on overall variety; upper case X,Y= effect of storage condition; lower case a,b,c,...=Within month; upper case A,B,C,...= Overall month; upper case M,N,O,P= Month v/s month.

Table 2 Effect of storage condition, storage period and chili varieties on the physicochemical and phytochemical properties of honey chili sauce

		Storage period (months)							Storage period (months)							
Variety		0	2	4	6	8	Total	Overall mean	0	2	4	6	8	Total	Overall mean	
		Viscosity (cP)								Total phenolics (mg/100ml GAE)						
CH 27 GREEN	A	12500±500.00 ^{bQ}		15500±500.08 ^{dQ}	17750±160.07 ^{aN}	19545±7.637 ^{cM}	15641±819.85 ^X	15270±763.5 ^w	719.66±0.75 ^{bM}	700.3±10.00 ^{dN}	678.6±1.57 ^{dQ}	618.5±2.15 ^{c^{BP}}	595±2.64 ^{dQ}	662.59±49.36 ^Y	669.43±44.10 ^Y	
	R	12750±500.0 ^{aP}	12900±500.0 ^{aP}	13750±600.55 ^{dQ}	17000±445.50 ^{bcN}	18265±500.00 ^{bM}	14900±344.69 ^Y		719.66±1.00 ^{bM}	709.1±0.87 ^{bcdN}	686.7±1.00 ^{bdQ}	640.2±1.0 ^{cP}	625.5±0.85 ^{abQ}	676.28±38.63 ^X		
CH 27 RED	A	12500±500.00 ^{bP}	13500±480.5 ^{aP}	15000±500.0 ^{bdQ}	16750±710.121 ^{cdM}	18598±281.307 ^{fM}	14903±379.79 ^X	14881±1190.3 ^Y	732.1±2.56 ^{abM}	718.7±2.15 ^{abN}	682.3±2.05 ^{cdQ}	630.2±0.85 ^{dP}	610.59±1.51 ^{dQ}	674.87±49.35 ^Y	679.46±45.91 ^W	
	R	12500±470.52 ^{bQ}	12750±590.3 ^{cP}	14000±470.52 ^{cQ}	17500±300.1 ^{abN}	19649±500.00 ^{bM}	14859±754 ^Y		732.1±2.01 ^{abM}	721.3±0.96 ^{aN}	695.5±1.15 ^{aQ}	645.2±0.80 ^{bP}	625.45±1.00 ^{abcQ}	684.05±43.34 ^X		
PS GREEN	A	12500±470.03 ^{bQ}	12000±300.1 ^{bP}	12500±460.45 ^{bdQ}	17500±400.10 ^{abN}	19965±100.00 ^{aM}	15262±263 ^X	15114±1209 ^X	728.4±1.85 ^{abM}	702.2±2.3 ^{cdN}	673.9±1.25 ^{cdQ}	650.2±0.85 ^{aP}	620.5±2.15 ^{bcQ}	674.97±39.24 ^Y	677.35±38.729 ^X	
	R	12750±500.50 ^{aP}	12250±600.0 ^{bP}	13500±400.10 ^{dQ}	16500±500.08 ^{cdN}	19288±300.055 ^{bM}	14966±603.68 ^Y		728.4±22.00 ^{abM}	712.3±2.0 ^{abN}	683.4±1.25 ^{cdQ}	647.1±1.00 ^{abP}	624.265±3.05 ^{dQ}	679.79±39.4 ^X		
PS RED	A	12500±510.11 ^{bQ}	12750±555.1 ^{cP}	14250±620.11 ^{cQ}	16000±558.621 ^{deN}	19287±400.58 ^{bM}	15274±926.0 ^X	14901±894.0 ^Y	710.1±0.96 ^{abM}	700.1±2.085 ^{dN}	669.3±1.00 ^{dQ}	646.1±1.02 ^{bP}	620.45±1.00 ^{cP}	669.26±34.48 ^Y	669.64±30.017 ^Y	
	R	12500±520.99 ^{bP}	12500±380.0 ^{bP}	14000±272.50 ^{dQ}	15500±500.08 ^{cdN}	18254±400.50 ^{bM}	14527±244.50 ^Y		710.1±1.41 ^{abM}	702±2.05 ^{cdN}	679.9±1.33 ^{cdQ}	637.2±1.01 ^{bP}	620.25±1.01 ^{baP}	670.03±36.74 ^X		
Total		12564±115.52 ^E	12675±429.83 ^D	14045±876.13 ^C	16820±774.13 ^B	19104±625.42 ^A			722.67±8.79 ^A	708.32±8.7 ^B	681.13±7.75 ^C	639.43±10.20 ^D	618.31±10.02 ^E			
		Water activity								Electrical conductivity (µs/cm)						
CH 27 GREEN	A	0.784±0.0213 ^{aM}	0.730±0.01 ^{cN}	0.682±0.010 ^{bdQ}	0.654±0.01 ^{cdQ}	0.62±0.010 ^{bp}	0.69±0.05 ^Y	0.71±0.05	2.20±0.100 ^{bdQ}	2.40±0.18 ^{cdQ}	2.58±0.085 ^{cdQ}	2.96±0.140 ^{dN}	3.10±0.12 ^{deM}	2.67±0.36 ^X	2.64±0.31 ^Y	
	R	0.784±0.007 ^{aM}	0.763±0.1 ^{abcMN}	0.742±0.022 ^{abNO}	0.712±0.011 ^{aOP}	0.70±0.010 ^{bp}	0.73±0.03 ^X		2.20±0.131 ^{bp}	2.47±0.01 ^{bdP}	2.62±0.10 ^{cdNO}	2.78±0.11 ^{cdMN}	2.96±0.08 ^{cdM}	2.60±0.267 ^Y		
CH 27 RED	A	0.797±0.025 ^{aM}	0.754±0.01 ^{abcM}	0.702±0.007 ^{bcdN}	0.647±0.0087 ^{aQ}	0.62±0.012 ^{bdQ}	0.70±0.06 ^X	0.72±0.05	2.61±0.098 ^{cdNO}	2.80±0.10 ^{bdQ}	2.97±0.19 ^{abNO}	3.19±0.111 ^{cdMN}	3.25±0.09 ^{abM}	2.69±0.176 ^Y	2.97±0.21 ^Y	
	R	0.797±0.010 ^{aM}	0.776±0.010 ^{aMN}	0.745±0.026 ^{cdNO}	0.726±0.012 ^{cdQ}	0.71±0.010 ^{cdQ}	0.74±0.03 ^Y		2.61±0.11 ^{ap}	2.85±0.04 ^{bdP}	2.96±0.140 ^{abNO}	3.16±0.100 ^{cdMN}	3.35±0.01 ^{cdM}	2.99±0.265 ^X		
PS GREEN	A	0.788±0.035 ^{aM}	0.746±0.01 ^{bcMN}	0.695±0.008 ^{cdNO}	0.658±0.010 ^{cdNP}	0.62±0.011 ^{bp}	0.70±0.06 ^Y	0.72±0.05	2.95±0.121 ^{cdQ}	3.17±0.01 ^{cdQ}	3.38±0.1677 ^{aQ}	3.67±0.11 ^{aN}	3.85±0.15 ^{aM}	3.38±0.34 ^X	3.36±0.31 ^Y	
	R	0.788±0.007 ^{aM}	0.762±0.009 ^{abM}	0.735±0.009 ^{abcM}	0.715±0.012 ^{aNQ}	0.705±0.01041 ^{cdQ}	0.73±0.03 ^X		2.95±0.20 ^{bp}	3.14±0.13 ^{adP}	3.35±0.169 ^{cdNO}	3.56±0.100 ^{abMN}	3.79±0.06 ^{abM}	3.33±0.32 ^Y		
PS RED	A	0.781±0.010 ^{aM}	0.768±0.02 ^{abM}	0.712±0.010 ^{abcdN}	0.671±0.012 ^{cdQ}	0.650±0.009 ^{bdQ}	0.71±0.05 ^Y	0.732±0.0	2.75±0.10 ^{bp}	2.92±0.01 ^{abOP}	3.10±0.10 ^{abNO}	3.29±0.105 ^{bcdN}	3.52±0.10 ^{bcM}	3.31±0.28 ^X	3.16±0.31 ^Y	
	R	0.781±0.10 ^{aM}	0.788±0.0157 ^{aM}	0.752±0.010 ^{abN}	0.723±0.0020 ^{cdQ}	0.715±0.0125 ^{cdQ}	0.75±0.03 ^X		2.75±0.100 ^{cdQ}	2.95±0.136 ^{cdQ}	3.20±0.109 ^{abN}	3.42±0.055 ^{avcdN}	3.72±0.01 ^{abM}	3.21±0.35 ^Y		
		0.784±0.060 ^A	0.75±0.0189 ^B	0.72±0.027 ^C	0.68±0.033 ^D	0.668±0.042 ^E			2.646±0.28 ^E	2.845±0.27 ^D	3.01±0.29 ^C	3.24±0.29 ^B	3.43±0.31 ^A			
		Ash content (%)								β-carotene (µg/100gm)						
CH 27 GREEN	A	2.41±0.14 ^{aN}	2.45±0.11 ^{aN}	2.55±0.010 ^{cN}	2.88±0.10 ^{abM}	3.00±0.064 ^{aM}	2.66±0.26 ^Y	2.68±0.244 ^Y	400±15.27 ^{cdM}	350±5.85 ^{deN}	290±10.06 ^{cdQ}	200±7.67 ^{bcP}	185±5.00 ^{cp}	286.20±87.57 ^Y	292.97±85.46 ^Y	
	R	2.45±0.10 ^{cdQ}	2.54±0.10 ^{cdQ}	2.62±0.10 ^{cdNO}	2.88±0.07 ^{bdMN}	3.00±0.07 ^{aM}	2.70±0.23 ^X		400±7.63 ^{cdM}	380±4.04 ^{abM}	300±6.42 ^{abN}	220±10.00 ^{cdQ}	195±15.00 ^{cdQ}	299.73±85.80 ^X		
CH 27 RED	A	2.26±0.08 ^{cdQ}	2.36±0.11 ^{cdQ}	2.63±0.010 ^{cN}	2.86±0.08 ^{abMN}	2.99±0.13 ^{aM}	2.61±0.30 ^X	2.67±0.301 ^Y	430±17.55 ^{cdM}	360±3.05 ^{cdN}	260±6.11 ^{deQ}	210±5.00 ^{cdP}	186±2.00 ^{cdQ}	289.00±95.12 ^Y	308.00±86.33 ^W	
	R	2.35±0.10 ^{aN}	2.49±0.30 ^{abN}	2.94±0.12 ^{abM}	2.86±0.01 ^{abM}	3.05±0.08 ^{aM}	2.47±0.29 ^Y		430±3.05 ^{cdM}	390±3.05 ^{aN}	310±4.50 ^{cdQ}	260±2.51 ^{bp}	245±5.00 ^{cdQ}	327.00±74.94 ^X		
PS GREEN	A	2.33±0.11 ^{aN}	2.37±0.11 ^{aN}	2.73±0.10 ^{bcN}	2.99±0.12 ^{abMN}	3.15±0.10 ^{aM}	2.71±0.34 ^Y	2.74±0.378 ^X	441±8.62 ^{bdM}	340±5.50 ^{cdN}	240±6.65 ^{cdQ}	200±5.00 ^{cdP}	180±5.032 ^{cdQ}	286.1±109.66 ^X	295.93±87.30 ^X	
	R	2.24±0.10 ^{aN}	2.42±0.01 ^{aN}	2.98±0.11 ^{abM}	2.99±0.169 ^{abM}	3.26±0.131 ^{abM}	2.78±0.41 ^X		410±4.04 ^{cdM}	370±3.00 ^{cdN}	300±8.08 ^{abQ}	250±3.51 ^{bp}	235±5.00 ^{cdQ}	205.53±100.3 ^Y		
PS RED	A	2.41±0.10 ^{aN}	2.49±0.122 ^{aN}	3.01±0.07 ^{aM}	3.11±0.11 ^{abM}	3.26±0.10 ^{aM}	2.85±0.36 ^Y	2.86±0.34w	470±5.00 ^{cdM}	330±4.50 ^{cdN}	250±7.09 ^{cdQ}	200±12.58 ^{cdP}	178±3.055 ^{cdQ}	280.80±101.6 ^Y	296.83±103.73 ^X	
	R	2.45±0.11 ^{cdQ}	2.52±0.01 ^{cdQ}	2.91±0.12 ^{abN}	3.11±0.063 ^{abMN}	3.29±010 ^{aM}	2.87±0.34 ^X		470±1.52 ^{cdM}	350±4.16 ^{deN}	280±6.02 ^{cdQ}	220±5.033 ^{bp}	205±1.527 ^{bdQ}	313.0±69.96 ^X		
		2.365±0.12 ^E	2.44±0.99 ^D	2.81±0.20 ^C	2.966±1433 ^B	3.12±0.136 ^A			431.96±27.34 ^A	359.04±19.19 ^B	279.75±25.19 ^C	220.42±22.55 ^D	201.00±25.24 ^E			

Note: PS= Punjab Sindhuri; n = 3; A= Room temperature (25±2°C); R= refrigeration temperature (4°C); °cP= Degree centi poise; GAE= Gallic acid equivalent;

Data present in the table are average values aa Mean ± Standard Deviation; Values in a column and rows with different upper and lower case superscripts differ significantly; lower case w,x,y,z= effect on overall variety; upper case X,Y= effect of storage condition; lower case

a,b,c,...=Within month; upper case A,B,C,...= Overall month; upper case M,N,O,P= Month v/s month.

Table 3 Effect of storage condition, storage period and chili varieties on the phytochemical properties of honey chili sauce

		Storage period (months)						Storage period (months)							
Variety		0	2	4	6	8	Total	Overall mean	0	2	4	6	8	Total	Overall mean
		Lycopene(µg/100gm)						Ascorbic acid (mg/100gm)							
CH 27	A	5.0±0.30 ^{aM}	4.7±0.10 ^{aMN}	4.2±0.15 ^{aNO}	3.9±0.20 ^{aOP}	3.4±0.20 ^{aP}	4.26±0.62 ^Y	4.35±0.56 ^y	6.1±0.15 ^{cMI}	5±0.20 ^{cMN}	5.2±0.10 ^{cMNO}	4.23±0.185 ^{cNO}	4.00±0.70 ^{bOJ}	4.730±0.88 ^Y	5.164±0.78 ^y
GREEN	R	5.0±0.20 ^{aM}	4.8±0.15 ^{aMN}	4.6±0.40 ^{aMN}	4.1±0.25 ^{aNO}	3.9±0.11 ^{aP}	4.44±0.493 ^X		6.1±0.10 ^{cMI}	5.8±0.10 ^{aMN}	5.6±0.050 ^{aMN}	4.81±0.12 ^{aNO}	4.69±0.121 ^{aP}	5.25±0.70 ^X	
CH 27	A	5.2±0.20 ^{aM}	5.0±0.55 ^{aM}	4.8±0.10 ^{aMN}	4.5±0.20 ^{aMN}	4.1±0.20 ^{aN}	4.72±0.47 ^X	4.59±0.53 ^w	6.5±0.057 ^{abM}	5.5±0.15 ^{abMN}	5.12±0.10 ^{aNO}	4.51±0.122 ^{bcNO}	4.15±0.083 ^{bP}	4.98±0.83 ^Y	5.32±0.82 ^x
RED	R	5.2±0.15 ^{aM}	4.9±0.20 ^{aM}	4.4±0.200 ^{aN}	4.0±0.25 ^{aNO}	3.8±0.055 ^{aO}	4.45±0.56 ^Y		6.5±0.10 ^{bMI}	5.9±0.15 ^{aMN}	5.6±0.20 ^{aMN}	4.84±0.11 ^{abMN}	4.65±0.10 ^{abJ}	5.31±0.80 ^X	
PS	A	5.4±0.251 ^{aM}	4.8±0.20 ^{aN}	4.5±0.15 ^{aNO}	4.0±0.35 ^{aOP}	3.6±0.20 ^{aP}	4.44±0.660 ^X	4.36±0.66 ^y	6.4±0.10 ^{bcMI}	5.3±0.10 ^{bcMN}	5.1±0.40 ^{aMN}	4.90±0.095 ^{abMN}	4.71±0.124 ^{aN}	5.12±0.68 ^X	5.14±0.70 ^y
GREEN	R	5.4±0.351 ^{aM}	4.4±0.20 ^{aN}	4.1±0.351 ^{aNO}	3.9±0.20 ^{aNO}	3.6±0.200 ^{aP}	4.29±0.669 ^Y		6.4±0.150 ^{bcMI}	5.3±0.15 ^{bcMN}	5.13±0.10 ^{aNO}	4.12±0.11 ^{aNO}	4.00±0.00 ^{abP}	4.82±0.89 ^Y	
PS RED	A	5.2±0.351 ^{aM}	4.9±0.200 ^{aM}	4.6±0.20 ^{aMN}	4.1±0.30 ^{aNO}	3.8±0.10 ^{aOJ}	4.51±0.58 ^X	4.503±0.54 ^{wx}	6.9±0.10 ^{aMI}	5.7±0.20 ^{abMN}	5.7±0.20 ^{aMNO}	4.91±0.140 ^{aNO}	4.68±0.106 ^{aP}	5.32±0.90 ^Y	5.54±0.90 ^w
	R	5.2±0.152 ^{aM}	4.8±0.10 ^{abMN}	4.5±0.200 ^{aN}	4.0±0.251 ^{aOJ}	3.9±0.10 ^{aOJ}	4.49±0.528 ^Y		6.9±0.15 ^{abMI}	5.8±0.15 ^{aMN}	5.6±0.20 ^{aNO}	4.76±0.12 ^{abNOJ}	4.66±0.11 ^{aOJ}	5.33±0.88 ^X	
Total		5.21±0.254 ^A	4.77±0.27 ^B	4.46±0.287 ^C	4.05±0.271 ^D	3.75±0.24 ^E			6.48±0.29 ^A	5.51±0.32 ^B	5.38±0.287 ^C	4.65±0.32 ^D	4.442±0.32 ^E		
		Antioxidant activity (DPPH %)						Antioxidant activity (FRAP mM/100gm)							
CH 27	A	63.59±6.79 ^a	58.8±1.080 ^a	43.66±1.002 ^{cd}	41.10±0.812 ^{abc}	39.5±0.68 ^b	48.74±9.54 ^Y	48.94±11.9 ^y	4.48±0.20bM	3.45±0.045 ^{aN}	3.00±0.075 ^{abOJ}	2.48±0.20 ^{cP}	2.15±0.11 ^{bQJ}	3.11±0.85 ^Y	3.28±0.77 ^y
GREEN	R	63.59±0.94 ^{ab}	55.14±1.11 ^{bc}	44.77±1.19 ^{bc}	41.77±1.30 ^{bic}	40.48±0.81 ^{ab}	49.133±9.2 ^X		4.48±0.035 ^{bMI}	3.85±0.045 ^{aN}	3.18±0.160 ^{abOJ}	2.99±0.08 ^{abP}	2.70±0.126 ^{aP}	3.44±0.66 ^X	
CH 27	A	67.59±1.08 ^a	58.9±1.005 ^a	49.05±0.866 ^a	43.65±1.00 ^{ab}	40.65±1.10 ^{ab}	51.98±10.3 ^Y	52.025±12.8 ^w	4.78±0.04 ^{aMI}	3.98±0.043 ^{abcN}	3.09±0.06 ^{abP}	2.78±0.10 ^{bcP}	2.59±0.137 ^{aP}	3.41±0.85 ^Y	3.433±0.84 ^w
RED	R	67.59±1.10 ^a	58.24±0.94 ^a	46.03±0.82 ^{ab}	44.55±1.24 ^a	42.65±0.48 ^{ab}	52.06±9.91 ^X		4.78±0.020 ^{bMI}	3.99±0.030 ^{abN}	3.21±0.11 ^{bo}	2.74±0.11 ^{abP}	2.58±0.100 ^{abP}	3.44±0.86 ^X	
PS	A	63.64±1.15 ^{ab}	53.84±1.0 ^{cd}	41.3±1.17 ^{cd}	39.3±0.76 ^c	36.59±1.00 ^c	47.12±10.4 ^X	48.49±9.35 ^y	4.21±0.035 ^{bMI}	3.89 ±0.030 ^{abcN}	3.15±0.10 ^{abOJ}	2.72±0.210 ^{abP}	2.55±0.120 ^{abP}	3.30±0.67 ^Y	3.280±0.67 ^a
GREEN	R	63.64±1.26 ^{ab}	52.38±1.19 ^d	48.27±1.13 ^a	43.21±1.80 ^{ab}	41.35±1.41 ^b	49.87±8.24 ^Y		4.21±0.070 ^{bMI}	4.00 ±0.015 ^{aMI}	3.54±0.100 ^{aN}	2.77±0.09 ^{abOJ}	2.57±0.100 ^{aOJ}	3.41±0.68 ^X	
PS RED	A	69.56±1.12 ^a	57.21±1.11 ^{ab}	49.52±0.792 ^a	42.55±1.26 ^{ab}	40.65±0.86 ^a	51.95±10.8 ^X	50.563±11.3 ^x	4.39±0.202 ^{bMI}	3.04±0.065 ^{aN}	2.95±0.060 ^{aN}	2.39±0.11 ^{abOJ}	2.19±0.117 ^{bo}	2.97±0.81 ^Y	3.1433±0.78 ^z
	R	69.56±0.96 ^a	55.01±0.8 ^{bcd}	41.06±0.91 ^d	40.22±1.16 ^{ab}	39.54±0.879	49.16±12.0 ^Y		4.39±0.020 ^{bMI}	3.87±0.045 ^{bcN}	3.09±0.086 ^{abOJ}	2.79±0.20 ^{abP}	2.49±0.123 ^{abQJ}	3.30±0.74 ^X	
Total		65.59±3.86 ^A	56.307±2.4 ^B	42.231±1.86 ^D	42.231±1.86 ^D	45.73±3.21 ^C	40.166±21.93 ^E		4.46±0.20 ^A	3.75±0.322 ^B	3.14±1.87 ^C	2.69±0.20 ^D	2.4596±0.227 ^E		
Note: PS= Punjab Sindhuri; n = 3; A= Room temperature (25±2°C); R= refrigeration temperature (4°C); DPPH= 1,1-diphenyl-2-picryl-hydrazyl; FRAP= Ferric reducing antioxidant power;															
Data present in the table are average values aa Mean ± Standard Deviation; Values in a column and rows with different upper and lower case superscripts differ significantly; lower case w,x,y,z= effect on overall variety; upper case X,Y= effect of storage condition; lower case a,b,c,...=Within month; upper case A,B,C,...= Overall month; upper case M,N,O,P= Month v/s month.															

Table 4 Effect of storage condition, storage period and chili varieties on the colour and microbial properties of honey chili sauce

		Storage period (months)							Storage period (months)									
Variety		0	2	4	6	8	Total	Overall mean	0	2	4	6	8	Total	Overall mean			
		Color (L value)								Color (a value)								
CH 27	A	31.83±1.17 ^{aM}	32.79±1.06 ^{aM}	32.41±1.04 ^{aM}	32.79±1.17 ^{aM}	31.79±1.11 ^{aM}	32.12±1.04 ^Y	32.24±1.11 ^w	2.32±0.14 ^{cMN}	2.32±0.06 ^{dMN}	2.45±0.045 ^{dM}	2.4±0.057 ^{cMN}	2.2±0.10 ^{aM}	2.3±0.121 ^Y	2.98±0.97 ^x			
GREEN	R	31.83±1.17 ^{aM}	32.3±0.76 ^{aM}	33.67±0.84 ^{aM}	32.67±1.33 ^{aM}	31.67±1.04 ^{aM}	32.36±1.21 ^X		2.32±2.3 ^{cN}	2.48±0.01 ^{dN}	4.58±0.045 ^{cM}	4.5±0.40 ^{bM}	4.2±0.10 ^{aM}	3.6±1.03 ^X				
CH 27	A	28.18±1.11 ^{aN}	34.29±1.11 ^{aM}	26.33±0.79 ^{bN}	34.29±0.67 ^{aM}	32.29±1.19 ^{aM}	31.23±3.42 ^X	28.81±3.56 ^x	4.1±0.09 ^{aO}	4.7±0.10 ^{cN}	4.88±0.02 ^{bMN}	4.8±0.036 ^{aM}	4.5±0.20 ^{aM}	4.59±0.31 ^Y	4.48±0.51 ^w			
RED	R	28.18±1.11 ^{aM}	25.98±0.97 ^{bCMN}	25.68±0.91 ^{bN}	26.68±1.1 ^{bMN}	25.68±0.90 ^{bCN}	26.38±1.42 ^Y		4.1±4.1 ^{aO}	5.15±0.00 ^{aN}	5.5±0.10 ^{aM}	5.45±0.27 ^{bMN}	5.35±0.07 ^{aMN}	5.10±0.54 ^X				
PS	A	30.44±1.05 ^{aM}	23.41±1.1 ^{cMO}	26.34±1.007 ^{bN}	25.41±0.7 ^{bNO}	24.41±0.86 ^{bCMO}	26.08±2.61 ^Y	26.61±2.56 ^y	1.67±1.6 ^{dM}	1.67±0.03 ^{eM}	0.73±0.055 ^{bM}	0.73±0.040 ^{dM}	0.7±4.24 ^{aM}	1.57±1.82 ^X	1.47±1.30 ^y			
GREEN	R	30.44±1.05 ^{aM}	28.27±1.01 ^{bMN}	26.42±0.94 ^{bN}	26.41±1.17 ^{bN}	23.41±0.82 ^{cO}	27.14±2.49 ^X		1.67±1.6 ^{dM}	1.12±0.02 ^{IM}	1.44±0.055 ^{eM}	1.4±0.40 ^{aM}	1.2±0.60 ^{aM}	1.37±0.33 ^Y				
PS RED	A	24.79±1.28 ^{bMN}	23.55±1.34 ^{bN}	26.2±0.92 ^{bM}	26±1.06 ^{bMN}	24±1.03 ^{bCMN}	24.92±1.58 ^Y	24.40±1.45 ^z	3.15±3.1 ^{bN}	5.12±0.09 ^{aM}	5.05±0.060 ^{bM}	4.98±0.051 ^{aM}	4.95±0.035 ^{aM}	4.64±0.77 ^Y	4.84±0.867 ^w			
	R	24.79±1.28 ^{bM}	25.44±1.07 ^{bCM}	26.33±0.95 ^{bM}	26.33±0.98 ^{bM}	26.33±0.86 ^{bM}	25.88±1.17 ^X		3.15±3.1 ^{bO}	4.98±0.02 ^{bN}	5.65±0.055 ^{aM}	5.6±0.36 ^{aM}	5.4±0.20 ^{bN}	4.93±0.95 ^X				
Total		28.72±2.90 ^{AB}	28.19±4.27 ^{ABC}	28.0017±3.9 ^{BC}	28.84±3.59 ^A	27.56±3.621 ^D			2.81±0.94 ^U	3.44±1.62 ^C	1.86±0.381 ^E	3.72±1.82 ^B	3.85±1.94 ^A					
		Color (b value)								Total plate count (cfu/ml)								
CH 27	A	7.74±0.045 ^a	10.22±0.055 ^a	7.75±0.04 ^b	7.7±0.20 ^b	7.9±0.20 ^a	8.26±1.02 ^Y	8.71±1.070 ^w	0.02±0.01 ^{AaM}	0.04±0.01 ^{aM}	0.08±0.01 ^{aM}	0.10±0.25 ^{aM}	0.15±0.04 ^{aM}	0.136±0.21 ^X	0.138±0.22 ^w			
GREEN	R	7.74±0.045 ^a	8.46±0.03055 ^b	10.02±0.056 ^a	9.89±0.049 ^a	9.75±0.03055 ^a	9.17±0.93 ^X		0.02±0.01 ^{aM}	0.04±0.01 ^{aM}	0.08±0.01 ^{aM}	0.10±0.01 ^{aM}	0.14±0.04 ^{aM}	0.129±0.23 ^Y				
CH 27	A	4.15±0.050 ^c	6.37±0.04 ^c	2.47±0.45 ^d	2.41±0.0305 ^c	2.35±0.04041 ^b	3.54±1.61 ^Y	3.071±1.35 ^x	0.02±0.01 ^{AaO}	0.05±0.01 ^{aM}	0.09±0.01 ^{aM}	0.11±0.015 ^{aMN}	0.16±0.04 ^{aM}	0.084±0.05 ^Y	0.087±0.05 ^x			
RED	R	4.15±0.050 ^c	1.94±0.030 ^f	2.01±0.058 ^e	2.45±0.045 ^c	2.4±0.10 ^b	2.59±0.83 ^Y		0.02±0.01 ^{aP}	0.05±0.01 ^{aM}	0.09±0.01 ^{aM}	0.11±0.48 ^{aMN}	0.15±0.045 ^{aM}	0.090±0.57 ^X				
PS	A	6.07±0.056 ^b	3.72±0.055 ^d	0.65±0.00 ^g	0.7±0.100 ^e	0.5±3.20 ^b	2.68±2.42 ^Y	2.82±2.077 ^x	0.03±0.01 ^{aO}	0.05±0.01 ^{aM}	0.09±0.01 ^{aM}	0.09±0.01 ^{aM}	0.15±0.04 ^{aM}	0.080±0.04 ^Y	0.086±0.05 ^y			
GREEN	R	6.07±0.056 ^b	3.44±0.0152 ^e	1.63±0.065 ^f	1.91±0.075 ^d	1.81±0.010 ^b	2.96±1.73 ^X		0.03±0.01 ^{aN}	0.06±0.0 ^{aMN}	0.08±0.0 ^{aMN}	0.12±0.01 ^{aM}	0.16±0.040 ^{aM}	0.091±0.05 ^X				
PS RED	A	-0.26±0.040 ^d	3.66±0.0404 ^e	1.69±0.01 ^f	2±0.100 ^d	1.5±0.100 ^b	1.71±1.29 ^X	1.70±1.20 ^y	0.02±0.01 ^{aN}	0.03±0.01 ^{bN}	0.07±0.01 ^{bMN}	0.12±0.01 ^{aM}	0.16±0.045 ^{aM}	0.081±0.06 ^X	0.077±0.05 ^z			
	R	-0.26±0.040 ^d	1.16±0.010 ^g	2.64±0.060 ^c	2.7±0.30 ^c	2.5±0.100 ^b	1.69±1.15 ^Y		0.02±0.01 ^{aO}	0.05±0.01 ^{aM}	0.09±0.01 ^{aM}	0.09±0.01 ^{aM}	0.12±0.036 ^{aM}	0.074±0.04 ^Y				
		4.4250±3.05 ^B	4.87±3.04 ^A	3.61±3.2210 ^E	3.68±3.10 ^D	3.8154±3.15 ^C			0.0225±0.009 ^C	0.046±0.12 ^C	0.085±0.01251 ^{BC}	0.187±0.234 ^A	0.145±0.0361 ^B					
Note: PS= Punjab Sindhuri; n = 3; A= Room temperature (25±2°C); R= refrigeration temperature (4°C); cfu= colony forming units;																		
Data present in the table are average values aa Mean ± Standard Deviation; Values in a column and rows with different upper and lower case superscripts differ significantly; lower case w,x,y,z= effect on overall variety; upper case X,Y= effect of storage condition; lower case a,b,c,...=Within month; upper case A,B,C...= Overall month; upper case M,N,O,P= Month v/s month.																		

Table S1 p- values from the univariate analysis of variance of factors

	TSS	pH	acidity	Total solid	Total sugar	Reducing sugars	Viscosity	Total Phenolic	Water Activity	Electrical Conductivity	Ash content	β-carotene	Lycopene	Ascorbic acid	FRAP	DPPH	<i>L</i>	<i>a</i>	<i>b</i>	TPC
CD (0.95)																				
Month	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Storage condition	NS	.006	NS	.022	NS	<.001	<.001	<.001	<.001	NS	.001	<.001	NS	<.001	<.001	NS	<.001	<.001	NS	NS
Variety	.018	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	.119
Month * Storage condition	NS	.030	.028	.015	NS	<.001	<.001	<.001	<.001	NS	NS	<.001	NS	<.001	<.001	.001	.011	.017	<.001	NS
Month * Variety	NS	NS	NS	<.001	<.001	<.001	<.001	<.001	NS	NS	<.001	<.001	NS	<.001	<.001	<.001	<.001	<.001	<.001	.012
Storage condition * Variety	NS	.020	.015	NS	NS	<.001	<.001	<.001	NS	NS	NS	<.001	.003	<.001	<.001	<.001	<.001	.001	<.001	NS
Month * Storage condition * Variety	NS	NS	.428	NS	NS	<.001	<.001	<.001	NS	NS	NS	<.001	NS	<.001	<.001	<.001	<.001	NS	<.001	NS

TSS= total soluble solids; DPPH= 1,1-diphenyl-2-picryl-hydrazyl; FRAP= Ferric reducing antioxidant power; TPC= total plate count

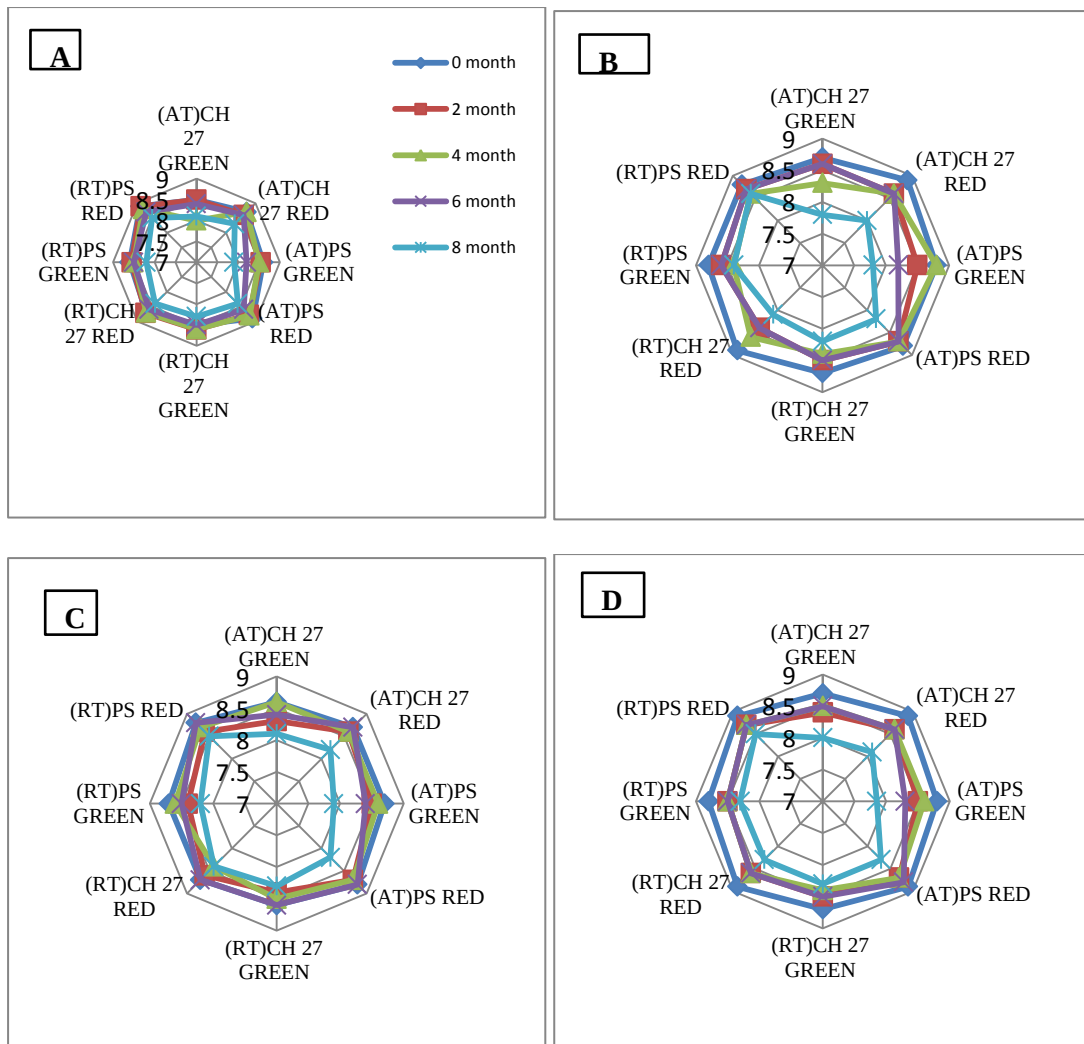


Figure 1 Sensory scores of honey chili sauce (A=Colour; B= Consistency; C= Mouth-feel; D= Overall acceptability); {AT= Room temperature, RT= refrigeration temperature}

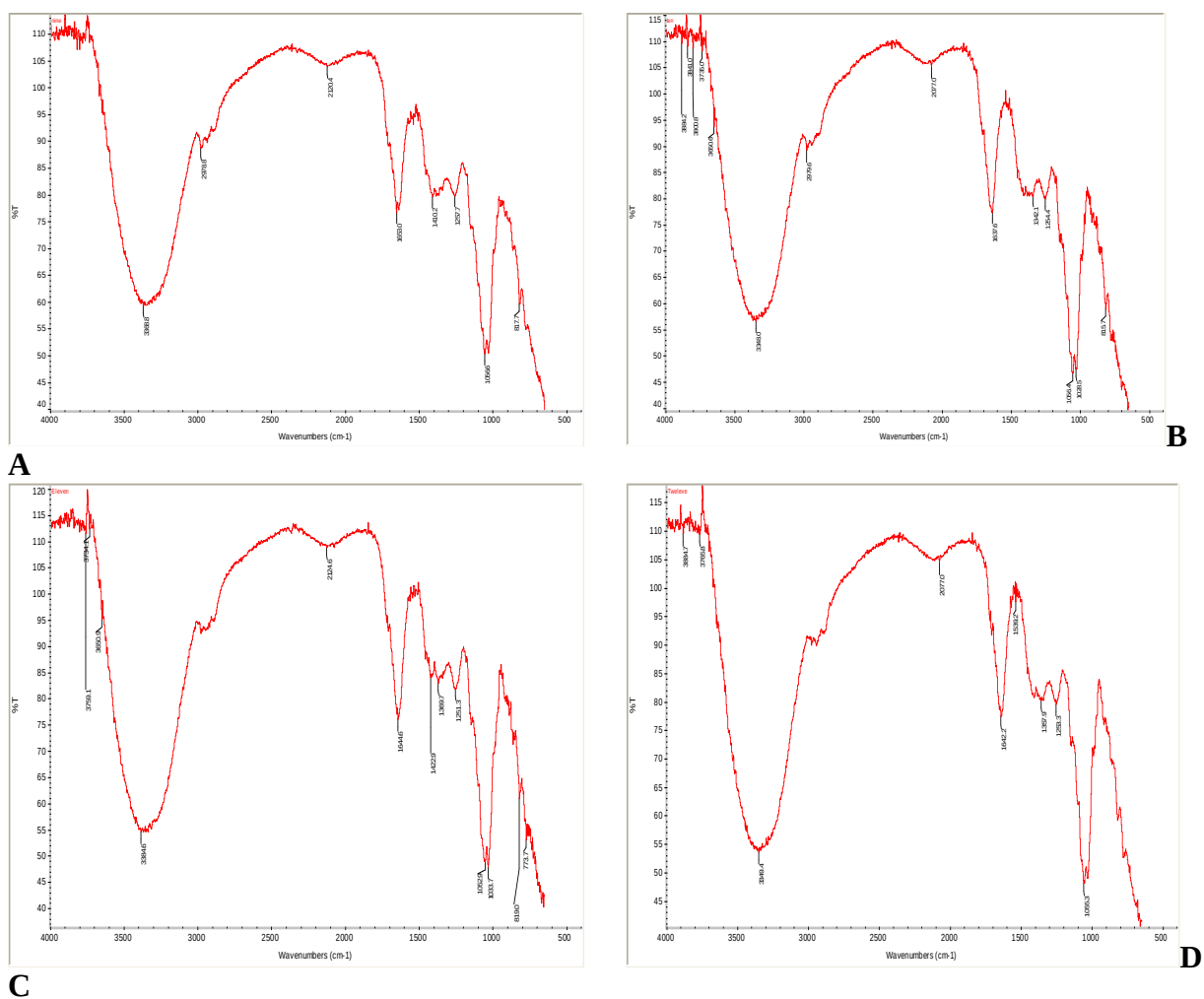


Figure 2 FTIR peak wavelength for honey chili sauce with CH-27 green (A), CH-27 red (B), Punjab sindhuri green (C) and Punjab sindhuri (D)

VITA

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