

CARROT JUICE CONCENTRATE PRODUCTION AND UTILIZATION

Thesis

by

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(H-2016-11-D)**

submitted to



**Dr. YASHWANT SINGH PARMAR UNIVERSITY
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SOLAN (NAUNI) HP - 173 230 INDIA**

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partial fulfilment of the requirements for the degree

of

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FOOD TECHNOLOGY
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CERTIFICATE - I

This is to certify that the thesis titled, “**Carrot juice concentrate production and utilization**” submitted in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY FOOD TECHNOLOGY** in the discipline of **Food Science and Technology** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh – 173 230 India is a bonafide research work carried out by **Ms Sakshi Sharma (H-2016-11-D)** daughter of Shri Suresh Kumar under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

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CERTIFICATE - II

This is to certify that the thesis titled, "Carrot juice concentrate production and utilization" submitted by **Ms Sakshi Sharma (H-2016-11-D)** daughter of **Shri Suresh Kumar** to the **Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (H.P) - 173 230, India** in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY FOOD TECHNOLOGY** in the discipline of **FOOD SCIENCE AND TECHNOLOGY** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

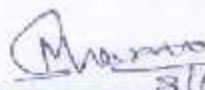

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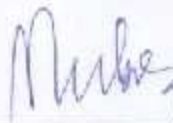

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Place:

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ABBREVIATIONS USED

%	:	Per cent
°B	:	Degree brix
°C	:	Degree Celsius
μM	:	Micro-molar
@	:	At the rate
a _w	:	Water activity
cm	:	Centimeter
cP	:	Centipoise
g	:	Gram
mg	:	Milligram
kg	:	Killogram
mL	:	Millilitre
mm	:	Millimeter
min	:	Minutes
h	:	Hour
Rs	:	Rupees
CD	:	Critical difference
cv.	:	Cultivar
<i>et al.</i>	:	Co-workers
ppb	:	Parts per billion
ppm	:	Parts per million
OD	:	Optical density
ABTS	:	2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid)
DPPH	:	2, 2-Diphenyl-1-picrylhydrazyl
FRAP	:	Ferric reducing anti-oxidant power
KMS	:	Potassium metabisulphite
TSS	:	Total soluble solids
GAE	:	Gallic acid equivalent
NEB	:	Non-enzymatic browning
NHB	:	National Horticulture Board
HMF	:	Hydroxymethyl furfural
RSM	:	Response surface methodology
cfu	:	Colony forming units
NTU	:	Nephelometric turbidity units

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Chapter-1

INTRODUCTION

Carrot (*Daucus carota* L.) is one of the most important food crops of Apiaceae family. Worldwide, this is one of the most commonly consumed vegetable after potato (Hardley and Fordham, 2003). China is the largest producer of carrot in the world followed by Russia, USA, Uzbekistan, Poland, Ukraine, UK, Turkey, Japan and France. India ranks 14th in its production amongst 125 carrot cultivating countries. During 2017-18, total carrot production in India was 1648, 000 tonnes from an area of 97, 000 hectare. Major carrot producing states in India are Haryana, Andhra Pradesh, Uttar Pradesh, Assam, Karnataka, Punjab and Tamil Nadu. In Himachal Pradesh, total carrot production was 6.06 thousand tonnes from an area of 0.38 thousand hectare during 2017-18 (NHB, 2018).

The roots of carrot were primitively used for medical purposes and gradually emerged as food. There is a wide variety of colour in carrot flesh (white, yellow, orange, red, purple and dark purple). The first cultivated carrots were yellow and purple fleshed cultivars (Singh *et al.*, 2019). However, a rapid rise in the popularity of orange carrots was observed with the recognition of its high α and β -carotene content (Simon and Wolff 1987; Roshni *et al.*, 2019). Carotenoids and anthocyanins are the major antioxidant pigments found in carrots. Carotenoids are the yellow, orange or red coloured phytochemicals found in most yellow and orange fleshed cultivars. Yellow colour in carrot is due to lutein which plays an important role in prevention of macular degeneration (Dias, 2014). Red colour in carrot is due to its high lycopene content while, white flesh cultivars contain very little pigments. The carotene content of the orange and yellow fleshed cultivars increases with root growth and maturity (Simon and Goldman, 2007; Dias, 2014). Besides, carrot provides a significant amount of vitamin A in human diet due to the high bioavailability of carotenoids (Van *et al.*, 2000; Singh *et al.*, 2020). However, the red/ purple colour pigments like water-soluble anthocyanin and water-insoluble lycopene are also present in the roots of some cultivars. Anthocyanin-rich carrots are usually purple and dark purple in colour (Sun *et al.*, 2009; Ulusoy and Tamer, 2019). In addition to their colouring properties, anthocyanins may also exhibit some health benefits such as the decrease in the risk of stroke, reduced risk of coronary heart disease,

antitumor properties, anti-inflammatory effects and improved cognitive behavior (Netzel *et al.*, 2007).

In many countries, the carrot has gained popularity in the 21st century due to the awareness of their nutritional value and health related benefits (Arscott and Tanumihardjo, 2010). Among 38 fruits and vegetables, carrot has been ranked 10th with respect to their nutritional quality and 7th for its contribution to nutrition (Alasalver *et al.*, 2005; Acharya *et al.*, 2015). The consumption of carrot and carrot products is increasing steadily owing to its recognition as an important source of natural antioxidants (Dreosti, 1993; Speizer *et al.*, 1999; Jacob *et al.*, 2013). Antioxidants are naturally occurring chemicals in food that help to counter the detrimental effects of reactive oxygen species (ROS) and free radicals which causes degenerative human diseases such as cancer and heart diseases (Wresburger, 2002). Carotenoids help in preventing heart diseases, improve vision, help in reducing blood sugar and reduce colon cancer. They also act as free-radical scavengers (Bast *et al.*, 1996; Bramley 2000; D'Odorico *et al.*, 2000). Phenolic compounds have received considerable attention because of their physiological functions, including antioxidant, antimutagenic and antitumor activities (Oviasogie *et al.*, 2009). Carrots have also a unique combination of three flavonoids i.e. kaempferol, quercetin and luteolin (Ching and Mohamed, 2001; Lila, 2004; Horbowicz *et al.*, 2008). They are also rich in other phenols, including chlorogenic, caffeic and p-hydroxybenzoic acids along with numerous cinnamic acid derivatives. Among hydroxycinnamic acid and its derivatives, chlorogenic acid represents 42.2 per cent to 61.8 per cent of total phenolic compounds detected in different carrot tissues (Zhang and Hamauzee, 2004; Goncalves *et al.*, 2010). Bioactive polyacetylenes such as falcarinol and falcarindiol are found in carrots (Lund and White, 1990). These compounds have been reported to stimulate cancer-fighting mechanisms in the human body. Similarly, carrot is a good source of dietary fibre and of the trace mineral molybdenum, rarely found in many vegetables. Molybdenum aids in metabolism of fats and carbohydrates and is important for absorption of iron. It is also a good source of magnesium and manganese. Magnesium is needed for bone, protein, making new cells, activating B vitamins, relaxing nerves and muscles, clotting blood, and in energy production (Guerrera *et al.*, 2009). Insulin secretion and function also require magnesium (Bartlett and Eperjesi, 2008; Kim *et al.*, 2010). Further, manganese is helpful in carbohydrate metabolism, in coordination with enzymes in the body (Dias, 2014). It is used

by the body as a co-factor for the antioxidant enzyme, superoxide dismutase. Potassium and magnesium in carrots help in functioning of muscles.

Though, the carrot is a cheapest source of carotenoids for the poor people but its availability is limited to only 3-4 months and it is not possible to make it readily available throughout the year. Processing of carrot into juice during the main growing season is the only alternatives to make it available for a common man besides, its use by the ancillary industry for incorporation into various food products. Commercially, this low-cost root vegetable is converted into various value-added products like fresh juice, candy, preserve, soups, stews, curries, pies, *halwa*, and various cooked vegetable dishes (Salunkhe *et al.*, 2015; Peng *et al.*, 2019). Moreover, carrot juice which is exceptionally rich in nutritive value has not been properly utilized for its value addition. In real sense, the potential of processing of this vegetable into modern products has not yet been fully explored.

The total global trade of fruit juice products in 2015 was 12.1 million tonnes worth of US\$15.0 billion. The orange juice products accounted for 41.70 per cent of global juice market. Apple juice products were the 2nd largest category, accounting for 14.20 per cent of global export followed by pineapple juice (6%), grape juice (4%), grapefruit juice (2%) and cranberry juice (2%). Carrot juice and its concentrate which currently has negligible contribution in global juice market needs to be explored for its potential. Scanty information is available from the developed world about carrot juice processing in to concentrate. Similarly, in India, there is not even a single commercial processing unit, using carrot for the manufacture of juice concentrate. Carrot juice concentrate production during the main growing season of this crop could be an economically viable alternative. Juice concentrates are considered to be very good supplementation agents for enrichment of different food products without compromising any flavour or sensory quality (Chantaro *et al.*, 2008).

Among staple food products, bakery products are one of the most popular food products and this sector has 3rd position in terms of revenue generation in food processing industry. Bakery products include items such as bread, cakes, biscuits (crackers and cookies) and breakfast cereals containing wheat flour as main ingredient to provide bulk and structure to the products (Lai and Lin, 2006). Cereals, sugar and fat are major constituents in bakery products and therefore, they have abundant source of energy but are deficient in fibers, minerals and phytochemicals such as carotenoids, anthocyanins and antioxidants. Moreover,

bakery products are consumed in large quantities on a daily basis by people of all age groups. Due to their high requirement in human body to meet out the basic nutritional demand, they can be used as a vehicle for fortification with the ultimate aim of adding healthful ingredients from other plant and animal sources. Recently, the addition of functional ingredients for the enrichment of bakery products has shown the increasing trend in their popularity due to their ability to reduce the risk of chronic diseases beyond basic nutritional functions (Eswaran *et al.*, 2013).

Therefore, keeping in view the nutritional, functional food and therapeutic importance of carrot and its availability in abundance during the main growing season, efforts have been made to develop carrot juice concentrate and its further incorporation for the development of various value-added bakery products with the following objectives:

- i) Standardization of pre-treatment(s) for carrot juice extraction.
- ii) Optimization of technology for the manufacture of carrot juice concentrate from different types of carrot and its quality assessment during storage.
- iii) Utilization of carrot juice concentrate for the development of functional food products and their evaluation during storage.

Chapter-2

REVIEW OF LITERATURE

Carrot (*Daucus carota* Sativus) is one of the most important seasonal root vegetable belonging to family Apiaceae (Umbelliferae) and is grown extensively in India during winter season for its edible tap root. Primary centre of origin of carrot is Afganistan from where it was distributed to Asia, Europe, North Africa and the Mediterranean region (Kalra *et al.*, 1987; Mazza and Miniati, 1993). Although, it has been widely cultivated for many centuries, the use of carrot as a food dates back only from the early 20th century. According to botanical classification of carrot seeds, they are divided into two groups viz., the carotene group (*Daucus carota* ssp. var. *Sativus*) and anthocyanin group (*Daucus carota* ssp. *Sativus* var. *Atrorubens* Alef.). Though, orange coloured carrot varieties are more common, consumption of black or purple carrots is currently increasing worldwide due to its health benefits. Black carrot has attracted the attention of the scientific community due to their higher total phenolics and anthocyanin content, which are significantly related to its antioxidant capacity (Alasalvar *et al.*, 2001; Priya and Santhi, 2015). Nutritionally, carrot is rich in both antioxidants i.e. lipophilic (xanthophylls, carotenoids) and hydrophilic (phenols), vitamin A, B₁, B₂, C, E, folic acid, flavonoids, phosphorus and extraordinary pectin fibers (Breithaupt and Bamedi, 2001; Sharma *et al.*, 2012; Aadil *et al.*, 2013; Leja *et al.*, 2013). Carotenes is the major pigment present in carrot and is a well known precursor of vitamin A, have long been recognized for their role in vision, cataract prevention but more recently claims has been made for its anti-cancer properties along with its role in prevention of cardiovascular diseases (Kaur *et al.*, 2019).

Carrots are generally consumed as raw (fresh, whole or baby carrots) and/ or processed/ value added form (canned foods, soups, juice and frozen products). One of the most important processed forms of carrot is carrot juice, which is a natural source of antioxidants along with other nutritional qualities as well. Therapeutic properties of carrot juice include boosting of immunity, minor wound and injury healing in addition to maintaining normal blood pressure. It also cleans the liver by excreting fats and bile (Bakhru, 1993; Wrolstad, 2004). Because of all these properties, carrot juice is often considered as a health drink or super food. Furthermore, due to massive volume (84-91% moisture content)

of single strength juices, their packaging, storage and transportation is economically very expensive. To overcome these challenges and to ensure supply of nutritionally rich juice and its products around the year, fruit juice concentration is a potential technique. In this process, volume of juices is often reduced by physical removal of naturally present water from the juices (Jeong *et al.*, 2004). It is done by three basic methods or their modifications i.e. membrane concentration, thermal concentration and freeze concentration or their modifications. Meanwhile, a large number of researchers and experts are investigating the synergism between the sensory, nutritional attributes of fruit juice/ concentrates and processing conditions.

Cereal-based foods are widely utilized in many developing nations as dietary staples for adults and weaning foods for infants (Adelakun and Oyelade, 2011). Cereal products are consumed daily by the majority of the population and for years the food industry has focused on increasing the nutritional value of these products (Ktenioudaki and Gallagher, 2012) because of the rising interest in functional food, especially bioactive substances, food producers look for new sources and carriers for those substances. Among many bioactive substances to be found in food such as antioxidants, plant sterols, probiotics, prebiotics and vitamins, a crucial role is played by dietary fibre (Rodriguez *et al.*, 2006). Emerging technology, intense participation in business life, urbanization and people's preferences for food consumption are changing rapidly. Consumers search those products which would allow them to maintain their physical and mental fitness (Gorecka *et al.*, 2010). Consumer believes that optimization of their diets will help them to improve personal wellbeing and reduce healthcare expenses (Milner, 2002). Bakery products are most widely consumed food items in the world and among these products and cakes are the most popular bakery item consumed by all levels of society. Among different types of food products bakery products has a special position due to its deliciousness, ready to eat nature, availability in different forms and affordable cost (Bazrafshan *et al.*, 2015; Yaqoob *et al.*, 2017) which can be utilized as nutritional tool to carry the functional product (Lebesi and Tzia, 2011). Majority of bakery products are high in carbohydrate, fat and calorie but low in functional contents and these characteristics make them as unhealthy choices for daily consumptions.

Therefore, the development of carrot juice concentrate has been attempted in order to make a nutritionally rich product and was further utilized in various food products for supplementation and/ or enrichment with phytonutrients. Some of the scientific research work

done in India and abroad on various aspects of carrot, pre-treatments like blanching and enzymatic treatment, juice extraction, juice concentration and its utilization in product development etc. have been reviewed under the following heads:

- 2.1 Present status of carrot in India
- 2.2 Physico-chemical composition, functional and medicinal properties of carrot
- 2.3 Pre-treatments and their effect on juice quality and yield
- 2.4 Juice concentration
- 2.5 Effect of storage on physico-chemical, nutritional and sensory quality of juice concentrate
- 2.6 Utilization of juice concentrates in food products

2.1 PRESENT STATUS OF CARROT IN INDIA

Accounting for 329 million hectares of total land, India ranks 7th area-wise after Russian Federation, Canada, USA, China, Brazil, and Australia in the world (13, 466 million hectares). Out of total land, only 48.32 per cent i.e. 159 million hectares is cultivated land in India. Due to India's diverse climatic conditions, there are 15 agro-climatic zones which ensures availability of all varieties of fresh fruits and vegetable throughout the year. Our presence in global market is significant as India is the second largest producer of vegetables and fruits in the world. India has witnessed significant progress in horticulture production over the last few decades. Over the last decade, the area under horticulture grew by 2.60 per cent per annum with an annual production increase by 4.80 per cent during 2017-18. The world production of fruit and vegetable crops was 866.00 million tonnes and 1075.00 million tonnes, respectively. In India, there was an increase in vegetable production from 101.20 million tonnes to 184.40 million tonnes and fruit production from 50.90 million tonnes to 97.35 million tonnes since 2004-05 to 2017-18 (NHB, 2018).

According to recent estimate of crop-wise area and production of horticulture crops, carrot accounts for 82, 86, 97 (000 hectare) area and 1338, 1350, 1648 (000 metric tonnes) production in the year 2015-16, 2016-17 and 2017-18, respectively. Carrot is grown extensively throughout India as one of the major vegetables. Major carrot producing states are Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Tamilnadu, Karnataka, Assam, Bihar, Andhra Pradesh, Jammu & Kashmir and Chattisgarh. In Himachal Pradesh, total area under

carrot was estimated to be 0.38 thousand hectare with an annual production of 7.67 thousand metric tonnes during the year 2017-2018 (NHB, 2018).

2.2 PHYSICO-CHEMICAL COMPOSITION, FUNCTIONAL AND MEDICINAL PROPERTIES OF CARROT

2.2.1 Fruit size and weight

Compositions of vegetable not only vary according to botanical variety, cultivation practices and weather, but also change with the degree of maturity prior to harvest, the condition of ripeness and storage conditions. Size of the carrot varies with variety, location and season. The length and diameter based on maturity of the Pusa Kesar variety of carrot ranges from 12.06 to 21.60 cm and 1.88 to 3.04 cm, respectively (Haq *et al.*, 2013). According to Yasuda *et al.* (2017) length of orange carrot root was 18.00 cm and diameter was 4.50 cm while, Singh *et al.* (2019) revealed a range of 7.90-11.90 cm, 1.84-4.27 cm for carrot root length and diameter, respectively. Similar reports for variability in germplasm of various heritable traits in carrot have been reported by Kumar *et al.* (2010), Gupta *et al.* (2012), Asima *et al.* (2013) and Priya and Shanthi (2015). Roshni *et al.* (2019) studied the effect of inorganic and bio-fertilizers on carrot root and they observed root length of 17.10-20.07 cm and root weight of 92.81-113.34 g. However, Chaitra *et al.* (2019) studied 96 germplasms of carrot and the root length, root diameter and root weight was reported as 17.51 cm, 2.45 cm and 41.25 g, respectively. Chen *et al.* (2020) analyzed main agronomic traits in 20 different varieties of carrots and noticed that the weight of single root ranged from 75.29-278.56 g, diameter from 2.34-5.50 cm and length from 14.85-24.10 cm. Singh *et al.* (2020) studied 81 genotypes of carrot and reported variation of 13.80-30.80 cm, 101.40-127.20 g, 2.50-3.50 cm in root length, root weight and root diameter, respectively. According to Kaur and Sogi (2020) length and breadth of black carrot root were 38.13 cm, 5.70 cm for Black Wonder and 32.37 cm, 4.10 cm for Pusa Asita variety, respectively. Similarly, a range 25.62-25.78 cm and 3.3-3.38 cm of length and diameter of black carrot has been reported by Singla *et al.* (2020).

2.2.2 Moisture

Moisture content in vegetable is an important constituent as it affects the physical, chemical aspects of food which relates with the freshness and stability of the food. Many researchers have reported a wide range (80-90%) of moisture in various varieties of carrot (Howard *et al.*, 1962; Gill and Kataria, 1974; Holland *et al.*, 1991; Gopalan *et al.*, 1991).

However, various workers (Prakash *et al.*, 2004; Sun and Temelli, 2006; Karmoker *et al.*, 2011; Raquel *et al.*, 2014; Varmudy, 2014; Al-Amin *et al.*, 2015) observed slightly lower range of moisture content in carrot roots as 85-88 per cent. The initial moisture content of 88.50 per cent before drying was observed by Castro *et al.* (2008). However, a lower value of moisture content (85.00%) was reported by Upadhyay *et al.* (2008). The values were similar to Karki (2009), who documented 89.92 and 85.14 per cent moisture content in raw carrot roots and carrot pomace, respectively. Further, Rashidi and Khabbaz (2010) revealed that carrot contains 75 to 88 per cent moisture. Similar values were observed by Rahman *et al.* (2010). A moisture content of 88.00 per cent was reported by Kumar and Kumar (2011). According to Kumar *et al.* (2012) the perishability of carrot pomace is due to its high moisture content (85%). Gani and Kumar (2013) studied drying of carrot roots and they documented 86.70 per cent moisture content in raw carrot. A higher value of 92.15 per cent moisture content in carrot roots was revealed by Velescu *et al.* (2013) and James and Matemu (2016). In another study, 87.00 per cent moisture was documented by Borowska *et al.* (2017) and Rubina *et al.* (2018). Kaur and Sogi (2020) revealed a range of 88.71-91.96 per cent moisture content in black carrot roots.

2.2.3 Total soluble solids (TSS)

Total soluble solids of fruit represent sugars and acids together with small amounts of vitamins, fructans, proteins, pigments, phenolics and minerals which are present in soluble/dissolved form (Tadeo *et al.*, 1987; Chope *et al.*, 2006). The total soluble solids in carrots range from 8.46-9.98 per cent (Sandhu *et al.*, 1988). However, a lower range of 6.00-9.00 per cent total soluble solids in pure carrot juice has been reported by Singh (1996). Sagar *et al.* (2004) analyzed four varieties of carrots viz., Pusa Kesar, Pusa Meghali, Sel-14 and Sel-16 which were found to have 8.85, 10.06, 11.17 and 10.04 per cent of total soluble solids, respectively. The variety PC-34 have been found to have total soluble solids of 8.50 per cent whereas, Selection-21 had 7.00 per cent total soluble solids (Pandove, 2007). Further, Kirca *et al.* (2007) recorded 10.80 per cent total soluble solids in carrot roots. A slightly higher value for TSS in black carrot i.e. 11.90 per cent have been reported by Ersus and Yurdagel (2007). Karki (2009) have reported 8.02 per cent TSS in fresh carrot. Rashidi and Khabbaz (2010) observed that carrot contains 8.50-12.50 per cent total soluble solids and a similar range of 8.60-12.30 per cent total soluble solids was observed by Rashidi and Gholami (2011) in fresh carrot. Kiraci and Padem (2016) revealed a range of 6.23-8.27 per cent total soluble solids. A value of 7.10, 6.08 and 7.77 per cent has been given by Yasuda *et al.*

(2017), Umair *et al.* (2019) and Chaitra *et al.* (2019), respectively. In another study, Bajaj and Singhal (2019) documented 7.27 per cent TSS of carrot. Total soluble solid content of 8.60 and 9.47 per cent in Black Wonder and Pusa Asita variety of black carrot has been observed by Kaur and Sogi (2020). Cheena *et al.* (2020) reported 11.30 per cent TSS in Kuroda variety of carrot. However, a slightly lower range of 7.80-9.50 per cent was recorded by Singh *et al.* (2020).

2.2.4 Sugars

Sugars are the smallest and simplest type of carbohydrates, which represents all the saccharides present in the food. Various workers have reported a wide range of reducing and total sugars in various varieties of carrot. Kaur *et al.* (1976) have observed a range of 1.67-3.35 per cent reducing sugars, 1.02-1.18 per cent non-reducing sugars and 2.71-4.53 per cent total sugars in 6 varieties of carrot. Whereas, Simon and Lindsay (1983) have reported that reducing sugars accounted for 6.00-32.00 per cent of total sugars in 4 hybrid varieties of carrot. A higher amount of total sugars (5.60%) in fresh carrot have been reported by Holland *et al.* (1991). Sagar *et al.* (2004) estimated the reducing sugars and total sugars present in Pusa Kesar, Pusa Meghali, Sel-14 and Sel-16 varieties of carrot as 2.48, 2.26, 3.20, 2.65 and 12.00, 11.46, 13.25, 12.20 per cent, respectively. Sharma (2004) has reported the reducing sugars as 2.76 per cent and total sugars as 6.36 per cent in Asiatic carrots. Similarly, Karki (2009) has recorded 3.60 per cent reducing sugars and 6.84 per cent total sugars content in fresh carrot. Further, reducing sugars as 3.04 per cent and total sugars as 4.15 per cent in fresh carrot have been reported by Rahman *et al.* (2010). Whereas, the total sugars as 4.30, 4.20, 4.40 and 4.42 per cent and reducing sugars as 1.98, 1.92, 1.56 and 1.52 per cent in SEL-21, PC-34, Ambala Local and Nantes varieties of carrot, respectively have been reported by Sra *et al.* (2011). Mishra (2012) documented 2.84 per cent reducing sugars and 6.58 per cent total sugars in raw carrot roots. Similar, results were observed by Kumar (2018). However, Raquel *et al.* (2014) have recorded 18.58 per cent reducing sugars in carrot on dry weight basis. Pragya (2018) documented 9.22 and 7.85 per cent carbohydrate content in red and black carrot, respectively. Singh *et al.* (2020) reported an average range of 5.80-11.80 per cent total sugars in 81 genotypes of carrot.

2.2.5 Titratable acidity and pH

Carrot roots have a low content of organic acids. These represent about 0.20 per cent of the fresh weight (Phan and Hsu, 1973). Wilson (1987) have estimated the titratable acidity

of carrot as 0.02 per cent. However, Luh and Woodroof (1982) documented 0.15 per cent titratable acidity in carrot roots. The titratable acidity in black and red carrot as 0.04 and 0.09 per cent, respectively has been reported by Sharma (1990). It was observed that the pH of carrot juice ranged from 6.18 to 6.24 (Singh, 1996). Sagar *et al.* (2004) have studied the physico-chemical constituents of fresh carrot varieties i.e. Pusa Kesar, Pusa Meghali, Sel-14, Sel-16 and observed the titratable acidity as 0.10, 0.10, 0.08 and 0.09 per cent, respectively. Slightly higher value of 0.12 per cent titratable acidity in fresh carrot have been reported by Karki (2009). Sra *et al.* (2011) have revealed a value of 0.06, 0.04, 0.06 and 0.05 per cent titratable acidity in SEL-21, PC-34, Ambala Local and Nantes varieties of carrot, respectively. Mishra (2012) have observed very low amount of 0.001 per cent organic acid in fresh carrot roots. Bajaj and Singhal (2019) reported pH value of 6.12 and acidity 0.15 mg/100 g in carrot roots. Pragya (2018) studied the physico-chemical characteristics of carrot and documented a value of 0.15 and 0.25 per cent titratable acidity along with pH value of 6.02 and 5.90 in red and black carrot respectively. However, a range of 0.12-0.18 per cent titratable acidity and 6.10-6.39 pH was showed by Kumar (2018). The values were similar with Reddy *et al.* (2018) who observed a pH value of 6.13 in carrot juice. A slightly higher value (6.74) of pH was reported by Chen *et al.* (2019) in carrot roots.

2.2.6 Ascorbic acid

Ascorbic acid is one of the most important vitamins present in vegetables having significant health benefits and antioxidant properties. Ascorbic acid content in fresh carrot was found to be 2.75 mg/ 100 g (Pruthi *et al.*,1980). Favell (1998) reported ascorbic acid content of 2.80-4.50 mg/ 100 g in fresh carrots. Similarly, Nicolle *et al.* (2004) observed 2.50-4.70 mg/ 100 g ascorbic acid in the fresh purple carrot. The values (4.47 mg/ 100 g) were similar to those documented by Mishra (2012). Miglio *et al.* (2008) revealed an ascorbic acid content of 2.30 and 10.80 mg/ 100 g in fresh and dried form of carrot, respectively. However, Karki (2009) reported 3.00 mg/ 100 g ascorbic acid in fresh carrot roots. According to Ludong *et al.* (2017) the content of ascorbic acid was 4.3-4.9 mg/ 100 g on fresh weight basis. A lower Vitamin C content (0.90 mg/ 100 g) was revealed by Reddy *et al.* (2018). Ascorbic acid varied from 0.96-4.11 and 0.70-3.44 mg/ 100 g for Pusa Asita and Black Wonder, respectively (Kaur and Sogi, 2020). An ascorbic acid content of 4.80 mg/ 100 g was documented by Cheena *et al.* (2020).

2.2.7 Fibre

Varying amount of crude fibers have been reported by various workers in carrot. The fibre content as 1.20 per cent and 2.40 per cent was reported by Gopalan *et al.* (1991) and Holland *et al.* (1991), respectively. However, a value of 1.87 per cent was observed by Upadhyay *et al.* (2008). A slightly lower value of 0.67 per cent crude fiber in fresh carrot has been documented by Karki (2009). Raquel *et al.* (2014) have also revealed a higher value of 3.07 per cent crude fibres in carrot. Varmudy (2014) has reported 1.20 per cent fibre in edible portion of carrot, the composition of which consists of 71.70, 13.00 and 15.20 per cent cellulose, hemi-cellulose and lignin, respectively. On dry weight basis 2.33 per cent crude fibres has been reported by Tadesse *et al.* (2015). Pragya (2018) revealed crude fibre content of 1.63 and 1.05 per cent (fresh weight basis) in red and black carrot, respectively. A range of 0.44-1.40 per cent crude fibre has been documented by Kumar (2018).

2.2.8 Ash

Ash represents the total amount of minerals present in the food. In a study, Holland *et al.* (1991) observed that carrot contains various minerals like calcium (34.00 mg/ 100 g), iron (0.40 mg/ 100 g), phosphorus (25.00 mg/ 100 g), sodium (40.00 mg/ 100 g), potassium (240.00 mg/ 100 g), magnesium (9.00 mg/ 100 g), copper (0.02 mg/ 100 g) and zinc (0.20 mg/ 100 g). A slightly higher values for calcium (80.00 mg/ 100 g), iron (2.20 mg/ 100 g), phosphorus (53.00 mg/ 100 g) and ash content of 1.10 per cent has been reported by Gopalan *et al.* (1991). Demir *et al.* (2004) detected 0.65 g/ 100 g ash content in carrot juice. Karki (2009) and Karmoker *et al.* (2011) discovered 0.70 per cent ash content in carrots. Total ash content of 0.87, 0.84, 0.89 and 0.88 per cent in SEL-21, PC-34, Ambala Local and Nantes varieties of carrot, respectively has been observed by Sra *et al.* (2011). Further, Varmudy (2014) have reported iron (2.20 mg/ 100 g), sodium (35.60 mg/ 100 g), potassium (108.0 mg/ 100 g), copper (0.13 mg/ 100 g), magnesium (14.00 mg/ 100 g) and phosphorus (30.00 mg/ 100 g) in edible portion of carrot. On dry weight basis ash content of 6.87 per cent and 8.00 per cent has been found by Raquel *et al.* (2014) and Tadesse *et al.* (2015), respectively. Al-Amin *et al.* (2015) reported 0.60 per cent ash content in fresh carrot. The ash contents of 0.92 per cent in Nerac F₁ variety and 1.24 per cent in Anastasia F₁ variety was observed by Jozef and Natalia (2016). According to Wierzbowska *et al.* (2017) crude ash content in carrot roots ranged from 71.25 to 80.10 g/ kg on dry weight basis. However, 5.89 per cent ash content in dried red carrot pomace has been observed by Megali *et al.* (2019).

2.2.9 Total carotenoids

Carotenoids are a group of yellow, orange and red phytochemicals found in most vegetables. β -carotene accounts for more than half of the total vitamin A contribution (Umiel and Gabelmal, 1971; Sun *et al.*, 2009). The predominant carotenoids are the pro-vitamin A carotenes, i.e. α and β -carotene, accounting for 13 to 40 and 45 to 80 per cent of the total carotenoids in orange carrot root, respectively (Simon and Wolff, 1987; Gross, 1991). Gill and Kataria (1974) have reported 4.17 mg/ 100 g carotenoids in Nantes variety of European carrot and 2.68, 3.01 mg/ 100 g in Delhi Desi, Pusa Kesar varieties of Asiatic carrot. The carotenoids content in the edible portion of carrot roots ranged from 6.00 to 54.80 mg/ 100 g (Simon and Wolff, 1987). Holland *et al.* (1991) have reported 5.33 mg/ 100 g carotenoids in fresh carrot. Total carotenoids ranged from 47.00 to 96.00 mg/ 100 g in Hisar Gairic and Pusa Kesar variety were observed by Kalloo *et al.* (1993). According to Velisek (1999), the carotenoid content of carrot ranges between 60-120 mg/ 100 g, but some varieties can contain up to 300 mg/ 100 g carotenoids. Surles *et al.* (2004) estimated 9.80 mg and 0.71 mg of total carotenoids (per 100 g fresh weight basis) in red and yellow carrots, respectively. Similar findings were revealed by Alasalvar *et al.* (2001) and Grassmann *et al.* (2007). A higher β -carotene content as 11.21 mg/ 100 g in carrot has been reported by Ahmad *et al.* (2007). Karki (2009) documented 5.69 mg/ 100 g total carotenoids in fresh carrot roots. Whereas, Miglio *et al.* (2008) reported 4.60 and 6.40 mg/ 100 g, α and β -carotene in red carrot. β -carotene content of 7.40 and 7.17 mg/ 100 g in fresh carrots have been reported by Rahman *et al.* (2010) and Tadesse *et al.* (2015), respectively. Whereas, Sra *et al.* (2011) have recorded 7.50, 7.70, 7.60 and 8.60 mg/ 100 g of β -carotene in SEL-21, PC-34, Ambala Local and Nantes varieties of carrot, respectively. Bystricka *et al.* (2015) have observed varying amount of β -carotene content in five varieties of carrot i.e. Jitka (2.46 mg/ 100 g), Kardila (4.74 mg/ 100 g), Katlen (4.42 mg/ 100 g), Rubina (2.92 mg/ 100 g) and Koloseum (12.43 mg/ 100 g). β -carotene content of 6.72 mg/ 100 g in fresh carrot have been reported by James and Matemu (2016). According to Singh *et al.* (2018), total carotenoids in different types of carrot varied greatly. They revealed that the highest carotenoids were found in red carrot roots (7.37 mg/ 100 g) followed by rainbow carrot roots (7.14 mg/ 100 g), orange carrot root (3.94 mg/ 100 g), black carrot roots (0.66 mg/ 100 g) and yellow carrot roots (0.64 mg/ 100 g). Simran *et al.* (2019) reported carotene content of 4.59 mg/ 100 g in red carrot. Similar value of β - carotene as 4.65 mg/ 100 g has been reported by Cheena *et al.* (2020). Further, a range of 2.30-9.50 mg/ 100 g was observed by Singh *et al.* (2020) in 81 genotypes of carrot.

2.2.10 Anthocyanins

Anthocyanins are the group of water-soluble pigments that are responsible for the brilliant red, orange and blue colour of the fruit (Fang, 2015). Mazza and Miniati (1993) reported that purple carrots contained about 138.70 mg/ 100 g anthocyanins. Kammerer *et al.* (2004) reported total anthocyanins ranged from 17.40 to 45.40 mg/ kg dry matter in 15 black carrot cultivars. Further, Ersus and Yurdagel (2007) estimated anthocyanin content of 2721.61 mg/ 100 g (dry matter) in black carrot. According to Cuevas *et al.* (2011) content of monomeric anthocyanin lies between 1.50 to 17.70 mg/ 100 g in fresh carrot roots. Similar values of monomeric anthocyanins were filed by Montilla *et al.* (2011). Leja *et al.* (2013) showed anthocyanin content as 74.00 and 55.80 mg/ 100 g (fresh weight basis) in Anthonina and Deep purple cultivars of black carrot. A higher value anthocyanins (168.70 mg/ 100 g on) in purple carrots was documented by Assous *et al.* (2014) estimated. Pragya (2018) observed 233.32 mg/ 100 g anthocyanin in black carrot. According to Kaur and Sogi (2020) anthocyanin content of Pusa Asita and Black Wonder varied from 11.46-519.39 and 0.62-3.29 mg/ 100 g, respectively.

2.2.11 Total polyphenolics

The phenolic or polyphenol is the substance which possesses an aromatic ring bearing one or more hydroxyl substituents including functional derivatives like esters, methyl ethers, glycosides etc (Ho, 1992). Phenolic compounds have free radical scavenging abilities, anti-mutagenic and anti-carcinogenic activities and are able to reduce the risk of cardiovascular and carcinogenic diseases (Nakamura *et al.*, 2003). Karakaya *et al.* (2001) have estimated 772 mg/ 100 g of total phenols content in violet carrot juice. A lower value of 350.50 mg/ 100 g total phenolics in black carrots have been reported by Kaur and Kapoor (2002). However, total phenolic content of fresh and frozen carrot juice as 0.26 and 0.20 mg/ g have been observed by Ninfali and Bacchiocca (2003). Zhang and Hamauzee (2004) reported 20.90 mg/ 100 g polyphenols in carrot. Further, Karki (2009) observed 19.20 mg/ 100 g total phenolics in fresh carrot. The total phenolic content in carrot as 2.66 and 12.40 mg/ 100 g have been reported by Oviasogie *et al.* (2009) and Ferreira *et al.* (2015). According to Cuevas *et al.* (2011) total phenolics ranged from 17.90 to 97.90 mg gallic acid equivalents (GAE)/ 100 g fresh weight basis in different carrot varieties. Total phenolic content of 12.66 mg/ 100 g was observed by Mishra (2012). Leja *et al.* (2013) reported phenolic content of 267.10 and 224.30 mg/ 100 g in Anthonina and Deep Purple variety of carrot. Similar findings were reported by

Koley *et al.* (2014). Bystricka *et al.* (2015) have reported total phenols in five varieties of carrot like Jitka, Kardila, Katlen, Rubina and Koloseum as 8.13, 8.87, 9.71, 10.22 and 11.37 mg/ 100 g, respectively. Pragya (2018) estimated total phenols as 28.32 and 283.53 in red and black type of carrot, respectively.

2.2.12 Antioxidant activity

Antioxidants are naturally occurring compounds that protect us from harmful effect of free radicals. They exist in the form of vitamins, minerals, anthocyanins, phenols and tannins in various foods. Purple carrots contained very high contents of phenolics and were characterized by a higher antioxidant capacity than orange, yellow or white varieties (Alasalvar *et al.*, 2001). Zhang and Hamauzee (2004) reported antioxidant activity of 19.40 per cent as free radical scavenging activity in carrot. A higher amount of 61.71 per cent antioxidants were observed by Mishra (2012). Leja *et al.* (2013) estimated radical scavenging ability among 35 genotypes, both temperate and tropical in nature. They observed five colour group of carrots and reported maximum antioxidant activity in purple carrot (51.30%), followed by red carrot (9.30%), orange carrot (6.60%), red carrot (6.00%) and white carrot (6.00%). Algarra *et al.* (2014) reported a range of 17.60-240.00 and 86.40-182.00 $\mu\text{M TE/}$ 100 g fresh weight basis for DPPH and FRAP, respectively in black carrot. Similarly, Kamiloglu (2015) stated antioxidant activity 1720.00 and 5617.00 mg TE/ 100 g dry weight basis for DPPH and FRAP, respectively. Pragya (2018) documented 26.03 and 73.04 per cent antioxidant activity in red and black carrot, respectively. The relative antioxidant potentiality in terms of ABTS among different carrot types was as black carrot (79.40%), rainbow carrot (7.30%), red carrot (4.60%), orange carrot (4.40%) and yellow carrot (4.40%). Overall, the antioxidant ability is higher in anthocyanins rich black carrot followed by rainbow carrot (contains blend of anthocyanins and carotenoids) and least in carotenoids rich, red, orange and yellow carrots (Singh *et al.*, 2018). According to Mishra *et al.* (2019), the antioxidant activity of encapsulated black carrot was reported to be 344.30 $\mu\text{M TE/}$ 100 g and 282.30 $\mu\text{M TE/}$ 100 g (dry matter) by using the CUPRAC method.

2.2.13 Functional properties of carrot

Carrot is among top 10 vegetables favored by the consumers throughout the world. It plays an important role in our lives as it provides many nutrients required by our body (Yahya *et al.*, 2019). Carrot contains approximately 88 per cent water and only 12-13 per cent remains as concentrated carrot itself, which includes sugars, organic acids, fibre, carotenoids,

anthocyanins, phenolic compounds and antioxidants etc. In primitive times carrot root and its products have been used for medicinal purposes for over a century (Kalra *et al.*, 1987; Mazza, 1989). For example an infusion of carrot has been used as a folk remedy for the treatment of threadworms. Further, carrot juice is reported to be used as a diuretic and to facilitate the elimination of uric acid as well as favorably affecting nitrogen balance in the body. In addition, it has been demonstrated that the juices extracted from raw carrots have antimicrobial properties, particularly against *Listeria* (Beuchat and Brackett 1990; Beuchat *et al.*, 1994). In view of its many health benefits, carrot juice is called the “miracle juice” (Adubofuor *et al.*, 2016).

Carotenoids are responsible for the brilliant colours ranging from pale yellow through bright orange to deep red, and absorb wavelengths ranging from 400 to 550 nm (Eldahshan and Singab 2013; Dias, 2014). Of all the vegetables, carrots is one of the richest sources of carotene, especially β -carotene. The presence of high concentration of β -carotene may account for the biological and medicinal properties of carrots (Sharma *et al.*, 2012). Carotenoid levels in carrots have significantly increased over the past four decades due to modern and improved breeding methods (Zhang *et al.*, 2016). While there is an increasing interest in the role of carotenoids as antioxidants, a sub-category of them are widely known as pro-vitamin A carotenoids due to their ability to be converted to Vitamin A. Carotenoids have been linked with the enhancement of immune system and decreased risk of age related macular degeneration and cataract formation (Mathews–Roth, 1985; Krinsky, 1994; Bast *et al.*, 1996, Santos *et al.*, 1996; Van, 1999). Along with their role in vision, carotenes have been claimed to provide protection against various forms of cancer and heart disease (Peto *et al.*, 1981; Olson 1986; Temple and Basu, 1988; Zeigler, 1989; Moon, 1989; Murakoshi *et al.*, 1992; Mayne *et al.*, 1992; Abbey *et al.*, 1995). Numerous animal experiments and epidemiological studies have indicated that carotenoids inhibit carcinogenesis in mice and rats and may have anti-carcinogenic effects in humans. Carotenoids have been identified as a potential inhibitor of Alzheimer’s disease (Zaman *et al.*, 1992). In biological systems, β -carotene functions as a free radical-trapping agent and single oxygen quencher, which protects cells from free radicals which may damage the basic cell structure of healthy cells. It has anti-mutagenic, chemo-preventive, photo-protective and immune-enhancing properties (Deshpande *et al.*, 1995; Hager and Howard, 2006; Leja *et al.*, 2013; Quitao-Teixeira *et al.*, 2009; Sharma *et al.*, 2012; Zhang *et al.*, 2016). The yellow carrot contains lutein, which plays a significant role in the prevention of macular degeneration (Dias, 2014). Macular

degeneration is a leading cause of vision loss in individuals 50 years of age or older. Macular degeneration is caused by the deterioration of the central portion of the retina. Lutein is an antioxidant that is found in the eye, it prevents or delays the progression of chronic eye diseases by filtering out high-energy blue wavelengths of light and is responsible for maintaining healthy cells in the eyes (Ma *et al.*, 2015). Most Western diets are deficient in lutein. Adding yellow carrots to the diet will help provide missing nutrients and will help promote good eye health, and reduce the risk of developing eye diseases that can lead to loss of vision.

Antioxidants are the chemicals which inhibit the process of oxidation of other molecules. They are grouped into two broad categories, hydrophilic and lipophilic (Yasuda *et al.*, 2017). Usually, water-soluble antioxidants react with oxidants in the cell cytosol and the blood plasma while lipid-soluble antioxidants protect cell membranes from lipid peroxidation. Most of the disorders/ illness in humans and plants are aroused through the production of deleterious reactive oxygen species (ROS) or free radicals which are invariably produced during metabolic processes as well as exposure to various stresses. The endogenous antioxidant enzymes such as superoxide dismutase, peroxidase and catalase counteract the detrimental effects of ROS. However, conditions when ROS production is excessive or when the antioxidant system is insufficient may favour oxidative damage to aerobic life (Singh *et al.*, 2009) responsible for various chronic diseases like cancer, cardiovascular diseases, rheumatoid arthritis and age related macular degeneration in human (Halliwell, 1991) and biotic and abiotic disorders in plants. The effects of ROS can be balanced by natural dietary antioxidants and antioxidant enzymes in living organisms (Alejandro *et al.*, 2013; Singh *et al.*, 2009). Fruits and vegetables are rich sources of natural antioxidants like carotenoids, phenolics, flavonoids, vitamin C, tocopherol, organo-sulfides and thus they reduce the risk of chronic diseases (Kaur and Kapoor, 2002; Koley *et al.*, 2014). Primary antioxidant activity of carrot roots is due to the presence of carotenoid and anthocyanin pigment. The antioxidants also referred to as anthocyanins, are a group of natural phytopigments that belong to the 6-flavonoid group of polyphenols (Pandey and Rizvi, 2009). Anthocyanins found in purple carrots can neutralize the effects of free radicals, have the ability to reduce oxidative stress, can restore redox homeostasis in the human body and can exert anti-carcinogenic activity (Zhang *et al.*, 2016). Each of these protective properties found in the anthocyanins can help to reduce the risk of developing cancer and decreasing inflammation in the body. The antioxidant ability of the anthocyanins in carrots adds health benefits that make the carrot

more desirable to consumers. Phenolic compounds are antioxidants that can be found in carrots. These phenolic compounds have the ability to scavenge reactive oxygen species and electrophiles, allowing them to inhibit nitrosation and chelate metal ions. Antioxidant assays have determined that the highest amount of phenolic compounds can be found in the carrot peel when compared to the phloem and xylem tissues (Zhang *et al.*, 2004). The carrot peel provides 54.10 per cent of the total phenolics present in a carrot, phloem tissue provides 39.50 per cent and the xylem tissue contains 6.40 per cent of phenolic activity (Zhang *et al.*, 2004).

Carrot is a significant source of phytonutrients including polyacetylenes, phenolics, vitamins, minerals and the trace mineral molybdenum (Babic *et al.*, 1993; Hansen *et al.*, 2003 and Kidmose *et al.*, 2004). Molybdenum is an essential nutritional component of carrots because it is rarely found in vegetables and aids in the metabolism of fats and carbohydrates as well as plays a significant role in iron absorption. Carrots offer number of nutritional advantages with the fresh product being low in energy value and a good source of fiber, potassium and other minerals (Walde *et al.*, 1992). Carrots are also an excellent source of dietary fiber. Fiber is a crucial part of a healthy diet. Fiber can be found in many fruits and vegetables and can help maintain a healthy weight and lower risk of heart disease. Carrots contain a wide variety of compounds that work together to improve the overall health of an individual by providing preventative and protective factors. Carrots have also been linked to providing mental health benefits. People who consume greater amounts of fruits and vegetable are less depressed, happier and more satisfied with their lives. Carrot being rich in β -carotene, ascorbic acid and tocopherol is classified as vitaminized food (Hashimoto and Nagayama, 2004). According to Dias (2014) the carrots contain a broad range of vitamins including vitamin C, K, thiamin (B_1) riboflavin (B_2), pyridoxine (B_6), and folate (B_9). All of these vitamins are beneficial to a person's overall health. Vitamin C promotes the absorption of non-heme iron and is also required for fighting off infections. Vitamin K is essential for promoting blood coagulation. Thiamin (B_1) in the diet has beneficial effects on the nervous system. Riboflavin (B_2) is needed for cellular respirations and the formation of red blood cells. Pyridoxine (B_6) inhibits the formation of homocysteine and reduces the risk of heart disease. Folate (B_9) also lowers homocysteine levels, which lowers the risk of heart attacks. B_6 and B_9 role in reducing homocysteine levels is beneficial to a person's health as high levels of homocysteine have been linked to the increased risk of hardening arteries caused by the accumulation of fatty plaques (Dias, 2014).

2.3 PRE-TREATMENTS AND THEIR EFFECT ON JUICE QUALITY AND YIELD

Carrot and its products including juices are widely accepted as a rich source of phyto-nutrients such as bioactive compounds, carotenoids, minerals and vitamins (Qin *et al.*, 2005; Yasuda *et al.*, 2017). Carrots belong to root vegetables with the characteristic of developed intercellular substance and solid cell wall therefore, the juice yield is generally low if juice is extracted directly without any pre-treatment. Currently, the steps involved in carrot juice processing are peeling, blanching, enzyme liquefaction and sterilization (Qin *et al.*, 2005; Khandare *et al.*, 2011; Jabbar *et al.*, 2014; Ma *et al.*, 2015). To solve the problem of low juice yield, different technologies/ processing techniques has been widely used in carrot juice extraction. However, quality of an end product depends on the processing method and conditions. The most common methods used for enhancing the juice yield and quality are blanching and enzyme treatment (Greve *et al.*, 1994; Reiter *et al.*, 2003; Zhou *et al.*, 2009; Jabbar *et al.*, 2014). In carrot juice production, the blanching treatment of carrots prior to juice extraction is important for improving the yield and colour of the extracted juice (Greve *et al.*, 1994; Reiter *et al.*, 2003; Zhou *et al.*, 2009). Further, thermal blanching is an important step for the processing of fruits, vegetables and their products including juices, to inactivate enzymes and microbes, remove entrapped air and make protopectin soluble (Barrett and Theerakulkait, 1995; Bahceci *et al.*, 2005). All these benefits of blanching depend on the heat supplied to the product but it also adversely affects the texture, heat sensitive nutrients, water soluble contents and ultimately the quality and bioactivity of the end product (Mizrahi, 1996; Wennberg *et al.*, 2006). Due to scientific evidences and increasing knowledge, consumers now want food not only with extended shelf-life but also with improved quality and safety. In order to fulfill the consumer's demand, researchers are looking for such food processing techniques that could not only retain but also improve the nutritional value of various food products such as fruit juices (Bhat *et al.*, 2014). Among many novel methods, ultrasound and microwave assisted blanching are the food processing technique that can meet the demands of consumer by enhancing health related nutrients and maintaining other quality attributes of fruit juices (Rawson *et al.*, 2011; Abid *et al.*, 2013; Bhat *et al.*, 2014). Jabbar *et al.* (2014) investigated the effects of blanching and sonication on carrot juice and reported that it lead to an increase in the total polyphenol content of the juice (Chukwumah *et al.*, 2007). Similarly, a large number of studies have shown that the application of enzymatic treatment significantly improve the juice yield of fruits and vegetables (Sims *et al.*, 1998; Noomen *et al.*, 2012) and also improve the stability of cloudy juice (Reiter *et al.*, 2003).

2.3.1 Blanching

Blanching is an essential operation for fruits and vegetables processing. It helps in the inactivation of polyphenol oxidase (PPO), peroxidase (POD) and also maintains the quality attributes of the end products. The purposes of blanching includes inactivating enzymes, enhancing drying rate and product quality, removing pesticide residues and toxic constituents, expelling air in plant tissues, decreasing microbial load, increasing the efficiency of bioactive compounds and increasing the juice yield. Assessment of the effectiveness of blanching process includes the judgment of the degree of peroxidase (POD) and polyphenol oxidase (PPO) enzyme. Other method involves ascorbic acid as indicator to evaluate nutrients loss during blanching and colour along with texture is also used as indicator of the effect of blanching on physical properties of product. Mayer-Miebach and Spieb (2003) reported that blanching treatment at 90°C can improve the yield and stability of carotenes in carrot juice after juicing. This is mainly because the blanching treatment can soften the carrot tissue and increase the permeability of carrot cell tissues so that the carotene in carrot cells can easily dissolve in the carrot juice after juicing. Meanwhile, the blanching treatment can also inhibit a variety of enzymes especially, some oxidases (Shivhare *et al.*, 2009) thereby improving the stability of carotenes (Goncalves *et al.*, 2011).

2.3.1.1 Water blanching

Hot water blanching is the most popular and commercially adopted blanching method, as it is easy to operate and simple to establish (Mukherjee and Chattopadhyay, 2007). In a typical hot water blanching, products are immersed in hot water (70-100°C) for several minutes, blanched samples are drained and cooled before being sent to the next processing operation. In general, after a certain amount of blanching time, the blanching water needs to be replenished as it becomes saturated with nutrients leached from the products. This step consume high amounts of water and energy (Bingol *et al.*, 2014). Further, in order to preserve the colour of product and inactivate microbial activity, acids, sodium sulfite and sodium metabisulfite are often added to the blanching water. This makes it more difficult to deal with the waste water generated from the blanching operation.

Mohammed and Hussein (1994) have indicated that blanching at 70°C for 20 min with calcium treatment and 0.1 per cent sodium metabisulphite improves the texture and preserves the carotenoids content of dried carrots. Kidmose and Martens (1999) reported that

peroxidase inactivation occurs after 4 min of hot water blanching (90°C) treatment of carrots. Shivhare *et al.* (2009) have concluded that water blanching at 95°C for 5 min was best for retention of vitamin C (8.192 mg/ 100 g). Rahman *et al.* (2010) have reported that hot water blanching for 6-9 min with dipping in 0.075 per cent sodium metabisulphite solution for 1.0 h was helpful in the retention of carotenoids. Water blanching at 85°C for 1.5 min in 1.0 per cent calcium chloride solution followed by 0.10 per cent sodium metabisulphite dip has been found best for the preservation of carotenoid content of carrots by Mansoor *et al.* (2013). Alam *et al.* (2013) have reported that citric acid blanching pre-treatment retained more total carotenoids (8.799 mg/ 100 g) and β -carotene content (387.41 μ g/ 100 g) in carrot pomace as compared to water blanching and steam blanching. They have witnessed minimum change in colour parameters when citric acid blanching pretreatment was given to carrot pomace. Barroca *et al.* (2014) have reported that carrot slices soaked in 0.25 per cent and 1 per cent ascorbic acid solution for 60 min have higher colour and texture values as compared to untreated samples. Kukanoor *et al.* (2014) witnessed best sensory characteristics like colour and appearance, texture, taste and overall acceptability when carrot slices were blanched for 2 min followed by steeping in 40°B syrup and 6 per cent salt for 2.0 hour. Sra *et al.* (2011) have reported that water blanching of carrot slices at 95°C for 4 min followed by dipping in 6 per cent potassium metabisulphite (KMS) solution for 40 min retained 72.1 mg/ 100 g β -carotene and 219.4 mg/ 100 g total carotenoids. Agiriga *et al.* (2017) have concluded that the carrot slices blanched in water at 80°C with 5 per cent salt was the most preferred among different treatments with retention of 70.44 ppm β -carotene. In another study, the effects of blanching treatments i.e. steam blanching, water blanching, acidified blanching (0.05 N acetic acid), calcium chloride blanching (0.2%) on the quality of carrots juice was analysed. These blanching treatments were evaluated with respect to the inactivation time of peroxidase (POD) and catalase, and the process was optimized on the basis of the maximum yield of carrot juice, minimum loss of vitamin C and β -carotene. The most effective blanching treatment was 5 min in hot water at 95°C. At this time-temperature combination, POD and catalase were completely inactivated and the juice yield, vitamin C and β -carotene contents were found to be 55 per cent, 8.19 mg/ 100 g and 3.18 mg/ 100 g, respectively (Shivhare *et al.*, 2009).

2.3.1.2 Steam Blanching

Superheated steam is commonly used as a heating media for steam blanching due to its high enthalpy contents. During the early stage of steam blanching, steam condenses on the

surface of the products and a large amount of latent heat transfers to the material because product temperature is lower than that of steam. The temperature of the products gradually increases until reaching the critical temperature of enzymes or organisms activity, after which they are inactivated. Steam blanching is relatively inexpensive and also retains most minerals, water-soluble components due to the negligible leaching effects (Roy *et al.*, 2009). However, during the steam blanching process, excessive softening of the tissue and undesirable quality changes are often resulted from prolong heating time. This occur due to the lower heat transfer in steam blanching, especially when the velocity of the steam is very low. Further, steam blanching carried out in thick layers on moving belts, often resulted in non-uniform blanching effects (Gibert *et al.*, 1980; Mukherjee and Chattopadhyay, 2007). It needs longer blanching time than hot water and therefore, it affect the capacity and the economics of processing.

Melinick *et al.* (1999) have reported that steam blanching is preferable to water blanching because of less leaching losses of soluble nutrients. Further, several studies have reported an increase in total carotenoids after steam blanching (Sulaeman *et al.*, 2001). According to Chafer *et al.* (2003), yield increase of up to 5 per cent after steam blanched over water blanched is possible depending on the product and application. Karki (2009) has reported that 3 min steam blanching followed by dipping in 500 ppm ascorbic acid was best for retention of ascorbic acid (15.10 mg/ 100 g) of carrot pomace. However, Santos *et al.* (2012) have reported that steam blanching for 2 min retains highest vitamin C (1.05-18.77 mg/ 100 g) as compared to other treatments.

The food-borne illness outbreaks have increased in recent years due to the consumption of raw or processed products polluted by microorganisms, such as *Salmonella* in fresh vegetables and fruits, *Listeria monocytogenes* in ready to eat meat (Beuchat, 2002). Reducing microbial load during food processing operation is a critical step for food safety. Dipersio *et al.* (2007) evaluated the effect of different blanching methods on the inactivating of *Salmonella* during preparation, dehydration and storage of carrot slices. The carrot sliced were subjected to steam blanching (88°C, 10 min), hot water blanching (88°C, 4 min), hot water blanching combined with 0.15 per cent or 0.21 percent citric acid solution. It was observed that bacterial populations were reduced by 3.8-4.1, 4.6-5.1 and 4.2-4.6 log cfu/ g immediately after following steam, hot water, and hot water combined with citric acid blanching, respectively. Additionally, after drying for 6 h, the total reductions were 4.0-5.0

log cfu/ g after steam blanching, 4.1-4.6 log cfu/ g after hot water blanching, and 4.9-5.4 log cfu/ g after hotwater combined with citric acid blanching. Hot water blanching at 88°C for 4 min combined with 0.21 per cent citric acid blanching was concluded as the best pretreatment method for inactivating *Salmonella*.

2.3.1.3 Microwave blanching

Heating microwaves are electromagnetic waves with wavelengths ranging from 1 mm to 1 m that have corresponding frequencies ranging from 300 MHz to 300 GHz (Thostenson and Chou, 1999). Microwaves have many uses in modern society including communication, radar, radio astronomy, navigation, and food processing. For industrial, scientific and medical heating applications, only 915 MHz and 2450 MHz microwaves are allowed because the Federal Communications Commission (FCC) of USA wants to prevent those devices from interfering with communication signals. In microwave heating, heated materials absorb microwave energy and convert it into heat by dielectric heating effect caused by molecular dipole rotation and agitation of charged ions within a high-frequency alternating electric field (Chandrasekaran *et al.*, 2013). Specifically, when the oscillating electric field interacts with high water content materials, the permanently polarized dipolar molecules particularly water molecules will align themselves in the direction of the electromagnetic field alternates at 915 or 2450 MHz (Thostenson and Chou, 1999). The internal resistance due rotating molecules that push, pull, and collide with other adjacent molecules or atoms, produces volumetric heating (Zhang *et al.*, 2016). Microwave heating not only takes place on the surface of wet biological materials, but also within them. Compared to conventional heating methods applied in the food industry, microwave heating has several advantages such as volumetric heating, high heating rates and short processing times. Therefore, it has been successfully used in drying, pasteurization, blanching, thawing, tempering, baking, etc. (Ramesh *et al.*, 2002; Rastogi, 2012; Bai *et al.*, 2013). One of the most important features of microwave blanching is that it involves direct interaction between the electromagnetic field and food materials for heating generation. Thus, compared to that in conventional hot water blanching, the amount of nutrients loss by leaching is significantly reduced (Kidmose and Martens, 1999; Ramesh *et al.*, 2002; Brewer and Begum, 2004). Despite being energy efficient and requiring less time, microwave blanching has some drawbacks that could limit its application. During microwave blanching, moisture in vegetables may evaporate. High intensity microwave power may cause cells folding and destruction of product microstructure (Kidmose and Martens, 1999). Further, the penetration depth of microwave in a sample is a

function of its dielectric properties, which determines the temperature distribution within the material (Gunasekaran and Yang, 2007). So the penetration depth of microwave is limited. Microwave heating mainly depends on the conversion of electromagnetic energy into heat via friction of dipolar molecules, especially water molecules, and ions that follow the oscillating electrical field at very high frequencies (Thostenson and Chou, 1999). Furthermore, the limited penetration depth made the heating with microwave more heterogeneous. All of these factors cause large temperature variations when it comes to processing large and bulky materials. The dielectric properties are mainly determined by the chemical composition, structure and density of the products (Chandrasekaran *et al.*, 2013). Water content and its state (free or bound water), along with ionic contents, play important roles in determining the dielectric properties of the products. Often water distribution in a product and ionic concentration in vegetables may not be uniform, will cause non-uniform heating. Due to the non-uniform distribution of water in the product, standing wave effect and rapid decay of microwave within heated foods, is hard to predict and precisely control the temperature and this results in overheating or inadequate heating during blanching. However, these challenges can be mitigated with a proper microwave system design for vegetables that have consistent compositions and are packed in well-defined geometries (e.g. diced carrots in vacuum sealed bags). However, since there is an uneven distribution of moisture and ions in different parts of the samples, the microwave heating also ends up being non-uniform. With the microwave applicator producing a non-uniform microwave field, the uneven energy distribution caused hot and cold points in the sample. To reduce water loss during blanching and increase heat absorption, vegetables may be heated while immersed water. However, water-soluble nutrients can be lost through leaching or diffusion to blanching water.

In a study, it was found that the ascorbic acid retention was higher in green beans, peas, and carrots blanched by microwave than those blanched by hot water (Gunes and Bayindirli, 1993). In addition, microwave heating is rapid, very energy efficient, easy to install and clean-up, and requires a short start-up time (Lin and Brewer, 2005). Kidmose and Martens (1999) compared the influence of microwave blanching with that of steam and hot water blanching on dry matter losses and quality attributes of carrot slices in terms of texture, microstructure, sugars and carotene contents and drip losses. The microwave blanching was performed using a continuous conveyermicrowave oven with 4 magnetrons (power of 1.25 KW for each magnetron) at 2450 MHz and a conveyer speed of 0.5 m/ min. No significant difference was found in the carrots texture after the three blanching methods. However, the

microwave-blanching sample had a significantly different appearance from those blanched by steam or hot water. The microwave-blanching samples had a texture composed of a patchwork of groups of well-preserved cells, layers of collapsed and sunken cells. The dry matter, sucrose, and carotene of the samples blanched by microwave were significantly higher than those of the steam blanching samples. Lemmens *et al.* (2009) studied the blanching of carrots using strong microwave blanching (90 °C, 1 min) and mild microwave blanching (60°C, 40 min). The microstructure of samples blanched in mild microwave was more similar to the fresh ones as compared to the samples blanched in strong microwave, which caused the cell walls to disappear and different cells to melt together.

Walde *et al.* (2006) found that microwave drying of mushroom resulted in the charring of edges due to non-uniform heating. Koskiniemi *et al.* (2011) used a 915 MHz and 4 KW continuous microwave system with a residence time of 4 min to pasteurize packaged acidified vegetables. It was found that the heating of the package was non-uniform. Additionally, carotenoid retentions in microwave blanching carrots and potatoes were determined to be 35.73, 22.7 per cent higher than the conventional blanching counterparts (Ramesh *et al.*, 2002). The carotenoid content increased by 2-25 per cent in carrots and by 4-11.9 per cent in potatoes and was converted to stable form by heat treatment (Sharma *et al.*, 2012). Sezer and Demirdoven (2015) studied the effect of microwave blanching conditions on carrot slices and observed that the peroxidase (POD) activities of all samples were inhibited and the pectin methylesterase (PMEs) of carrot slices were at least 97 per cent inactivated in all optimum points and conventional blanching conditions. They concluded that the thermostable form of PME in carrots was inactivated by microwave blanching treatment in the 360 and 630 W optimum points.

2.3.1.4 Ultrasonic blanching

In the past few years, food industry has seen that even a minimum processing to food results in a significant amount of change in the nutritional aspect of food products. Also, it changes the physical and chemical aspects of the food thereby affecting the organoleptic acceptability. In order to reduce these changes, new techniques have been developed to retain the physical, chemical and sensory aspects of food. Ultrasonic is one of the method which is used rapidly to lower the food processing, enhancing quality and safety of food products (Knorr *et al.*, 2011). Ultrasonic is an innovative preservation method which uses 10-1000 W/cm² and 20-100 KHz of power and high intensity-low frequency, respectively. Various

studies have shown that this treatment is best to inactivate the microbial activity. Moreover, it has been observed that this method results in lower degradation of nutrition and quality when used in processing of various fruit juices and puree (Cai *et al.*, 2019). This method works on the phenomenon of generating, growing and eventually collapsing of bubbles. As the waves propagate, the bubbles in liquid oscillate and collapse thereby causing thermal, mechanical and chemical effects. Chemical effects include generation of free radicals whereas collapse pressure, turbulences and shear stresses are the mechanical effects. These effects result in elevation of temperature (500 K) and pressure up to 1000 Atmosphere (Soria and Villamiel, 2010). Ultrasound causes water hydrolysis inside the oscillating bubbles which results in formation of H^+ and OH^- free radicals that are captured in chemical reactions.

Recently ultrasound treatment combined with heat (thermosonication) has been employed in fruit juice processing as a better substitute for thermal treatment to retain most of juice health beneficial properties (Anaya-Esparza *et al.*, 2017). Tiwari *et al.* (2009) found that anthocyanins exhibit a high degree of stability to sonication. These results indicated that the content and stability of bioactive compounds could be improved by ultrasound treatment. Similarly, Abid *et al.* (2013) reported that ultrasound treatment increased ascorbic acid content of apple juice. Jabbar *et al.* (2014) investigated the effects of blanching and sonication on the total carotenoids, chlorogenic acid and microbial stability of carrot juice. Blanching of carrots was done in normal water and acidified water (45 g/ L citric acid, pH 1.3) at 100°C for 4 min and juice was extracted. Sonication of juice was done (frequency 20 KHz and amplitude level 70%) at 15°C for 2 min. Significant increase ($p < 0.05$) was observed in total carotenoids, lycopene and lutein in blanched samples however, this increase was more in simultaneously blanched and sonicated samples. Additionally, highest increase was observed in all these pigments as a result of combined treatment of acid blanching and sonication. Sucrose, glucose, fructose, chlorogenic acid and mineral elements (Na and K) were decreased significantly in all blanched samples while increased significantly ($P < 0.05$) in all sonicated samples. Significant decrease was observed in total plate count, yeast and mold in all samples treated with blanching and sonication but this decrease was more in samples treated with acid blanching and sonication. Martinez-Flores *et al.* (2015) reported significantly higher amounts of carotenoids, ascorbic acid and polyphenolics in thermosonicated carrot juice as compared to thermally treated juices. Carrot juice with orange peel was subjected to ultrasonic treatment (ultrasound process time 6.5 min and ultrasound process temperature 52.78°C) has maximum total phenolic content (30.25 mg GAE/ 100 mL)

and DPPH scavenging activity (61.22%). It was concluded that by optimization of thermosonication treatment there was a significant improvements in the functional quality of functional carrot juice (Adiamo *et al.*, 2018). Zou and Jiang (2016) observed a significant increase in total carotenoids and ascorbic acid contents in the sample sonicated for 40 min compared to sample sonicated for 20 min and control (non-sonicated) sample.

2.3.2. Enzyme treatment

The enzymatic hydrolysis is frequently used in fruits and vegetables juice production. It is known that enzymes allow to improve the technological properties of pulp, facilitate the recovery and micronutrients extraction (Zelenkova and Yegorova, 2019). As a result, finished products have high quality characteristics and nutritional value. Extraction of juice using enzymatic treatment is the most commonly use method these days. This process has several advantages as compared to other thermal and mechanical processing methods used for juice extraction (Sharma *et al.*, 2016). This method relies on the ability of enzymes to catalyze the reaction and to function under minimal processing conditions. Pectic substances, hemicellulose and cellulose are the structural components of plant cell wall. When commercial enzymes are added during the juice processing, the pectic substances in the middle lamella of plant cells gets degraded. Also, enzymatic treatment have minimal impact of the final product characteristics (Nigam and Pandey, 2009). Out of these commercially used enzymes, cellulase and pectinase are most common.

Cellulases are the enzymes that degrades cellulose into glucose. They are naturally produced by different bacteria, aerobes, anaerobes, fungi etc. Basically, cellulose breakdown occurs through three different hydrolases. Firstly, endoglucanase fragments the amorphous regions leading to formation of new terminal groups which are used as a substarte in the following step. Then, cellobiohydrolase splits the cellobiose and the synergistic effect between cellobiohydrolase and endoglucanase results in the cellobiose molecules formation. These molecules are further broken into glucose using cellobiase which is also known as beta-glucosidase (Whitehurst and Law, 2002). Pectinases which are also known as pectinolytic enzymes are divided into three groups namely, esterases, protopectinases and depolymerases. Esterarses catalyze the deesterification of pectin by removing methoxy esters while protoprectinases works by solubilizing protopectin which is present in unripe fruit thereby leading to the formation of highly polymerized soluble pectin that is present in ripe fruits. Depolymerases act on pectic substances and break the glycosidic bond in two different

ways. The first mechanism is hydrolysis in which the water is introduced across the oxygen bridge and second one is trans-elimination lysis (Murad and Azzaz, 2011). Carrot juice has a high nutritional value and is rich in biologically active micronutrients, such as α , β -carotene and lutein. In production of carrot juice, enzymatic treatment of carrot pulp improve juice yield, amount of soluble solids, content of carotenoids (Sharma *et al.*, 2005; Demir *et al.*, 2007; Sun *et al.*, 2009). Numerous researches (Demir *et al.*, 2004; Liao *et al.*, 2007; Sun *et al.*, 2009) have devoted to study the influence of pre-treatment of grated carrot with enzymes on juice characteristics. The analysis of literature showed that pectolytic enzymes were the most important enzymes for enhancing juice recovery. On the other hand, it is known that the increase in the content of carotene and other micronutrients as well as soluble solids in carrot juice, is promoted by cellulolytic enzymes (Vora *et al.*, 1999; Chadha *et al.*, 2003; Demir *et al.*, 2004; Liao *et al.*, 2007; Demir *et al.*, 2007; Sun *et al.*, 2009; Khandare *et al.* 2011; Yu and Rupasinghe, 2013). They destroy cell walls and provide the release of nutrients from cells. The combined use of pectolytic and cellulolytic enzymes enhances their pectolytic and cellulolytic activity through a synergetic effect (Margo *et al.*, 2016). Thus, combination of different enzymes affords to achieve good results not only in the yield of carrot juice, but also in improving its organoleptic characteristics (colour, taste and appearance) e.g. Vora *et al.* (1999) reported that content of β -carotene in the juice increased substantially when enzyme preparations under the trade name Rohament PL and Rohament MAX, the complex of which includes pectinase, hemi-cellulase, cellulase and polygalacturonase were used. At the same time, yield of the desired product was also high i.e. 72.40 per cent.

Cinar (2004) reported that adding 10 mL/ 100 g pectinase and 0.5 g/ 100 g cellulose for 6 h, improved the extraction rate of carotenoids from carrot. Sharma *et al.* (2005) reported that enzymatic treatment resulted in increasing the juice yield by 13.95 per cent and decrease in viscosity by 0.45 cP. Similar results were shown by Sun *et al.* (2009) and Wang *et al.* (2009). The role of pectinase have been investigated. Sun *et al.* (2006) observed the effect of Pectinex Smash XXL, Pectinex Ultra SP-L, Pectinase FNP-1 and cellulose FNC-1 on carrot juice extraction. They concluded that Pectinex Smash XXL preparation was proved to be better than other enzymes resulting in 63.50 per cent juice yield and was recommended by the authors for the production of carrot juice. According to Demir *et al.* (2007), carrot juice yield have been increased from 59.90 per cent (control sample) up to 90.43 per cent when enzyme preparation Pectinex Ultra SP-L (pectinase) by Novozymes (Denmark) was used. Similarly, Liao *et al.* (2007) carried out an experiment in which Pectinex Smash XXL was used for

maceration of carrot pulp. It was concluded that there was an increase in the juice yield from 44.92 per cent to 64.40 per cent. The results were in agreement with work of Puupponen-Pimia *et al.* (2008) and Wang *et al.* (2009) who reported significant increase in phenolic compounds with cell wall degrading enzymes in berry juices. Khandare *et al.* (2011) studied the effect of four different doses of pectinase enzyme (0.10%, 0.15%, 0.20% and 0.25%) on the black carrot juice yield. The juice yield in control juice (pressed without enzyme) was 45 per cent while, the maximum yield was 64 per cent at 0.20 per cent pectinase. Enhanced juice yield was a result of the enzyme-catalyzed degradation of the pectin in the plant cell wall matrix releasing water. The total phenolic content in straight pressed carrot juice was 300 mg GAE/ 100 mL which enhanced to 382 mg GAE/ 100 mL (27% increase) by enzyme treatment. The *in vitro* total antioxidant activity in black carrot juice extracted through enzyme-assisted processing was 30.0 and 62.0 $\mu\text{mol TE/ mL}$ in ferric reducing antioxidant power (FRAP) and cupric reducing antioxidant capacity (CUPRAC) assays, respectively. They reported that there was an overall increase of 33 per cent in juice yield, 27 per cent in total phenolics and 46 per cent in total flavonoids in enzyme-assisted black carrot juice. The total anthocyanin content in black carrot juice was almost doubled. It was concluded that enzyme-assisted preparation prior to pressing can remarkably improve the juice yield, total phenols, anthocyanins and total antioxidant activity in black carrot juice.

Sharma *et al.* (2005) obtained a maximum juice yield of 74.03 per cent for at enzyme concentration of 210 mg/ kg, incubation time of 130 min and temperature 47°C in carrot. Similar result of juice yield (71.50%) was obtained by Chadha *et al.* (2003). Sun *et al.* (2009) observed enhancement the content of β -carotene to 54.2 mg/ kg in juice treated with pectolytic and cellulose enzymes, as compared to control sample 40.1 mg/ kg. Kaur and Sharma (2013) reported an increase in β -carotene (mg/ 100 g) from 3.88 to 3.93, reducing sugars (%) from 2.43 to 2.47, titratable acidity (as % citric acid) from 0.29 to 0.32 and a decrease in pH from 4.48 to 4.47, pectin (%) from 1.01 to 0.97 in control and enzyme treated samples, respectively. According to the work of Yu and Rupasinghe (2013), the joint use of enzyme preparations of pectinase, cellulase and β glucosidase made it possible to improve the qualitative characteristics of carrot juice by β -carotene content 1.6 times (33.71 mg/ kg compared to control of 21.39 mg/ kg). The amount of soluble solids was 8.93 per cent (22% higher than the control sample). Ma *et al.* (2015) and Ma *et al.* (2016) have demonstrated that single enzyme treatment or mixed enzyme treatment could significantly raise the contents of the three carotenoids in carrot juice (α -carotene, β -carotene and lutein). However, the use of

pectinase and cellulase at the same time exhibited an antagonistic effect. The maximum possible juice yield, total soluble solids, colour and minimum viscosity of carrot juice were obtained under optimal conditions for enzyme concentration, pectolytic-cellulolytic enzyme ratio and incubation time of 120.00 mg/ kg carrot, 4:6 and 119.99 min, respectively.

According to Li *et al.* (2007), Pectinex 3XL (pectinase) increased the carrot juice yield by 31 per cent as compared to control. However, when the same enzyme preparation was used in combination with Celluclast 1.5 L (cellulase) and Novozyme 188 (β -glucosidase) for enzymatic hydrolysis of carrot pulp, juice yield was increased by 30 per cent. At the same time, authors obtained a very low yield of carrot juice (at a level of 30-40%) when only cellulolytic enzymes were used. Ma *et al.* (2015) used five different enzyme liquefaction methods in carrot juice extraction. They concluded that the contents of the three carotenoids in the five enzyme liquefaction groups were significantly higher than those in the non-enzyme liquefaction group (control group). Thus, it was recommended that the use of pectinase or cellulase treatment can significantly raise the amount of the carotenoids in carrot juice. In another study, Ma *et al.* (2016) reported that 1.5 per cent pectinase and 1.5 per cent cellulose treatment can significantly improve the juice yield and carotenoids in carrot juice extraction. Enzymatic treatment alone or in combination with others, is one of the potential pretreatment, which results in increased yield with better juice quality, colour and acceptability. The process of enzymatic hydrolysis of carrot pulp was investigated for increase of carrot juice yield and carotene content in it (Zelenkova and Yegorova, 2019). It was revealed that enzymatic preparations Pectinex BEXXL, Vegazim P, Vegazim P-CS demonstrated high efficacy in juice yield and Vegazim M, Vegazim P-CS in carotene content. Vegazim P-CS was chosen from seven enzyme preparations according to the aggregate of estimated characteristics i.e. carrot juice yield was equal to 71.60 per cent (18.20% increase as compared with the control sample) and carotene content was 4.83 mg/ 100 g (1.7 times as compared with the control). Increase of juice yield was shown when enzyme concentration was raising up to 0.30 mL/ 1000 g of carrot pulp. Further, increase in the enzyme concentration had led to decrease of the response due to thinning pulp and deterioration of juice extraction. Increasing the temperature and incubation time of enzymatic hydrolysis greater than 65°C and 120 min haven't led to a further increase in juice yield too. Thus, the optimal parameters were established as temperature 52°C, incubation time 85 min, concentration of Vegazim P-CS 0.30 mL/ 1000 g of carrot pulp.

2.4 JUICE CONCENTRATION

Fruits and vegetables are a wonderful source of minerals, vitamins, fiber and various phytochemicals which have therapeutic properties along with disease preventive effects. On the other hand, majority of these fruits and vegetables are short-lived and grown in geographically far apart regions (Yabsley and Cross, 2001). However, the entire production cannot be consumed directly as such and sometimes have to be shipped into different areas of the country/ world (Berk, 2016). Therefore, fruits and vegetables are processed into various products such as dried and dehydrated forms, juice concentrates, canned foods, frozen foods, jam, jelly, and beverages (alcoholic and non-alcoholic) for the consumption during off-season in different parts of the country/ world. Further, the natural single strength juices (unaltered/ non-concentrated natural juice) are in such a huge volume that their packaging, storage or transportation is hardly practicable from an economic point of view. To overcome these challenges and supply nutritionally rich juice products around the year, the volume of juices is often reduced by a process known as “Juice concentration”. In this process, a major part of the naturally present water content is physically removed (Jeong *et al.*, 2004). The most frequently adopted techniques involve evaporation of water from fruit juices either under ambient pressure or under vacuum. The single-strength juices are often boiled under vacuum to evaporate a definite portion of the water from juices. In addition to this, juice concentrates have also been prepared by freezing out the water as ice from concentrated juices (Jiao *et al.*, 2004).

Bala (1999) evaluate debittering of lime juice and its concentration. The findings revealed that the preserved lime juice can be successfully debittered using sorbent XAD-16 and used for preparation of concentrate (45, 60 and 72⁰B). Thakur and Gupta (2006) studied clarification and concentration of beetroot juice. The juice was clarified using enzyme, fining agent, centrifugation and ultrafiltration, while reverse osmosis (RO) and thermo-vacuum evaporation were used for concentration. The juices were concentrated to 23-25⁰B. Beetroot juices concentrated by RO and thermal methods were comparable in quality. The enzyme treatment alone produced a concentrated juice of good quality, while enzyme treatment followed by ultrafiltration improved the clarity, colour values and permeate flux (RO concentration) considerably. Elik *et al.* (2016) developed blueberry juice concentrate by three different concentration processes i.e. open-pan, rotary vacuum evaporator and microwave heating. The final juice concentration of 65⁰B was achieved in 12, 15, 45 and 77 min, for

microwave at 250 and 200 W, rotary vacuum and open-pan evaporation processes, respectively. It was observed that the severity of colour loss was higher in open-pan technique than, rotary vacuum evaporator and microwave heating. Further, the total phenolics loss during concentration was highest in open-pan technique (36.54%) and lowest in microwave heating at 200 W (34.20%). Further, Szaloki-Dorko *et al.* (2016) observed the effect of fruit concentrate production on individual anthocyanin species in elderberry. They concluded that juice concentration resulted in more than five-fold concentration increase in anthocyanins.

Bozkir and Baysal (2016) prepared apple juice concentrate (66.50⁰B) by microwave-assisted evaporation, rotary evaporation and rising film evaporator. The evaporation rate of microwave-assisted evaporation was higher than that of rotary evaporation and rising film evaporator. It also preserved the greatest quality characteristics of the apple juice. The physicochemical, biochemical, and sensory properties of the concentrated apple juices processed using vacuum microwave assisted evaporation were found to be better rotary evaporation and rising film evaporator. It was concluded that the vacuum microwave assisted evaporation was faster and easier than the traditional rotary and rising film evaporator techniques. Dincer *et al.* (2016) studied black mulberry juice concentration using thermal evaporation and osmotic distillation after clarification and pasteurization. The parameters investigated were colour, turbidity, pH, titratable acidity, anthocyanin content, percent polymeric colour, antioxidant activity, 5-hydroxymethylfurfural (HMF) content and volatile profile. The anthocyanin content (604.63 mg/ L), antioxidant content (107.14 mg dw/ mg DPPH) and turbidity values (11.60 NTU) of osmotically distilled samples were found to be higher than those of the thermal concentrates. They concluded that black mulberry juice processed by osmotic distillation had superior quality in comparison to thermal evaporation process especially in anthocyanin content and volatile components.

Jujube extract was concentrated by vacuum, microwave and conventional heating. The desired level of concentration (65.0⁰B) was achieved in 45, 96 and 117 min by the microwave, vacuum and conventional heating, respectively. The concentrate obtained with microwave method had the highest total phenolic content (159.32 mg GAE/ g) and total monomeric anthocyanin content (48.84 mg/ 100 g) in comparison to the other methods. Cyanidin-3,5-diglucoside was determined as the major anthocyanin in all concentrates, while its degradation was more pronounced in the conventional heating (25.59%) comparing to the

microwave (11.14%) and vacuum methods (17.59%). It was concluded that, microwave energy could be successfully used in production of jujube concentrate followed by 90-day storage (Najafabadi *et al.*, 2017). Janiszewska-Turak *et al.* (2017) investigated the influence of carrier material on some physical and structural properties of carrot juice microcapsules. The powder prepared with gum arabic resulted in more adequate for microencapsulation of carrot juice, in terms of better carotenoids retention and higher stability of powders.

In another study, Leong and Chua (2018) aimed to optimize the concentrating process of pineapple juice using a rotary vacuum evaporation statistically. The concentrating process was varied at temperatures (50-70°C) and time (30-120 min) at the fixed pressure, in 13 experimental runs. The results found that rotary vacuum evaporation was able to reduce 44.30 per cent water content, and increase total sugars content from 7.70 to 14.65°B. A significant increment of total acidity from 4.43 to 10.91 g/ 100 mL was observed, which might be due to the presence of citric acid along with other organic acids in concentrated pineapple juice. Based on the Response Surface Methodology (RSM), 60°C temperature for 75 min at 200 mBar using a central composite design was optimized for concentrating pineapple juice. Similarly, Response Surface Methodology (RSM) was used to optimize spray-drying process for concentrated orange juice. Independent variables were inlet air temperature (130-170°C) and maltodextrin 12 DE content (60-75% wet basis). Responses estimated were powder yield, moisture and ascorbic acid retention. Moisture content was negatively affected by inlet air temperature, while ascorbic acid retention was directly related. Powder yield and ascorbic acid retention increased with the rise in maltodextrin content while moisture content was negatively affected by maltodextrin content. Multiple response optimisation indicated that an inlet air temperature of 155°C and maltodextrin content of 74 per cent were predicted to provide 77 per cent powder yield, 3.70 per cent moisture content and 89 per cent ascorbic acid retention (Pino *et al.*, 2018).

Kumar *et al.* (2020) evaluate the ultrafiltration, reverse osmosis and osmotic distillation process for concentrating Nagpur mandarin (*Citrus reticulata* Blanco) juice. During process, ultra filtration clarified the juice feed to 8.90°B and reverse osmosis upto 21.0°B, finally osmotic distillation concentrates the juice and yielded a concentrate of 60.0°B. A novel concentration technique JEVA, which is featured by the connection of moisture condensation with moderate warming of the juice in a circulation loop was used to produce passion fruit and guava juice concentrates at moderate temperature and ambient pressure. The concentration of products achieved up to 70°Brix. A significant retention of

vitamin C (87.50-91.80%), polyphenol (54.60-87.70%) and antioxidant capacity (77.60-88.90%) in concentrate was recorded which much higher than that of concentrate produced by conventional thermal evaporation. Further, the volatile constituents which are responsible for the characteristic aroma of fruits have shown a minor loss and were still found in concentrated form in the juice products (Pham *et al.*, 2019).

Sabanci and Icier (2019) prepared sour cherry concentrate using vacuum ohmic evaporation (VOE) and vacuum evaporation (VE). It was found that vacuum ohmic evaporation reduced the evaporation time to obtain the juice concentrate having TSS content of 65 per cent. Total monomeric anthocyanin content of sour cherry concentrate was found in the range of 1561.67-1777.38 mg/ L whereas, total phenolic content varied in the range of 9071.22-78347.53 mg/ L concentrate. Total phenolic content and TMAC Total monomeric anthocyanin content of juice concentrates were least affected by vacuum ohmic evaporation process as compared to vacuum evaporation while there was no significant difference between the total antioxidant activities of sour cherry juice concentrates obtained by both methods. VOE process also preserved the colour properties of juice concentrates better compared to the VE process. It was concluded that VOE method could be an alternative fast evaporation method to obtain high-quality fruit juice concentrates. Yahya *et al.* (2019) study the efficiency of vertical finned crystallizer for concentration of carrot juice. It was found that best coolant temperature was at -8°C as it shows the highest point for the average concentration efficiency value and air circulation rate was 2800 mL/ min has maximum value of beta carotene i.e. 18.67 $\mu\text{g/ mL}$. Further, Bhattacharjee *et al.* (2020) evaluated the potential of tight ultrafiltration for the concentration of bioactive compounds in watermelon juice. The concentration of the juice was performed at two different temperatures of $30 \pm 2^{\circ}\text{C}$ and $23 \pm 2^{\circ}\text{C}$ and at pressures of 2 and 3 bar for concentration factors of 1.50, 2.00 and 3.00. The ultrafiltration (UF) process was successful in retaining a high percentage of bioactive compounds in the watermelon juice concentrate. Flavonoids showed the highest levels of concentration among the four important bioactive compounds. The ultrafiltration experimental set of temperature $23 \pm 2^{\circ}\text{C}$, pressure 3 bar and volumetric concentration factor 1.50 was found to be most feasible.

2.5 EFFECT OF STORAGE ON PHYSICO-CHEMICAL, NUTRITIONAL AND SENSORY QUALITY OF JUICE CONCENTRATE

Storage of food products has notable effect on various biochemical as well as sensory attributes. The physico-chemical, sensory and microbiological characteristics of different

concentrates have been evaluated during storage and noticed that the remarkable changes in pH, TSS, acidity, reducing sugars, total sugars, sensory parameters and microbial count of the concentrates. Colour is an important attribute in food products, since it is perceived immediately by the consumer. Wavelength coming from the surface of the object falls on the retina of the eyes which determines the colour of the object (Tijskens *et al.*, 2001). Therefore, angle of view, light, source of light etc are the important factors affecting the colour of object (Giese, 2000). Carrot juice is rich in colour due to the pigments. The change in colour of juice during storage may be due to degradation of β -carotene which may be due to presence of air in the head space, because β -carotene reacts with air present in head space resulting in loss of carotene and colour of the juice during storage (Demir *et al.*, 2004). Other factors affecting colour of carrot juice during storage are pH, acidity, processing temperature, duration and fruit cultivar. Kinetic modeling is necessary to derive basic information for a system in order to describe the reaction rate as a function of experimental variables and to predict changes in a particular food during processing and storage (Mohammadi *et al.*, 2008).

Various authors have reported the effect of storage on nutritional quality of the beverages. Babsky *et al.* (1986) studied the influence of storage on the composition of clarified apple juice concentrate. Results showed that storage cause 87 per cent loss in free amino acids, 9 per cent reduction in organic acids and maximum accumulation of HMF after 100 days of storage. Kumar and Singh (2016) studied the effect of processing and storage on sweet cherry juice concentrate. Sweet cherry juice concentrate was packed in low density polyethylene bags of size (22 cm $\times$ 14 cm) and stored at (-20°C) after being frozen in blast freezer (-40°C). Storage of sweet cherry juice concentrate for 6 months indicated no significant changes in TSS (76.00 to 76.60%), acidity (0.33 to 0.34 as % citric acid), ascorbic acid (13.00 to 12.60 mg/ 100 g), total sugars (67.00 to 66.50%) and pH (4.60 to 4.50). Hunter colour lightness L*, and redness a* values of sweet cherry juice concentrate decreased whereas b* values increased during storage. Sweet cherry juice concentrate was stable during 6 months storage could be reconstituted for preparing ready-to-serve beverages with acceptable sensory quality. Walkowiak-Tomczak *et al.* (2016) assessed the change in colour during storage of elderberry juice concentrate and they concluded that samples with pH 3.0 had the highest stability of dyes, which confirms the advisability of using an anthocyanin as colourant in high acidity foods. Muzaffar *et al.* (2017) studied the changes in various quality parameters i.e. anthocyanin, ascorbic acid, total phenolic content and antioxidant activity of pomegranate juice concentrate at refrigerated storage (4°C) for 42 days of storage period after

every 7 days of time interval. The highest reduction of 90.29 per cent was reported in ascorbic acid content. Likewise, with an increase in the storage time there was a reduction in anthocyanin content (823.00 mg/ 100 mL to 342.00 mg/ 100 mL), ascorbic acid content (9.89 mg/ 100 g to 0.96 mg/ 100 g), total phenolic content (4795.00 mg/ 100 mL to 3728.00 mg/100 mL) and antioxidant activity of 19.23 to 7.29 per cent.

Siow and Wong (2017) evaluated the effect of juice concentration on storage stability, betacyanin degradation kinetics and sensory acceptance of red-fleshed dragon fruit (*Hylocereus polyrhizus*) juice. Yeast and mold growth was only observed in juice stored at 25°C in week 7. Samples stored at 4°C had a better acceptance than samples stored at 25°C. The maximum betacyanin retention was observed in concentrate stored at 4°C followed by juice stored at 4°C, concentrate stored at 25°C and juice stored at 25°C. As for ascorbic acid, the concentrate samples had a better retention than juice samples and the trend followed was as concentrate 4°C > concentrate 25°C > juice 4°C > juice 25°C. Overall, it was found that the drink reconstituted from red-fleshed dragon fruit concentrate was more well-liked compared to the juice without prior concentration. Storage temperature impact on anthocyanins degradation, colour changes and haze development in juice of Merlot and Ruby grapes (*Vitis vinifera*) was studied by Muche *et al.* (2018). Five major anthocyanins namely Malvidin-3-O-glucoside (M3G), Delphinidin-3-O-glucoside (D3G), Petunidin-3-O-glucoside (Pt3G), Peonidin-3-O-glucoside (Pn3G), and Cyanidin-3-O-glucoside (C3G) were identified and analysed. Juice from Merlot had significantly higher ($p < 0.05$) content of all individual anthocyanins as compared to Ruby. During the long-term storage, total, and individual anthocyanins from both cultivars degraded following first-order reaction kinetics at the rate strongly dependent on temperature. At the end of the storage, noticeably higher loss of anthocyanins (95.00-99.90%) was observed at 25 and 35°C as compared to storage at 5°C (50-60% in Merlot and 74-81% in Ruby). Considerably, lower rate of decay was observed at 5°C as compared to 25°C and 35°C of storage temperatures. The most temperature sensitive anthocyanin compounds were Cyanidin-3-O-glucoside (C3G) and Delphinidin-3-O-glucoside (D3G). At higher storage temperatures, significant ($p < 0.05$) and strong negative correlations were observed between anthocyanin concentrations and the levels of haze, polymeric and brown colour development during storage. It was concluded that storing grape juice (360 days) at lower temperature conditions could reduce the continuous loss of biologically active anthocyanins as well as the development of haze and brown colour.

In another study, Fathi *et al.* (2019) assessed the effect of frozen storage (-18°C) on the quality attributes of the fresh and the concentrate cut-back strawberry juices for 6 months. A significant decline in titratable acidity (%) after freezing was observed in both types of strawberry juices, it decreased from 0.85 to 0.41 and from 0.98 to 0.49 for fresh strawberry juice and concentrate cut-back juice, respectively. However, the pH increased from 3.81 to 4.34 and from 3.60 to 4.25 for fresh strawberry juice and concentrate cut-back juice, respectively. The initial vitamin C content was 9.45 and 29.23 mg/ 100 mL which decreased by 53 and 36 per cent after 6 months of frozen storage in fresh and concentrate cutback strawberry juice, respectively. The concentrated cut-back strawberry juice prior to freezing was found to be rich in ferulic acid, resorcinol and quercetin being 10.09, 0.24 and 731.98 ppm which were by respectively compared to fresh strawberry juice. Quercetin was the dominant compound, it was the only one that found in the two juices after 6 months of frozen storage. While, kaempferol was appeared after freezing for the two types of juices and showed gradual increase by increasing the duration of frozen storage. The cut-back strawberry juice showed higher antioxidant activity and viscosity than fresh juice. A slight decrease in viscosity was observed for the two types of juice after storage at -18°C for 6 months. The colour was not stable during the frozen storage at -18°C , The colour values increased in fresh strawberry juice for L^* , a^* and b^* from 12.73, 21.00 and 7.77 to 16.89, 25.94 and 9.91, respectively, but in cut-back strawberry juice the value of L^* was only increased from 13.23 to 13.55 while, a^* and b^* values decreased from 25.75 and 8.11 to 22.68 and 7.00, respectively. The obtained results showed that the concentrate cut-back strawberry juice was more acceptable by panelists. From results, it could be concluded that the cut-back strawberry juice had the best quality after 6 months of frozen storage (Fathi *et al.*, 2019).

Ulusoy and Tamer, (2019) determined the suitability of black carrot juice concentrate, cherry laurel, blackthorn and red raspberry for kombucha production. Total phenolic content and antioxidant activities of the products increased when compared to uncultivated substrates. However, total monomeric anthocyanin content of the samples was reduced during storage. According to sensory analysis, the kombucha beverages made with red raspberry and black carrot juice concentrate lost their acceptability before other beverages and cherry laurel kombucha had the best scores. In this study, changes in ascorbic acid (AA), phenolics, anthocyanins (ACNs) and antioxidant activity (AOA) were monitored during storage at -25 , 4 , 10 and 20°C to observe the stability of bioactive compound in strawberry juice concentrates. Half-life periods for anthocyanins and ascorbic acid degradations were 8 and 50

days at 20°C, respectively. On the contrary, much higher half-life values were found for the reduction in antioxidant activity and phenolics *i.e.* 251 and 430 days at 20°C, respectively. Antioxidant activity and phenolics were more stable during storage than ascorbic acid and anthocyanins. Strong correlations were found between antioxidant activity and anthocyanins ($r = 0.99$), phenolics ($r = 0.94$) and AA ($r = 0.92$) in SJC stored at 20°C. Significant anthocyanins and ascorbic acid degradations occurred at storage temperature as low as 4°C. Therefore, storage at -25°C was suggested for strawberry juice concentrates to maximize the stabilities of especially anthocyanins and ascorbic acid in strawberry juice concentrates (Menevseoglu *et al.*, 2020). Bhattacharjee *et al.* (2020) analyzed the effectiveness of frozen storage in watermelon juice concentrate. Evaluation of total phenolic contents showed a 21 per cent decrease after 30 day storage at -18°C. Although, the enzyme activity in frozen concentrate has been slowed down by the absence of heat for the oxidation process, a significant amount of vitamin C was still lost during the overall storage period. The concentrate juice was organoleptically acceptable with all the important nutritional compounds were well preserved during the storage period.

Dey *et al.* (2020) develop fruit juice concentrate from Citron and evaluate its kinetics during storage at 10°C, 25°C and 40°C, respectively for 3 months. Degradation kinetics of ascorbic acid content of citron juice concentrate at each and every storage temperature was followed first-order reaction. They observed that at a higher temperature (40°C) rate of degradation of ascorbic acid was higher. The degradation of antioxidant activity of the juice concentrate was quite low at lower storage temperature. However, the change of the total phenolic contents was quite different. It was increased with storage time and temperature. Orellana-Palma *et al.* (2020) evaluate the potential of centrifugal block cryoconcentration (CBCC) at three cycles, applied to fresh calafate juice. The fresh juice and cryoconcentrate at each cycle were stored for five weeks at 4°C and quality attributes were analyzed every 7 days. CBCC had significant effects in the calafate juice, in the last cycle, the cryoconcentrate reached a high value of total soluble solids (42°B), with final attractive colour and an increase of approximately 2.5, 5.2, 5.1, 4.0 and 5.3 times in relation to the fresh juice values for total bioactive compounds (TBC), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,20-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), ferric reducing antioxidant power (FRAP) and oxygen radical absorbance capacity (ORAC), respectively. However, at 35 days under storage, these values decreased by 5, 13, 15, 19, 24 and 27 per cent, for TSS,

TBC, DPPH, ABTS, FRAP and ORAC, respectively. Additionally, until the day 14, the panelists indicated a good acceptability of the reconstituted cryoconcentrate.

2.6 UTILIZATION CONCENTRATE IN FOOD PRODUCTS

The consumers' knowledge on functional foods has led to an increasing interest in foods not only intended to feed but also to prevent chronic and nutritional-related diseases as well as to improve overall human well-being. High intake of fruit and vegetables has been proved to prevent a wide range of diseases, such as degenerative disorders, cancer and cardiovascular problems (Slavin and Lloyd, 2012). However, the current lifestyle makes the preparation of these plant products difficult. Thus, their consumption should be promoted through the development of attractive ready-to-eat and functionally enriched products that should be processed with minimal processing to preserve as much as possible the quality parameters of the raw materials (Artes-Hernandez *et al.*, 2009). Therefore, fruits and vegetables in its various forms are added to various food products to enhance its nutritional, functional and sensory properties.

Black carrots are a good source of anthocyanin pigments (Mazza and Miniati, 1993). Black carrot anthocyanins provide excellent bright strawberry red shade in acidic pH values. Therefore, black carrot juice can be a good choice in colouring fruit juices and nectars, soft drinks, conserves, jellies and confectionery (Downham and Collins, 2000). Furthermore, black carrot juice is considered as an ingredient when added to foods as a colourant, it does not require declaration with an E-number on food labels. Many studies have been conducted to improve the colour and anthocyanin stability of strawberry products. These studies are mostly concentrated on the fortification with anthocyanins and co-pigmentation (Skrede *et al.*, 1992). Garzon and Wrolstad (2001) found that fortification of strawberry juice and concentrate with pelargonidin-based anthocyanins increased the stability of anthocyanins during storage. Rein and Heinonen (2004) reported that the colour stability of strawberry juice can be enhanced with three colourants i.e. grape skin, black carrot and rosemary extracts. The addition of grape skin extract to strawberry juice initially helped to maintain the colour, while the maximum stability of juice colour during storage was found to be with the addition of black carrot extract. In another study, anthocyanin contents of non-coloured jams was 6.30 and 11.82 mg/ kg which was increased to 29.69 and 26.31 mg/ kg, respectively with addition of black carrot juice concentrate (Kirca *et al.*, 2007).

Ersus and Yurdagel (2007) prepared powdered form of natural food colourant by microencapsulating black carrot anthocyanins along with maltodextrin by spray drying to increase its stability. Bandyopadhyay *et al.* (2007) studied physical and sensory characteristics of low fat dairy dessert (*Rasogolla*) fortified with carrot. *Rasogolla* was prepared by boiling mashed fresh cheese or cottage cheese ball in concentrated sugar syrup fortified with carrot paste (10, 20, 30, 40 and 50 per cent). Carrot *Rasogolla* depicted similarity with respect to their moisture, sucrose and ash content but has significant difference in protein and fat content. Carrot *Rasogolla* also possessed significantly higher beta carotene. Organoleptic evaluation revealed that carrot *Rasogolla* had higher sensory score than control *Rasogolla*. Turksoy *et al.* (2011) studied the impact of incorporation of black carrot (0, 5, 10 and 15%) on the quality and composition characteristics of cookies. Extensibility of the dough, maximum resistance and resistance, accelerated with an increase in black carrot fiber level. The dietary fiber content increase from 0.19 to 3.72 per cent at 15 per cent black carrot level. A significant increase in total phenols and antioxidant capacity of cookies was also noticed.

An anthocyanin-rich black carrot concentrate (63.5⁰B) was encapsulated with the emulsion method to make thermally induced whey protein-based microcapsules and the microencapsulated black carrot concentrate was used as a natural colourant in yoghurt. At 5 per cent level, 2.0 g/ kg phenolics, 1.43 g/ kg for flavonoids, 0.86 g/ kg for anthocyanin (dry weight basis) have been reported in yoghurt (Bilek *et al.*, 2017). Kamiloglu *et al.* (2017) studied an enrichment of cake flour with black carrot at levels of 50 g/ kg, 100 g/ kg and 150 g/ kg caused a dose-dependent increase in anthocyanins (72-267 mg/ g dry weight), phenolic acids (49-148 µg/ g dry weight), total phenolics (54-202 mg GAE/ 100 g dry weight) and total antioxidant capacity (21-478 mg TE/ 100 g dry weight). Sahni and Shree (2017) prepared fibre rich cookies by substituting refined wheat flour with carrot pomace powder (CPP) at 5, 10, 15, 20 and 25 per cent. The weight, thickness, moisture, crude fibre and ash content of the cookies increased whereas the diameter, spread ratio, spread factor, protein and carbohydrate decreased with the increase in CPP in flour blend. Nazan and Gokhan (2018) prepared functional probiotic yoghurt with black mulberry juice concentrate (1% and 2% w/v) fortification. It was concluded that this fortification results in improvement of functional properties of yoghurt samples. Kaur *et al.* (2019) prepared lassi with 10 per cent carrot pulp. Further, being prepared from carrots, it was purely safe for public health and can be used as vitaminized food supplement (Vitamin A 58.57 µg/ 100 g) content as well. Peng *et al.* (2019)

used apple juice concentrate as osmotic pre-treatment to enhance the physical properties of the carrot chips, comparable to chips obtained using sucrose and maltitol osmotic solutions. It was observed that apple juice concentrate treated chips had improved hardness (38.28 N), crispness (2.01 mm), porosity (66.72%) and homogeneous microstructure. Additionally, compared to the sucrose and maltitol impregnated chips, a higher retention of carotenoids (302.81 $\mu\text{g g}^{-1}$ dry basis), a higher multiplicity of phenolic compounds, stronger antioxidant activities and a superior sensory score were observed in the chips pretreated with apple juice concentrate.

Mohtarami (2019) analysed the effect of carrot pomace powder and dushab (traditional grape juice concentrate) on physical and sensory properties of cake. Moisture content, colour difference and browning index of cakes increased with an increase in the amount of CPP and Dushab substitution. By increasing the level of CPP and Dushab, the firmness of the cakes increased whereas cohesiveness decreased. Chewiness and gumminess were not affected by Dushab substitution but increased by the increment of CPP. The specific volume of the cakes reduced in the supplemented CPP and Dushab cakes. Dushab substitution led to the decline of cake springiness compared to the control one. Jiang *et al.* (2020) used pear juice concentrate along with rice syrup for the sweetening of sesame bar. It was found that addition of pear juice concentrate at more than 3 per cent increased the colour value, decreased the cohesiveness, hardness and compactness. There was a significant increase in antioxidant activity, sugars and organic acids with corresponding increase in the levels of juice concentrate from 1 to 5 per cent. However, on the basis of sensory sesame bar with 3 percent pear juice concentrate showed highest overall acceptability.

Chapter-3

MATERIALS AND METHODS

The present investigations entitled, “**Carrot juice concentrate production and utilization**” was carried out in the Department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the years 2017-2020. The materials used, experimental details and techniques employed during the investigation have been described under following heads:

3.1 RAW MATERIAL

3.2 EXPERIMENTAL DETAIL

3.3 ANALYSIS

3.1 RAW MATERIAL

3.1.1 Carrot

Four types of carrot viz., black, orange, purple and red were procured from the Department of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The roots were brought to the Fruit Processing Laboratory, Department of Food Science and Technology, Nauni, Solan for conducting further studies (Plate 1).

3.1.2 Chemicals and packaging material

The chemicals and packaging materials (glass vials and polyethylene pouches) used in the study were procured from M/S International Scientific and Surgicals, Solan and the enzymes (Cellulase and Pectinase) were supplied by M/S Mahamaya Promotors, Solan.

3.2 EXPERIMENTAL DETAILS

The present study was focused on the development of carrot juice concentrate and its utilization. The whole investigation was divided into various experiments and sub-experiments comprising of optimization of technique for the extraction of carrot juice, standardization of the process for carrot juice concentration, utilization of carrot juice

concentrates in different food products such as cookies, cereal bar and muffins, and quality evaluation studies.

3.2.1 Standardization of methodology for carrot juice extraction

The carrot roots were washed under running tap water, trimmed using stainless steel knife, dirty skin and undesirable hair were removed. Further, the roots were subjected to different pre-treatments for standardization of methodology for juice extraction.

3.2.1.1 Effect of blanching method and time on juice extraction

The carrot roots were either shredded with stainless steel vegetable grater or whole carrots (10 cm) were subjected to different blanching treatments i.e. as hot water blanching, steam blanching, acidified water blanching (citric acid @ 4.50%), ultrasound assisted blanching and microwave assisted blanching for variable time intervals i.e. 1, 2, 3, 4 and 5 minutes, as per details given in Table 3.1.

Table 3.1 Treatment detail of juice extraction using different blanching methods and time

Treatments		Time of blanching (min)				
Control (without blanching)	Whole carrot	-	-	-	-	-
	Grated carrot	-	-	-	-	-
Hot water blanching	Whole carrot	1	2	3	4	5
Steam blanching	Whole carrot	1	2	3	4	5
	Grated carrot	1	2	3	4	5
Acidified water blanching	Whole carrot	1	2	3	4	5
Ultrasound assisted blanching	Whole carrot	1	2	3	4	5
	Grated carrot	1	2	3	4	5
Microwave assisted blanching	Whole carrot	1	2	3	4	5
	Grated carrot	1	2	3	4	5

3.2.1.2 Effect of enzymatic treatment on juice extraction

The carrot roots were shredded using a stainless-steel vegetable grater and subjected to the treatment of different enzymes. Different concentrations of enzymes (0.1, 0.2 and 0.3%) were used to treat carrot shreds for different time interval (60, 90 and 120 minutes) at a constant temperature of 50°C. Details of the experiment are given in Table 3.2.



Black carrot



Orange carrot



Purple carrot



Red carrot



Ultrasound assisted blanching



Microwave assisted blanching



Enzymatic treatment



Carrot juice concentration



Carrot juice concentrate

Plate 1: Carrot Juice Concentrate Production

Table 3.2 Treatment detail of juice extraction using enzyme treatment

Pectinase Concentration (%)	Time (min)	Cellulase Concentration (%)	Time (min)	Pectinase + Cellulase (1:1) Concentration (%)	Time (min)
0.1	60	0.1	60	0.1	60
0.1	90	0.1	90	0.1	90
0.1	120	0.1	120	0.1	120
0.2	60	0.2	60	0.2	60
0.2	90	0.2	90	0.2	90
0.2	120	0.2	120	0.2	120
0.3	60	0.3	60	0.3	60
0.3	90	0.3	90	0.3	90
0.3	120	0.3	120	0.3	120

Juice extracted by these methods was compared on the basis of juice yield and quality. The best selected treatment was further recommended for juice extraction.

3.2.2 Standardization of technology for the concentration of carrot juice and its stability during storage

3.2.2.1 Optimization of process parameters for the concentration of carrot juice

Extracted juice was stored in glass bottles after pasteurization and heat processing. The juice was further used for concentration by removal of water in vacuum rotatory evaporator (Igene labserver) at different temperatures. Different combinations of temperature and concentration were obtained according to the Central Composite Design (CCD). The range of temperature and concentration was 30-60°C and 40-70 per cent, respectively. The treatment detail is given in Table 3.3 and 3.4.

Table 3.3 Treatment detail for range of coded and actual values of independent variable by RSM for carrot juice concentration

Independent variables	Coded values				
	-α (-1.41)	-1	0	+1	+α (1.41)
Temperature (°C)	23.79	30	45	60	66.21
Concentration (%)	33.79	40	55	70	76.21

Table 3.4 Treatment detail for the preparation of carrot juice concentrate as designed by RSM

Run	Temperature (°C)		Concentration (%)	
	Coded value	Actual value	Coded value	Actual value
1	-1	30	1	70
2	- α	23.79	0	55
3	0	45	0	55
4	0	45	0	55
5	1	60	-1	40
6	-1	30	-1	40
7	0	45	0	55
8	0	45	0	55
9	0	45	- α	33.79
10	0	45	0	55
11	1	60	1	70
12	0	45	+ α	76.21
13	+ α	66.21	0	55

3.2.2.2 Storage stability of carrot juice concentrate

The best treatment from previous sub-experiment (3.2.2.1) was then packed in glass vials (transparent and amber coloured) and stored under different storage conditions [ambient (10.2-28.3°C) and refrigerated (4-7°C)]. The concentrates were further analysed for various physico-chemical and sensory characteristics at different intervals i.e. 0, 3- and 6-months during storage.

3.2.3 Utilization of carrot juice concentrate for the development of functional food products

In this experiment, carrot juice concentrate (best) was incorporated into the food products (cookies, muffin and cereal bar) to supplement their nutritional and functional properties. The method of preparation and optimization of incorporation level in these products are discussed here under;

3.2.3.1 Optimization of level of carrot juice concentrate in cookies

The cookies were prepared according to the method described Vanlalliani (2019) with slight modifications. The ingredient such as wheat flour, oil, powdered sugar, skimmed milk



Ingredients



Beating of sugar



Addition of dry ingredients



Kneading of dough



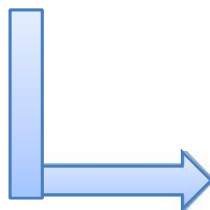
Dough



Sheeting of dough



Cutting with cookie cutter



Baking



Cooling and packaging

Plate 2: Preparation of cookies

powder, salt and sodium bicarbonate were for the preparation of cookies (Table 3.5). The powdered sugar was mixed with oil and mixture was beaten until light and fluffy. The sieved refined wheat flour, salt along with sodium bicarbonate and skimmed milk powder were added to the fluffy mass for the formation of soft dough (Fig. 3.1). In control sample, water was used for dough preparation, which was replaced with carrot juice concentrate (Table 3.6) in functionally enriched cookies. The mixture was kneaded properly for about 10 min and wrapped in an aluminium foil. The dough was allowed to stand at room temperature and after that it was converted into small balls. The balls were flattened into sheets and cut into circular shapes with the help of cookie cutter. The cut shapes were placed on a baking tray lined with butter paper and baked in an oven at 180°C for 35 min (Plate 2). The best combination was selected on the basis of sensory evaluation for further studies.

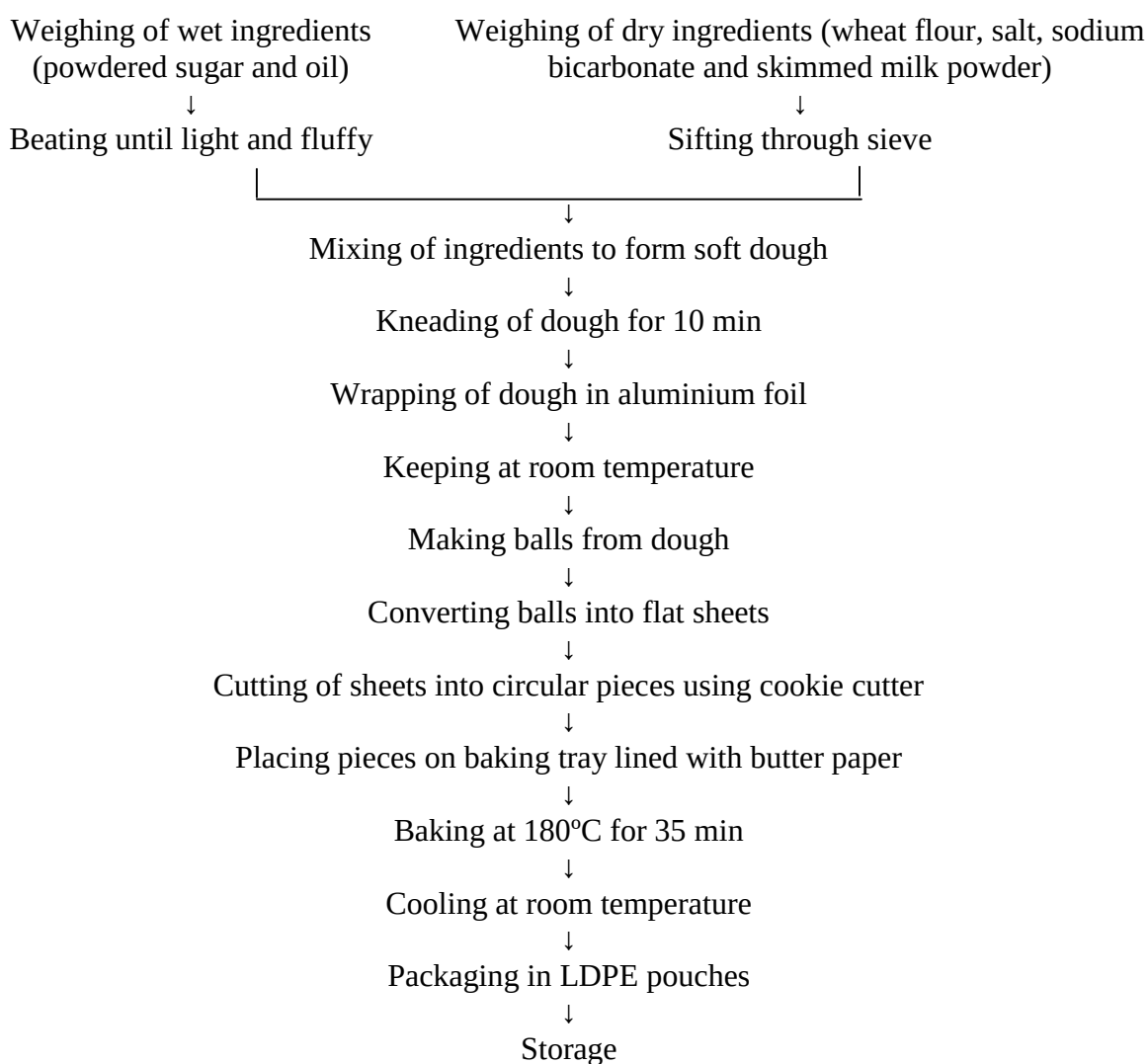


Fig 3.1 Unit operation for preparation of cookies

Table 3.5 Recipe for cookie preparation

Ingredients	Amount
Wheat flour (g)	100
Vegetable oil (mL)	40
Sugar powder (g)	35
Skim milk powder (g)	10
Salt (g)	0.75
Baking powder (g)	1
Water (mL)	25

Table 3.6 Treatment detail for the incorporation of different levels of carrot juice concentrate in cookie

Treatment	Carrot juice concentrate (%)
T ₁	0
T ₂	5
T ₃	10
T ₄	15
T ₅	20
T ₆	25

3.2.3.2 Optimization of level of carrot juice concentrate in muffins

The recipe suggested by Singh *et al.* (2017) with slight modifications was followed for the development of muffins (Plate 3). The fat and powdered sugar were mixed together and beaten until the mixture became light and fluffy. Pre-weighed dry ingredients i.e. wheat flour, baking powder and baking soda were sieved and the fluffy mixture. In control muffin sample milk was added however, it was replaced with carrot juice concentrate (0, 5, 10, 15, 20 and 25%) in functionally enriched muffins (Table 3.7 and 3.8). Continuous mixing and whipping of the mixture were done until the desired consistency was achieved. The prepared batter was poured in pre-greased baking mould. Baking was done in pre-heated oven at 200°C temperatures for 30 min (Fig. 3.2). After baking, cake was allowed to cool at room temperature. Best treatment was selected on the basis of sensory evaluation.



Ingredients



Sieving of dry ingredients



Addition of oil/water



Beating by cut and fold method



Pouring into muffin tray



Baking in oven



Cooling and packing

Plate 3: Preparation of muffin

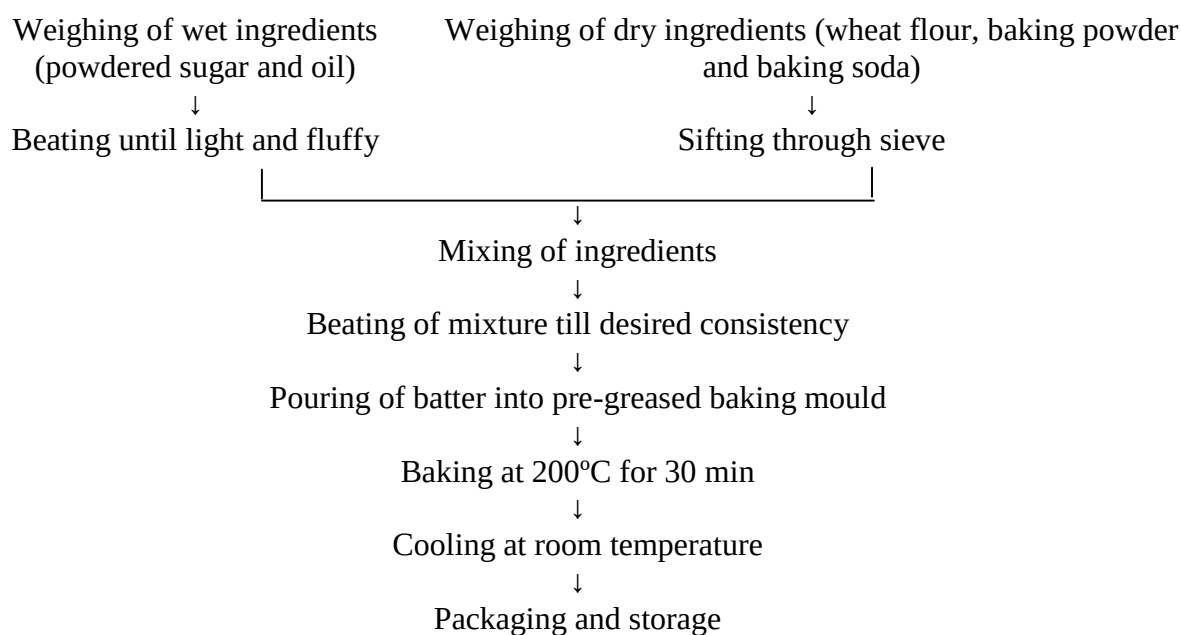


Fig 3.2 Unit operation for preparation of muffin

Table 3.7 Recipe for muffin preparation

Ingredients	Amount
Wheat flour (g)	100
Vegetable oil (mL)	8
Sugar powder (g)	54
Milk (mL)	80
Baking soda (g)	0.75
Baking powder (g)	5

Table 3.8 Treatment detail for the incorporation of different levels of carrot juice concentrate in muffin

Treatment	Carrot juice concentrate (%)
T ₁	0
T ₂	5
T ₃	10
T ₄	15
T ₅	20
T ₆	25

3.2.3.3 Optimization of level of carrot juice concentrate in cereal bar

Cereal bar was prepared by using oats, peanut powder and honey (Plate 4). Base recipe of Padmashree *et al.* (2012) was used with slight modifications. Roasted oats and peanut powder (1:1) were weighed and mixed thoroughly. Mixture was then added to honey on a low flame. Honey was used as binding agent in control samples. However, for the

formation of functionally enriched cereal bar, honey was replaced with carrot juice concentrate. The mixture was put in to pre-greased moulds after through mixing. The mixture was pressed to remove air gaps and kept in refrigerator for setting (15 min). Best treatment was selected on the basis of highest sensory score and was packed and stored for further studies (Table 3.9).

Table 3.9 Treatment detail for the incorporation of different levels of carrot juice concentrate in cookie

Treatment	Carrot juice concentrate (%)
T ₁	0
T ₂	5
T ₃	10
T ₄	15
T ₅	20
T ₆	25

3.3 ANALYSIS

Fresh carrot roots, carrot juice, carrot juice concentrate and the developed products were analysed for various physico-chemical and sensory characteristics (as applicable) viz., size, weight, volume, visual colour, pulp/ juice recovery, total soluble solids (TSS), titratable acidity, pH, ascorbic acid, sugars, moisture, ash, antioxidant potential, total phenolics, antimicrobial activity and sensory attributes as per standard methods described below under different heads:

3.3.1 Physical Characteristics

The randomly selected 10 carrot roots/ samples were analysed for following characteristics.

3.3.1.1 Size (cm)

The size of randomly selected carrot root/ samples was determined with the help of digital Vernier caliper (Mitutoyo Absolute Digimatic Caliper) by measuring the dimensions in centimetres (cm).

3.3.1.2 Diameter (cm)

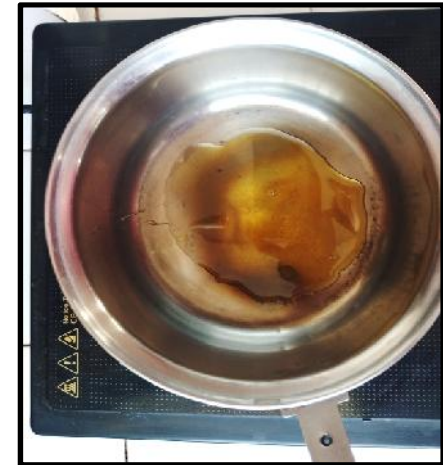
The diameter (Distance across the sample) was measured with a Vernier caliper (Mitutoyo Absolute Digimatic Caliper) and expressed in cm.



Ingredients



Roasting of ingredients



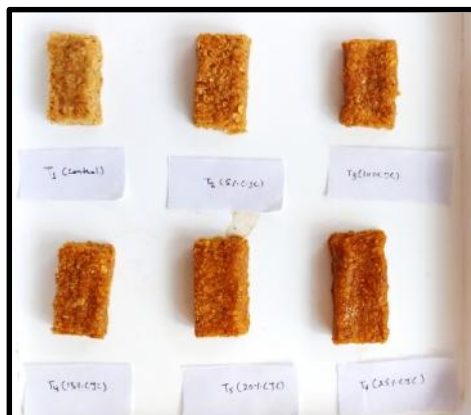
Heating of honey



Mixing of ingredients with honey



Setting and refrigerating



Final product

Plate 4: Preparation of cereal bar

3.3.1.3 Thickness (cm)

The thickness (Distance between top and bottom surface of sample) was measured with a Vernier caliper (Mitutoyo Absolute Digimatic Caliper) and expressed in cm.

3.3.1.4 Weight (g)

The weight of the sample was measured with the help of electronic weighing balance and the average weight was calculated and expressed as gram per unit.

3.3.1.5 Volume (cc)

Volume was measured using displacement method given by Greene and Benjamin (2004). In the case of carrot roots water was used as a medium which has to be displaced while for bakery product samples small rapeseed grains were used. Water/ Rapeseeds were poured into the container of known volume until the bottom was covered. The sample was placed inside the container. The displaced extra water/ rapeseeds were measured in measuring cylinder and expressed as volume (cc) of sample.

3.3.1.6 Colour

The colour of randomly selected carrot roots was observed visually by comparing with the colour cards of Royal Horticulture Society, London and the card numbers were mentioned along with the colour.

3.3.1.7 Edible portion (%)

For the calculation of edible portion, weight of whole carrot root and edible portion was measured separately and per cent edible portion was calculated as:

$$\text{Edible portion (\%)} = \frac{\text{Weight of edible portion (g)}}{\text{Weight of whole root (g)}} \times 100$$

3.3.1.8 Pith size (cm)

Vernier caliper was used to measure the pith diameter of randomly selected carrot roots and the average pith size was expressed in centimeters (cm).

3.3.1.9 Spread ratio

Spread ratio was calculated as the ratio of width/diameter to the thickness of the sample.

$$\text{Spread ratio} = \frac{\text{Average value of width}}{\text{Average value of thickness}}$$

3.3.1.10 Yield (%)

Yield was calculated by dividing the weight of final product obtained by the original weight of the sample. It was expressed in terms of per cent.

3.3.2 Chemical Characteristics

3.3.2.1 Moisture (%)

The moisture content of the sample was determined by drying the weighed sample in hot air oven at $65 \pm 2^\circ\text{C}$ till it had a constant weight. Prior to weighing, the dried sample was transferred to desiccator and cooled at room temperature (Ranganna, 2009). Dried samples were weighed on weighing balance and moisture content of the samples was calculated using the formula given below:

$$\text{Moisture (\%)} = \frac{\text{Weight of fresh sample} - \text{Weight of dried sample}}{\text{Weight of fresh sample}} \times 100$$

3.3.2.2 Water activity

Water activity (a_w) of the sample was estimated by computer digital water activity meter (HW₃ model, Rotronic International, Switzerland), where direct measurements were taken at room temperature. Standard cuvette was used in which sample was filled up to the rim and placed below the sensor of the water activity meter, which gave direct reading of water activity of the sample.

3.3.2.3 Total soluble solids (°B)

Total soluble solids (TSS) were determined by using a digital refractometer (M/S Milwaukee Limited Company, Italy) of 0-85°B calibration. The sample preparation was done according to AOAC (2012).

3.3.2.4 Sugars

3.3.2.4.1 Reducing sugars (%)

Reducing sugars were estimated by the Lane and Eynon (1923) volumetric method. A known quantity of sample was crushed in 100 mL distilled water and filtered (Whatman No.

4). The extract was further neutralized with NaOH and 2 mL of lead acetate (45%) was added to the given sample. After 10 min excess of lead acetate was removed from the sample by using 2 mL of potassium oxalate (22%). After diluting it, the solution was filtered and clear filtrate was taken to estimate reducing sugars by titrating against a mixed solution of equal quantity of Fehling's A and Fehling's B solutions using methylene blue as an indicator. The appearance of brick red precipitate was noted as the end point. Reducing sugars were estimated as per cent and calculated as per the given formula:

$$\text{Reducing sugars (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of sample taken}} \times 100$$

3.3.2.4.2 Total sugars (%)

Total sugars content was estimated by Lane and Eynon (1923) volumetric method by titrating the prepared sample, after hydrolysis with citric acid (5 g citric acid to 50 mL clarified solution), heating it for 10 min for complete inversion of sugars. The samples were neutralized with NaOH and volume was made up in a 250 mL volumetric flask. The end point of titration was attained when a brick red precipitate appeared in the solution. Total sugars were estimated as per cent and calculated as given below:

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of sample taken}} \times 100$$

Factor = 0.5

3.3.2.5 Titratable acidity (as % citric acid)

Titratable acidity as per cent citric acid was estimated by titrating a known amount of sample against standard NaOH using phenolphthalein as an indicator. The titratable acidity was expressed as per cent citric acid (Ranganna, 2009) as per given following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{Eq.wt. of acid}}{\text{Weight of sample taken} \times \text{Aliquot taken for estimation} \times 1000} \times 100$$

3.3.2.6 pH

The pH of samples was determined by using a digital pH meter (CRISON Instrument Ltd, Spain). The samples were finely crushed and mixed with distilled water to make an

extract. Before estimating the pH of sample, pH meter was calibrated with standard buffers of 4, 7 and 9 (Ranganna, 2009).

3.3.2.7 Crude fibre (%)

Crude fibre estimation was done by using FibroTRON-FRB-2 instrument. One gram of the sample (W) was weighed in the crucibles, fixed to the fibre plus instrument and then 100 mL of 1.25 per cent H₂SO₄ was added to all the samples by closing the knobs (AOAC, 2012). The temperature was set to 350°C and leaves the sample for 30 min. After 30 min, draining of acid and washed with distilled water twice. Then knob was opened to remove all H₂SO₄ by suction and washed with distilled water and distilled water was removed by suction. The same procedure was repeated by adding 100 mL of 1.25 per cent NaOH to all the samples. Then crucibles were taken and kept in an oven at 100°C for 3 h and the crucibles were cooled and weighed (W₁). After weighing, crucibles were kept in a muffle furnace at 450°C for 1 h, allowed to cool and reweighed (W₂). Per cent of crude fibre was calculated by using the following formula:

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

3.3.2.8 Protein (%)

The crude protein content was estimated as per method described by AOAC (2012) by using semi-automatic instrument i.e. KjelTRON (KDIGB 6M & KjeldISTEA). A pre-weighed moisture free sample of approximately 0.20 g was digested in digestion tubes after adding 10 mL of concentrated sulphuric acid and 3.00 g of digestion/ catalyst mixture (Potassium sulphate and copper sulphate in 5:1 ratio) at 400°C in the digestion unit. Leave the tubes for one hour and the appearance of clear bluish green colour liquid indicated the completion of digestion. After cooling, an aliquot was transferred to the automatic distillation unit where aliquot was diluted, made alkaline by mixing with 40 per cent NaOH solution and was distilled. Liberated ammonia was collected in a conical flask containing 25 mL of 4 per cent boric acid solution and 2-3 drops of mixed indicator (Methyl red and bromocresol green). The distillate (Bluish green colour) obtained was titrated against standard 0.1 N H₂SO₄ to light pink end point. The percentage crude protein was calculated by multiplying percent nitrogen by factor 6.25. A parallel blank was run to eliminate the error.

$$\text{Nitrogen (\%)} = \frac{14 \times \text{Normality of acid} \times \text{Titre value}}{\text{Weight of sample taken} \times 1000} \times 100$$

$$\% \text{ of Protein} = \% \text{ of Nitrogen} \times 6.25$$

3.3.2.9 Fat (%)

Fat content was determined by the method given by AOAC (2012) by using the automatic SoxTron fat extraction system (Model: Sox-2 version 0.1) instrument. Initially weight of the collection vessel was taken (Initial weight) and 5 g of the sample was taken in thimbles and placed in thimble holder and keep the holder in a collection vessel and to this 80 mL petroleum ether was added. The fat extraction process was carried out for 45 min by setting the temperature at 90°C. After 45 min, the collection vessels were kept in an oven at 100°C for 10-15 min to evaporate the petroleum ether. The beakers were then cooled in desiccators and weighed again (Final weight). The fat content was calculated using the following formula:

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

Where:

W_1 = Empty weight collection vessels

W_2 = Final weight collection vessels

W = Initial weight of sample

3.3.2.10 Ash (%)

Total ash was determined gravimetrically by the method given by Ranganna (2009) by taking known weight of sample in tarred silica crucibles. The oven dried sample after moisture determinations were slowly heated over hot plate until the bulk of organic matter was burnt. The crucible was then placed in muffle furnace for ashing at $550 \pm 2^\circ\text{C}$ to obtain a carbon free white ash with a constant weight. The ash content of sample was then calculated and expressed as per cent on fresh weight basis as given below:

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.3.2.11 Pectin (%)

50 g sample was taken in 500 mL glass beakers and was added with 400 mL of 0.05N HCL. It was then processed at 80-90°C for 2 h, cooled and volume was made up to 500 mL

with distilled water followed by filtration in conical flask. After that 200 mL of filtered aliquot was taken in 1000 mL glass beaker and was added with 250 mL of distilled water. It was then neutralized with 1N NaOH and was left standing for overnight. After that 50 mL of 1N acetic acid was added to it followed by addition of 25 mL calcium carbonate after 5 min with continuous stirring. It was then left standing for 1 h and after that it was boiled for 1-2 min and after cooling down the precipitates were filtered with a pre-weighed filter paper followed by washing of precipitates with distilled water in the end. After that, filter paper was transferred to a petri plate and was kept for drying at 100°C for overnight. Final weight of dried calcium pectate was measured after drying for the calculation pectin percentage in the respective samples.

$$\text{Calcium pectate (\%)} = \frac{\text{Weight of calcium pectate} \times 500 \times 100}{\text{mL of filtrate taken for estimation} \times \text{Weight of sample}}$$

3.3.2.12 Ascorbic acid (mg/ 100 g)

Ascorbic acid content was determined by the method described by Ranganna (2009) by using 2, 6-Di-chlorophenol-indophenol visual titration method. The samples were prepared in 3 per cent meta-phosphoric acid solution and titrated against dye solution till pink colour persisted for few seconds. Ascorbic acid content was expressed as mg of ascorbic acid per 100 g of sample.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume of sample taken} \times \text{Aliquot taken for estimation}} \times 100$$

3.3.2.13 Total carotenoids (mg/ 100 g)

The total carotenoids content of products was estimated by solvent extraction method described by Ranganna (2009). A pre-weighed sample (5 g) was ground using acetone in mortar and pestle and filtered, till the residue in the filter paper became colourless. The extracted sample was transferred to a separating funnel to which eluent and 5 per cent sodium sulphate solution were added. The separated coloured layer was collected in a beaker and the optical density of sample (with or without dilution) was measured at 452 nm using UV-VIS spectrophotometer. The reading was compared with the standard curve and quantity of total carotenoids was calculated by using the following formula:

$$\text{Total Carotenoids (mg/ 100 g)} = \frac{\text{Concentration of carotene in solution from standard curve} \times \text{Final volume} \times \text{Dilution}}{\text{Weight of sample (g)}} \times 100$$

3.3.2.14 Anthocyanins (mg/ 100 g)

Total anthocyanins present in the samples were determined by the method given by Ranganna (2009). The procedure involved extraction of the anthocyanins with ethanolic-HCl and measurement of colour at the wavelength of 535 nm against blank of ethanolic-HCl using a UV-Vis spectrophotometer (Model Shimadzu, Japan). The anthocyanins were calculated and expressed as mg per 100 mL using the formula given below:

$$\text{Total OD/ 100 mL (x)} = \frac{\text{OD at 535 nm} \times \text{Volume made up} \times \text{Total volume}}{\text{Volume of extract used} \times \text{Weight of sample taken}} \times 100$$

$$\text{Total anthocyanins (mg/ 100 g)} = \frac{X}{*98.20} \times 100$$

*98.20 = Extraction coefficient

3.3.2.15 Total phenolics (mg GAE/ 100 g)

The amounts of total phenols in the sample were determined by using the method given by Bray and Thorpe (1954) with the Folin-Ciocalteu reagent using catechol as a standard. 1 g of sample was taken and ground with 10 mL 80 per cent ethanol in pestle and mortar and centrifuged for 20 min at 1000 rpm and filtered. The filtrate was evaporated in oven up to dryness and residue was dissolved in 5 mL of distilled water. An aliquot of 0.2 to 2 mL was taken in separate test tubes and volume was made up to 3 mL with water. Then 0.5 mL Folin-Ciocalteu reagent was added. After 3 min, 2 mL of Na₂CO₃ (20%) was added and mixed. Test tubes were placed in boiling water bath for one min and then cooled. Optical density of the sample was recorded at 650 nm with the help of UV-VIS spectrophotometer (Shimadzu, Japan). The concentration was determined as per the standard procedure from the standard curve. The standard curve was prepared using different concentrations (8-32 µg/mL) of catechol and results were expressed as mg per 100 g on fresh weight basis.

3.3.2.16 Antioxidant activity (% free radical scavenging activity)

Antioxidant activity (Free radical scavenging activity) was measured as per the method of Williams *et al.* (1995). DPPH (2, 2- diphenyl-1- picrylhydrazyl) was used as a source of free radical. A quantity of 3.9 mL of 6×10^{-5} mol/ L DPPH in methanol was put in a cuvette with 0.1 mL of sample extract and the decrease in absorbance was measured at 515

nm for 30 min or until the absorbance become steady. Methanol was used as blank. The remaining DPPH concentration was calculated using the following equation:

$$\text{Antioxidant activity (\%)} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100$$

3.3.2.17 Non-enzymatic browning

Non-enzymatic browning in sample involved measuring of optical density of alcoholic extracts of centrifuged samples (2000 rpm) at 440 nm in UV-Vis spectrophotometer (Shimadzu, Japan) using 60 per cent ethanol as blank as per the method described by Ranganna (2009).

3.3.18 Microbial Evaluation

Total plate count (TPC) was determined by aseptically inoculating 0.1 g of serially diluted samples in standard plate count agar medium prepared according to Ranganna (1997). One mL of the sample after serial dilution (10^{-2} , 10^{-4} , 10^{-6} and 10^{-8}) was aseptically inoculated in pre-sterilized plates followed by pouring total plate count agar (10-15 mL) under sterilized environment of laminar air flow. The plates were then inoculated at 37°C for 72 h prior counting of microbes. The results of the TPC were expressed as log CFU/ mL of sample.

3.3.3 Sensory Evaluation

Nine-point Hedonic scale method as given by Amerine *et al.* (1965) was followed for conducting the sensory evaluation of sample. The panel of ten judges comprising of faculty members and post-graduate students of the department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh was selected to evaluate the products for sensory parameters such as colour, texture, taste and overall acceptability depending upon the type of product on 9-point Hedonic scale (Appendix-III). Efforts were made to keep the same panel for sensory evaluation throughout the entire period of study. The sample was presented to judges and plain water was given to them to rinse their mouth in between the evaluation of samples. No discussion during evaluation was allowed. Each sample was evaluated for various sensory attributes *viz.*, colour, body, flavour and overall acceptability on 9-point Hedonic scale signifying:

Score	Rating
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

3.3.4 Statistical analysis

Statistical analysis of the quantitative data of chemical parameters obtained from the experiments was determined by Completely Randomized Design (CRD) Factorial. Whereas, the data pertaining to the sensory evaluation of the samples was analysed by Randomized Block Design (RBD) as given by Mahony (1985) using one factor, two factor and three factor analysis of variance (ANOVA) with the help of OPSTAT. However, for the development of carrot juice concentrate, optimization of variables viz., temperature and concentration as well as the statistical analysis was carried out by using Expert version 7.00. Central Composite Design of Response Surface Methodology and multiple regressions ANOVA was used to analyse and predict the conditions using second order polynomial equations (regression equation) and three-dimensional surface plots.

A second order response for two independent variables was expressed by the equation below:

$$Y = \beta_0 + \beta_1A + \beta_2B + \beta_{12}AB + \beta_{11}A^2 + \beta_{22}B^2$$

Where, Y is the response to be calculated

β_0 is the model coefficient

β_1 and β_2 are linear regression coefficients

β_{12} is the interactive regression coefficients

β_{11} and β_{22} are quadratic regression coefficients

The sign and magnitude of coefficient tells about the nature of effect. Positive sign before terms indicate synergistic effect, whereas negative sign indicates antagonistic effect. Positive coefficient of linear level indicates that response value increases when the levels of

variables increased whereas; negative coefficient of linear level indicates that response decreases when the levels of variables increased. Negative interaction suggests that the level of one of the predictors can be increased while that of other decreased for constant value of the response whereas; positive interaction suggests that the level of one of the predictors can be increased while that of other increased for constant value of the response. Negative sign of quadratic terms means that the maximum response is at the center value of the variables and it decreases with increase or decrease in parameter level and positive sign means that the minimum response at the center value of the variables and it increases with the increase or decrease in parameter level. ANOVA was used to find out lack of fit (LOF), significance of linear, quadratic and interactive effect of independent variable on dependent variables. LOF measures failure of model to characterize data in the experiment domain at which points were not included in the regression. R^2 value greater than 80 per cent was considered as adequate for the appropriateness of the model. F value of LOF should be less than the tabulated value at same degree of freedom i.e. should be non-significant and adequate precision should be more than 4. Adequate precision compared the range of predicted values at the design points to be the average prediction error. After obtaining adequate model, each variable was predicted for probability values, if the value was less than 0.01, the effect of variable was considered significant at 1 per cent level, if value was lies between 0.01 to 0.05, the effect of variable was significant at 5 per cent level of significance and if greater than 0.05, the effect was considered non-significant.

3.3.5 Cost of production

The raw material, other ingredients, additives and packaging material etc. were procured as per present prices in the market. Further, the cost of respective products was calculated by taking in to account the cost of raw material, ingredients, packaging material and processing cost.

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled, “**Carrot juice concentrate production and utilization**” was carried out in the Department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2017-2020. The results obtained in different experiments are presented and discussed in this chapter under suitable captions:

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF RAW CARROT (BLACK, ORANGE, PURPLE AND RED)

Data pertaining to physico-chemical characteristics of fresh carrot roots (black, orange, purple and red) are presented in Table 4.1.

4.1.1 Physical characteristics

The results obtained for physical characteristics of raw carrot roots (black, orange, purple and red) are presented in Table 4.1. The maximum root length of 25.90 cm was reported in red carrot which was followed by black carrot (22.85 cm), purple carrot (20.76 cm) and orange carrot (16.53 cm). The findings are in conformity with the results of Chen *et al.* (2020) and Singh *et al.* (2020). It was concluded that the highest root weight was noted in red carrot (96.84 g), while the minimum weight was observed in orange carrots (84.14 g). A similar range of root weight (92.81-113.34 g) has been documented by Roshni *et al.* (2019). The visual colour of black, orange, purple and red carrot was found to be purple (79-A), greyed orange group (165-B), purple (79-B) and red group (45-D). The average pith size was 1.16 cm, 1.78 cm, 1.20 cm and 1.37 cm in black, orange, purple and red carrot, respectively. The results were in conformity with Haq *et al.* (2013) and Kumar (2018).

4.1.2 Chemical characteristics

The data revealed a range of 83.35 to 91.50 per cent moisture content in carrot roots. Similar values of moisture content have been reported by Kumar *et al.* (2012), Gani and Kumar (2013), Borowska *et al.* (2017) and Rubina *et al.* (2018). The average total soluble solids (TSS), total sugars, reducing sugars, titratable acidity, pH, fibre, ash, pectin and ascorbic acid in black carrot were recorded as 8.0 per cent, 4.97 per cent, 2.36 per cent, 0.25

per cent, 5.80 per cent, 1.02 per cent, 1.40 per cent, 0.17 per cent and 12.75 mg/ 100 g, respectively. Whereas, total carotenoids, anthocyanins, total phenolic content and antioxidant activity were found to be 1.50 mg/ 100 g, 249.32 mg/ 100 g, 290.63 mg GAE/ 100 g and 80.25 per cent free radical scavenging activity, respectively. Similar values of total soluble solids (7.80%), total sugars (4.81%), reducing sugars (2.10%), titratable acidity (0.21%), pH (5.92), fibre (1.17%), ash (1.43%), pectin (0.20%), ascorbic acid (10.58 mg/ 100 g) and slightly lower values of anthocyanin (235.17 mg/ 100 g), total phenolic content (278.20 mg GAE/ 100 g) and antioxidant activity (73.69% free radical scavenging activity) were estimated in purple carrot. The results were in conformity with Kaur and Sogi (2020) and Singla *et al.* (2020).

Table 4.1 Physico-chemical characteristics of fresh carrot roots

Parameter*	Black carrot (Mean $\pm$ SD)	Orange carrot (Mean $\pm$ SD)	Purple carrot (Mean $\pm$ SD)	Red carrot (Mean $\pm$ SD)
Weight (g)	90.37 $\pm$ 3.47	84.14 $\pm$ 2.76	92.75 $\pm$ 3.19	96.84 $\pm$ 2.87
Length (cm)	22.85 $\pm$ 1.87	16.53 $\pm$ 1.53	20.76 $\pm$ 1.14	25.90 $\pm$ 1.23
Diameter (cm)	3.50 $\pm$ 0.15	4.26 $\pm$ 0.09	4.10 $\pm$ 1.06	3.59 $\pm$ 0.12
Colour** (visual)	Purple (79-A)	Greyed orange group (165-B)	Purple (79-B)	Red group (45-D)
Pith size (cm)	1.16 $\pm$ 0.08	1.78 $\pm$ 0.06	1.20 $\pm$ 0.03	1.37 $\pm$ 0.07
Moisture (%)	89.70 $\pm$ 1.46	83.35 $\pm$ 1.50	91.50 $\pm$ 1.17	87.44 $\pm$ 1.28
TSS (%)	8.00 $\pm$ 0.13	7.50 $\pm$ 0.10	7.80 $\pm$ 0.09	9.00 $\pm$ 0.12
Total sugars (%)	4.97 $\pm$ 0.07	4.25 $\pm$ 0.05	4.81 $\pm$ 0.08	5.60 $\pm$ 0.03
Reducing sugars (%)	2.36 $\pm$ 0.10	2.04 $\pm$ 0.07	2.10 $\pm$ 0.04	3.15 $\pm$ 0.03
Titratable acidity (as % citric acid)	0.25 $\pm$ 0.03	0.09 $\pm$ 0.02	0.21 $\pm$ 0.01	0.15 $\pm$ 0.03
pH	5.80 $\pm$ 0.06	6.50 $\pm$ 0.08	5.92 $\pm$ 0.03	6.40 $\pm$ 0.05
Fibre (%)	1.02 $\pm$ 0.02	1.95 $\pm$ 0.01	1.17 $\pm$ 0.02	1.76 $\pm$ 0.01
Ash (%)	1.40 $\pm$ 0.03	1.32 $\pm$ 0.07	1.43 $\pm$ 0.05	1.27 $\pm$ 0.04
Pectin (%)	0.17 $\pm$ 0.01	0.35 $\pm$ 0.02	0.20 $\pm$ 0.02	0.24 $\pm$ 0.01
Ascorbic acid (mg/ 100 g)	12.75 $\pm$ 0.28	15.43 $\pm$ 0.18	10.58 $\pm$ 0.09	10.43 $\pm$ 0.14
Total carotenoids (mg/ 100 g)	1.50 $\pm$ 0.05	12.30 $\pm$ 0.03	1.25 $\pm$ 0.04	8.68 $\pm$ 0.02
Anthocyanins (mg/ 100 g)	249.32 $\pm$ 2.76	0.16 $\pm$ 0.01	235.17 $\pm$ 2.12	0.74 $\pm$ 0.02
Total phenolics (mg GAE/ 100 g)	290.63 $\pm$ 2.54	25.78 $\pm$ 1.76	278.20 $\pm$ 2.81	34.07 $\pm$ 1.80
Antioxidant activity (% free radical scavenging activity)	80.25 $\pm$ 1.67	35.42 $\pm$ 0.76	73.69 $\pm$ 1.34	26.80 $\pm$ 0.52

*Each value is average of 10 determinations; SD = Standard deviation

**Visual colour value of different carrot roots was recorded by using color cards of Royal Horticulture Society, London

As shown in Table 4.1, orange carrot contained 7.50 per cent total soluble solids, 4.25 per cent total sugars, 2.04 per cent reducing sugars, 0.09 per cent acidity, 6.50 pH, 1.95 per cent fibre, 1.32 per cent ash, 0.35 per cent pectin. Total carotenoids, total phenolics and antioxidant activity was reported to be 12.30 mg/ 100 g, 25.78 mg GAE/ 100 g and 35.42 per cent free radical scavenging activity. Red carrot roots were analyzed for various chemical

characteristics and it was found that it contained 9.0 per cent total soluble solids, 5.60 per cent total sugars, 3.15 per cent reducing sugars, 0.15 per cent acidity, 6.40 pH, 1.76 per cent fibre, 1.27 per cent ash, 0.24 per cent pectin, 8.68 mg/ 100 g total carotenoids, 34.07 mg GAE/ 100 g total phenolic content and 26.80 per cent free radical scavenging antioxidant activity. Similar results have been reported by Cheena *et al.* (2020) and Singh *et al.* (2020).

4.2 OPTIMIZATION OF METHODOLOGY FOR CARROT (BLACK, ORANGE, PURPLE AND RED) JUICE EXTRACTION

The carrot roots were washed under running tap water, trimmed using stainless steel vegetable knife, dirty and undesirable hair were removed. Further, carrot roots were either shredded (with stainless steel vegetable grater) or whole carrots (10 cm) according to the treatment detail were subjected to different blanching treatments i.e. hot water blanching, steam blanching, acidified water blanching (citric acid @ 4.50%), ultrasound assisted blanching and microwave assisted blanching for variable time intervals i.e. 1, 2, 3, 4 and 5 minutes. Further, to study the effect of enzymatic treatments on juice, shredded carrots were exposed to Pectinase and Cellulase enzymes at different concentration and time combinations. The juice extracted was then analyzed for various quality parameters.

4.2.1 Standardization of blanching pre-treatment for carrot (black, orange, purple and red) juice extraction

In total, 42 treatment combinations were tried to standardize the blanching method and time in each type of carrot for the extraction of juice. The data pertaining to the effect of blanching method and time on various quality attributes is presented in Table 4.2, Table 4.3, Table 4.4 and Table 4.5. The results obtained have been explained under the following heads:

4.2.1.1 Black carrot

Among different treatments (Table 4.2), the maximum juice yield (65.30%) was noticed in treatment where whole carrots were exposed to acidified water blanching for 4 min. With the increase in blanching time, there was an increase in juice yield up to a certain level beyond which it either become constant or started to decrease slightly. This decrease in juice yield might be due to leaching and leaking of juice into water. The results were in conformity with Yasuda *et al.* (2017) and Sucheta *et al.* (2019). The total soluble solids ranged from 6.00 to 7.40 per cent. The maximum value was found in carrot juice extracted from unblanched (control) whole carrot and minimum total soluble solids were observed in juice extracted from microwave assisted blanched grated carrots (5 min). A slight decrease in

TSS in blanched carrot was due to leaching of soluble solids in water (Sharma *et al.*, 2000). Among different treatments, maximum total sugars (4.78%) and reducing sugars (2.78%) were detected in ultrasound assisted blanched whole carrots (3 min).

The titratable acidity in the extracted carrot juice was noticed to be in the range of 0.03 to 0.12 per cent as highlighted in Table 4.2. The blanching method and time had significant effect on titratable acidity of extracted juice. The highest acidity (0.12%) was recorded in carrot juice extracted from acidified water blanched carrots (4 min). The decrease in acidity might be due to the destruction of heat liable acids and further dissolution of soluble acids. The results were in accordance with Quarcoo and Manu (2016). It is evident from the Table 4.2 that blanching method and time had a significant effect on fibre and pectin content of extracted carrot juice. The maximum fibre content i.e. 0.18 per cent was observed in juice extracted from ultrasonic blanched carrot for 4 min which remained statistically at par with acidified water blanched carrot (4 min) juice. The maximum ascorbic acid (11.39 mg/ 100 g) was estimated in carrot juice extracted from unblanched whole carrots. Ascorbic acid content was found to decrease in blanched carrot, which may be due to oxidation, thermal degradation and leaching into water (Lee and Kader, 2000; Leskova *et al.*, 2006). However, the maximum retention was found in ultrasound assisted blanched carrot (whole carrot 10.87 mg/ 100 g and grated carrot 8.48 mg/ 100 g) after 5 min. The predominant polyphenols found in black carrot are anthocyanins, which are most exclusively present in the glycosylated form (Kirca *et al.*, 2006). Table 4.2 also reflects the data on the effect of blanching method and time on the anthocyanin content of carrot juice. The results indicate a range from 133.56 to 185.76 mg/ 100 g where, microwave assisted carrot (grated) for 5 min had minimum value and acidified water blanched (4 min) carrot juice had the maximum value. The blanching step has caused decrease in anthocyanin content, which could be a result of the loss of water-soluble solids and gain of water inside cells (Uyan *et al.*, 2004). The results are in conformity with Pragya (2018).

In the present study, the total phenolic content ranged from 77.26 to 97.82 mg GAE/ 100 g. Blanching caused significant reduction in the total phenolic content. The reduction in total phenols may be attributed due to leaching of polyphenols in water from vegetable tissues (Danesi and Bordoni, 2008). Further, the maximum retention (92.50 mg GAE/ 100 g) after 5 min of blanching treatment was found in ultrasound assisted blanched whole carrot juice.

Table 4.2 Effect of blanching method and time on the physico-chemical properties of extracted black carrot juice

Characteristics	Black carrot																					
	Control		Water blanching					Steam blanching										Acidified Water blanching				
	WC	GC	Whole carrot (WC)					Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)				
	Time (min)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Yield (%)	58.10	51.30	58.20	58.70	60.40	62.10	61.50	58.40	59.30	61.10	64.20	62.80	51.20	51.70	52.50	53.20	52.70	58.50	59.70	62.80	65.30	59.90
Total soluble solids (%)	7.40	6.90	7.40	7.20	7.10	6.80	6.80	7.40	7.30	7.30	7.10	7.10	6.90	6.70	6.60	6.50	6.50	7.40	7.35	7.20	7.20	7.10
Total sugars (%)	4.25	4.09	4.20	4.23	4.17	4.09	4.18	4.29	4.25	4.29	4.09	4.05	4.09	4.10	3.92	3.87	3.70	4.37	4.51	4.28	4.30	4.25
Reducing sugars (%)	2.56	2.32	2.78	2.56	2.42	2.39	2.26	2.70	2.56	2.54	2.17	2.10	2.56	2.50	2.38	2.12	2.02	2.60	2.73	2.53	2.47	2.70
Titrateable acidity (as % citric acid)	0.07	0.05	0.07	0.06	0.05	0.03	0.03	0.05	0.05	0.05	0.04	0.03	0.05	0.05	0.04	0.04	0.03	0.07	0.08	0.11	0.12	0.10
Fibre (%)	0.10	0.08	0.10	0.11	0.13	0.12	0.11	0.10	0.13	0.14	0.11	0.12	0.08	0.07	0.06	0.05	0.06	0.10	0.14	0.13	0.16	0.12
Pectin (%)	0.05	0.03	0.04	0.04	0.02	0.01	0.01	0.04	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.01
Ascorbic acid (mg/ 100 g)	11.39	8.74	11.35	10.76	8.85	8.59	8.42	11.36	11.28	11.09	10.80	10.78	8.74	8.30	8.12	7.98	7.60	11.35	11.02	10.96	10.82	10.65
Anthocyanins (mg/ 100 g)	180.64	142.10	176.80	172.34	165.53	160.56	158.24	179.78	167.49	169.80	164.35	162.64	142.09	140.98	138.43	137.67	136.10	180.58	182.10	183.83	185.76	184.19
Total phenolics (mg GAE/ 100 g)	97.82	85.24	97.80	94.34	91.79	87.32	85.49	97.80	96.10	94.65	91.29	90.85	85.22	84.69	81.34	80.56	79.78	97.80	95.83	93.24	93.50	89.76
Antioxidant activity (% free radical scavenging activity)	70.15	62.87	70.10	68.36	68.51	63.68	63.42	70.14	69.89	68.62	64.94	63.70	62.85	61.34	60.86	59.54	59.62	70.12	69.72	68.93	68.98	63.57
Non-enzymatic browning	0.15	0.37	0.13	0.12	0.12	0.09	0.08	0.12	0.09	0.06	0.05	0.02	0.32	0.29	0.21	0.15	0.12	0.13	0.09	0.06	0.05	0.05

Table 4.2 contd.....

Table 4.2 contd.....

Characteristics	Black carrot																				CD _{0.05}
	Ultrasound assisted blanching										Microwave assisted blanching										
	Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)					Grated carrot (GC)					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Yield (%)	58.60	60.50	63.80	65.00	64.80	51.20	52.60	55.80	55.70	54.90	58.10	58.50	59.60	60.30	60.80	51.20	51.50	51.80	52.40	52.50	0.25
Total soluble solids (%)	7.40	7.35	7.40	7.20	7.30	6.90	6.80	6.70	6.70	6.60	7.40	7.17	6.46	6.31	6.12	6.90	6.50	6.30	6.10	6.00	0.31
Total sugars (%)	4.61	4.72	4.78	4.36	4.28	4.38	4.32	4.17	4.24	4.13	4.65	4.50	4.21	4.09	3.86	4.36	4.31	4.16	3.54	3.20	0.17
Reducing sugars (%)	2.49	2.43	2.78	2.25	2.19	2.41	2.54	2.60	2.51	2.39	2.60	2.43	2.03	1.76	1.82	2.29	2.25	2.18	1.89	1.68	0.04
Titrateable acidity (as % citric acid)	0.05	0.04	0.05	0.04	0.04	0.05	0.04	0.05	0.03	0.03	0.05	0.04	0.04	0.03	0.03	0.05	0.03	0.04	0.03	0.03	0.01
Fibre (%)	0.10	0.13	0.14	0.18	0.15	0.08	0.06	0.04	0.04	0.03	0.10	0.12	0.11	0.11	0.12	0.07	0.07	0.06	0.05	0.04	0.02
Pectin (%)	0.04	0.03	0.01	0.02	0.01	0.04	0.02	0.01	0.01	0.01	0.04	0.03	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01
Ascorbic acid (mg/ 100 g)	11.36	11.30	11.24	10.95	10.87	8.74	8.70	8.65	8.51	8.48	11.35	10.08	8.21	8.01	7.92	8.74	8.14	7.83	7.54	7.37	0.51
Anthocyanins (mg/ 100 g)	179.78	176.40	173.85	167.52	165.49	142.09	141.93	141.53	140.70	139.50	176.80	170.43	161.35	157.65	155.42	142.09	140.23	137.65	134.83	133.56	2.75
Total phenolics (mg GAE/ 100 g)	97.80	97.36	95.78	93.65	92.50	85.22	85.69	84.79	82.95	81.64	97.80	95.09	90.83	86.00	82.45	85.22	83.37	80.65	78.19	77.26	4.50
Antioxidant activity (% free radical scavenging activity)	70.14	69.94	69.46	66.57	65.17	62.87	62.43	61.96	60.41	60.05	70.10	65.63	62.15	62.00	60.34	62.85	60.02	57.45	56.24	55.27	1.12
Non-enzymatic browning	0.12	0.07	0.05	0.03	0.02	0.36	0.26	0.22	0.20	0.18	0.13	0.07	0.02	0.03	0.02	0.37	0.35	0.39	0.40	0.42	0.03

Unblanched carrot juice of whole carrot was found to have 70.15 per cent free radical scavenging antioxidant activity. However, blanched carrots had lower antioxidant activity. The decrease in antioxidant activity might be due to decrease in polyphenol content and loss of ascorbic acid due to thermal degradation and leaching. Duddone *et al.* (2009) found that antioxidant activity was correlated to phenolic compound concentration. Among the different treatments, the maximum non-enzymatic browning (0.42) was found in juice extracted after microwave assisted blanching of carrots for 5 min.

4.2.1.2 Orange carrot

The effect of blanching method and time on extraction of orange carrot juice is highlighted in Table 4.3. It is evident that there was a significant effect of blanching on juice yield and total soluble solids of carrot juice. Minimum juice yield (36.50%) was obtained in juice obtained from unblanched (control) grated carrots. However, maximum juice yield (52.90%) was found in ultrasound assisted blanched carrots (5 min). The total soluble solids were noticed to be in the range of 3.60 to 7.0 per cent. However, the maximum total sugars and reducing sugars were 4.62 per cent and 2.25 per cent in unblanched whole carrot juice and steam blanched whole carrot juice respectively. Further, the maximum titratable acidity was found in juice extracted from acidified water blanched carrots (4 min). There was a significant effect of blanching method and time on fibre as well as pectin content of carrot juice. There was a gradual increase in the fibre content of carrot juice with increase in blanching time up to a certain level whereas, inverse relationship between blanching time and pectin content was noticed.

The amount of ascorbic acid, carotenoids and total phenols was 12.36 mg/ 100 g, 10.75 mg/ 100 g and 11.07 mg GAE/ 100 g in control whole carrot juice. Further, maximum retention or amount of these phytochemicals were found in ultrasound assisted blanched whole carrot juice i.e. 11.67 mg/ 100 g, 12.72 mg/ 100 g and 10.61 mg GAE/ 100 g. Minimum non-enzymatic browning was also found in ultrasound assisted extracted carrot juice (0.28). Similar results were reported by Torregrosa *et al.* (2005), Cortes *et al.* (2008) and Barba *et al.* (2012).

Table 4.3 Effect of blanching method and time on the extraction of orange carrot juice

Characteristics	Orange carrot																					
	Control		Water blanching					Steam blanching										Acidified Water blanching				
	WC	GC	Whole carrot (WC)					Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)				
	Time (min)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Yield (%)	45.00	36.50	46.10	45.50	46.20	48.90	49.50	46.80	47.20	49.70	50.40	51.00	36.80	37.40	41.30	42.20	43.50	46.80	47.10	49.80	52.70	52.20
Total soluble solids (%)	7.00	4.20	6.50	5.70	5.20	4.10	4.00	6.80	6.20	5.60	5.30	5.00	4.10	3.90	3.70	3.50	3.40	6.60	6.20	5.80	4.90	4.50
Total sugars (%)	4.62	2.43	3.70	3.48	3.29	2.80	2.41	4.36	4.10	3.82	3.41	3.22	2.30	2.15	1.76	1.60	1.52	4.20	4.18	3.86	3.45	3.20
Reducing sugars (%)	2.17	1.68	2.00	1.70	1.52	1.03	0.88	2.25	1.93	1.58	1.45	1.37	1.68	1.27	0.97	0.74	0.70	2.17	2.01	1.72	1.23	1.04
Titratable acidity (as % citric acid)	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.04	0.07	0.11	0.16	0.15
Fibre (%)	0.20	0.14	0.18	0.19	0.16	0.22	0.23	0.21	0.23	0.22	0.26	0.25	0.15	0.17	0.18	0.22	0.23	0.18	0.20	0.23	0.22	0.25
Pectin (%)	0.09	0.06	0.08	0.08	0.08	0.05	0.07	0.09	0.08	0.05	0.05	0.03	0.06	0.04	0.04	0.02	0.02	0.07	0.07	0.04	0.05	0.04
Ascorbic acid (mg/ 100 g)	12.36	8.28	12.20	11.10	10.50	8.28	7.06	12.31	11.75	11.24	10.65	10.60	8.20	8.13	7.87	7.54	7.40	12.32	12.10	11.95	10.17	9.65
Total carotenoids (mg/ 100 g)	10.75	8.87	10.72	10.72	10.86	11.49	11.52	10.78	10.80	11.57	12.19	12.22	8.90	8.94	9.07	9.10	9.12	10.79	10.96	11.86	12.25	12.52
Total phenolics (mg GAE/ 100 g)	11.07	9.85	10.98	10.65	10.23	9.70	9.56	11.05	11.00	10.85	10.40	10.31	9.81	9.78	9.25	9.03	8.97	11.05	10.92	10.37	10.09	9.86
Antioxidant activity (% free radical scavenging activity)	59.24	48.70	59.00	58.86	57.45	56.21	55.73	59.20	58.96	58.90	58.17	57.86	48.63	47.38	46.50	42.84	44.78	59.21	59.06	58.68	57.32	56.97
Non-enzymatic browning	0.43	0.65	0.41	0.40	0.40	0.37	0.36	0.40	0.37	0.34	0.33	0.30	0.64	0.62	0.58	0.57	0.54	0.41	0.37	0.34	0.33	0.30

Table 4.3 contd.....

Table 4.3 contd.....

Characteristics	Orange carrot																				CD _{0.05}
	Ultrasound assisted blanching										Microwave assisted blanching										
	Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)					Grated carrot (GC)					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Yield (%)	47.10	48.20	51.20	52.40	52.90	37.70	38.60	42.50	44.60	43.90	45.00	45.20	45.70	46.10	46.50	36.60	36.80	37.50	37.90	38.10	2.80
Total soluble solids (%)	6.80	6.70	6.60	6.60	6.40	4.30	4.32	3.90	4.00	4.10	6.50	5.60	5.10	4.50	4.10	4.10	4.00	3.90	3.70	3.60	1.04
Total sugars (%)	4.58	4.23	4.12	4.01	3.92	2.45	2.12	1.92	1.60	1.72	3.75	3.69	3.42	2.06	2.29	2.40	2.37	2.15	2.10	1.97	0.85
Reducing sugars (%)	2.12	1.95	1.78	1.65	1.73	1.38	1.57	1.26	1.08	1.70	2.13	1.74	1.50	1.53	1.18	1.52	1.46	1.39	1.42	1.05	0.27
Titratable acidity (as % citric acid)	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.03	0.03	0.01	0.02	0.01	0.01
Fibre (%)	0.23	0.22	0.24	0.25	0.26	0.15	0.15	0.20	0.23	0.22	0.18	0.16	0.15	0.20	0.21	0.14	0.12	0.13	0.10	0.10	0.01
Pectin (%)	0.09	0.07	0.05	0.04	0.03	0.06	0.05	0.05	0.02	0.03	0.08	0.08	0.07	0.05	0.05	0.06	0.06	0.05	0.03	0.03	0.01
Ascorbic acid (mg/ 100 g)	12.31	12.15	12.04	11.85	11.67	8.20	8.17	8.09	7.95	7.90	12.20	11.00	10.20	8.08	7.00	8.25	7.95	7.82	7.54	7.50	1.28
Total carotenoids (mg/ 100 g)	10.78	10.98	11.87	12.60	12.72	8.94	9.24	9.57	10.13	10.72	10.72	10.75	10.76	11.20	11.32	8.87	8.96	9.35	9.87	10.03	0.52
Total phenolics (mg GAE/ 100 g)	11.05	11.00	10.95	10.75	10.61	9.81	9.80	9.50	9.37	9.06	10.98	10.45	10.02	9.50	9.17	9.82	9.73	9.40	9.10	8.87	0.16
Antioxidant activity (% free radical scavenging activity)	59.20	58.96	58.90	58.77	57.68	48.72	48.93	49.25	49.84	50.19	59.00	58.45	57.20	56.28	54.82	48.70	48.62	48.20	46.41	45.39	1.73
Non-enzymatic browning	0.40	0.35	0.30	0.31	0.28	0.64	0.54	0.56	0.52	0.50	0.41	0.35	0.30	0.31	0.32	0.65	0.63	0.67	0.68	0.70	0.02

4.2.1.3 Purple carrot

Among different treatments (Table 4.4), the maximum juice yield (66.60%) was detected in treatment where whole carrots were exposed to acidified water blanching for 3 min. The total soluble solids ranged from 5.80 to 7.30 per cent. The maximum value of total soluble solids was found in carrot juice extracted from unblanched (control) whole carrots and minimum total soluble solids were observed in microwave assisted blanched whole carrots (5 min). Among different treatments, the maximum total sugars (4.58%) was detected in acidified water blanched whole carrots for 3 min. The titratable acidity in the extracted carrot juice was noticed to be in the range of 0.02 to 0.17 per cent as highlighted in Table 4.4. The blanching method and time had significant effect on titratable acidity of extracted juice. The highest acidity (0.17%) was recorded in carrot juice extracted from acidified water blanched carrots (4 min). The maximum ascorbic acid (10.18 mg/ 100 g) was estimated in carrot juice extracted from unblanched whole carrots. However, the maximum retention was found in acidified water blanched carrot (whole carrot 9.42 mg/ 100 g). Table 4.4 also reflects the data on the effect of blanching method and time on the anthocyanin content of carrot juice. The results indicate a range from 122.41 to 177.36 mg/ 100 g where steam blanched carrot (grated) for 5 min had minimum anthocyanin content and acidified water blanched (3 min) carrot juice had the maximum value. The total phenolic content ranged from 70.36 to 88.92 mg GAE/ 100 g. Further, the maximum retention (82.50 mg GAE/ 100 g) after 5 min of blanching treatment was found in ultrasound assisted blanched whole carrot juice. Acidified water blanched carrot juice (whole carrot) had maximum antioxidant activity of 68.13 per cent. The results were in accordance with Uyan *et al.* (2004), Nicolle *et al.* (2004) and Baranski *et al.* (2012).

4.2.1.4 Red carrot

The effect of blanching method and time on extraction of red carrot juice is highlighted in Table 4.5. It is evident that there was a significant effect of blanching method and time on juice yield and total soluble solids of carrot juice. Minimum juice yield (47.30%) was obtained in juice obtained from unblanched (control) grated carrots. However, maximum value (72.40%) was found in ultrasound assisted blanched carrots for 4 min. The total soluble solids were noticed to be in the range of 4.10 to 8.10 per cent. However, the maximum total sugars and reducing sugars were 4.96 per cent and 2.80 per cent in unblanched whole carrot juice and acidified water blanched (4 min) whole carrot juice, respectively.

Table 4.4 Effect of blanching method and time on the extraction of purple carrot juice

Characteristics	Purple carrot																					
	Control		Water blanching					Steam blanching										Acidified Water blanching				
	WC	GC	Whole carrot (WC)					Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)				
	Time (min)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Yield (%)	59.30	53.80	59.80	60.40	61.30	64.80	62.50	59.30	59.90	62.40	65.70	63.30	53.70	54.30	54.80	52.60	51.90	59.30	61.40	66.60	62.70	60.10
Total soluble solids (%)	7.30	6.50	7.20	7.15	7.00	6.70	6.60	7.25	7.20	7.15	7.00	7.00	6.50	6.40	6.30	6.25	6.20	7.20	7.15	7.10	6.80	6.70
Total sugars (%)	4.35	4.19	4.32	4.23	4.13	4.09	3.93	4.29	4.25	4.29	4.09	4.05	4.09	4.10	3.92	3.87	3.70	4.37	4.51	4.58	4.30	4.25
Reducing sugars (%)	2.62	2.52	2.51	2.45	2.32	2.24	2.15	2.70	2.56	2.54	2.17	2.10	2.56	2.50	2.38	2.12	2.02	2.60	2.73	2.70	2.53	2.47
Titrateable acidity (as % citric acid)	0.08	0.04	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.08	0.10	0.16	0.17	0.15
Fibre (%)	0.17	0.12	0.16	0.13	0.13	0.12	0.10	0.12	0.11	0.10	0.11	0.08	0.12	0.11	0.08	0.08	0.16	0.14	0.07	0.06	0.04	0.05
Pectin (%)	0.08	0.05	0.06	0.06	0.03	0.03	0.01	0.06	0.05	0.02	0.03	0.02	0.05	0.05	0.02	0.01	0.01	0.05	0.03	0.01	0.01	0.01
Ascorbic acid (mg/ 100 g)	10.18	6.48	10.15	9.86	9.18	8.65	8.13	10.16	9.83	9.46	9.08	8.68	6.45	6.23	5.73	5.21	4.88	10.15	10.02	9.69	9.53	9.42
Anthocyanins (mg/ 100 g)	172.85	131.67	172.82	171.57	166.35	159.24	157.98	172.78	170.94	168.76	163.55	163.09	131.58	130.27	126.75	125.19	122.41	172.81	173.30	177.36	174.84	173.99
Total phenolics (mg GAE/ 100 g)	88.82	79.42	88.75	86.43	81.64	80.27	80.04	88.73	87.30	85.92	79.64	79.05	88.52	87.73	83.42	81.78	80.53	88.92	87.79	82.19	80.95	80.17
Antioxidant activity (% free radical scavenging activity)	67.51	58.78	66.10	64.36	64.51	59.68	59.42	66.14	65.89	64.62	60.94	59.70	58.85	57.34	56.86	55.54	55.62	67.51	68.00	68.13	62.98	59.57
Non-enzymatic browning	1.22	1.44	1.20	1.19	1.19	1.16	1.15	1.19	1.16	1.13	1.12	1.09	1.43	1.41	1.37	1.36	1.33	1.20	1.16	1.13	1.12	1.11

Table 4.4 contd.....

Table 4.4 contd.....

Characteristics	Purple carrot																				CD _{0.05}
	Ultrasound assisted blanching										Microwave assisted blanching										
	Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)					Grated carrot (GC)					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Yield (%)	60.35	62.25	63.55	65.95	64.55	52.95	54.35	57.55	57.45	56.65	59.85	60.25	61.35	62.05	62.55	52.95	54.25	54.55	54.15	54.25	0.26
Total soluble solids (%)	7.10	7.05	7.10	6.90	7.00	6.60	6.50	6.40	6.40	6.30	7.10	6.80	6.15	6.01	5.80	6.60	6.30	6.20	6.30	6.25	0.10
Total sugars (%)	4.31	4.25	4.14	3.89	3.81	3.91	3.85	3.70	3.77	3.66	4.18	4.03	3.74	3.62	3.39	3.89	3.84	3.69	3.07	2.73	0.15
Reducing sugars (%)	2.26	2.20	2.15	2.02	1.96	2.18	2.31	2.37	2.28	2.16	2.37	2.20	1.80	1.53	1.59	2.06	2.02	1.95	1.66	1.45	0.04
Titrateable acidity (as % citric acid)	0.08	0.07	0.07	0.06	0.06	0.04	0.04	0.05	0.03	0.03	0.08	0.08	0.07	0.05	0.05	0.05	0.03	0.04	0.03	0.03	0.01
Fibre (%)	0.16	0.15	0.11	0.10	0.09	0.12	0.11	0.09	0.06	0.07	0.16	0.14	0.16	0.11	0.12	0.12	0.11	0.12	0.10	0.11	0.05
Pectin (%)	0.06	0.05	0.04	0.04	0.03	0.05	0.03	0.02	0.02	0.02	0.06	0.05	0.04	0.04	0.02	0.05	0.03	0.03	0.02	0.03	0.02
Ascorbic acid (mg/ 100 g)	10.16	9.96	9.64	9.15	8.73	6.74	6.70	6.65	6.51	6.48	10.25	9.08	7.21	7.01	6.92	6.46	6.14	5.83	5.54	5.37	0.12
Anthocyanins (mg/ 100 g)	172.78	170.40	173.85	167.52	165.49	142.09	141.93	141.53	140.70	139.50	176.80	170.43	161.35	157.65	155.42	142.09	140.23	137.65	134.83	133.56	1.06
Total phenolics (mg GAE/ 100 g)	88.80	88.36	85.78	83.65	82.50	79.22	79.69	78.79	76.95	75.64	88.80	86.09	80.76	79.21	78.59	79.38	77.65	74.28	72.54	70.36	0.42
Antioxidant activity (% free radical scavenging activity)	67.07	66.87	66.39	63.5	62.1	59.8	59.36	58.89	57.34	56.98	67.03	62.56	59.08	58.93	57.27	59.78	56.95	54.38	53.17	52.2	0.21
Non-enzymatic browning	1.19	1.14	1.09	1.10	1.07	1.43	1.33	1.35	1.31	1.29	1.20	1.14	1.09	1.10	1.05	1.44	1.42	1.46	1.47	1.49	0.03

Table 4.5 Effect of blanching method and time on the extraction of red carrot juice

Characteristics	Red carrot																					
	Control		Water blanching					Steam blanching										Acidified Water blanching				
	WC	GC	Whole carrot (WC)					Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)				
	Time (min)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Yield (%)	54.80	47.30	55.20	57.60	62.50	63.30	64.40	56.40	60.80	63.90	65.50	66.80	49.30	50.90	52.10	53.50	53.80	56.80	59.60	65.50	68.70	69.80
Total soluble solids (%)	8.10	5.15	7.90	7.75	7.65	7.60	7.50	7.90	7.80	7.85	7.70	7.65	5.10	4.90	4.70	4.50	4.40	7.90	7.85	7.80	7.70	7.60
Total sugars (%)	4.96	3.59	4.80	4.76	4.57	4.33	4.27	4.82	4.70	4.63	4.26	4.18	3.55	3.49	3.35	3.28	3.17	4.93	4.80	4.48	4.35	4.30
Reducing sugars (%)	2.57	1.34	2.32	2.15	2.08	1.98	1.99	2.55	2.47	2.34	2.35	2.23	1.40	1.32	1.28	1.17	1.08	2.58	2.60	2.73	2.80	2.77
Titrateable acidity (as % citric acid)	0.05	0.03	0.04	0.04	0.02	0.02	0.02	0.05	0.04	0.04	0.03	0.04	0.03	0.03	0.02	0.01	0.01	0.05	0.08	0.10	0.13	0.15
Fibre (%)	0.12	0.09	0.11	0.12	0.14	0.14	0.16	0.11	0.14	0.13	0.15	0.14	0.10	0.12	0.13	0.12	0.12	0.12	0.14	0.15	0.18	0.17
Pectin (%)	0.06	0.05	0.06	0.05	0.03	0.03	0.02	0.06	0.05	0.05	0.04	0.04	0.05	0.05	0.04	0.03	0.03	0.04	0.03	0.03	0.02	0.02
Ascorbic acid (mg/ 100 g)	8.10	4.86	8.00	7.84	6.47	5.32	4.01	8.03	7.56	6.12	4.98	4.88	4.86	4.60	4.37	4.10	4.00	7.95	6.37	5.80	5.10	4.25
Total carotenoids (mg/ 100 g)	6.35	5.80	6.37	6.40	6.47	6.56	6.60	6.36	6.40	6.68	6.93	7.08	5.82	5.97	6.04	6.15	6.18	6.39	6.48	6.93	7.37	7.40
Total phenolics (mg GAE/ 100 g)	10.98	8.56	10.80	10.12	9.53	8.96	7.87	10.96	10.21	9.50	8.65	8.50	8.53	8.17	7.82	7.76	7.75	10.78	10.20	9.45	8.90	8.10
Antioxidant activity (% free radical scavenging activity)	54.80	50.67	54.76	54.27	53.76	53.04	51.54	54.82	54.37	53.75	52.90	52.20	50.60	49.10	48.23	47.62	47.10	54.60	54.38	53.92	52.67	52.18
Non-enzymatic browning	0.56	0.79	0.55	0.52	0.52	0.50	0.48	0.52	0.49	0.42	0.36	0.35	0.78	0.76	0.71	0.69	0.65	0.55	0.51	0.50	0.42	0.36

Table 4.5 contd.....

Table 4.5 contd.....

Characteristics	Red carrot																				CD _{0.05}
	Ultrasound assisted blanching										Microwave assisted blanching										
	Whole carrot (WC)					Grated carrot (GC)					Whole carrot (WC)					Grated carrot (GC)					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Yield (%)	56.80	59.30	65.10	72.40	71.60	49.90	52.40	55.90	54.30	55.80	53.40	52.70	54.50	57.90	59.40	50.60	50.90	51.60	52.30	53.10	2.54
Total soluble solids (%)	7.90	7.88	7.80	7.75	7.70	5.15	5.10	5.00	4.95	4.90	7.90	7.80	7.60	7.30	7.20	5.00	4.80	4.65	4.40	4.10	1.31
Total sugars (%)	4.93	4.86	4.70	4.58	4.43	3.54	3.42	3.30	3.05	2.98	4.86	4.75	4.70	4.35	4.26	3.52	3.42	3.04	2.70	2.69	0.64
Reducing sugars (%)	2.46	2.50	2.32	1.37	1.29	1.38	1.25	1.20	1.13	1.02	2.55	2.57	2.32	2.20	2.09	1.31	1.26	1.18	1.05	1.00	0.19
Titrateable acidity (as % citric acid)	0.04	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.01	0.02	0.04	0.03	0.03	0.02	0.02	0.03	0.01	0.02	0.02	0.01	0.01
Fibre (%)	0.12	0.14	0.16	0.19	0.17	0.09	0.10	0.10	0.12	0.11	0.11	0.13	0.16	0.15	0.16	0.09	0.12	0.14	0.15	0.15	0.02
Pectin (%)	0.06	0.05	0.03	0.02	0.02	0.05	0.04	0.04	0.03	0.03	0.06	0.04	0.04	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.01
Ascorbic acid (mg/ 100 g)	8.00	7.40	6.52	6.10	5.36	4.80	4.46	4.30	4.26	4.22	8.05	7.00	5.92	4.80	3.73	4.78	4.50	4.10	4.00	3.96	1.64
Total carotenoids (mg/ 100 g)	6.40	6.66	7.18	7.94	8.02	5.83	6.10	6.23	6.30	6.32	6.38	6.40	6.43	6.50	6.47	5.86	5.93	6.15	5.72	5.29	0.24
Total phenolics (mg GAE/ 100 g)	10.90	10.71	10.60	10.25	10.08	8.50	8.42	8.21	8.04	7.90	10.91	10.70	9.84	9.50	9.41	8.54	8.30	8.00	7.70	7.47	0.10
Antioxidant activity (% free radical scavenging activity)	54.77	54.53	54.30	54.12	53.90	50.60	50.43	50.39	49.69	49.32	53.96	53.15	52.70	52.00	51.90	50.47	49.76	48.73	47.98	47.15	1.20
Non-enzymatic browning	0.54	0.48	0.42	0.40	0.39	0.78	0.71	0.70	0.62	0.57	0.58	0.60	0.72	0.75	0.79	0.80	0.93	0.95	0.99	1.10	0.02

Further, the maximum titratable acidity (0.15) was found in juice extracted from acidified water blanched carrots (5 min). There was a significant effect of blanching method and time on fibre and pectin content of carrot juice. There was a gradual increase in the fibre content of carrot juice up to a certain level whereas, inverse relationship between blanching time and pectin content was noticed. The amount of ascorbic acid, carotenoids and total phenolics was 8.10 mg/ 100 g, 6.35 mg/ 100 g and 10.98 mg GAE/ 100 g in control whole carrot juice. Further, maximum retention or amount of these phytochemicals were found in ultrasound assisted blanched whole carrot juice i.e. 5.36 mg/ 100 g, 8.02 mg/ 100 g and 10.08 mg GAE/ 100 g. Minimum non-enzymatic browning was also found in ultrasound assisted extracted carrot juice. Alegria *et al.* (2016), Yasuda *et al.* (2017) and Santana-Galvez *et al.* (2019) have also observed similar results in carrot juice.

In black carrot, juice extracted after 4 min of acidified water blanching of whole carrot was selected as best treatment on the basis of juice yield, anthocyanin content, total phenolic content and antioxidant activity. However, in orange carrot ultrasound assisted blanched whole carrot (5 min) had better juice quality as compared to rest of the treatments. Likewise, acidified water blanched whole carrot for 3 min and ultrasound assisted whole carrot for 4 min were recorded as best treatments in purple carrot and red carrot, respectively.

4.2.2 Standardization of enzymatic pre-treatment for carrot (black, orange, purple and red) juice extraction

The data pertaining to quality characteristics of carrot (black, orange, purple and red) juice extracted by use of different enzymes viz., Pectinase, Cellulase and Pectinase + Cellulase (1:1) is given in Table 4.6, Table 4.7, Table 4.8 and Table 4.9.

4.2.2.1 Black carrot

Data pertaining to the effect of enzymatic pre-treatment on black carrot juice extraction (Table 4.6) show that maximum juice yield (57.10%) was recorded in treatment T₁₂ which was at par with treatment T₁₁. A non-significant difference was observed in TSS of black carrot juice. Among different treatments maximum total sugars (4.15%) was recorded in treatment T₁₁ which was at par with treatment T₁, T₁₀, T₁₃, T₁₉ and T₂₀. Similarly, highest value of reducing sugars (2.80%) was observed in treatment T₁₂ which was at par with treatment T₁₁ (2.76%). Further, type of enzyme, its concentration and time of application has non-significant effect on the titratable acidity of extracted juice.

Table 4.6 Effect of enzymatic treatment, concentration and time of application on the extraction of black carrot juice

Treatment		Concentration (%)	Time (min)	Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titratable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Pectinase	T ₁	0.1	60	52.90	6.92	4.13	2.40	0.05	0.07	0.03	6.60	140.89	80.59	59.46	0.40
	T ₂	0.1	90	53.60	6.89	4.10	2.46	0.04	0.08	0.01	6.53	139.95	78.56	59.59	0.37
	T ₃	0.1	120	54.10	6.90	4.08	2.52	0.03	0.07	0.01	6.24	139.84	77.50	58.22	0.39
	T ₄	0.2	60	53.70	6.88	3.92	2.41	0.03	0.07	0.02	6.56	140.90	79.98	59.49	0.41
	T ₅	0.2	90	54.40	6.91	3.85	2.56	0.03	0.06	0.01	6.50	138.87	78.53	58.44	0.39
	T ₆	0.2	120	55.60	6.93	3.87	2.68	0.03	0.07	0.01	6.43	138.80	78.20	57.77	0.38
	T ₇	0.3	60	54.10	6.94	3.86	2.39	0.03	0.07	0.02	6.58	140.88	79.57	59.06	0.36
	T ₈	0.3	90	54.90	6.93	3.80	2.52	0.03	0.08	0.01	6.51	140.85	78.56	59.59	0.39
	T ₉	0.3	120	55.00	6.91	3.79	2.60	0.03	0.06	0.01	6.30	139.81	78.50	59.41	0.40
Cellulase	T ₁₀	0.1	60	54.10	6.88	4.13	2.50	0.05	0.05	0.04	6.59	140.89	80.30	59.48	0.38
	T ₁₁	0.1	90	56.80	6.91	4.15	2.76	0.04	0.01	0.03	6.54	140.84	79.98	59.55	0.40
	T ₁₂	0.1	120	57.10	6.92	4.11	2.80	0.03	0.01	0.02	6.46	139.80	78.53	59.30	0.39
	T ₁₃	0.2	60	54.20	6.89	4.12	2.48	0.04	0.03	0.04	6.58	140.90	78.60	59.52	0.37
	T ₁₄	0.2	90	55.30	6.93	4.05	2.66	0.04	0.01	0.03	6.53	138.86	78.57	58.46	0.39
	T ₁₅	0.2	120	55.70	6.95	3.90	2.73	0.03	0.01	0.03	6.24	138.79	78.56	56.37	0.38
	T ₁₆	0.3	60	55.20	7.03	3.86	2.47	0.04	0.04	0.04	6.60	140.85	80.60	59.55	0.36
	T ₁₇	0.3	90	56.30	6.97	3.80	2.59	0.03	0.01	0.03	6.56	139.76	78.59	59.44	0.38
	T ₁₈	0.3	120	56.20	6.93	3.79	2.67	0.03	0.01	0.03	6.34	138.83	78.57	57.34	0.37
Pectinase + Cellulase (1:1)	T ₁₉	0.1	60	52.80	6.88	4.14	2.56	0.05	0.07	0.04	6.59	140.89	79.60	59.44	0.37
	T ₂₀	0.1	90	53.10	6.88	4.13	2.57	0.04	0.06	0.03	6.56	138.65	78.53	59.46	0.39
	T ₂₁	0.1	120	52.90	6.89	4.10	2.55	0.03	0.06	0.02	6.49	140.86	78.50	59.39	0.40
	T ₂₂	0.2	60	53.20	6.88	3.91	2.61	0.04	0.07	0.03	6.58	139.92	80.48	59.41	0.38
	T ₂₃	0.2	90	54.40	6.90	3.82	2.67	0.03	0.06	0.02	6.52	140.23	78.49	58.44	0.40
	T ₂₄	0.2	120	54.50	6.92	3.84	2.64	0.03	0.06	0.02	6.54	138.56	78.50	57.49	0.37
	T ₂₅	0.3	60	54.70	6.91	3.85	2.59	0.04	0.05	0.01	6.56	140.85	80.46	58.41	0.36
	T ₂₆	0.3	90	55.10	6.90	3.81	2.66	0.03	0.04	0.01	6.50	138.12	79.44	59.39	0.39
	T ₂₇	0.3	120	55.60	6.91	3.79	2.60	0.03	0.04	0.01	6.34	139.81	78.47	59.36	0.39
CD _{0.05}		-	-	-	0.46	NS	0.03	0.06	NS	0.01	0.01	0.08	0.12	0.07	0.01

Table 4.7 Effect of different enzyme, concentration and time of application on the extraction of orange carrot juice

Treatments		Concentration (%)	Time (min)	Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Pectinase	T ₁	0.1	60	43.50	4.20	2.44	1.68	0.03	0.14	0.05	4.86	5.89	8.59	45.65	0.79
	T ₂	0.1	90	44.20	4.21	2.46	1.76	0.02	0.12	0.04	4.79	5.86	8.56	44.78	0.76
	T ₃	0.1	120	44.70	4.22	2.50	1.79	0.01	0.11	0.02	4.50	5.84	8.50	42.41	0.78
	T ₄	0.2	60	45.10	4.20	2.47	1.64	0.01	0.13	0.04	4.82	5.90	8.58	45.68	0.80
	T ₅	0.2	90	45.80	4.23	2.49	1.69	0.01	0.14	0.02	4.76	5.87	8.53	44.63	0.78
	T ₆	0.2	120	46.30	4.25	2.49	1.81	0.01	0.13	0.01	4.69	5.80	8.50	43.96	0.77
	T ₇	0.3	60	45.80	4.26	2.52	1.72	0.01	0.13	0.04	4.84	5.88	8.57	46.25	0.75
	T ₈	0.3	90	45.60	4.25	2.54	1.65	0.01	0.11	0.01	4.77	5.85	8.56	44.78	0.78
	T ₉	0.3	120	45.70	4.23	2.50	1.70	0.01	0.09	0.01	4.56	5.81	8.50	44.60	0.79
Cellulase	T ₁₀	0.1	60	43.60	4.20	2.44	1.68	0.03	0.09	0.06	4.85	5.89	8.60	45.67	0.77
	T ₁₁	0.1	90	44.80	4.23	2.46	1.76	0.01	0.05	0.06	4.80	5.84	8.61	45.74	0.79
	T ₁₂	0.1	120	45.20	4.24	2.53	1.79	0.01	0.04	0.05	4.72	5.80	8.53	45.49	0.78
	T ₁₃	0.2	60	43.70	4.21	2.53	1.67	0.02	0.07	0.06	4.84	5.90	8.60	45.71	0.76
	T ₁₄	0.2	90	45.00	4.25	2.66	1.79	0.02	0.07	0.05	4.79	5.86	8.57	46.65	0.78
	T ₁₅	0.2	120	47.10	4.27	2.71	1.86	0.01	0.05	0.05	4.50	5.79	8.56	46.56	0.77
	T ₁₆	0.3	60	47.90	4.35	2.70	1.70	0.02	0.06	0.06	4.86	5.85	8.60	46.74	0.75
	T ₁₇	0.3	90	50.00	4.29	2.79	1.82	0.01	0.03	0.05	4.82	5.86	8.59	45.63	0.77
	T ₁₈	0.3	120	49.90	4.25	2.80	1.80	0.01	0.02	0.05	4.60	5.84	8.57	45.53	0.76
Pectinase + cellulase (1:1)	T ₁₉	0.1	60	43.50	4.20	2.46	1.59	0.03	0.08	0.06	4.85	5.89	8.60	45.63	0.76
	T ₂₀	0.1	90	43.70	4.20	2.49	1.70	0.02	0.07	0.05	4.82	5.85	8.53	45.65	0.78
	T ₂₁	0.1	120	43.60	4.21	2.54	1.48	0.01	0.05	0.04	4.75	5.86	8.50	45.58	0.79
	T ₂₂	0.2	60	44.80	4.20	2.62	1.44	0.02	0.07	0.05	4.84	5.87	8.48	45.60	0.77
	T ₂₃	0.2	90	44.90	4.22	2.63	1.60	0.01	0.08	0.04	4.78	5.87	8.49	46.63	0.79
	T ₂₄	0.2	120	45.20	4.24	2.65	1.67	0.01	0.04	0.04	4.80	5.83	8.50	46.68	0.76
	T ₂₅	0.3	60	45.10	4.23	2.66	1.62	0.02	0.06	0.05	4.82	5.85	8.46	46.60	0.75
	T ₂₆	0.3	90	44.40	4.22	2.62	1.59	0.01	0.05	0.05	4.76	5.85	8.44	45.58	0.78
	T ₂₇	0.3	120	44.20	4.23	2.60	1.53	0.01	0.05	0.04	4.60	5.81	8.47	45.55	0.78
CD _{0.05}		-	-	0.35	NS	0.02	0.03	NS	0.02	0.01	0.14	0.03	0.02	0.05	0.01

The fibre and pectin content of the juice was decreased with application of Cellulase and Pectinase enzyme, respectively. Likewise, a significant decrease in anthocyanin, total phenolic content and antioxidant activity was recorded. The enzymatic breakdown of pectin and hemicellulose unit might explain the decrease in fibre and pectin content of the juice (Acar and Demir, 1999). Ascorbic acid degradation during enzymatic treatment might be due to the heat treatment and exposure of oxygen during processing. Further, decrease in total phenolic content might be due to the polymerization or precipitation of phenols (Talcott and Howard, 1999). Similar observations were made by Zepka and Mercadante (2009), Fratianni *et al.* (2010), Achir *et al.* (2010) and Ma *et al.* (2015).

4.2.2.2 Orange carrot

The data presented in Table 4.7 show the effect of enzyme type (Cellulase and Pectinase), concentration (0.1, 0.2 and 0.3%) and their time of application (60, 90 and 120 min) on chemical characteristics of orange carrot juice. The maximum juice yield (50.00%) was recorded in treatment T₁₇ in which Cellulase @ 0.3 per cent was applied for 90 min. The total soluble solids and titratable acidity were non-significantly affected by the enzyme. Among different treatments maximum total sugars (2.80%) was recorded in treatment T₁₈ which was at par with treatment T₁₇ (2.79%). Similarly, highest value of reducing sugars (1.86%) was observed in treatment T₁₅ which was followed with treatment T₁₇ (1.82%). Further, the fibre and pectin content of the juice range from 0.14 to 0.02 per cent and 0.06 to 0.01 per cent, respectively. The fibre and pectin content of the juice was decreased with application of enzyme. Maximum ascorbic content was found in treatment T₁ (4.86 mg/ 100 g) and minimum value was recorded in treatment T₃ and T₁₅ (4.50 mg/ 100 g). Decrease in total phenolic content was observed with the increase in the application time of enzyme. Similar trend was reported in antioxidant activity and its range varied from 42.41 to 46.74 per cent. The results were in conformity with Khandare *et al.* (2011) and Dal Magro *et al.* (2016).

4.2.2.3 Purple carrot

The effect of enzyme treatment on purple carrot is depicted in Table 4.8. The maximum juice yield i.e. 57.80 per cent was recorded in treatment T₁₁ which was statistically at par with treatment T₁₀ and T₁₅. However, no significant effect of enzyme treatment, concentration and time of application was reported on total soluble solids and titratable acidity. The total sugars content varied from 3.72 to 4.13 per cent.

Table 4.8 Effect of enzymatic treatment, concentration and time of application on the extraction of purple carrot juice

Treatment		Concentration (%)	Time (min)	Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Pectinase	T ₁	0.1	60	55.80	6.48	4.06	2.33	0.05	0.07	0.03	5.33	133.57	76.27	55.83	0.39
	T ₂	0.1	90	56.10	6.52	4.03	2.39	0.04	0.08	0.01	5.26	132.63	74.24	55.96	0.38
	T ₃	0.1	120	56.60	6.60	4.01	2.45	0.03	0.07	0.01	4.96	132.52	73.18	54.59	0.39
	T ₄	0.2	60	55.70	6.50	3.85	2.34	0.03	0.07	0.02	5.29	133.58	75.66	55.86	0.40
	T ₅	0.2	90	56.40	6.51	3.78	2.49	0.03	0.06	0.01	5.23	131.55	74.21	54.81	0.39
	T ₆	0.2	120	56.60	6.57	3.80	2.61	0.03	0.07	0.01	5.16	131.48	73.88	54.14	0.38
	T ₇	0.3	60	55.90	6.52	3.79	2.32	0.03	0.07	0.02	5.31	133.56	75.25	55.43	0.37
	T ₈	0.3	90	54.90	6.58	3.73	2.45	0.03	0.08	0.01	5.24	133.53	74.24	55.96	0.40
	T ₉	0.3	120	55.00	6.62	3.72	2.53	0.03	0.06	0.01	5.03	132.49	74.18	55.78	0.40
Cellulase	T ₁₀	0.1	60	57.50	6.78	4.08	2.43	0.05	0.05	0.04	5.32	133.57	75.98	55.85	0.39
	T ₁₁	0.1	90	57.80	6.80	4.10	2.69	0.04	0.01	0.03	5.27	133.52	75.66	55.92	0.38
	T ₁₂	0.1	120	57.10	6.84	4.11	2.73	0.03	0.01	0.02	5.19	132.48	74.21	55.67	0.39
	T ₁₃	0.2	60	56.20	6.81	4.10	2.41	0.04	0.03	0.04	5.31	133.58	74.28	55.89	0.35
	T ₁₄	0.2	90	57.30	6.86	4.13	2.59	0.04	0.01	0.03	5.26	131.54	74.25	54.83	0.40
	T ₁₅	0.2	120	57.70	6.90	4.10	2.66	0.03	0.01	0.03	4.97	131.47	74.24	52.74	0.38
	T ₁₆	0.3	60	57.20	6.87	4.00	2.40	0.04	0.04	0.04	5.32	133.53	76.28	55.92	0.36
	T ₁₇	0.3	90	57.30	6.96	3.90	2.52	0.03	0.01	0.03	5.29	132.44	74.27	55.81	0.38
	T ₁₈	0.3	120	57.20	6.93	4.10	2.60	0.03	0.01	0.03	5.07	131.51	74.25	53.71	0.37
Pectinase + Cellulase (1:1)	T ₁₉	0.1	60	55.80	6.58	4.07	2.49	0.05	0.07	0.04	5.32	133.57	75.28	55.81	0.40
	T ₂₀	0.1	90	55.10	6.60	4.06	2.50	0.04	0.06	0.03	5.29	131.33	74.21	55.83	0.42
	T ₂₁	0.1	120	55.90	6.69	4.03	2.48	0.03	0.06	0.02	5.22	133.54	74.18	55.76	0.40
	T ₂₂	0.2	60	55.20	6.58	3.84	2.54	0.04	0.07	0.03	5.31	132.6	76.16	55.78	0.38
	T ₂₃	0.2	90	55.40	6.60	3.75	2.60	0.03	0.06	0.02	5.25	132.91	74.17	54.81	0.40
	T ₂₄	0.2	120	55.50	6.62	3.77	2.57	0.03	0.06	0.02	5.27	131.24	74.18	53.86	0.43
	T ₂₅	0.3	60	55.00	6.61	3.78	2.52	0.04	0.05	0.01	5.29	133.53	76.14	54.78	0.44
	T ₂₆	0.3	90	55.10	6.65	3.74	2.59	0.03	0.04	0.01	5.23	130.8	75.12	55.76	0.45
	T ₂₇	0.3	120	55.40	6.66	3.72	2.53	0.03	0.04	0.01	5.07	132.49	74.15	55.73	0.44
CD _{0.05}	-	-	-	0.46	NS	0.10	0.05	NS	0.01	0.01	0.07	0.17	0.44	0.07	0.01

Table 4.9 Effect of different enzyme, concentration and time of application on the extraction of red carrot juice

Treatments		Concentration (%)	Time (min)	Yield (%)	TSS (°B)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Pectinase	T ₁	0.1	60	49.10	5.15	3.90	1.86	0.03	0.08	0.04	4.86	5.80	8.56	50.60	0.79
	T ₂	0.1	90	51.60	5.16	3.87	1.92	0.02	0.07	0.03	4.79	5.76	8.52	50.40	0.76
	T ₃	0.1	120	52.00	5.17	3.85	1.95	0.01	0.08	0.02	4.50	5.74	8.48	50.33	0.78
	T ₄	0.2	60	51.30	5.15	3.69	1.85	0.01	0.07	0.04	4.82	5.72	8.55	50.67	0.80
	T ₅	0.2	90	52.40	5.18	3.52	1.89	0.01	0.08	0.02	4.76	5.35	8.51	49.65	0.78
	T ₆	0.2	120	53.10	5.20	3.64	1.97	0.01	0.07	0.01	4.69	5.20	8.50	48.98	0.77
	T ₇	0.3	60	52.60	5.21	3.63	1.88	0.01	0.06	0.04	4.84	5.77	8.57	50.27	0.75
	T ₈	0.3	90	52.90	5.20	3.57	1.90	0.01	0.07	0.03	4.77	5.23	8.54	49.80	0.78
	T ₉	0.3	120	51.70	5.18	3.56	1.86	0.01	0.07	0.01	4.56	5.20	8.50	48.62	0.79
Cellulase	T ₁₀	0.1	60	51.10	5.15	3.89	1.86	0.03	0.08	0.05	4.85	5.76	8.56	49.69	0.77
	T ₁₁	0.1	90	51.80	5.18	3.92	1.92	0.02	0.05	0.05	4.80	5.56	8.54	48.76	0.79
	T ₁₂	0.1	120	52.40	5.19	3.88	1.95	0.01	0.04	0.04	4.72	5.40	8.47	48.51	0.78
	T ₁₃	0.2	60	51.20	5.16	3.89	1.87	0.02	0.07	0.05	4.84	5.78	8.55	50.53	0.76
	T ₁₄	0.2	90	52.60	5.20	3.82	1.95	0.02	0.06	0.04	4.79	5.91	8.47	49.67	0.78
	T ₁₅	0.2	120	55.80	5.22	3.67	2.02	0.01	0.02	0.04	4.50	6.12	8.50	49.58	0.77
	T ₁₆	0.3	60	53.50	5.30	3.63	1.88	0.02	0.05	0.04	4.86	5.70	8.54	50.76	0.75
	T ₁₇	0.3	90	54.40	5.24	3.57	1.91	0.01	0.04	0.05	4.82	5.93	8.46	49.65	0.77
	T ₁₈	0.3	120	54.60	5.20	3.56	1.96	0.03	0.03	0.04	4.60	6.00	8.47	49.55	0.76
Pectinase + Cellulase (1:1)	T ₁₉	0.1	60	51.10	5.15	3.92	1.85	0.02	0.07	0.05	4.85	5.80	8.50	50.50	0.76
	T ₂₀	0.1	90	51.20	5.15	3.89	1.88	0.02	0.05	0.05	4.82	5.76	8.43	49.67	0.78
	T ₂₁	0.1	120	51.90	5.16	3.87	1.94	0.01	0.04	0.04	4.75	5.80	8.40	48.60	0.79
	T ₂₂	0.2	60	52.30	5.15	3.68	1.90	0.02	0.07	0.05	4.84	5.81	8.48	50.17	0.77
	T ₂₃	0.2	90	52.40	5.17	3.59	1.96	0.01	0.06	0.04	4.78	5.82	8.49	49.65	0.79
	T ₂₄	0.2	120	52.80	5.19	3.61	1.93	0.01	0.04	0.03	4.80	5.87	8.50	48.70	0.76
	T ₂₅	0.3	60	52.60	5.18	3.62	1.88	0.02	0.06	0.05	4.82	5.80	8.46	50.43	0.75
	T ₂₆	0.3	90	51.90	5.17	3.55	1.85	0.01	0.06	0.05	4.76	5.83	8.44	49.60	0.78
	T ₂₇	0.3	120	52.70	5.18	2.82	1.89	0.01	0.05	0.04	4.60	5.85	8.43	49.57	0.78
CD _{0.05}		-	-	0.10	NS	0.07	0.04	NS	0.01	0.01	0.13	0.05	NS	0.11	0.02

Maximum total sugars were found in treatment T₁₄. Whereas, treatment T₁₂ had the highest value for reducing sugars i.e. 2.73 per cent which was at par with treatment T₁₁ (2.69%). The fibre content was decreased with the application of Cellulase enzyme however, Pectinase had negligible effect on fibre content. The pectin content ranged from 0.04 to 0.01 per cent. Maximum ascorbic content was found in treatment T₁ (5.33 mg/ 100 g) and minimum value was recorded in treatment T₁₅ (4.97 mg/ 100 g). Highest anthocyanin content (133.58 mg/ 100 g) was found in treatment T₄ and T₁₃. Similarly, total phenolic content ranged from 73.18 to 76.28 mg GAE/ 100 g. Minimum antioxidant activity was recorded in treatment T₁₅ (52.74%) having 0.2 per cent Cellulase applied for 120 Min. The results were in accordance with Garba and Kaur (2014) and Khoo *et al.* (2017).

4.2.2.4 Red carrot

The data presented in Table 4.9 show the effect of enzyme type (Cellulase and Pectinase), concentration (0.1, 0.2 and 0.3%) and their time of application (60, 90 and 120 min) on chemical characteristics of red carrot juice. The maximum juice yield (55.80%) was recorded in treatment T₁₅ in which Cellulase @ 0.2 per cent was applied for 120 min. The total soluble solids, titratable acidity and total phenolics were non-significantly affected by the enzyme.

Among different treatments maximum total sugars (3.92%) was recorded in treatment T₁₁ and T₁₉. Similarly, highest value of reducing sugars (2.02%) and total carotenoids (6.12 mg/ 100 g) was observed in treatment T₁₅ having 0.2 per cent Cellulase enzyme applied for 120 min. Further, the fibre and pectin content of the juice ranged from 0.02 to 0.08 per cent and 0.01 to 0.05 per cent, respectively. With increase in enzyme concentration and time, decreasing trend in ascorbic acid content and antioxidant activity was observed. The results were in conformity with Zelenkova and Yegorova (2019).

It was concluded that Cellulase @ 0.1 per cent applied for 120 min had the maximum juice yield (57.10%) and better retention of juice quality in black carrot. Similarly, in orange carrot 0.3 percent Cellulase for 90 min was found to be the best. Further Cellulase @ 0.1 and 0.3 per cent for 90 and 120 min was optimized for juice extraction in purple carrot and red carrot, respectively.

4.3 OPTIMIZATION OF PROCESS PARAMETERS FOR THE DEVELOPMENT OF CARROT JUICE CONCENTRATES (BLACK, ORANGE, PURPLE AND RED) USING RESPONSE SURFACE METHODOLOGY (RSM)

4.3.1 Preliminary experiment for the development of carrot juice concentrates

During preliminary experiments, different treatments were carried out to check the feasibility of different temperature levels, pressure values to obtain carrot juice concentrate of required concentration. Further, based on these preliminary experimental results, different combinations of temperature and concentration were designed using Response Surface Methodology (RSM) and 13 treatment/ run of carrot juice concentrate were prepared. The responses estimated for each experiment are given in Table 4.10, 4.14, 4.18 and 4.22.

4.3.2 Physico-chemical and sensory responses for black carrot juice concentrate

The data on physico-chemical and sensory responses for black carrot juice concentrate is presented in Table 4.10 and Table 4.11. The effect of different temperature and concentration levels has been explained under following heads:

4.3.2.1 Physico-chemical and sensory responses

4.3.2.1.1 Yield

Data pertaining to the effect of different levels of temperature and concentration on black carrot juice concentrate yield is shown in Table 4.10. It has been observed that concentrate produced in Run 3, employing 45°C temperature and 76.21 per cent concentration had minimum yield of 9.78 per cent whereas, concentrate produced in Run 12 having 45°C temperature and 33.79 per cent concentration had maximum yield of 20.01 per cent. Linear terms of temperature influenced the recovery of concentrate non-significantly whereas, in case of concentration the linear effect as well as quadratic effect along with interactive effect of temperature and concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. As evident from Figure 4.1, yield was affected by temperature and concentration. With the increase in concentration level, yield was decreased. Similar results were reported by Sabanci and Icier (2017) in ohmic heating assisted vacuum evaporation for concentration of sour cherry juice. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 118.13 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of yield in black carrot juice concentrate was 98.83 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 35.23

which imply that the data was adequate to predict yield of the carrot juice concentrate. Therefore, it can be inference that the model was found to be appropriate to follow the design space for yield (%) of black carrot juice concentrate. The overall second- order polynomial equation can be written as Equation 1 was adequate to predict the yield of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 2.

$$\text{Equation 1: } Y = 13.97 - 3.34*B - 0.48*A*B^2 + 0.50*B^2$$

$$\text{Equation 2: } Y = 13.97 + 0.092*A - 3.34*B - 0.48*A*B + 0.085*A^2 + 0.50*B^2$$

Where, Y = Yield, A = Temperature, B = Concentration

4.3.2.1.2 Titratable acidity

The experimental results related to the effect of variation in the levels of temperature and concentration as used in present investigation on titratable acidity are presented in Table 4.10. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of acidity (1.55%) while Run 12 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest acidity (0.74%). Similar values of 0.18 and 0.48 per cent titratable acidity were reported by Jan *et al.* (2016) in two different types of apple juice concentrate.

Linear terms of temperature influenced the titratable acidity of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. As evident from Figure 4.2, titratable acidity was directly proportional to concentration; while there was negligible effect with respect to temperature. With the increase in concentration level, titratable acidity was increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 337.39 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of titratable acidity in black carrot juice concentrate was 99.59 per cent, which indicated that the model could account for 99.59 per cent data. The lack of fit was found to be non-significant and precision value was 60.31 which imply that the data was adequate to predict titratable acidity of carrot juice concentrates. The overall second-order polynomial equation can be written as Equation 3 and considered adequate to predict the titratable acidity of the concentrate and to interpret the

effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 4.

Equation 3: $Y = 1.13 + 0.29*B - 6.25*B^2$

Equation 4: $Y = 1.13 + 0.013*A + 0.29*B + 0.018*A*B - 0.011*A^2 - 6.25*B^2$

Where, Y = Titratable acidity, A = Temperature, B = Concentration

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Yield
20.01
9.78

X1 = A: Temperature
X2 = B: Concentration

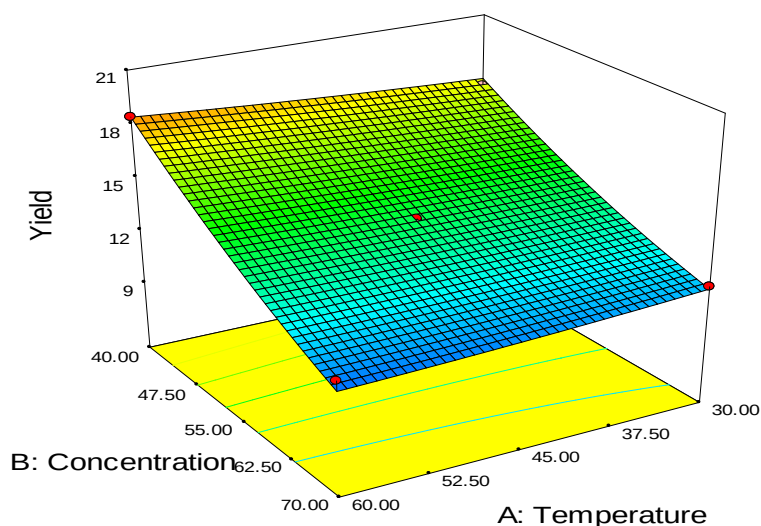


Figure 4.1: 3D graph showing the effect of temperature and concentration on yield of black carrot juice concentrate

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Acidity
1.55
0.74

X1 = A: Temperature
X2 = B: Concentration

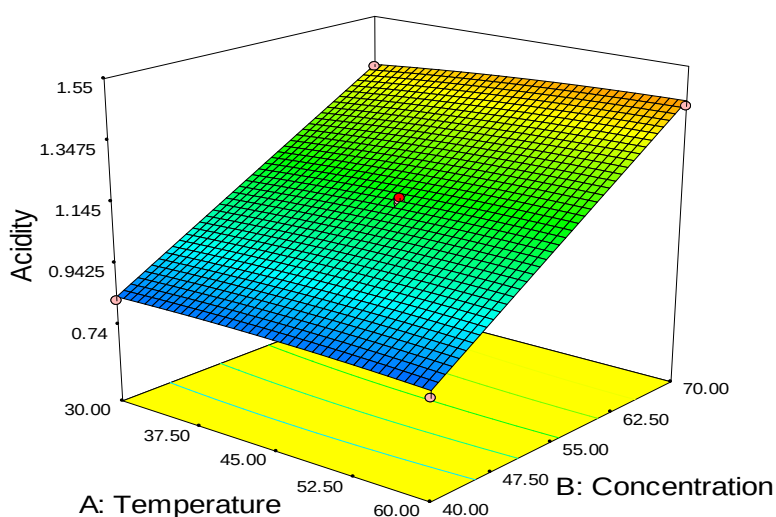


Figure 4.2: 3D graph showing the effect of temperature and concentration on titratable acidity of black carrot juice concentrate

Table 4.10 Experimental design and responses obtained for black carrot juice concentrate

Number / Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	60	70	11.38	1.42	33.10	1476.39	2637.15	79.51	1.03	7.88	7.67	7.62	7.71
2	45	55	14.02	1.12	27.30	1145.68	2072.45	62.97	0.80	8.10	7.46	7.53	7.79
3	45	76.2132	9.78	1.55	37.75	1580.3	2870.12	88.41	1.29	7.92	7.50	7.56	7.83
4	45	55	13.8	1.14	27.33	1143.42	2075.65	63.10	0.82	8.08	7.43	7.50	7.81
5	60	40	18.47	0.80	18.75	847.23	1497.2	48.27	0.71	7.9	7.62	7.60	7.72
6	30	70	11.74	1.37	34.50	1461.05	2640.78	80.12	1.34	7.75	7.40	7.39	7.70
7	45	55	13.86	1.12	27.43	1147.53	2072.45	63.21	0.76	8.12	7.48	7.55	7.81
8	66.2132	55	13.90	1.15	25.92	1137.21	2169.18	59.24	0.67	8.00	7.70	7.65	7.81
9	23.7868	55	14.24	1.10	28.76	1150.75	2082.97	66.34	0.98	7.85	7.35	7.30	7.50
10	30	40	16.89	0.82	19.47	852.10	1509.75	50.28	0.87	7.88	7.38	7.35	7.56
11	45	55	14.05	1.14	27.40	1142.21	2071.23	63.50	0.85	8.15	7.50	7.57	7.81
12	45	33.7868	20.01	0.74	17.92	690.61	1243.2	38.21	0.74	7.89	7.45	7.50	7.73
13	45	55	14.11	1.13	27.45	1145.5	2073.18	63.51	0.78	8.12	7.48	7.55	7.81

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.11 Regression coefficient and ANOVA for dependent parameters of black carrot juice concentrate

Variables	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning	Colour	Body	Flavour	Overall acceptability
A	0.5288	0.1179	0.0155	0.7984	0.1296	0.0458	0.0002	0.0303	<0.0001	<0.0001	0.0017
B	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.4475	0.0597	0.0483	0.0643
AB	0.0435	0.1233	0.6333	0.4112	0.8435	0.7159	0.1391	0.2828	0.5204	0.6551	0.1301
A ²	0.5859	0.2035	0.2779	0.3465	0.0352	0.8475	0.1398	0.0005	0.0068	0.0032	0.0012
B ²	0.0126	0.9366	0.8329	0.9715	0.1537	0.5859	0.0002	0.0003	0.4404	0.3508	0.1870
Model F-value	118.13	337.39	179.67	1165.44	1105.17	129.15	51.80	16.50	55.36	56.76	11.98
R ² (%)	98.83	99.59	99.23	99.88	99.87	98.93	97.37	92.18	97.53	97.59	89.54
Adequate precision	35.23	60.310	43.828	112.346	109.285	37.220	21.101	9.854	23.590	23.66	9.458
LOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.3.2.1.3 Ascorbic acid

The effect of variation in the levels of temperature and concentration as used in present investigation on the ascorbic acid content has been presented in Table 4.10. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of ascorbic acid (37.75 mg/ 100 g) while Run 12 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest ascorbic acid (17.92 mg/ 100 g). Similar reports were given by Mercali *et al.* (2014) in ohmic heating of acerola pulp. Linear terms of temperature influenced the ascorbic acid content of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. With the increase in concentration level, ascorbic acid was increased (Figure 4.3). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 179.67 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of ascorbic acid in black carrot juice concentrate was 99.23 per cent, which indicated that the model could account for 99.23 per cent data. The lack of fit was found to be non-significant but the precision value was quite high i.e. 43.83. Therefore, the model was considered satisfactory to follow the design space for ascorbic acid. The overall second-order polynomial equation can be written as Equation 5 and considered adequate to predict the ascorbic acid content of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 6.

Equation 5: $Y = 27.38 - 0.77*A + 7.18*B$

Equation 6: $Y = 27.38 - 0.77*A + 7.18*B - 0.17*A*B - 0.30*A^2 - 0.057*B^2$

Where, Y = Ascorbic acid, A = Temperature, B = Concentration

4.3.2.1.4 Anthocyanins

Table 4.10 reflects the effect of variation in the levels of temperature and concentration on anthocyanins. It was observed that the concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of anthocyanins (1580.30 mg/ 100 g) while Run 12 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest anthocyanin content (690.61 mg/ 100 g). Linear terms of temperature influenced the anthocyanins of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.11.

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Ascorbic acid



X1 = A: Temperature
X2 = B: Concentration

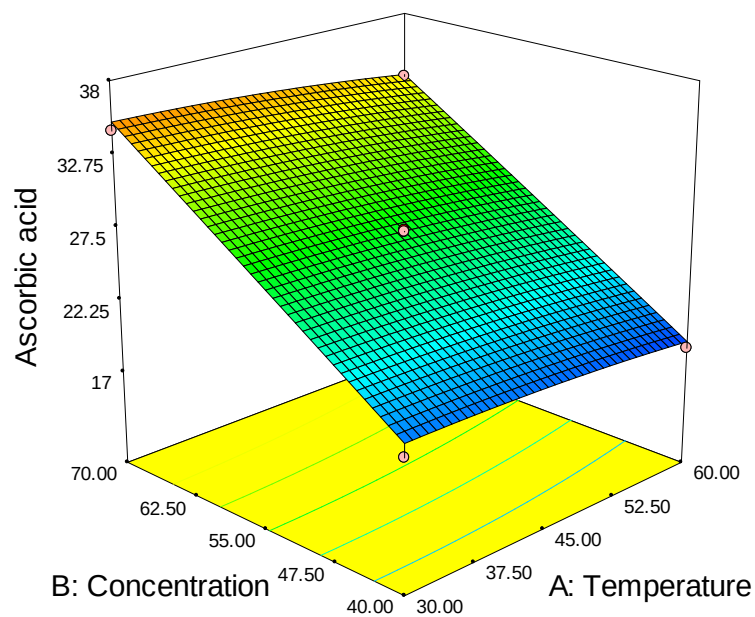


Figure 4.3: 3D graph showing the effect of temperature and concentration on ascorbic acid of black carrot juice concentrate

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Anthocyanins



X1 = A: Temperature
X2 = B: Concentration

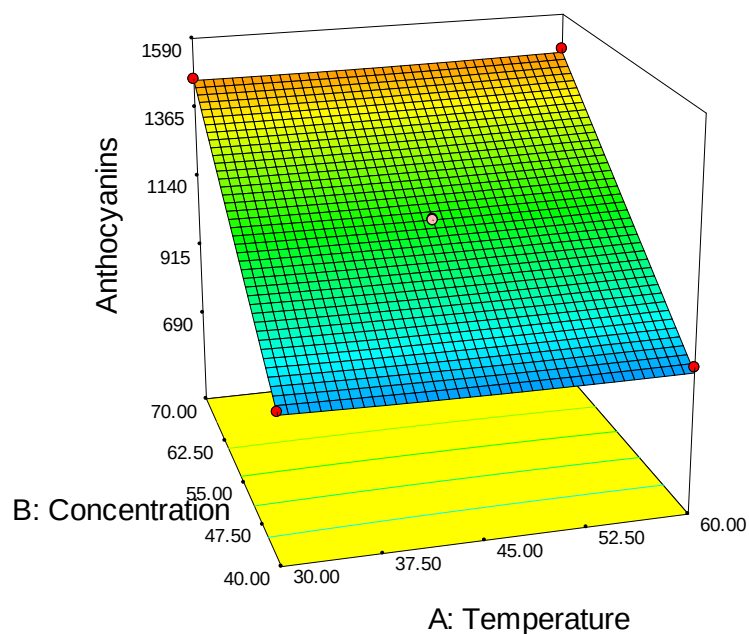


Figure 4.4: 3D graph showing the effect of temperature and concentration on anthocyanins of black carrot juice concentrate

As evident from Figure 4.4, concentration was directly proportion to the anthocyanin content whereas, they were unaffected with increased levels of temperature. Similar results were observed in pomegranate juice concentrate prepared by ohmic heating assisted vacuum evaporation (Sabanci *et al.*, 2018). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 1165.44 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of anthocyanins in black carrot juice concentrate was 99.88 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 112.35 which imply that the data was adequate to predict anthocyanins of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 7 and considered adequate to predict the anthocyanins of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 8.

Equation 7: $Y = 1144.87 + 312.04*B + 5.05*A*B$

Equation 8: $Y = 1144.87 - 1.08*A + 312.04*B + 5.05*A*B + 4.42*A^2 + 0.16*B^2$

Where, Y = Anthocyanins, A = Temperature, B = Concentration

4.3.2.1.5 Total phenolics

As shown in Table 4.10, concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total phenolic content (2870.12 mg GAE/ 100 g) while Run 12 had lowest total phenolic content (1243.20 mg GAE/ 100 g). Similar trends were reported by Sabanci and Icier (2019) in sour cherry juice concentrates. They reported a range of 9071.22 to 78347.53 mg/ L in total phenolic content in sour cherry concentrate (65°B). Linear terms of temperature influenced the total phenolic content of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. Total phenolic content was minorly affected with change in temperature however evident difference was noticed with varying levels of concentration (Figure 4.5). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 1105.17 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the

regression model of total phenolic content in black carrot juice concentrate was 99.87 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 109.29 which imply that the data was adequate to predict total phenolic content of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 9 and considered adequate to predict the total phenolic content of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 10.

$$\text{Equation 9: } Y = 2072.99 + 571.47*B + 21.50*A^2$$

$$\text{Equation 10: } Y = 2072.99 + 13.22*A + 571.47*B + 2.23*A*B + 21.50*A^2 - 13.20*B^2$$

Where, Y = Total phenolics, A = Temperature, B = Concentration

4.3.2.1.6 Antioxidant activity

According to Table 4.10 which shows the experimental results concerning the effect of different levels of temperature and concentration used in present investigation on the antioxidant activity, it was observed that concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of antioxidant activity (88.41%) while Run 12 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest antioxidant activity (38.21%). Similar reports were given by Ulusoy and Tamer (2019) in black carrot juice concentrate. Linear terms of temperature influenced the antioxidant activity of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. As evident from Figure 4.6, with the increase in concentration level, antioxidant activity increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11.

The Model F-value of 129.15 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of antioxidant activity in black carrot juice concentrate was 98.93 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 37.22 which imply that the data was adequate to predict antioxidant activity of the carrot juice concentrate. The overall second-order

polynomial equation can be written as Equation 11 and considered adequate to predict the antioxidant activity of the concentrate and to interpret the effect of temperature and

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Total phenolic content



X1 = A: Temperature
X2 = B: Concentration

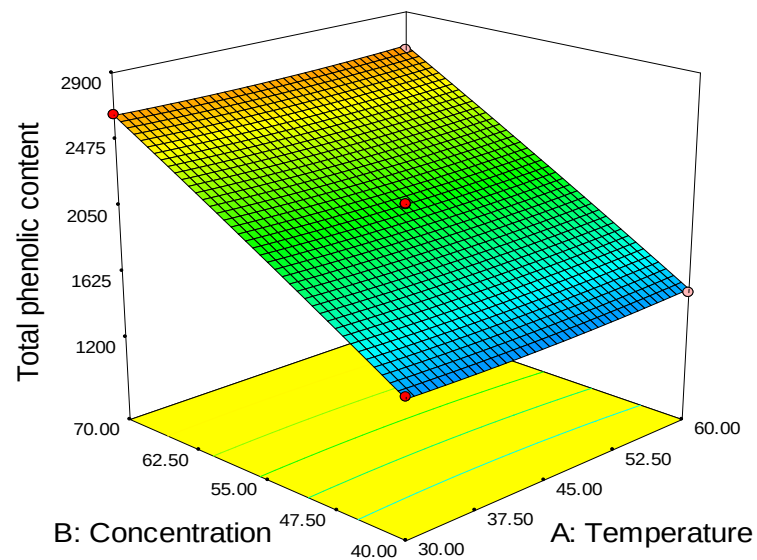


Figure 4.5: 3D graph showing the effect of temperature and concentration on total phenolic content of black carrot juice concentrate

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Antioxidant activity



X1 = A: Temperature
X2 = B: Concentration

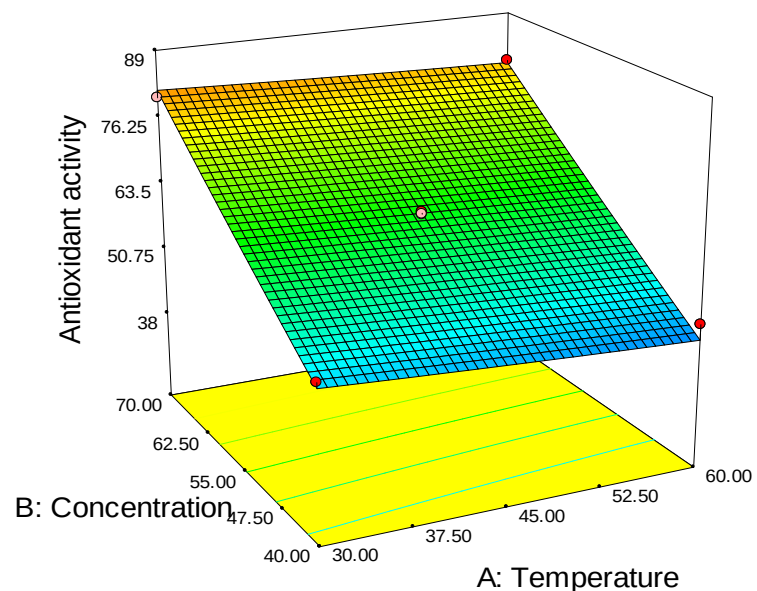


Figure 4.6: 3D graph showing the effect of temperature and concentration on antioxidant activity of black carrot juice concentrate

concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 12.

$$\text{Equation 11: } Y = 63.26 - 1.58*A + 16.51*B$$

$$\text{Equation 12: } Y = 63.26 - 1.58*A + 16.51*B + 0.35*A*B + 0.14*A^2 + 0.40*B^2$$

Where, Y = Antioxidant activity, A = Temperature, B = Concentration

4.3.2.1.7 Non-enzymatic browning

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on non-enzymatic browning is presented in Table 4.10. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of non-enzymatic browning (1.29) while Run 8 with corresponding variables to be 66.21°C temperature and 55 per cent concentration had lowest non-enzymatic browning (0.67). The results were in accordance with Chandel *et al.* (2019) in apple pomace pectin concentration.

Linear terms of temperature influenced the non-enzymatic browning of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. With the increase in concentration levels, there was an increase in non-enzymatic browning (Figure 4.7). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 51.80 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of non-enzymatic browning in black carrot juice concentrate was 97.37 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 21.10 which imply that the data was adequate to predict non-enzymatic browning of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 13 and considered adequate to predict the non-enzymatic browning of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 14.

$$\text{Equation 13: } Y = 0.80 - 0.11*A + 0.20*B + 0.12*B^2$$

$$\text{Equation 14: } Y = 0.80 - 0.11*A + 0.20*B - 0.037*A*B + 0.028*A^2 + 0.12*B^2$$

Where, Y = Non-enzymatic browning, A = Temperature, B = Concentration

Design-Expert® Software

Non-enzymetic browning



X1 = A: Temperature

X2 = B: Concentration

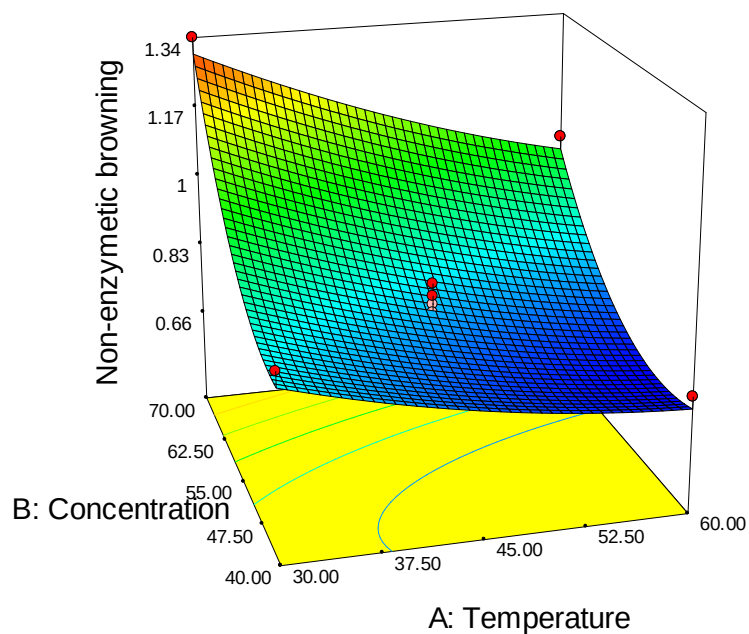


Figure 4.7: 3D graph showing the effect of temperature and concentration on non-enzymatic browning of black carrot juice concentrate

Design-Expert® Software

Colour



X1 = A: Temperature

X2 = B: Concentration

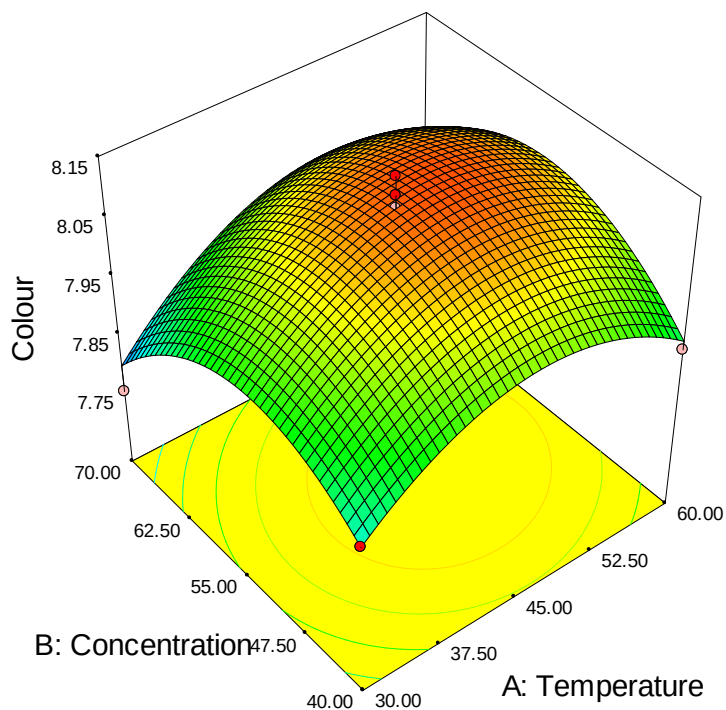


Figure 4.8: 3D graph showing the effect of temperature and concentration on colour score of black carrot juice concentrate

4.3.2.1.8 Colour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on colour are presented in Table 4.10. Concentrate prepared in Run 11 with 45°C temperature and 55 per cent concentration recorded the highest score of colour (8.15) while Run 6 with corresponding variables to be 30 °C temperature and 70 per cent concentration had lowest colour score (7.75). Bazaria and Kumar (2016) also reported similar trends of decrease in colour value at higher temperature and time. This might be due to increase in browning and accumulation of dark coloured compounds in beet root juice concentrate. Linear terms of temperature and concentration influenced the colour score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.11. With the increase in concentration level, there was an increase in colour score (Figure 4.8). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 16.50 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of colour score in black carrot juice concentrate was 92.18 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 9.85 which imply that the data was adequate to predict colour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 15 and considered adequate to predict the colour of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 16.

$$\text{Equation 15: } Y = 8.11 + 0.045*A - 0.013*B - 0.11*A^2 - 0.12*B^2$$

$$\text{Equation 16: } Y = 8.11 + 0.045*A - 0.013*B + 0.028*A*B - 0.11*A^2 - 0.12*B^2$$

Where, Y = Colour, A = Temperature, B = Concentration

4.3.2.1.9 Body

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on body score is presented in Table 4.10. Concentrate prepared in Run 1 with 60°C temperature and 70 per cent concentration recorded the highest value of body score (7.67) while Run 9 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest

body score (7.35). Linear terms of temperature influenced the body score of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. With the increase in concentration level, there was an increase in body score (Figure 4.9) was observed. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 55.36 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of body score in black carrot juice concentrate was 97.53 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 23.59 which imply that the data was adequate to predict body score of the carrot juice concentrate.

The overall second-order polynomial equation can be written as Equation 17 and considered adequate to predict the body score of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 18.

$$\text{Equation 17: } Y = 8.11 + 0.045*A - 0.11*A^2$$

$$\text{Equation 18: } Y = 8.11 + 0.045*A - 0.013*B + 0.028*A*B - 0.11*A^2 - 0.12*B^2$$

Where, Y = Body, A = Temperature, B = Concentration

4.3.2.1.10 Flavour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on flavour score has been presented in Table 4.10. Concentrate prepared in Run 8 with 66.21°C temperature and 55 per cent concentration recorded the highest value of flavour score (7.65) while Run 9 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest body score (7.30). Linear terms of temperature influenced the flavour score of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.11. With the increase in concentration level, there was an increase in flavour score (Figure 4.10). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 56.76 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of flavour score in black carrot juice concentrate was 97.59 per cent, which indicated that the model was adequate in representing the real relationship among the selected

variables. The lack of fit was found to be non-significant and precision value was 23.66 which imply that the data was adequate to predict flavour score of the carrot juice concentrate.

Design-Expert® Software

Body
7.7
7.35

X1 = A: Temperature
X2 = B: Concentration

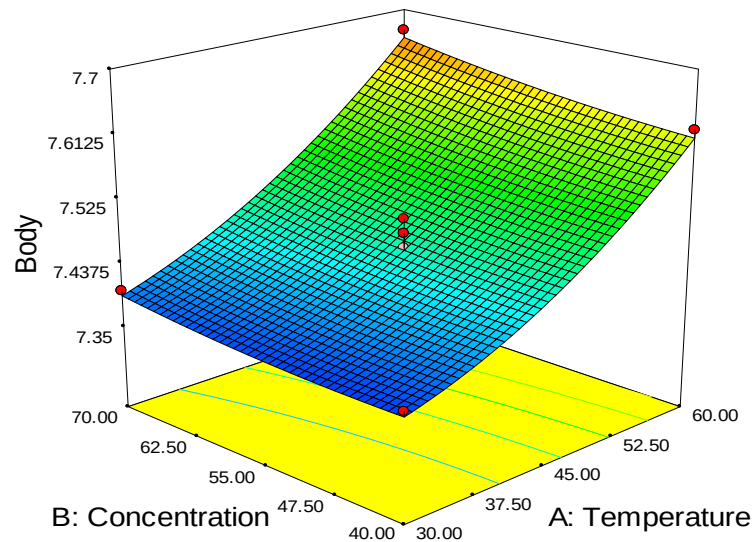


Figure 4.9: 3D graph showing the effect of temperature and concentration on body score of black carrot juice concentrate

Design-Expert® Software

Flavour
7.65
7.3

X1 = A: Temperature
X2 = B: Concentration

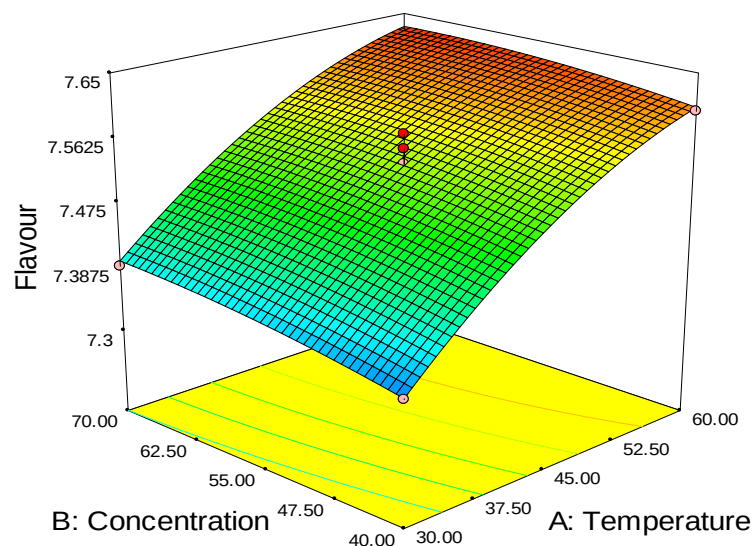


Figure 4.10: 3D graph showing the effect of temperature and concentration on flavour score of black carrot juice concentrate

The overall second-order polynomial equation can be written as Equation 19 and considered adequate to predict the flavour score of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 20.

$$\text{Equation 19: } Y = 7.54 + 0.12*A + 0.018*B - 0.036*A^2$$

$$\text{Equation 20: } Y = 7.54 + 0.12*A + 0.018*B - 5.00*A*B - 0.036*A^2 - 8.12*B^2$$

Where, Y = Flavour, A = Temperature, B = Concentration

4.3.2.1.11 Overall acceptability

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on overall acceptability score has been presented in Table 4.10. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of overall acceptability (7.83) while Run 9 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest body score (7.50). Dhumal *et al.* (2013) documented similar overall acceptability score of 8.60 in pomegranate juice concentrate prepared using rotary vacuum evaporator. Linear terms of temperature influenced the overall acceptability score of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.11. With the increase in concentration level, increase in overall acceptability score (Figure 4.11) was observed. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.11. The Model F-value of 11.98 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of overall acceptability score in black carrot juice concentrate was 89.54 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 9.46 which imply that the data was adequate to predict overall acceptability score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 21 and considered adequate to predict the overall acceptability score of the concentrate and to interpret the effect of temperature and concentration on black carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 22.

Equation 21: $Y = 7.81 + 0.076*A - 0.087*A^2$

Equation 22: $Y = 7.81 + 0.076*A + 0.034*B - 0.037*A*B - 0.087*A^2 - 0.024*B^2$

Where, Y = Overall acceptability, A = Temperature, B = Concentration

Design-Expert® Software

Overall acceptability



X1 = A: Temperature

X2 = B: Concentration

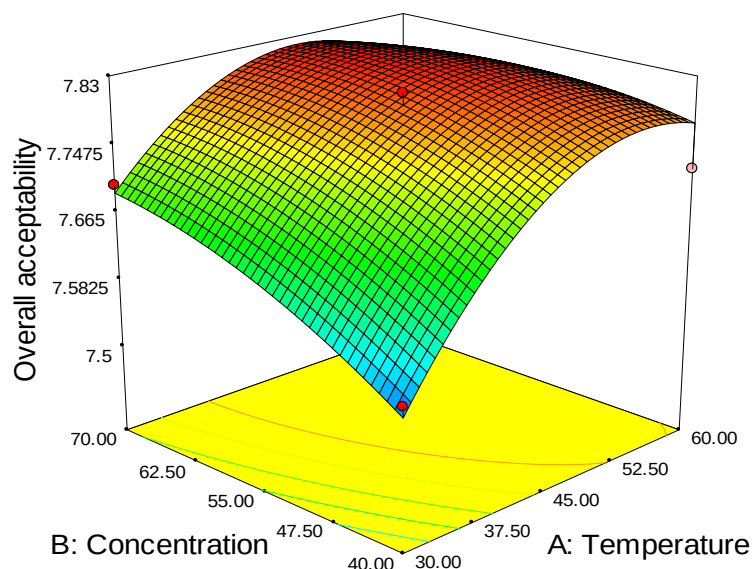


Figure 4.11: 3D graph showing the effect of temperature and concentration on overall acceptability score of black carrot juice concentrate

Design-Expert® Software

Overlay Plot

● Design Points

X1 = A: Temperature

X2 = B: Concentration

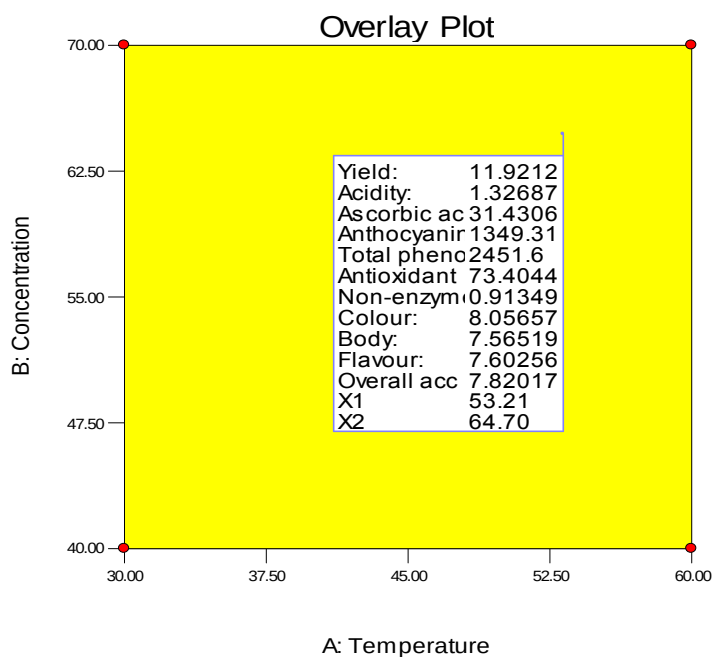


Figure 4.12: Overlay plot showing the effect of interaction of temperature and concentration on desirability of black carrot juice concentrate

4.3.2.2 Process optimizations for development of black carrot juice concentrate

Optimization is the process of making compromises between the variables, to get a common target. Goal seeking was used to get the best carrot juice concentrate with good nutritional quality and optimum taste. The criteria for goal allotment was based on the functional and sensory properties of the carrot juice concentrate. Goal was set for each independent variable and response before optimization as given Table 4.12. All the independent variables were kept in range based on the results obtained during preliminary experiments so that an optimum product could be obtained with respect to its desirable composition and functional properties. Yield, titratable acidity, ascorbic acid content, anthocyanins, total phenolics, antioxidant activity, non-enzymatic browning, colour, body, flavor and overall acceptability were set in range.

Table 4.12 Goals for optimization of formulation to prepare black carrot juice concentrate

Parameter	Goal	Lower limit	Upper limit
Temperature (°C)	In range	30	60
Concentration (°B)	In range	40	70
Yield (%)	In range	9.78	20.01
Titratable acidity (as % citric acid)	In range	0.74	1.55
Ascorbic acid (mg/ 100 g)	In range	17.92	37.75
Anthocyanins (mg/ 100 g)	In range	690.61	1580.30
Total phenolics (mg GAE/ 100 g)	In range	1243.20	2870.12
Antioxidant activity (% free radical scavenging activity)	In range	38.21	88.41
Non-enzymatic browning	In range	0.67	1.34
Colour	In range	7.75	8.15
Body	In range	7.35	7.70
Flavour	In range	7.30	7.65
Overall acceptability	In range	7.5	7.83

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Based on the above goals the RSM suggested solutions for optimization of process parameters (Appendix-IV). Perusal of data in Figure 4.12 indicated that the optimized conditions were temperature 53.21°C and concentration 64.70 per cent at which the desirability of the fit was 0.998, which was quite good. A confirmatory test was conducted for the optimized levels of ingredients for preparation of black carrot juice concentrate and the responses were studied. The predicted values of variables and the result obtained for responses were compared with the observed values using t-test. The significance of

difference between predicted values and observed values during preparation of black carrot juice concentrate has been presented in Table 4.13. No significant difference was observed between predicted values and observed values of the responses. Therefore, it was concluded that these conditions were found suitable preparation of black carrot juice concentrate.

Table 4.13 Predicted and observed values of responses of black carrot juice concentrate

Responses	Predicted value	Observed value	t-test
Temperature (°C)	50.93	50.00	NS
Concentration (°B)	65.88	66.00	NS
Yield (%)	11.72	12.00	NS
Titrateable acidity (as % citric acid)	1.35	1.26	NS
Ascorbic acid (mg/ 100 g)	32.16	31.85	NS
Anthocyanins (mg/ 100 g)	137.95	1380.16	NS
Total phenolics (mg GAE/ 100 g)	2489.70	2490.17	NS
Antioxidant activity (% free radical scavenging activity)	74.94	75.34	NS
Non-enzymatic browning	0.96	0.92	NS
Colour	8.05	8.12	NS
Body	7.54	7.60	NS
Flavour	7.59	7.63	NS
Overall acceptability	7.82	7.89	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.3.3 Physico-chemical and sensory responses for orange carrot juice concentrate

The data on physico-chemical and sensory responses for orange carrot juice concentrate is presented in Table 4.14 and Table 4.15. The effect of different temperature and concentration has been explained under following heads:

4.3.3.1 Physico-chemical and sensory responses

4.3.3.1.1 Yield

Data pertaining to the effect of different levels of temperature and concentration on orange carrot juice concentrate yield is shown in Table 4.14. It has been observed that concentrate produced in Run 3, employing 45°C temperature and 76.21 per cent concentration had minimum yield of 10.24 per cent whereas, concentrate produced in Run 13 having 45°C and 33.79 per cent of temperature and concentration, respectively had maximum yield of 20.19 per cent. The results were in conformity with Yahya *et al.* (2019) in carrot juice concentrate. Linear terms of temperature influenced the recovery of concentrate non-

significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.15. The effect of temperature and concentration on yield has been depicted in Figure 4.13. It was observed that with an increase in concentration level, concentrate yield was decreased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 29.87 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of yield in orange carrot juice concentrate was 95.52 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 17.71 which imply that the data was adequate to predict yield of the carrot juice concentrate. Therefore, it can be inference that the model was found to be appropriate to follow the design space for yield (%) of the concentrate. The overall second-order polynomial equation can be written as Equation 23 was adequate to predict the yield of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 24.

Equation 23: $Y = 14.11 - 2.95*B - 0.22*A*B$

Equation 24: $Y = 14.11 - 0.15*A - 2.95*B - 0.22*A*B - 0.11*A^2 + 0.48*B^2$

Where, Y = Yield, A = Temperature, B = Concentration

4.3.3.1.2 Titratable acidity

The experimental results related to the effect of variation in the levels of temperature and concentration as used in present investigation on the titratable acidity is presented in Table 4.14. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of acidity (0.80%) while Run 13 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest acidity (0.09 %). The results were in accordance with Oikeh *et al.* (2016). Linear terms of temperature influenced the titratable acidity of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.14. As evident from Figure 4.14, titratable acidity was directly proportional to concentration while there was negligible effect with respect to temperature. With the increase in concentration level, titratable acidity was increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 303.54

implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of titratable acidity in orange carrot juice concentrate was 99.54 per cent. The lack of fit was found to be non-significant and precision value was 57.15 which imply that the data was adequate to predict titratable acidity of the carrot juice concentrate. The overall second- order polynomial equation can be written as Equation 25 and considered adequate to predict the titratable acidity of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 26.

Equation 25: $Y = 0.44 + 0.021*A + 0.26*B$

Equation 26: $Y = 0.44 + 0.021*A + 0.26*B + 5.00*A*B - 2.50*A^2 - 2.50*B^2$

Where, Y = Titratable acidity, A = Temperature, B = Concentration

4.3.3.1.3 Ascorbic acid

The effect of variation in the levels of temperature and concentration as used in present investigation on the ascorbic acid content is presented in Table 4.14. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of ascorbic acid (39.20 mg/ 100 g) while Run 9 with corresponding variables to be 30°C temperature and 40 per cent concentration had lowest ascorbic acid (18.12 mg/ 100 g). Linear terms of temperature influenced the ascorbic acid of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.15. With the increase in concentration level, ascorbic acid was increased (Figure 4.15). The results were in accordance with Oikeh *et al.* (2013). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 26.76 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of ascorbic acid content in orange carrot juice concentrate was 95.03 per cent, which indicated that the model could account for 95.03 per cent data. The lack of fit was found to be non-significant but the precision value was quite high i.e. 16.84. Therefore, the model was considered satisfactory to follow the design space for ascorbic acid. The overall second-order polynomial equation can be written as Equation 27 and considered adequate to predict the ascorbic acid of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice

Table 4.14 Experimental design and responses obtained for orange carrot juice concentrate

Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	45	55	13.99	0.44	29.25	23.14	206.75	20.86	0.72	8.08	7.75	8.05	7.82
2	30	70	12.05	0.68	33.78	29.75	258.41	39.10	0.73	7.97	7.81	8.17	8.13
3	45	76.2132	10.24	0.80	39.20	31.87	273.10	43.55	0.82	7.85	7.96	8.19	8.26
4	23.7868	55	14.62	0.40	30.85	23.46	210.76	23.67	0.38	8.16	7.00	8.01	7.82
5	60	70	11.82	0.71	35.27	29.27	260.89	37.04	0.98	7.91	8.12	8.20	8.21
6	60	40	17.03	0.17	19.51	21.39	174.23	19.76	0.91	7.40	7.26	7.93	7.56
7	45	55	14.23	0.45	29.92	22.76	210.02	22.06	0.65	8.08	7.78	8.05	8.02
8	66.2132	55	13.45	0.49	27.46	27.09	197.67	20.12	1.07	7.73	7.62	8.00	7.64
9	30	40	16.37	0.16	18.12	20.57	179.55	17.89	0.40	7.58	7.17	7.95	7.90
10	45	55	14.00	0.42	29.68	27.40	206.77	20.80	0.64	8.10	7.74	8.08	8.04
11	45	55	14.23	0.45	29.92	23.76	210.14	21.98	0.66	8.08	7.76	8.09	7.96
12	45	55	14.08	0.43	29.75	25.98	208.32	21.60	0.69	8.10	7.75	8.07	8.01
13	45	33.7868	20.19	0.09	19.68	18.71	139.92	14.15	0.44	7.50	7.48	7.81	7.54

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.15 Regression coefficient and ANOVA for dependent parameters of orange carrot juice concentrate

Variables	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging)	Non-enzymatic browning	Colour	Body	Flavour	Overall acceptability
A	0.5522	0.0162	0.7216	0.2802	0.3728	0.3572	<0.0001	0.0122	0.0118	0.9683	0.1126
B	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0008	0.0009	0.0007	<0.0001	0.0003
AB	0.5415	0.6112	0.9789	0.7060	0.3679	0.3281	0.0639	0.5238	0.4373	0.5043	0.0746
A ²	0.6819	0.9730	0.2200	0.6211	0.7171	0.2067	0.0800	0.0262	0.0050	0.2602	0.0577
B ²	0.1121	0.9730	0.2915	0.6132	0.4726	0.0004	0.9442	0.0003	0.9886	0.2012	0.9747
Model F-value	29.87	303.54	26.76	12.03	50.16	54.27	29.66	18.40	12.39	21.63	11.53
R ²	95.52	99.54	95.03	89.58	97.28	97.49	95.49	92.93	89.84	93.92	89.17
Adequate precision	17.71	57.15	16.84	11.23	23.23	22.29	18.75	11.64	11.25	15.05	12.13
LOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Design-Expert® Software

Yield
20.19
10.24

X1 = A: Temperature
X2 = B: Concentration

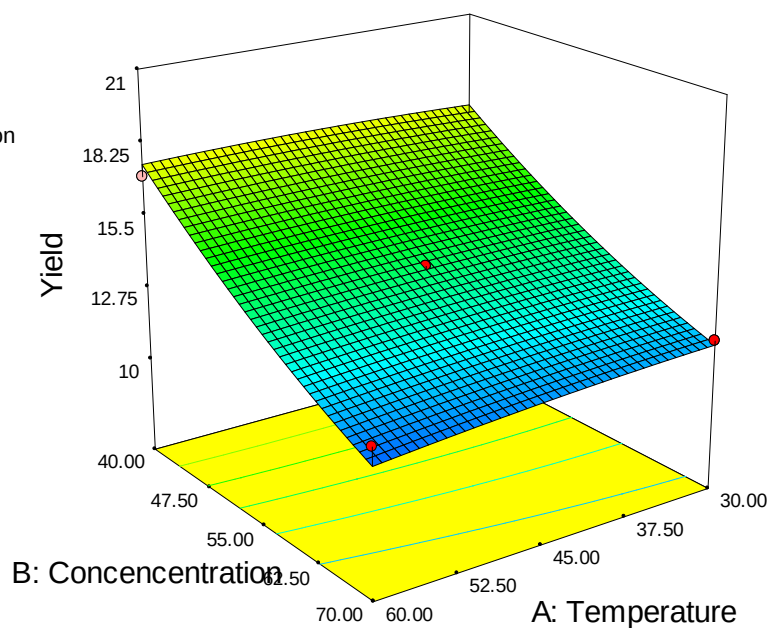


Figure 4.13: 3D graph showing the effect of temperature and concentration on yield of orange carrot juice concentrate

Design-Expert® Software

Acidity
0.8
0.09

X1 = A: Temperature
X2 = B: Concentration

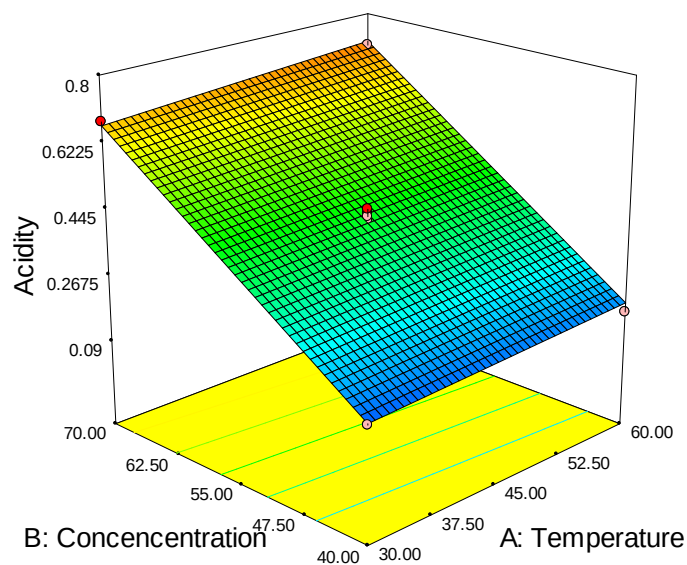


Figure 4.14: 3D graph showing the effect of temperature and concentration on titratable acidity of orange carrot juice concentrate

Design-Expert® Software

Ascorbic acid



X1 = A: Temperature
X2 = B: Concentration

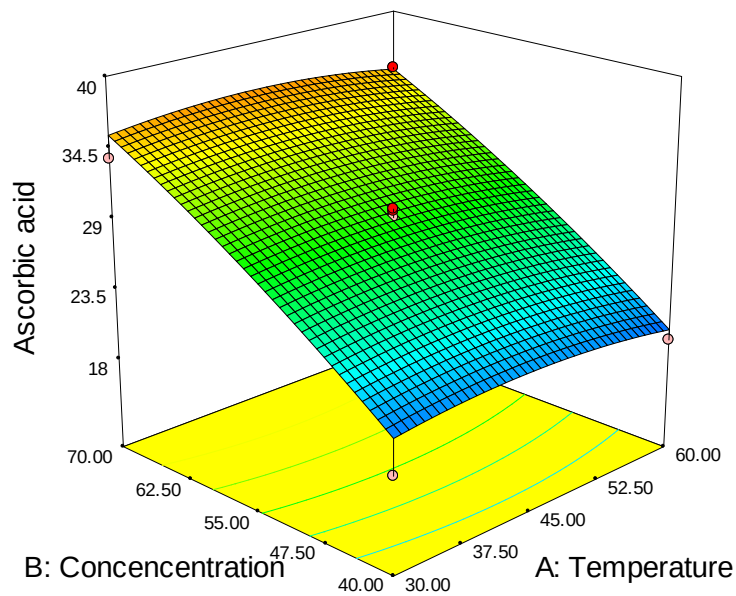


Figure 4.15: 3 D graph showing the effect of temperature and concentration on ascorbic acid of orange carrot juice concentrate

Design-Expert® Software

Total carotenoids



X1 = A: Temperature
X2 = B: Concentration

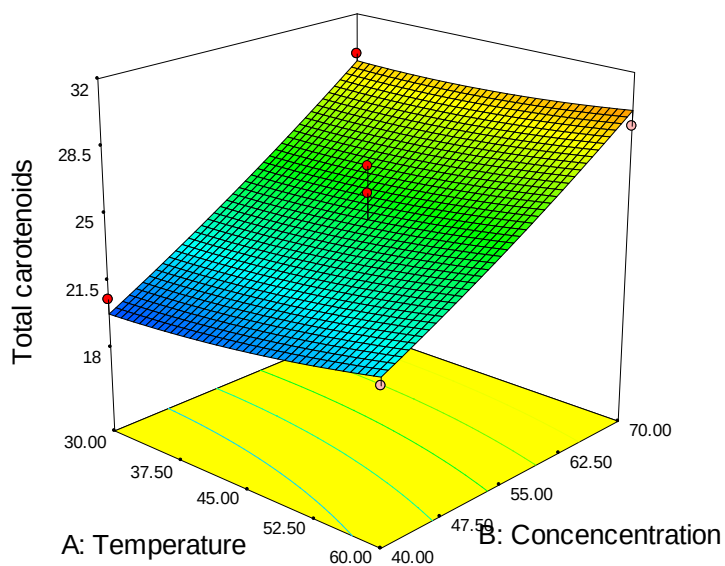


Figure 4.16: 3D graph showing the effect of temperature and concentration on total carotenoids of orange carrot juice concentrate

concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 28.

$$\text{Equation 27: } Y = 29.70 + 7.38*B - 0.79*B^2$$

$$\text{Equation 28: } Y = 29.70 - 0.24*A + 7.38*B + 0.025*A*B - 0.93*A^2 - 0.79*B^2$$

Where, Y = Ascorbic acid, A = Temperature, B = Concentration

4.3.3.1.4 Total carotenoids

The effect of variation in the levels of temperature and concentration on total carotenoids is depicted in Table 4.14. It was observed that the concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total carotenoids (31.87 mg/ 100 g) while Run 13 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest total carotenoids (18.71 mg/ 100 g). Linear terms of temperature influenced the total carotenoids of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.15. As evident from Figure 4.16, concentration was directly proportion to the total carotenoids whereas, they were unaffected with increased levels of temperature. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15.

The Model F-value of 12.03 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of total carotenoids in orange carrot juice concentrate was 89.58 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 11.23 which imply that the data was adequate to predict total carotenoids of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 29 and considered adequate to predict the total carotenoids of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 30.

$$\text{Equation 29: } Y = 24.61 + 4.46*B - 0.32*A*B$$

$$\text{Equation 30: } Y = 24.61 + 0.68*A + 4.46*B - 0.32*A*B - 0.32*A^2 + 0.33*B^2$$

Where, Y = Total carotenoids, A = Temperature, B = Concentration

4.3.3.1.5 Total phenolics

As shown in Table 4.14, concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total phenolics (273.10 mg GAE/ 100 g) while Run 13 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest total phenolics (139.92 mg GAE/ 100 g). Linear terms of temperature influenced the total phenolics of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.15. Total phenolics were minorly affected with change in temperature however, evident difference was noticed with varying levels of concentration (Figure 4.17). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 50.16 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of total phenolics in orange carrot juice concentrate was 97.28 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 23.23 which imply that the data was adequate to predict total phenolics of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 31 and considered adequate to predict the total phenolics of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 32.

$$\text{Equation 31: } Y = 208.40 + 44.23*B + 2.28*B^2$$

$$\text{Equation 32: } Y = 208.40 - 2.67*A + 44.23*B + 1.95*A*B + 1.13*A^2 + 2.28*B^2$$

Where, Y = Total phenolics, A = Temperature, B = Concentration

4.3.3.1.6 Antioxidant activity

According to Table 4.14 which shows the experimental results concerning the effect of different levels of temperature and concentration used in present investigation on the antioxidant activity, it was observed that concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of antioxidant activity (43.55%) while Run 13 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest antioxidant activity (14.15%). The results were in accordance with Ulusoy and Tamer (2019). Linear terms of temperature influenced the

antioxidant activity of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.15. As evident from Figure 4.18, with the increase in concentration level, antioxidant activity increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 54.27 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of antioxidant activity in orange carrot juice concentrate was 97.49 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 22.29 which imply that the data was adequate to predict antioxidant activity of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 33 and considered adequate to predict the antioxidant activity of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 34.

Equation 33: $Y = 208.40 + 44.23*B + 2.28*B^2$

Equation 34: $Y = 21.46 - 0.65*A + 10.01*B - 0.98*A*B + 0.99*A^2 + 4.46*B^2$

Where, Y = Antioxidant activity, A = Temperature, B = Concentration

4.3.3.1.7 Non-enzymatic browning

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on non-enzymatic browning is presented in Table 4.14. Concentrate prepared in Run 8 with 66.21°C temperature and 55 per cent concentration recorded the highest value of non-enzymatic browning (1.07) while Run 9 with corresponding variables to be 30°C temperature and 40 per cent concentration had lowest non-enzymatic browning (0.40). Linear terms of temperature influenced the non-enzymatic browning of concentrate significantly however, concentration had non-significant effect ($p < 0.01$) as shown in Table 4.15. The effect of temperature and concentration (Figure 4.19) was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 29.66 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of non-enzymatic browning in orange carrot juice concentrate was 95.49 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to

be non-significant and precision value was 18.75 which imply that the data was adequate to predict non-enzymatic browning of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 35 and considered adequate to predict the non-enzymatic browning of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 36.

$$\text{Equation 35: } Y = 0.67 + 0.22*A + 0.12*B$$

$$\text{Equation 36: } Y = 0.67 + 0.22*A + 0.12*B - 0.065*A*B + 0.046*A^2 - 1.62*B^2$$

Where, Y = Non-enzymatic browning, A = Temperature, B = Concentration

4.3.3.1.8 Colour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on colour are presented in Table 4.14. Concentrate prepared in Run 4 with 23.78°C temperature and 55 per cent concentration recorded the highest value of colour (8.16) while Run 6 with corresponding variables to be 60°C temperature and 40 per cent concentration had lowest colour value (7.40). Linear terms of temperature and concentration influenced the colour of concentrate non-significantly ($p < 0.01$) as shown in Table 4.15. However, with the increase in concentration level, there was an increase in colour score (Figure 4.20). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 18.40 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of colour in orange carrot juice concentrate was 92.93 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 11.64 which imply that the data was adequate to predict colour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 37 and considered adequate to predict the colour score of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 38.

$$\text{Equation 37: } Y = 8.09 - 0.11*A + 0.17*B - 0.095*A^2 - 0.23*B^2$$

$$\text{Equation 38: } Y = 8.09 - 0.11*A + 0.17*B + 0.030*A*B - 0.095*A^2 - 0.23*B^2$$

Where, Y = Colour, A = Temperature, B = Concentration

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Total phenolic content



X1 = A: Temperature

X2 = B: Concentration

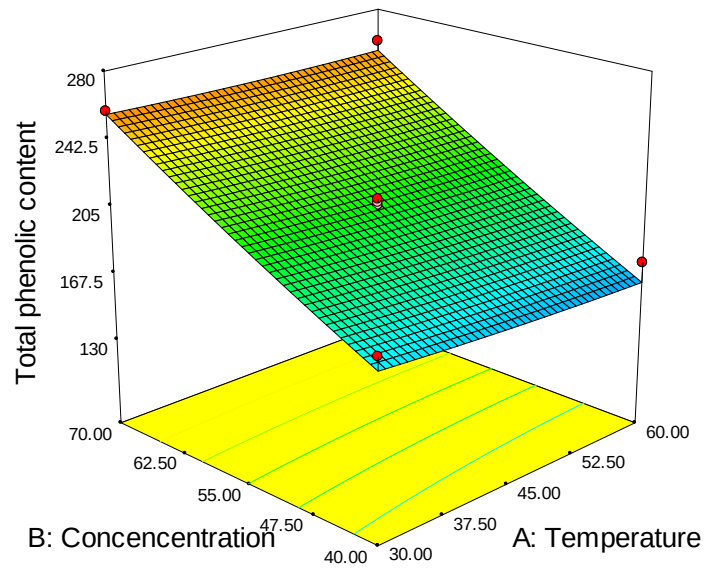


Figure 4.17: 3D graph showing the effect of temperature and concentration on total phenolics of orange carrot juice concentrate

Design-Expert® Software

Antioxidant activity



X1 = A: Temperature

X2 = B: Concentration

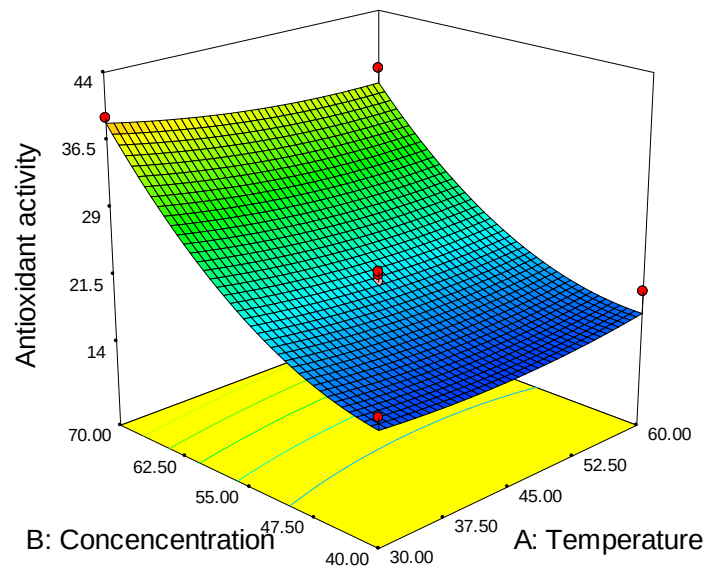


Figure 4.18: 3D graph showing the effect of temperature and concentration on antioxidant activity of orange carrot juice concentrate

Design-Expert® Software

Non-enzymatic browning



X1 = A: Temperature

X2 = B: Concentration

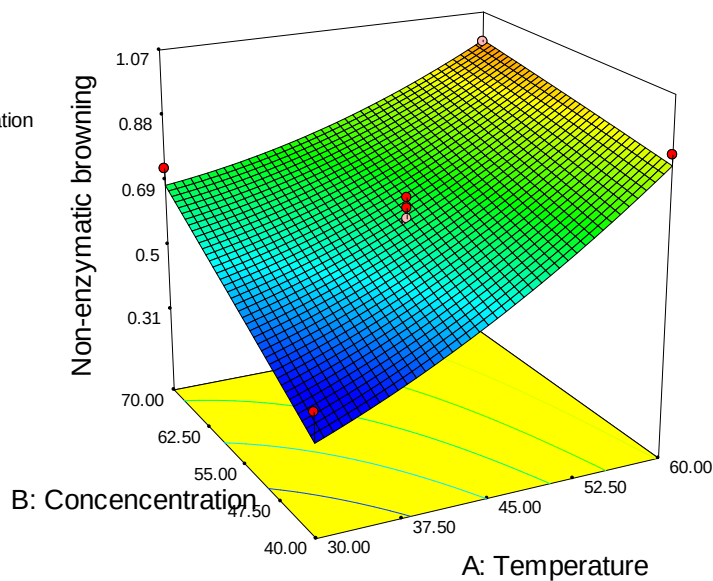


Figure 4.19: 3D graph showing the effect of temperature and concentration on non-enzymatic browning of orange carrot juice concentrate

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Colour



X1 = A: Temperature

X2 = B: Concentration

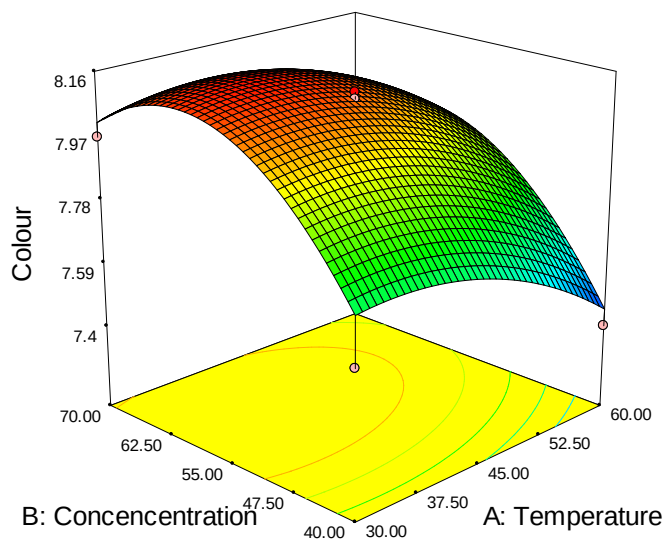


Figure 4.20: 3D graph showing the effect of temperature and concentration on colour of orange carrot juice concentrate

4.3.3.1.9 Body

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on body score has been presented in Table 4.14. Concentrate prepared in Run 5 with 60°C temperature and 70 per cent concentration recorded the highest value of body score (8.12) while Run 4 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest body score (7.00). Linear terms of temperature and concentration affect the body score non-significantly ($p < 0.01$) as shown in Table 4.15.

With the increase in concentration level, there was an increase in body score (Figure 4.21). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 12.39 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of body score in orange carrot juice concentrate was 89.84 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 11.25 which imply that the data was adequate to predict body score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 39 and considered adequate to predict the body score of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 40.

$$\text{Equation 39: } Y = 7.76 + 0.16*A + 0.27*B - 0.20*A^2$$

$$\text{Equation 40: } Y = 7.76 + 0.16*A + 0.27*B + 0.055*A*B - 0.20*A^2 + 7.50*B^2$$

Where, Y = Body, A = Temperature, B = Concentration

4.3.3.1.10 Flavour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on flavour score has been presented in Table 4.14. Concentrate prepared in Run 5 with 60°C temperature and 70.00 per cent concentration recorded the highest value of flavour score (8.20) while Run 13 with corresponding variables to be 45°C temperature and 33.78 per cent concentration had lowest body score (7.81). Linear terms of temperature influenced the flavour score of concentrate

non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.15. With the increase in concentration level, there was an increase in flavour score (Figure 4.22). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 21.63 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of flavour score in orange carrot juice concentrate was 93.92 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 15.05 which imply that the data was adequate to predict flavour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 41 and considered adequate to predict the flavour score of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 42.

Equation 41: $Y = 8.07 + 0.13*B - 0.019*B^2$

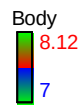
Equation 42: $Y = 8.07 - 5.17*A + 0.13*B + 0.013*A*B - 0.016*A^2 - 0.019*B^2$

Where, Y = Flavour, A = Temperature, B = Concentration

4.3.3.1.11 Overall acceptability

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on overall acceptability score has been presented in Table 4.14. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of overall acceptability (8.26) while Run 13 with corresponding variables to be 45°C temperature and 33.78 per cent concentration had lowest body score (7.54). Linear terms of temperature and concentration influenced the overall acceptability score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.15. With the increase in concentration level, there was an increase in overall acceptability score (Figure 4.23). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.15. The Model F-value of 11.53 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of overall acceptability score in orange carrot juice concentrate was 89.17 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables.

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X1 = A: Temperature
X2 = B: Concentration

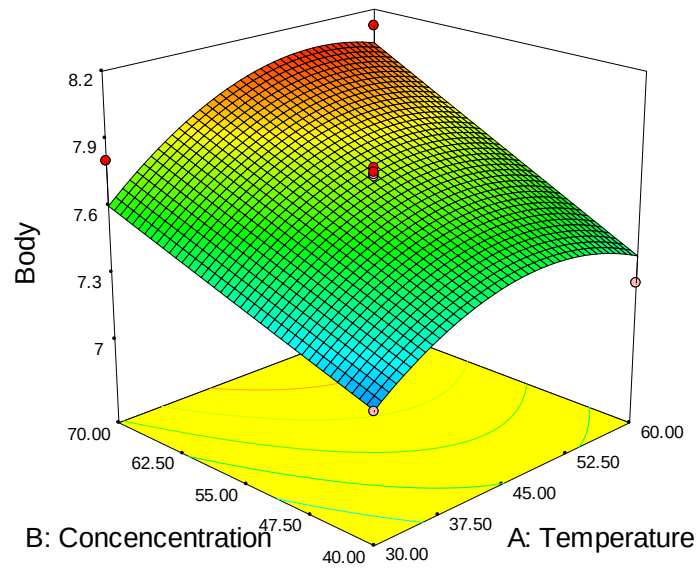
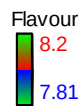


Figure 4.21: 3D graph showing the effect of temperature and concentration on body of orange carrot juice concentrate

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X1 = A: Temperature
X2 = B: Concentration

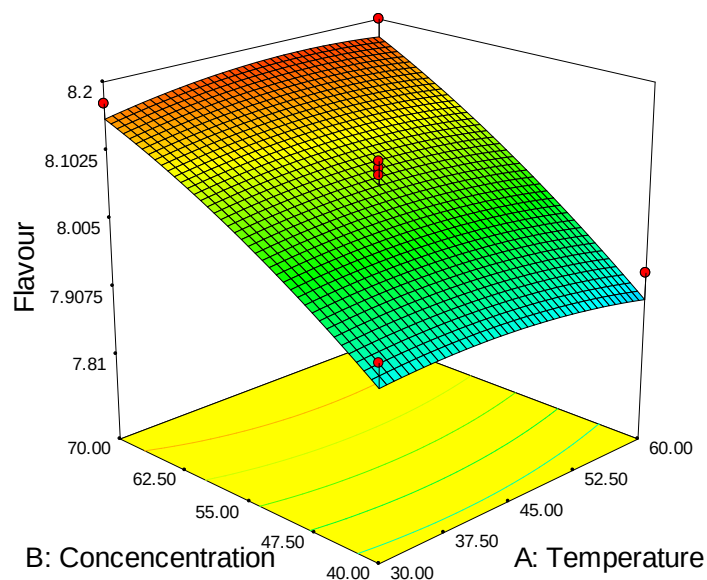


Figure 4.22: 3D graph showing the effect of temperature and concentration on flavour of orange carrot juice concentrate

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Overall acceptability



X1 = A: Temperature

X2 = B: Concentration

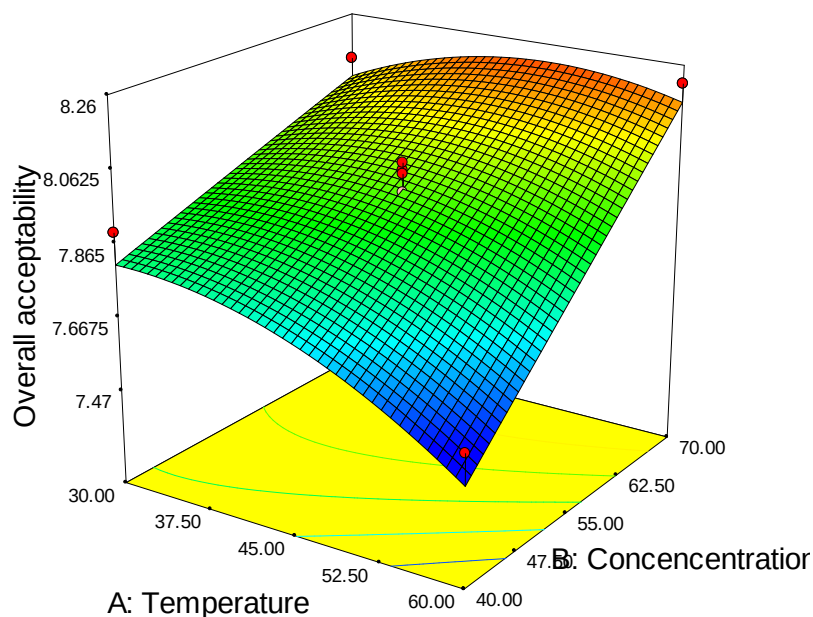


Figure 4.23: 3D graph showing the effect of temperature and concentration on overall acceptability of orange carrot juice concentrate

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Overlay Plot

● Design Points

X1 = A: Temperature

X2 = B: Concentration

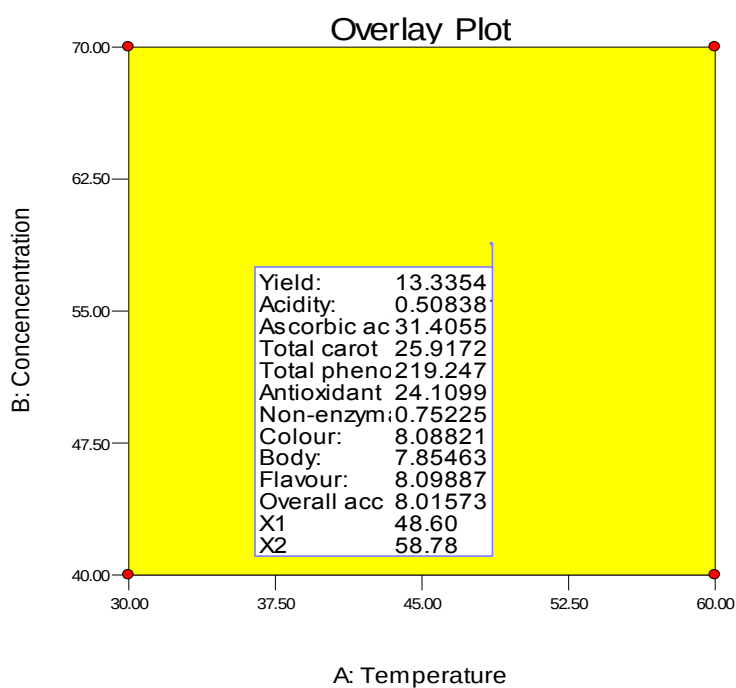


Figure 4.24: Overlay plot showing the effect of interaction of temperature and concentration on desirability of orange carrot juice concentrate

The lack of fit was found to be non-significant and precision value was 12.13 which imply that the data was adequate to predict overall acceptability score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 43 and considered adequate to predict the overall acceptability score of the concentrate and to interpret the effect of temperature and concentration on orange carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 44.

Equation 43: $Y = 7.97 + 0.24*B + 0.11*A*B$

Equation 44: $Y = 7.97 - 0.064*A + 0.24*B + 0.11*A*B - 0.086*A^2 - 1.25*B^2$

Where, Y = Overall acceptability, A = Temperature, B = Concentration

4.3.3.2 Process optimizations for development of orange carrot juice concentrate

Optimization is the process of making compromises between the variables, to get a common target. Goal seeking was used to get the best orange carrot juice concentrate with good nutritional quality and optimum taste. The criteria for goal allotment was based on the functional and sensory properties of the carrot juice concentrate. Goal was set for each independent variable and response before optimization as given Table 4.16. All the independent variables were kept in range based on the results obtained during preliminary experiments so that an optimum product could be obtained with respect to its desirable composition and functional properties. Yield, titratable acidity, ascorbic acid content, total carotenoids, total phenolics, antioxidant activity, non-enzymatic browning, colour, body, flavor and overall acceptability were set in range.

Table 4.16 Goals for optimization of formulation to prepare orange carrot juice concentrate

Parameter	Goal	Lower limit	Upper limit
Temperature (°C)	In range	30	60
Concentration (°B)	In range	40	70
Yield (%)	In range	10.24	20.19
Titratable acidity (as % citric acid)	In range	0.09	0.80
Ascorbic acid (mg/ 100 g)	In range	18.12	39.20
Total carotenoids (mg/ 100 g)	In range	18.71	31.87
Total phenolics (mg GAE/ 100 g)	In range	139.92	273.10
Antioxidant activity (% free radical scavenging activity)	In range	14.15	43.55
Non-enzymatic browning	In range	0.40	0.98
Colour	In range	7.40	8.16
Body	In range	7.00	8.12
Flavour	In range	7.81	8.19
Overall acceptability	In range	7.54	8.21

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Based on the above goals the RSM suggested solutions for process optimization (Appendix-IV). Perusal of data in Figure 4.24 indicated that the optimized conditions were temperature 48.60°C and concentration 58.78 per cent at which the desirability of the fit was 0.998, which was quite good. A confirmatory test was conducted for the optimized levels of ingredients for preparation of orange carrot juice concentrate and the responses were studied. The predicted values of variables and the result obtained for responses were compared with the observed values using t-test. The significance of difference between predicted values and observed values during preparation of orange carrot juice concentrate is given in Table 4.17. No significant difference was observed between predicted values and observed values of the responses. Therefore, it was concluded that these conditions were found suitable preparation of orange carrot juice concentrate.

Table 4.17 Predicted and observed values of responses of orange carrot juice concentrate

Responses	Predicted value	Observed value	t-test
Temperature (°C)	56.23	56.00	NS
Concentration (°B)	63.96	64.00	NS
Yield (%)	12.24	12.16	NS
Titrateable acidity (as % citric acid)	0.61	0.58	NS
Ascorbic acid (mg/ 100 g)	33.14	33.25	NS
Total carotenoids (mg/ 100 g)	27.93	28.38	NS
Total phenolics (mg GAE/ 100 g)	235.15	236.26	NS
Antioxidant activity (% radical scavenging activity)	28.66	29.34	NS
Non-enzymatic browning	0.90	0.87	NS
Colour	7.99	8.00	NS
Body	7.95	7.97	NS
Flavour	8.13	8.09	NS
Overall acceptability	8.06	8.00	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.3.4 Physico-chemical and sensory responses for purple carrot juice concentrate

The data on physico-chemical and sensory responses for purple carrot juice concentrate is presented in Table 4.18 and Table 4.19. The effect of different temperature and concentration has been explained under following heads:

4.3.4.1 Physico-chemical and sensory responses

4.3.4.1.1 Yield

Data pertaining to the effect of different levels of temperature and concentration on concentrate yield has been shown in Table 4.18. It has been observed that concentrate produced in Run 3, employing 45°C temperature and 76.21 per cent concentration had minimum yield of 10.65 per cent whereas, concentrate produced in Run 2 having 45°C and 33.79 per cent of temperature and concentration, respectively had maximum yield of 20.88 per cent. Similar results have been reported by Szaloki-Dorko *et al.* (2016) elderberry juice concentrate. Linear terms of temperature influenced the recovery of the concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.19. The effect of temperature and concentration on yield is depicted in Figure 4.25. With the increase in concentration level, yield was decreased.

The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 118.13 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of yield in purple carrot juice concentrate was 98.83 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 35.23 which imply that the data was adequate to predict yield of the carrot juice concentrate. Therefore, it can be inference that the model was found to be appropriate to follow the design space for yield (%) of the concentrate. The overall second-order polynomial equation can be written as Equation 45 was adequate to predict the yield of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 46.

$$\text{Equation 45: } Y = 14.84 - 3.34*B - 0.48*A*B + 0.50*B^2$$

$$\text{Equation 46: } Y = 14.84 + 0.092*A - 3.34*B - 0.48*A*B + 0.085*A^2 + 0.50*B^2$$

Where, Y = Yield, A = Temperature, B = Concentration

4.3.4.1.2 Titratable acidity

The experimental results related to the effect of variation in the levels of temperature and concentration as used in present investigation on the titratable acidity has been presented

in Table 4.18. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of acidity (1.17%) while Run 2 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest acidity (0.36%).

Linear terms of temperature influenced the titratable acidity of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.19. As evident from Figure 4.26, titratable acidity was directly proportional to concentration, while there was negligible effect with respect to temperature. With the increase in concentration level, titratable acidity was increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented in Table 4.19. The Model F-value of 337.39 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of titratable acidity in purple carrot juice concentrate was 99.59 per cent, which indicated that the model could account for 99.59 per cent data. The lack of fit was found to be non-significant and precision value was 60.31 which imply that the data was adequate to predict titratable acidity of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 47 and considered adequate to predict the titratable acidity of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 48.

$$\text{Equation 47: } Y = 1.13 + 0.29*B - 6.25*B^2$$

$$\text{Equation 48: } Y = 1.13 + 0.013*A + 0.29*B + 0.018*A*B - 0.011*A^2 - 6.25*B^2$$

Where, Y = Titratable acidity, A = Temperature, B = Concentration

4.3.4.1.3 Ascorbic acid

The effect of variation in the levels of temperature and concentration as used in present investigation on the ascorbic acid content has been presented in Table 4.18. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of ascorbic acid (36.08 mg/ 100 g) while Run 2 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest ascorbic acid (16.25 mg/ 100 g).

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Yield
20.88
10.65

X1 = A: Temperature
X2 = B: Concentrate

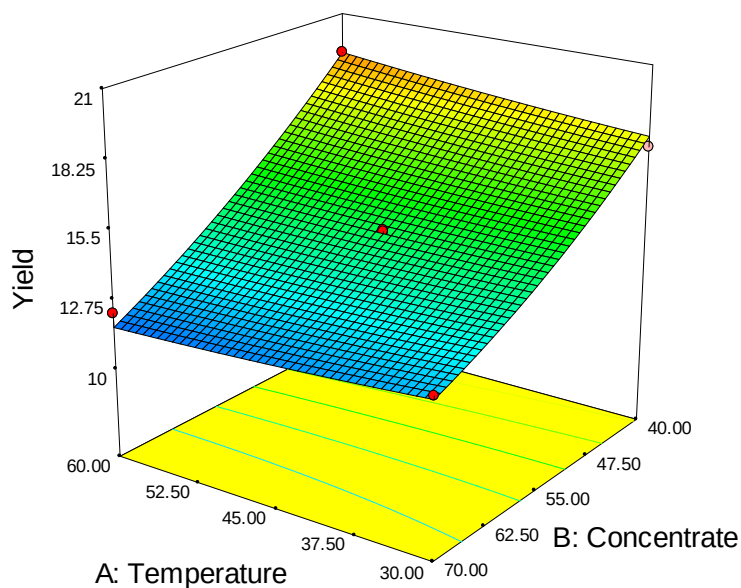


Figure 4.25: 3D graph showing the effect of temperature and concentration on yield of purple carrot juice concentrate

Design-Expert® Software

Acidity
1.17
0.36

X1 = A: Temperature
X2 = B: Concentrate

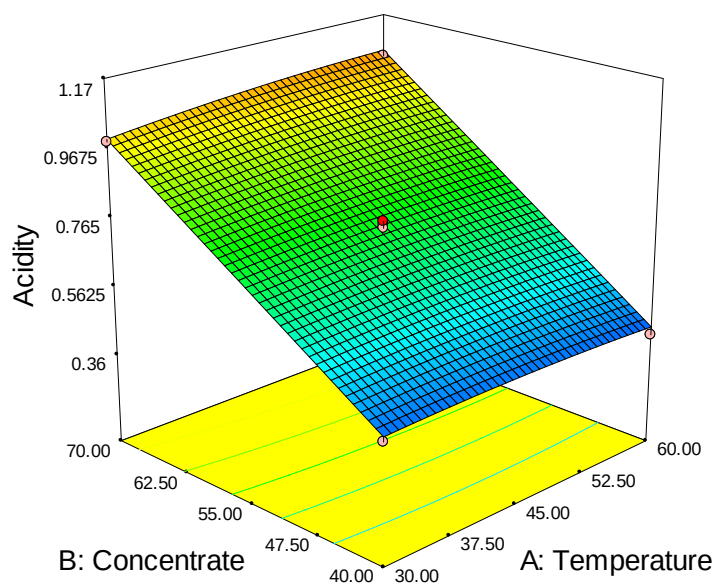


Figure 4.26: 3D graph showing the effect of temperature and concentration on titratable acidity of purple carrot juice concentrate

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Ascorbic acid

36.075

16.246

X1 = A: Temperature

X2 = B: Concentrate

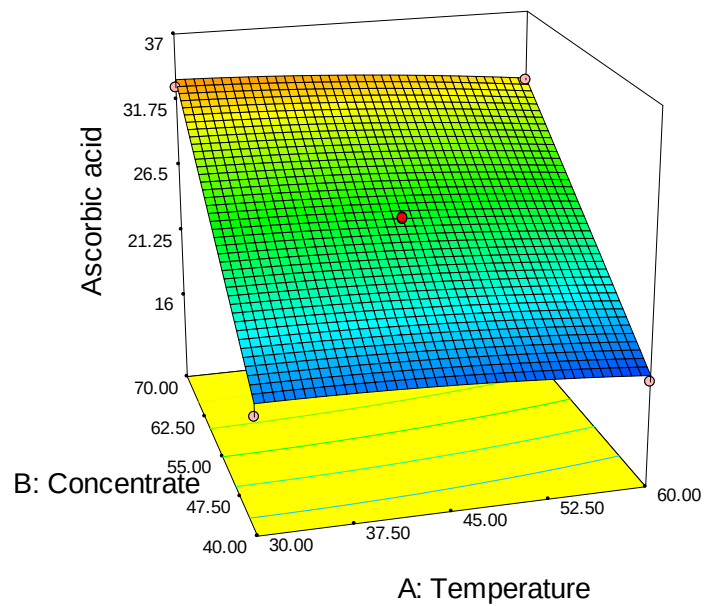


Figure 4.27: 3D graph showing the effect of temperature and concentration on ascorbic acid of purple carrot juice concentrate

Design-Expert® Software

Anthocyanins

1552.43

662.737

X1 = A: Temperature

X2 = B: Concentrate

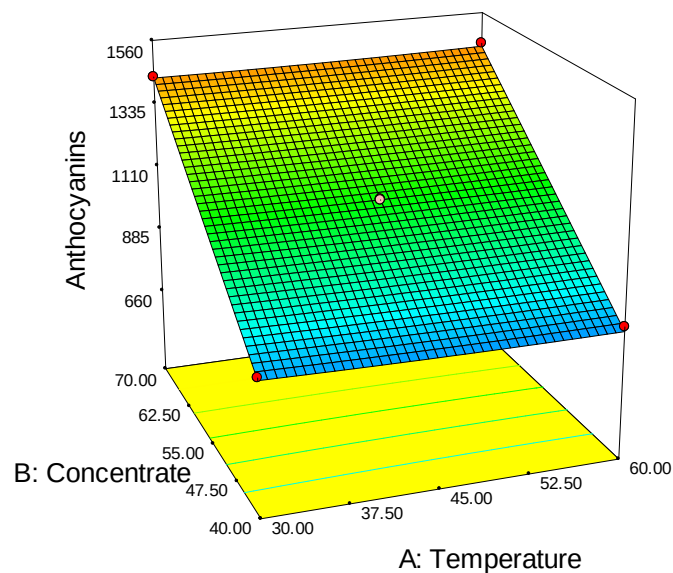


Figure 4.28: 3D graph showing the effect of temperature and concentration on anthocyanins of purple carrot juice concentrate

Linear terms of temperature influenced the ascorbic acid of concentrate non-significantly whereas, the effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.19. With the increase in concentration level, ascorbic acid was increased (Figure 4.27). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 179.37 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of ascorbic acid in purple carrot juice concentrate was 99.23 per cent, which indicated that the model could account for 99.23 per cent data. The lack of fit was found to be non-significant but the precision value was quite high i.e. 43.79. Therefore, the model was considered satisfactory to follow the design space for ascorbic acid. The overall second-order polynomial equation can be written as Equation 49 and considered adequate to predict the ascorbic acid of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 50.

Equation 49: $Y = 25.71 - 0.77*A + 7.18*B$

Equation 50: $Y = 25.71 - 0.77*A + 7.18*B - 0.17*A*B - 0.30*A^2 - 0.057*B^2$

Where, Y = Ascorbic acid, A = Temperature, B = Concentration

4.3.4.1.4 Anthocyanins

Table 4.18 reflects the effect of variation in the levels of temperature and concentration on anthocyanins. It was observed that the concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of anthocyanins (1552.43 mg/ 100 g) while Run 2 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest anthocyanin content (662.74 mg/ 100 g). Similar results have been reported by Szaloki-Dorko *et al.* (2016).

Linear terms of temperature influenced the anthocyanins of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.19. As evident from Figure 4.28, concentration was directly proportion to the anthocyanin content whereas, they were unaffected with increased levels of temperature. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 1173.15 implied that model was significant

at 5 per cent level. The coefficient of determination (R^2) for the regression model of anthocyanins in purple carrot juice concentrate was 99.88 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 112.72 which imply that the data was adequate to predict anthocyanins of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 51 and considered adequate to predict the anthocyanins of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 52.

Equation 51: $Y = 117.60 - 1.08*A + 312.04*B$

Equation 52: $Y = 117.60 - 1.08*A + 312.04*B + 5.05*A*B + 4.12*A^2 - 0.14*B^2$

Where, Y = Anthocyanins, A = Temperature, B = Concentration

4.3.4.1.5 Total phenolics

As shown in Table 4.18, concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total phenolics (2816.35 mg GAE/ 100 g) while Run 2 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest total phenolics (1189.43 mg GAE/ 100 g). The results are in conformity with Kirca *et al.* (2007).

Linear terms of temperature influenced the total phenolics of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.19. Total phenolics was minorly affected with change in temperature however, evident difference was noticed with varying levels of concentration (Figure 4.29). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 1105.17 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of total phenolics in purple carrot juice concentrate was 99.87 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 109.28 which imply that the data was adequate to predict total phenolics of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 53 and considered adequate to predict the total phenolics of the concentrate and to interpret the effect of temperature and

Table 4.18 Experimental design and responses obtained for purple carrot juice concentrate

Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanin s (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	45	55	14.89	0.74	25.63	1117.81	2018.68	55.47	0.73	7.87	7.87	8.04	7.97
2	45	33.7868	20.88	0.36	16.25	662.74	1189.43	30.68	0.67	7.53	7.45	7.87	7.63
3	45	76.2132	10.65	1.17	36.08	1552.44	2816.35	80.88	1.22	7.88	8.22	7.97	8.24
4	60	40	19.34	0.42	17.08	819.36	1443.43	40.74	0.64	7.65	7.39	7.90	7.59
5	23.7868	55	15.11	0.72	27.09	1122.88	2029.19	58.81	0.91	7.43	7.32	7.56	7.40
6	45	55	14.67	0.76	25.66	1115.55	2021.88	55.57	0.75	7.90	7.90	8.00	7.95
7	45	55	14.98	0.75	25.78	1118.63	2019.41	55.98	0.71	7.83	7.90	8.05	7.88
8	45	55	14.73	0.74	25.76	1119.66	2018.68	55.68	0.69	8.03	7.95	7.99	7.56
9	30	70	12.61	0.99	32.83	1433.18	2587.01	72.59	1.27	7.26	8.18	7.95	7.80
10	60	70	12.25	1.04	31.43	1448.52	2583.38	71.98	0.96	7.98	8.50	8.30	8.00
11	45	55	14.92	0.76	25.73	1116.34	2017.46	55.97	0.78	7.86	7.95	7.98	7.87
12	66.2132	55	14.77	0.77	24.25	1109.34	2115.41	51.71	0.59	7.74	7.70	8.02	7.68
13	30	40	17.76	0.44	17.79	824.23	1455.98	42.75	0.79	7.36	7.55	7.60	7.45

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.19 Regression coefficient and ANOVA for dependent parameters of purple carrot juice concentrate

Variables	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
A	0.5288	0.1179	0.0155	0.7977	0.1296	0.0458	0.0002	0.0025	0.1719	0.0019	0.0797
B	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.0556	0.0005	0.0131	0.0027
AB	0.0435	0.1233	0.6336	0.4097	0.8435	0.7158	0.1391	0.0959	0.1821	0.8009	0.8201
A ²	0.5859	0.2035	0.2787	0.3766	0.0352	0.8506	0.1398	0.0041	0.0517	0.0412	0.0128
B ²	0.0126	0.9366	0.8332	0.9757	0.1537	0.5885	0.0002	0.0280	0.7706	0.5059	0.4603
Model F-value	118.13	337.39	179.37	1173.15	1105.17	129.24	51.80	10.48	9.69	8.11	7.43
R ²	98.83	99.59	99.23	99.88	99.87	98.93	97.38	98.21	97.38	95.28	94.15
Adequate precision	35.23	60.31	43.79	112.72	109.285	37.23	21.10	9.15	9.53	8.96	9.41
LOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 54.

$$\text{Equation 53: } Y = 2019.22 + 571.47*B + 21.50*A^2$$

$$\text{Equation 54: } Y = 2019.22 + 13.22*A + 571.47*B + 2.23*A*B + 21.50*A^2 - 13.20*B^2$$

Where, Y = Total phenolics, A = Temperature, B = Concentration

4.3.4.1.6 Antioxidant activity

According to Table 4.18 which shows the experimental results concerning the effect of different levels of temperature and concentration used in present investigation on the antioxidant activity, it was observed that concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of antioxidant activity (80.88%) while Run 2 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest antioxidant activity (30.68%). Similar trends were given by Kumar (2018).

Linear terms of temperature influenced the antioxidant activity of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.19. As evident from Figure 4.30, with the increase in concentration level, antioxidant activity increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 129.24 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of antioxidant activity in purple carrot juice concentrate was 98.93 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 37.23 which imply that the data was adequate to predict antioxidant activity of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 55 and considered adequate to predict the antioxidant activity of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 56.

$$\text{Equation 55: } Y = 55.73 - 1.58*A + 16.51*B$$

$$\text{Equation 56: } Y = 55.73 - 1.58*A + 16.51*B + 0.35*A*B + 0.14*A^2 + 0.40*B^2$$

Where, Y = Antioxidant activity, A = Temperature, B = Concentration

4.3.4.1.7 Non-enzymatic browning

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on non-enzymatic browning is presented in Table 4.18. Concentrate prepared in Run 9 with 30°C temperature and 70.00 per cent concentration recorded the highest value of non-enzymatic browning (1.27) while Run 12 with corresponding variables to be 66.21°C temperature and 55 per cent concentration had lowest non-enzymatic browning (0.59).

Linear terms of temperature and concentration influenced the non-enzymatic browning of concentrate non-significantly ($p < 0.01$) as shown in Table 4.19. With the increase in concentration level, there was an increase in non-enzymatic browning (Figure 4.31). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 51.80 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of non-enzymatic browning in purple carrot juice concentrate was 97.38 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 21.10 which imply that the data was adequate to predict non-enzymatic browning of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 57 and considered adequate to predict the non-enzymatic browning of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 58.

Equation 57: $Y = 0.67 + 0.22*A + 0.12*B$

Equation 58: $Y = 0.73 - 0.11*A + 0.20*B - 0.037*A*B + 0.028*A^2 + 0.12*B^2$

Where, Y = Non-enzymatic browning, A = Temperature, B = Concentration

4.3.4.1.8 Colour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on colour score are presented in Table 4.18.

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Total phenolic content



X1 = A: Temperature

X2 = B: Concentrate

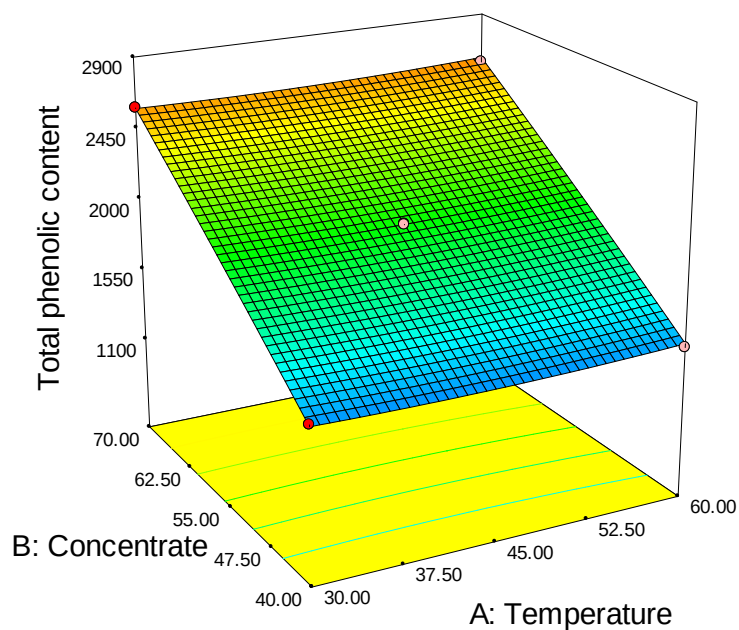


Figure 4.29: 3D graph showing the effect of temperature and concentration on total phenolics of purple carrot juice concentrate

Design-Expert® Software

Antioxidant activity



X1 = A: Temperature

X2 = B: Concentrate

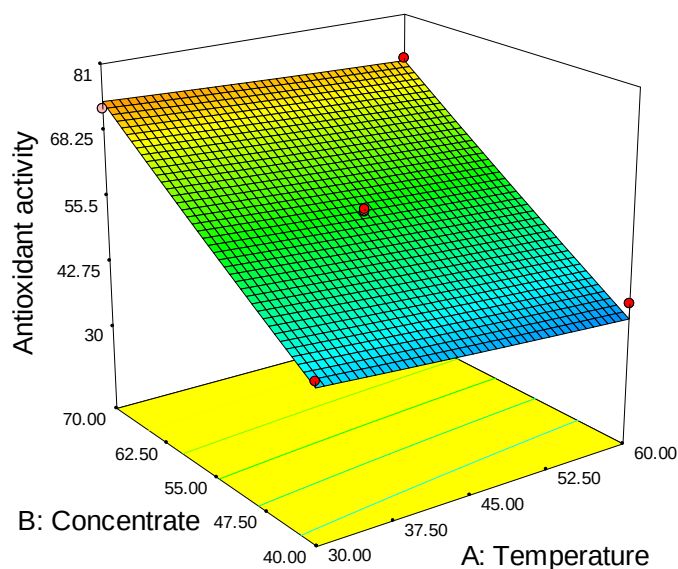


Figure 4.30: 3D graph showing the effect of temperature and concentration on antioxidant activity of purple carrot juice concentrate

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Non-enzymatic browning



X1 = A: Temperature

X2 = B: Concentrate

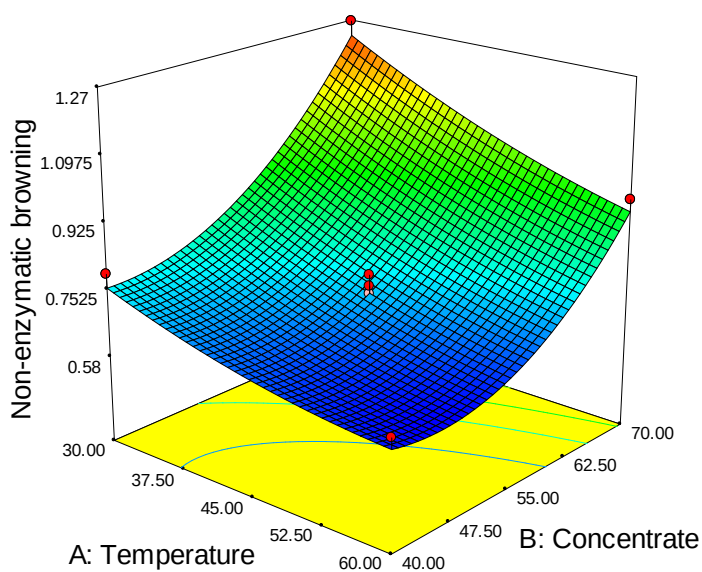


Figure 4.31: 3D graph showing the effect of temperature and concentration on non-enzymatic browning of purple carrot juice concentrate

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Colour



X1 = A: Temperature

X2 = B: Concentrate

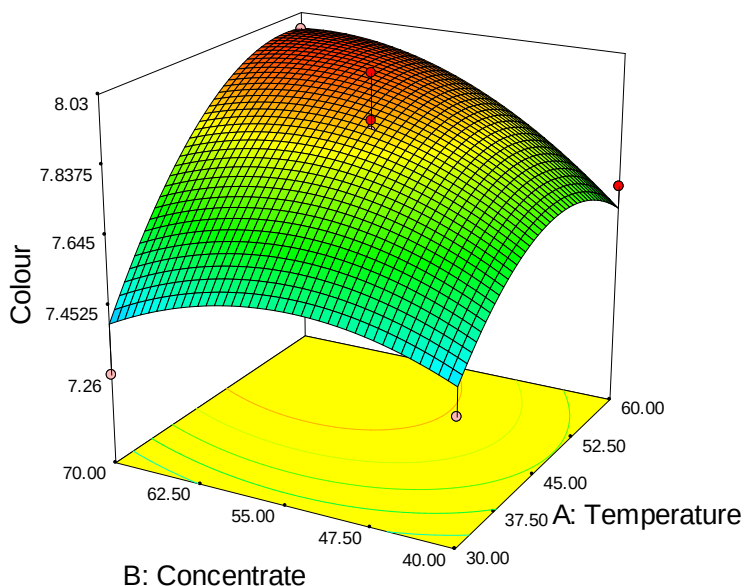


Figure 4.32: 3D graph showing the effect of temperature and concentration on colour of purple carrot juice concentrate

Concentrate prepared in Run 8 with 45°C temperature and 55 per cent concentration recorded the highest value of colour score (8.03) while Run 9 with corresponding variables to be 30°C temperature and 70 per cent concentration had lowest colour value (7.26). The results were in accordance with Rubina *et al.* (2018). Linear terms of temperature and concentration influenced the colour of concentrate non-significantly ($p < 0.01$) as shown in Table 4.19. With the increase in concentration level, there was an increase in colour (Figure 4.32). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 10.48 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of colour in purple carrot juice concentrate was 98.21 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 9.15 which imply that the data was adequate to predict colour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 59 and considered adequate to predict the colour score of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 60.

$$\text{Equation 59: } Y = 7.90 + 0.18*A - 0.18*A^2 - 0.12*B^2$$

$$\text{Equation 60: } Y = 7.90 + 0.18*A + 0.019*B + 0.11*A*B - 0.18*A^2 - 0.12*B^2$$

Where, Y = Colour, A = Temperature, B = Concentration

4.3.4.1.9 Body

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on body score has been presented in Table 4.18. Concentrate prepared in Run 10 with 60°C temperature and 70 per cent concentration recorded the highest value of body score (8.50) while Run 5 with corresponding variables to be 23.79 °C temperature and 55 per cent concentration had lowest body score (7.32). The results were in accordance with Vergeldt *et al.* (2014) in freeze dried carrots. Linear terms of temperature and concentration influenced the body score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.19. With the increase in concentration level, there was an increase in body score (Figure 4.33). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and

presented Table 4.19. The Model F-value of 9.69 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of body score in purple carrot juice concentrate was 97.38 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 9.53 which imply that the data was adequate to predict body score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 61 and considered adequate to predict the body score of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 62.

Equation 61: $Y = 7.91 + 0.35*B - 0.14*A^2$

Equation 62: $Y = 7.91 + 0.087*A + 0.35*B + 0.12*A*B - 0.14*A^2 + 0.019*B^2$

Where, Y = Body, A = Temperature, B = Concentration

4.3.4.1.10 Flavour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on flavour score has been presented in Table 4.18. Concentrate prepared in Run 10 with 60°C temperature and 70 per cent concentration recorded the highest value of flavour score (8.30) while Run 5 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest flavour score (7.56). Similar results have been reported by Aboltins and Upitis (2011). Linear terms of temperature influenced the flavour score of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.19. The effect of temperature and concentration (Figure 4.34) was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 8.11 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of flavour score in purple carrot juice concentrate was 95.28 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 8.96 which imply that the data was adequate to predict flavour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 63 and considered adequate to predict the flavour score of the concentrate and to interpret the effect of temperature and

concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 64.

$$\text{Equation 63: } Y = 8.01 + 0.16*A + 0.11*B - 0.090*A^2$$

$$\text{Equation 64: } Y = 8.01 + 0.16*A + 0.11*B + 0.013*A*B - 0.090*A^2 - 0.025*B^2$$

Where, Y = Flavour, A = Temperature, B = Concentration

4.3.4.1.11 Overall acceptability

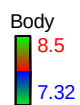
The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on overall acceptability score is presented in Table 4.18. Concentrate prepared in Run 3 with 45°C temperature and 76.21 per cent concentration recorded the highest value of overall acceptability (8.24) while Run 5 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest body score (7.40). The results were in conformity with Rubina *et al.* (2018). Linear terms of temperature and concentration influenced the overall acceptability score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.19. The effect of temperature and concentration (Figure 4.35) was analyzed using analysis of variance (ANOVA) and presented Table 4.19. The Model F-value of 7.43 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of overall acceptability score in purple carrot juice concentrate was 94.15 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 9.41 which imply that the data was adequate to predict overall acceptability score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 65 and considered adequate to predict the overall acceptability score of the concentrate and to interpret the effect of temperature and concentration on purple carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 66.

$$\text{Equation 65: } Y = 7.97 + 0.24*B + 0.11*A*B$$

$$\text{Equation 66: } Y = 7.85 + 0.092*A + 0.20*B + 0.015*A*B - 0.16*A^2 + 0.038*B^2$$

Where, Y = Overall acceptability, A = Temperature, B = Concentration

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X1 = A: Temperature
X2 = B: Concentrate

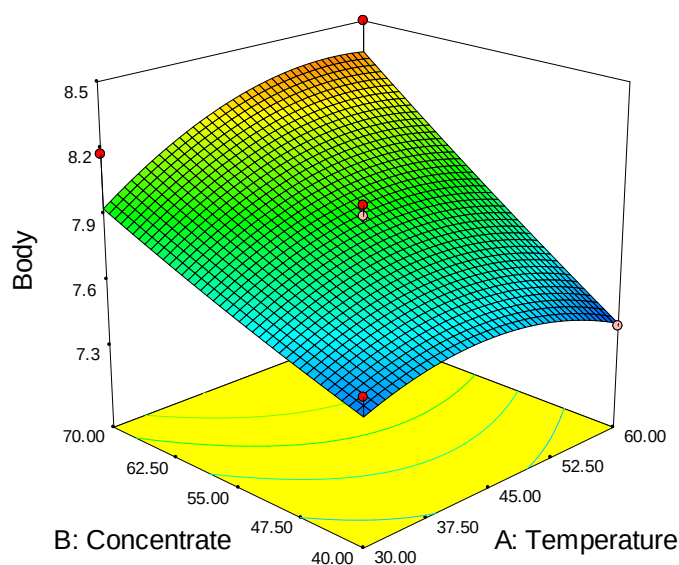
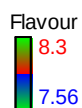


Figure 4.33: 3D graph showing the effect of temperature and concentration on body of purple carrot juice concentrate

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X1 = A: Temperature
X2 = B: Concentrate

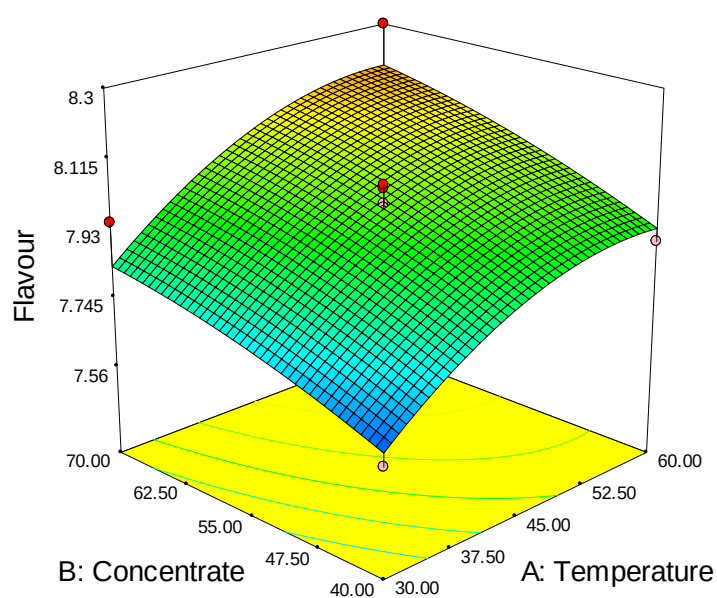


Figure 4.34: 3D graph showing the effect of temperature and concentration on flavour of purple carrot juice concentrate

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Overall acceptability



X1 = A: Temperature
X2 = B: Concentrate

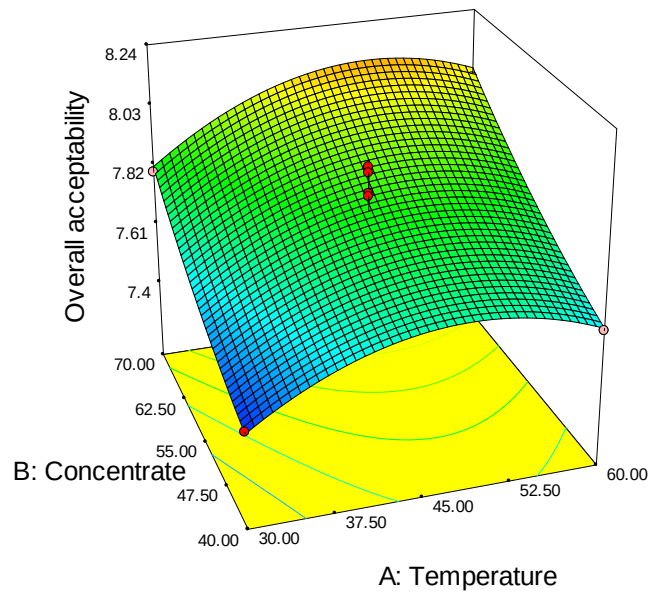


Figure 4.35: 3D graph showing the effect of temperature and concentration on overall acceptability of purple carrot juice concentrate

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Overlay Plot

● Design Points

X1 = A: Temperature
X2 = B: Concentrate

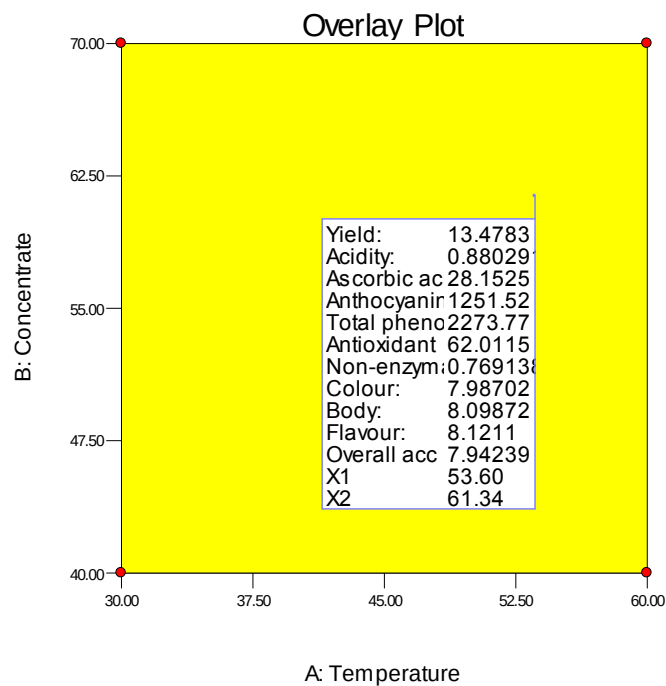


Figure 4.36: Overlay plot showing the effect of interaction of temperature and concentration on desirability of purple carrot juice concentrate

4.3.4.2 Process optimizations for development of purple carrot juice concentrate

Optimization is the process of making compromises between the variables, to get a common target. Goal seeking was used to get the best purple carrot juice concentrate with good nutritional quality and optimum taste. The criteria for goal allotment was based on the functional and sensory properties of the carrot juice concentrate. Goal was set for each independent variable and response before optimization as given Table 4.20. All the independent variables were kept in range based on the results obtained during preliminary experiments so that an optimum product could be obtained with respect to its desirable composition and functional properties. Yield, titratable acidity, ascorbic acid content, anthocyanins, total phenolics, antioxidant activity, non-enzymatic browning, colour, body, flavor and overall acceptability were set in range.

Table 4.20 Goals for optimization of formulation to prepare purple carrot juice concentrate

Parameter	Goal	Lower limit	Upper limit
Temperature (°C)	In range	30	60
Concentration (°B)	In range	40	70
Yield (%)	In range	9.78	20.01
Titratable acidity (as % citric acid)	In range	0.74	1.55
Ascorbic acid (mg/ 100 g)	In range	17.92	37.75
Anthocyanins (mg/ 100 g)	In range	690.61	1580.30
Total phenolics (mg GAE/ 100 g)	In range	1243.20	2870.12
Antioxidant activity (% free radical scavenging activity)	In range	38.21	88.41
Non-enzymatic browning	In range	0.67	1.34
Colour	In range	7.75	8.15
Body	In range	7.35	7.70
Flavour	In range	7.30	7.65
Overall acceptability	In range	7.50	7.83

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Based on the above goals the RSM suggested solutions for process optimization (Appendix-IV). Perusal of data in Figure 4.36 indicated that the optimized conditions were temperature 53.60°C and concentration 61.34 per cent at which the desirability of the fit was 0.988, which was quite good. A confirmatory test was conducted for the optimized levels of ingredients for preparation of purple carrot juice concentrate and the responses were studied. The predicted values of variables and the result obtained for responses were compared with the observed values using t-test. The significance of difference between predicted values and

observed values during preparation of purple carrot juice concentrate is given in Table 4.21. No significant difference was observed between predicted values and observed values of the responses. Therefore, it was concluded that these conditions were found suitable preparation of purple carrot juice concentrate.

Table 4.21 Predicted and observed values of responses of purple carrot juice concentrate

Responses	Predicted value	Observed value	t-test
Temperature (°C)	56.38	57.00	NS
Concentration (°B)	64.64	65.00	NS
Yield (%)	12.78	12.30	NS
Titrateable acidity (as % citric acid)	0.95	0.97	NS
Ascorbic acid (mg/ 100 g)	29.46	30.14	NS
Anthocyanins (mg/ 100 g)	1322.13	1320.46	NS
Total phenolics (mg GAE/ 100 g)	2404.58	2402.13	NS
Antioxidant activity (% free radical scavenging activity)	65.56	66.18	NS
Non-enzymatic browning	0.82	0.79	NS
Colour	7.99	8.05	NS
Body	8.19	8.20	NS
Flavour	8.15	8.12	NS
Overall acceptability	7.98	7.96	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.3.5 Physico-chemical and sensory responses for red carrot juice concentrate

The data on physico-chemical and sensory responses for red carrot juice concentrate is presented in Table 4.22 and Table 4.23. The effect of different temperature and concentration has been explained under following heads:

4.3.5.1 Physico-chemical and sensory responses

4.3.5.1.1 Yield

Data pertaining to the effect of different levels of temperature and concentration on concentrate yield has been presented in Table 4.22. It has been observed that concentrate produced in Run 2, employing 45°C temperature and 76.21 per cent concentration had minimum yield of 9.37 per cent whereas, concentrate produced in Run 7 having 45°C and 33.79 per cent of temperature and concentration, respectively had maximum yield of 18.86 per cent. Linear terms of temperature influenced the recovery of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.23.

The effect of temperature and concentration on yield is depicted in Figure 4.37. With the increase in concentration level, yield was decreased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 33.61 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of yield in red carrot juice concentrate was 96.00 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 18.31 which imply that the data was adequate to predict yield of the carrot juice concentrate. Therefore, the inference is that the model was found to be an appropriate to follow the design space for yield (%) of the concentrate. The overall second-order polynomial equation can be written as Equation 67 was adequate to predict the yield of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 68.

Equation 67: $Y = 14.57 - 2.86*B - 0.84*A^2$

Equation 68: $Y = 14.57 - 0.22*A - 2.86*B - 0.040*A*B - 0.84*A^2 - 0.34*B^2$

Where, Y = Yield, A = Temperature, B = Concentration

4.3.5.1.2 Titratable acidity

The experimental results related to the effect of variation in the levels of temperature and concentration as used in present investigation on the titratable acidity has been presented in Table 4.22. Concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of acidity (0.65%) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest acidity (0.06%).

As evident from Figure 4.38, titratable acidity was directly proportional to concentration, while there was negligible effect with respect to temperature. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 127.46 implied that model was significant ($p < 0.01$). The coefficient of determination (R^2) for the regression model of titratable acidity in red carrot juice concentrate was 98.91 per cent, which indicated that the model could

account for 98.91 per cent data. The lack of fit was found to be non-significant and precision value was 34.55 which imply that the data was adequate to predict titratable acidity of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 69 and considered adequate to predict the titratable acidity of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 70.

Equation 69: $Y = 0.75 + 0.29*B + 0.018*A*B$

Equation 70: $Y = 0.22 + 6.339*A + 0.21*B + 1.018*A*B + 0.056*A^2 + 0.076*B^2$

Where, Y = Titratable acidity, A = Temperature, B = Concentration

4.3.5.1.3 Ascorbic acid

The effect of variation in the levels of temperature and concentration as used in present investigation on the ascorbic acid is presented in Table 4.22. Concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of ascorbic acid (51.96 mg/ 100 g) while Run 8 with corresponding variables to be 30°C temperature and 40 per cent concentration had lowest ascorbic acid (29.78 mg/ 100 g).

Linear terms of temperature influenced the ascorbic acid of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.23. With the increase in concentration level, ascorbic acid was increased (Figure 4.39). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.24. The Model F-value of 18.98 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of ascorbic acid in red carrot juice concentrate was 93.13 per cent, which indicated that the model could account for 93.13 per cent data. The lack of fit was found to be non-significant but the precision value was quite high i.e. 14.14. Therefore, the model was considered satisfactory to follow the design space for ascorbic acid. The overall second-order polynomial equation can be written as Equation 71 and considered adequate to predict the ascorbic acid of the concentrate and to interpret the effect of temperature and concentration on red carrot

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Yield
18.86
9.37

X1 = A: Temperature
X2 = B: Concentration

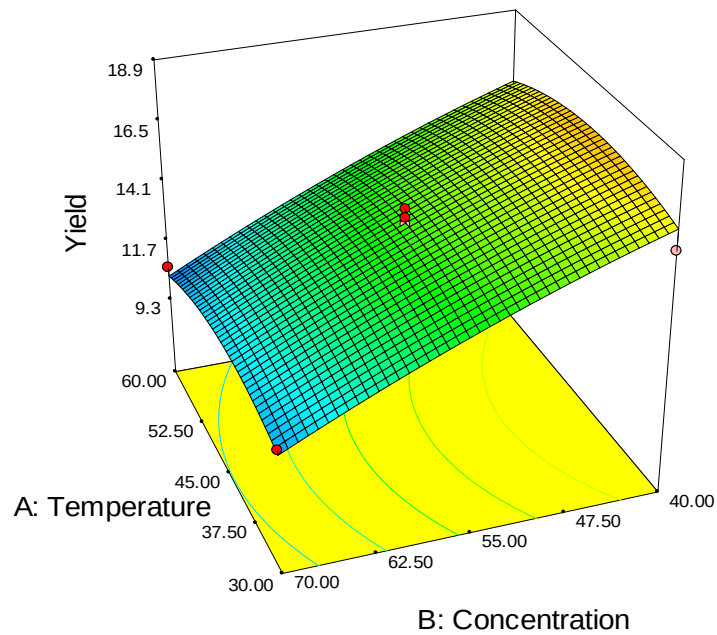


Figure 4.37: 3D graph showing the effect of temperature and concentration on yield of red carrot juice concentrate

Design-Expert® Software

Acidity
0.65
0.06

X1 = A: Temperature
X2 = B: Concentration

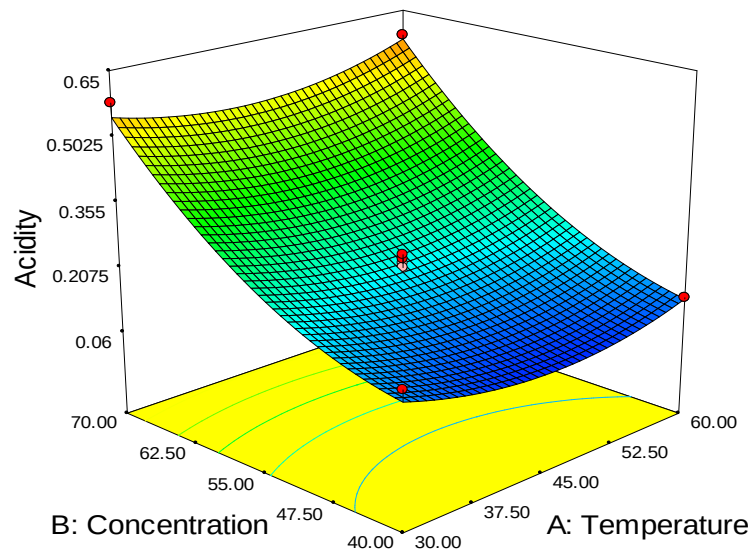


Figure 4.38: 3D graph showing the effect of temperature and concentration on titratable acidity of red carrot juice concentrate

Design-Expert® Software

Ascorbic acid



X1 = A: Temperature
X2 = B: Concentration

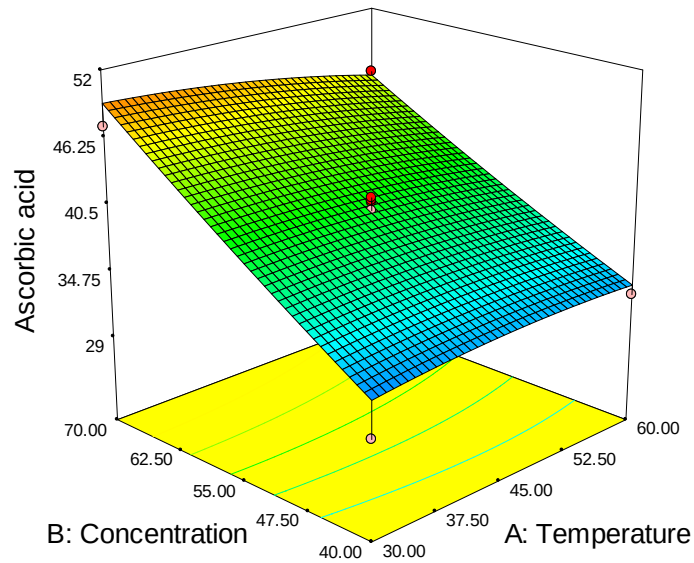


Figure 4.39: 3D graph showing the effect of temperature and concentration on ascorbic acid of red carrot juice concentrate

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Total carotenoids



X1 = A: Temperature
X2 = B: Concentration

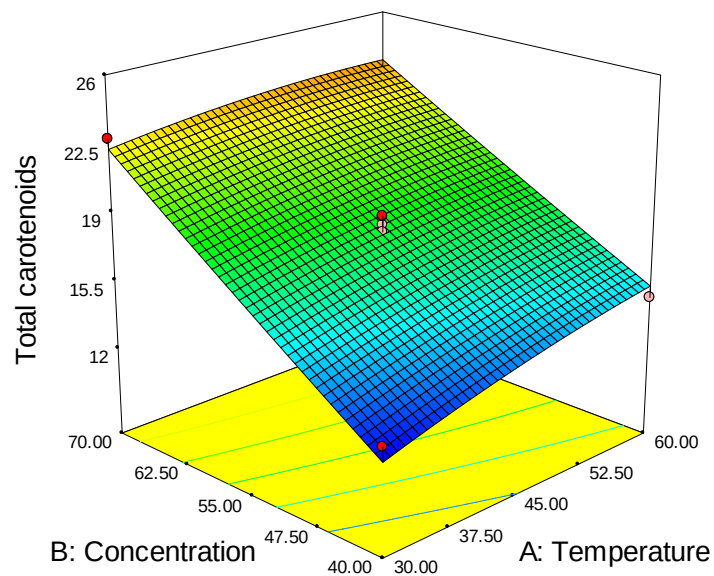


Figure 4.40: 3D graph showing the effect of temperature and concentration on total carotenoids of red carrot juice concentrate

juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 72.

$$\text{Equation 71: } Y = 40.60 + 7.12*B - 0.56*A^2$$

$$\text{Equation 72: } Y = 40.60 - 0.69*A + 7.12*B - 1.03*A*B - 0.56*A^2 + 0.35*B^2$$

Where, Y = Ascorbic acid, A = Temperature, B = Concentration

4.3.5.1.4 Total carotenoids

Table 4.22 reflects the effect of variation in the levels of temperature and concentration on total carotenoids. It was observed that the concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total carotenoids (25.35 mg/ 100 g) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest carotenoids (12.06 mg/ 100 g).

Linear terms of temperature influenced the total carotenoids of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.23. As evident from Figure 4.40, concentration was directly proportion to the total carotenoids content whereas, they were unaffected with increased levels of temperature. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.24. The Model F-value of 55.89 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of total carotenoids in red carrot juice concentrate was 97.56 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 24.06 which imply that the data was adequate to predict total carotenoids of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 73 and considered adequate to predict the total carotenoids of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 74.

$$\text{Equation 73: } Y = 18.48 - 1.07*A + 4.59*B$$

$$\text{Equation 74: } Y = 18.48 - 1.07*A + 4.59*B - 0.55*A*B - 0.32*A^2 + 0.092*B^2$$

Where, Y = Total carotenoids, A = Temperature, B = Concentration

4.3.5.1.5 Total phenolics

As shown in Table 4.22, concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of total phenolics (212.48 mg GAE/ 100 g) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest total phenolics (70.36 mg GAE/ 100 g).

Linear terms of temperature influenced the total phenolics of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.23. Total phenolics were minorly affected with change in temperature however, evident difference was noticed with varying levels of concentration (Figure 4.41). The effect of temperature and concentration were analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 80.74 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of total phenolics in red carrot juice concentrate was 98.30 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 29.40 which imply that the data was adequate to predict total phenolics of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 75 and considered adequate to predict the total phenolics of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 76.

Equation 75: $Y = 142.65 - 3.60*A + 46.41*B$

Equation 76: $Y = 142.65 - 3.60*A + 46.41*B + 1.71*A*B - 2.93*A^2 + 1.76*B^2$

Where, Y = Total phenolics, A = Temperature, B = Concentration

4.3.5.1.6 Antioxidant activity

According to Table 4.22 which shows the experimental results concerning the effect of different levels of temperature and concentration used in present investigation on the antioxidant activity, it was observed that concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of antioxidant activity (53.08%) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest antioxidant activity (20.18%).

Table 4.22 Experimental design and responses obtained for red carrot juice concentrate

Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	45	55	14.28	0.22	40.83	18.47	142.55	32.93	0.63	8.47	7.92	7.88	7.65
2	45	76.2132	9.37	0.65	51.96	25.35	212.48	53.08	0.78	8.24	8.13	8.02	8.09
3	60	40	15.44	0.14	32.75	14.68	98.86	27.55	0.85	7.79	7.43	7.76	7.39
4	23.7868	55	13.54	0.29	43.50	15.42	137.84	31.46	0.32	8.55	7.17	7.84	7.65
5	66.2132	55	12.68	0.34	38.30	20.36	126.23	28.18	0.96	8.12	7.79	7.83	7.47
6	45	55	14.75	0.24	41.24	18.93	143.67	33.41	0.62	8.47	7.95	7.88	7.85
7	45	33.7868	18.86	0.06	33.47	12.06	70.36	20.18	0.41	7.89	7.65	7.64	7.37
8	30	40	15.62	0.17	29.78	12.78	108.45	24.12	0.35	7.97	7.34	7.78	7.73
9	60	70	10.63	0.59	46.12	22.54	187.42	45.26	0.90	8.30	8.29	8.03	8.04
10	45	55	15.10	0.20	39.80	17.98	141.82	31.96	0.61	8.49	7.91	7.91	7.87
11	30	70	10.97	0.58	47.26	22.83	190.18	47.09	0.65	8.36	7.98	8.00	7.96
12	45	55	14.20	0.21	40.12	18.10	142.23	32.34	0.64	8.47	7.93	7.92	7.79
13	45	55	14.50	0.23	40.99	18.90	142.96	33.11	0.61	8.49	7.92	7.90	7.84

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.23 Regression coefficient and ANOVA for dependent parameters of red carrot juice concentrate

Variables	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
A	0.3767	0.5051	0.3829	0.0068	0.1656	0.5945	<0.0001	0.0122	0.0118	0.9683	0.1126
B	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.004	0.0009	0.0007	<0.0001	0.0003
AB	0.9056	0.4590	0.3599	0.2142	0.6194	0.2145	0.0399	0.5238	0.4373	0.5043	0.0746
A ²	0.0114	0.0007	0.5075	0.3339	0.2780	0.3269	0.2018	0.0262	0.0050	0.2602	0.0577
B ²	0.2136	0.0001	0.6714	0.7710	0.5024	0.0087	0.8377	0.0003	0.9886	0.2012	0.9747
Model F-value	33.61	127.46	18.98	55.89	80.74	54.73	37.21	18.40	12.39	21.63	11.53
R ²	96.00	98.91	93.13	97.56	98.30	97.51	96.37	92.93	89.84	93.92	89.17
Adequate precision	18.31	34.55	14.14	24.06	29.40	23.56	20.57	11.64	11.25	15.05	12.14
LOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Linear terms of temperature influenced the antioxidant activity of concentrate non-significantly whereas, effect of concentration was found to be significant ($p < 0.01$) as shown in Table 4.23. As evident from Figure 4.42, with the increase in concentration level, antioxidant activity increased. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 54.73 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of antioxidant activity in red carrot juice concentrate was 97.51 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 23.56 which imply that the data was adequate to predict antioxidant activity of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 77 and considered adequate to predict the antioxidant activity of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 78.

Equation 77: $Y = 32.75 + 10.90*B + 2.64*B^2$

Equation 78: $Y = 32.75 - 0.38*A + 10.90*B - 1.31*A*B - 0.77*A^2 + 2.64*B^2$

Where, Y = Antioxidant activity, A = Temperature, B = Concentration

4.3.5.1.7 Non-enzymatic browning

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on non-enzymatic browning is presented in Table 4.22. Concentrate prepared in Run 4 with 23.79°C temperature and 55 per cent concentration recorded the lowest value of non-enzymatic browning (0.32) while Run 5 with corresponding variables to be 66.21°C temperature and 55 per cent concentration had highest value for non-enzymatic browning (0.96).

Linear terms of temperature influenced the non-enzymatic browning of concentrate significantly whereas, effect of concentration was found to be non-significant ($p < 0.01$) as shown in Table 4.23. With the increase in concentration level, there was an increase in non-enzymatic browning (Figure 4.43). The effect of temperature and concentration was analyzed using analysis

of variance (ANOVA) and presented Table 4.23. The Model F-value of 37.21 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of non-enzymatic browning in red carrot juice concentrate was 96.37 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 20.57 which imply that the data was adequate to predict non-enzymatic browning of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 79 and considered adequate to predict the non-enzymatic browning of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 80.

Equation 79: $Y = 0.62 + 0.21*A + 0.11*B - 0.062*A*B$

Equation 80: $Y = 0.62 + 0.21*A + 0.11*B - 0.062*A*B + 0.027*A^2 + 4.00*B^2$

Where, Y = Non-enzymatic browning, A = Temperature, B = Concentration

4.3.5.1.8 Colour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on colour score are presented in Table 4.22. Concentrate prepared in Run 5 with 23.79°C temperature and 55 per cent concentration recorded the highest value of colour (8.55) while Run 3 with corresponding variables to be 60°C temperature and 40 per cent concentration had lowest colour value (7.79).

Linear terms of temperature and concentration influenced the colour of concentrate non-significantly ($p < 0.01$) as shown in Table 4.23. The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 18.40 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of colour score in red carrot juice concentrate was 92.93 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 11.64 which imply that the data was adequate to predict colour score of the carrot juice concentrate.

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Total phenolic content



X1 = A: Temperature

X2 = B: Concentration

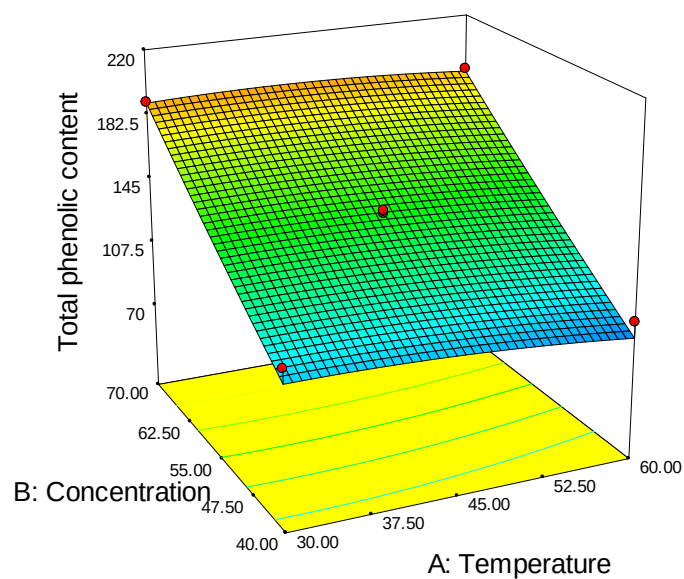


Figure 4.41: 3D graph showing the effect of temperature and concentration on total phenolics of red carrot juice concentrate

Design-Expert® Software

Antioxidant activity



X1 = A: Temperature

X2 = B: Concentration

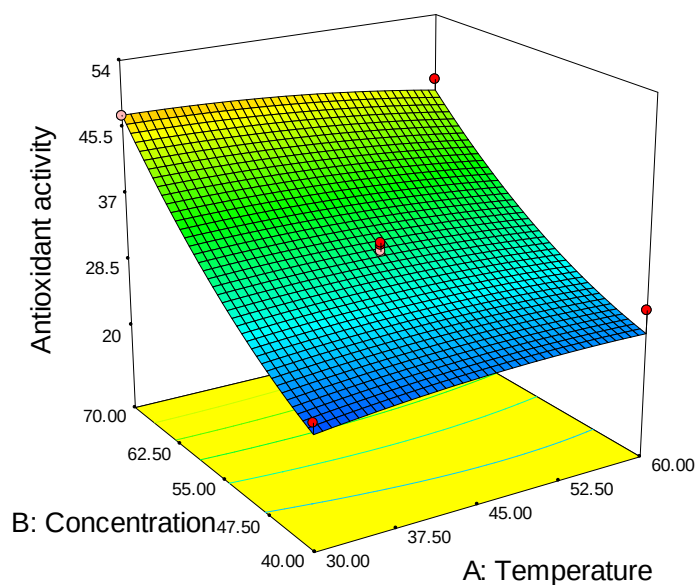


Figure 4.42: 3D graph showing the effect of temperature and concentration on antioxidant activity of red carrot juice concentrate

Design-Expert® Software

Non-enzymatic browning



X1 = A: Temperature

X2 = B: Concentration

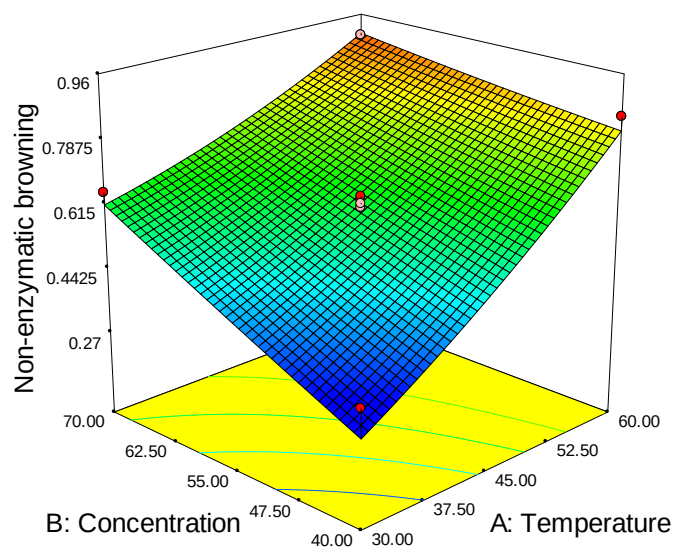


Figure 4.43: 3D graph showing the effect of temperature and concentration on non-enzymatic browning of red carrot juice concentrate

Design-Expert® Software

Colour



X1 = A: Temperature

X2 = B: Concentration

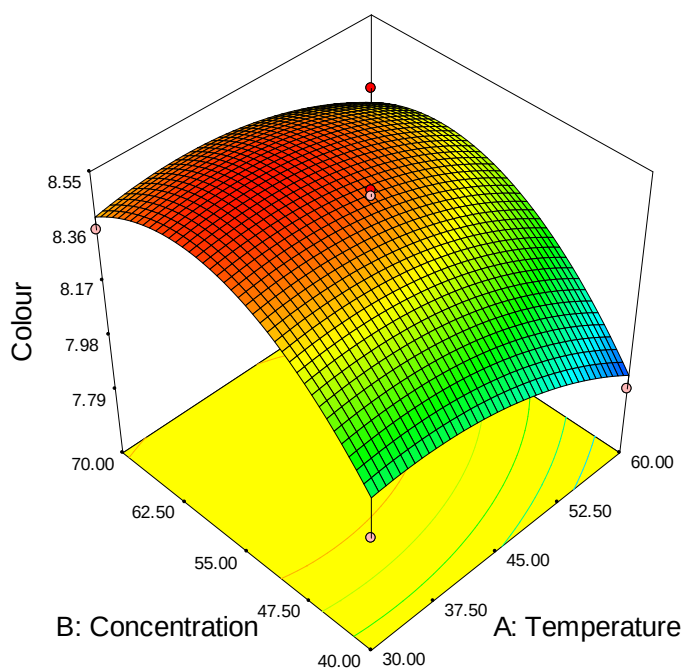


Figure 4.44: 3D graph showing the effect of temperature and concentration on colour of red carrot juice concentrate

The overall second-order polynomial equation can be written as Equation 81 and considered adequate to predict the colour of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 82.

$$\text{Equation 81: } Y = 8.48 - 0.11*A + 0.17*B - 0.095*A^2 - 0.23*B^2$$

$$\text{Equation 82: } Y = 8.48 - 0.11*A + 0.17*B + 0.030*A*B - 0.095*A^2 - 0.23*B^2$$

Where, Y = Colour, A = Temperature, B = Concentration

4.3.5.1.9 Body

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on body score is presented in Table 4.22. Concentrate prepared in Run 9 with 60°C temperature and 70 per cent concentration recorded the highest value of body score (8.29) while Run 4 with corresponding variables to be 23.79°C temperature and 55 per cent concentration had lowest body score (7.17).

Linear terms of temperature concentration and influenced the body score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.23. With the increase in concentration level, there was an increase in body score (Figure 4.45). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 12.39 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of body score in red carrot juice concentrate was 89.84 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 11.25 which imply that the data was adequate to predict body score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 83 and considered adequate to predict the body score of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 84.

$$\text{Equation 83: } Y = 7.93 + 0.16*A + 0.27*B + 0.055*A*B - 0.20*A^2 + 7.50*B^2$$

$$\text{Equation 84: } Y = 7.93 + 0.16*A + 0.27*B + 0.055*A*B - 0.20*A^2 + 7.50*B^2$$

Where, Y = Body, A = Temperature, B = Concentration

4.3.5.1.10 Flavour

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on flavour score is presented in Table 4.22. Concentrate prepared in Run 9 with 60°C temperature and 70 per cent concentration recorded the highest value of flavour score (8.03) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest flavour score (7.64).

Linear terms of temperature influenced the flavour score of concentrate non-significantly whereas, effect of concentration was found significant ($p < 0.01$) as shown in Table 4.23. With the increase in concentration level, there was an increase in flavour score (Figure 4.46). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 21.63 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of flavour score in red carrot juice concentrate was 93.92 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 15.05 which imply that the data was adequate to predict flavour score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 85 and considered adequate to predict the flavour score of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 86.

$$\text{Equation 85: } Y = 7.90 + 0.13*B - 0.016*A^2$$

$$\text{Equation 86: } Y = 7.90 - 5.17*A + 0.13*B + 0.013*A*B - 0.016*A^2 - 0.019*B^2$$

Where, Y = Flavour, A = Temperature, B = Concentration

4.3.5.1.11 Overall acceptability

The experimental results pertaining to the effect of variation in the levels of temperature and concentration as used in present investigation on overall acceptability score has been presented in Table 4.22. Concentrate prepared in Run 2 with 45°C temperature and 76.21 per cent concentration recorded the highest value of overall acceptability (8.09) while Run 7 with corresponding variables to be 45°C temperature and 33.79 per cent concentration had lowest overall acceptability score (7.37).

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Body
8.29
7.17

X1 = A: Temperature
X2 = B: Concentration

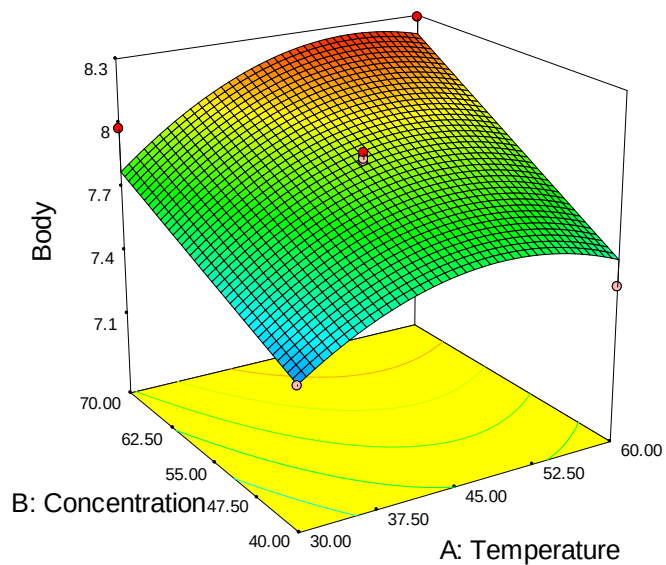


Figure 4.45: 3D graph showing the effect of temperature and concentration on body of red carrot juice concentrate

Design-Expert® Software

Flavour
8.03
7.64

X1 = A: Temperature
X2 = B: Concentration

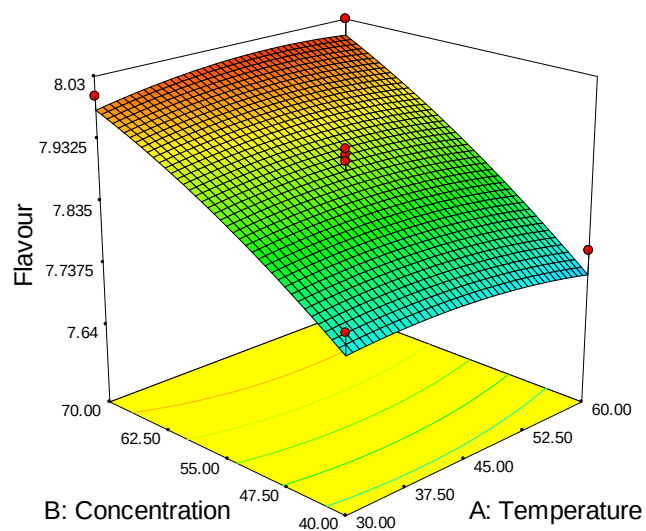


Figure 4.46: 3D graph showing the effect of temperature and concentration on flavour of red carrot juice concentrate

Design-Expert® Software

Overall acceptability



X1 = A: Temperature

X2 = B: Concentration

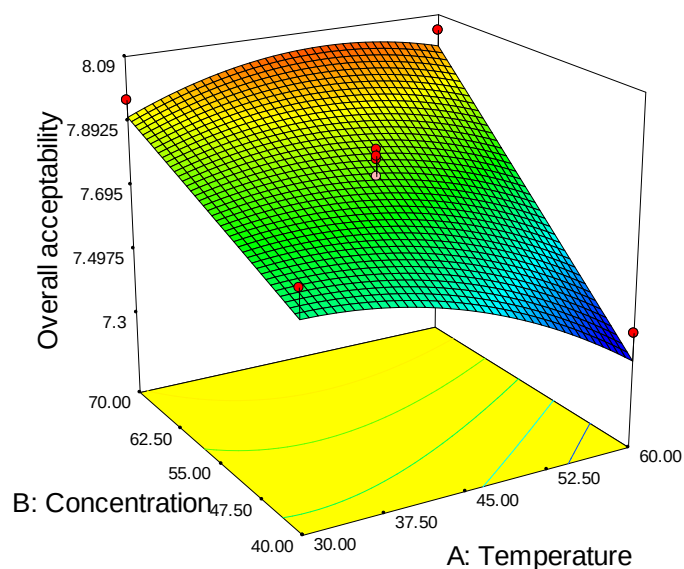


Figure 4.47: 3D graph showing the effect of temperature and concentration on overall acceptability of red carrot juice concentrate

Design-Expert® Software

Overlay Plot

● Design Points

X1 = A: Temperature

X2 = B: Concentration

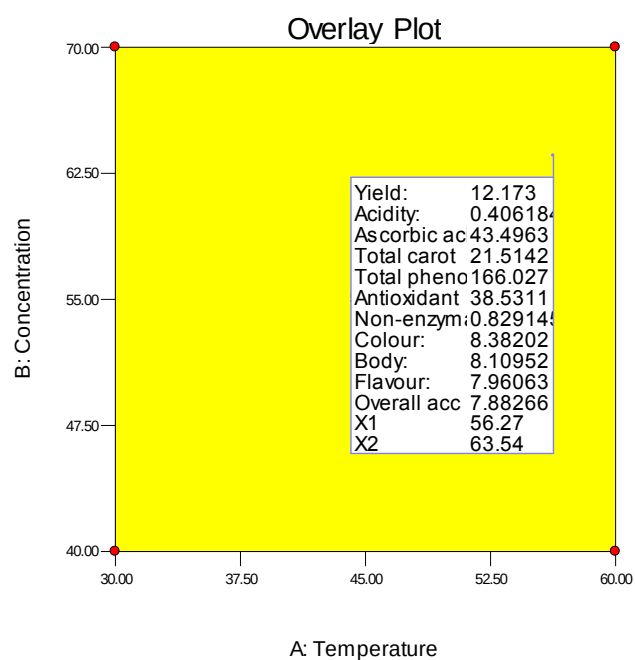


Figure 4.48: Overlay plot showing the effect of interaction of temperature and concentration on desirability of red carrot juice concentrate

Linear terms of temperature and concentration influenced the overall acceptability score of concentrate non-significantly ($p < 0.01$) as shown in Table 4.23. With the increase in concentration level, there was an increase in overall acceptability score (Figure 4.47). The effect of temperature and concentration was analyzed using analysis of variance (ANOVA) and presented Table 4.23. The Model F-value of 11.53 implied that model was significant at 5 per cent level. The coefficient of determination (R^2) for the regression model of overall acceptability score in red carrot juice concentrate was 89.17 per cent, which indicated that the model was adequate in representing the real relationship among the selected variables. The lack of fit was found to be non-significant and precision value was 12.14 which imply that the data was adequate to predict overall acceptability score of the carrot juice concentrate. The overall second-order polynomial equation can be written as Equation 87 and considered adequate to predict the overall acceptability score of the concentrate and to interpret the effect of temperature and concentration on red carrot juice concentrate that was obtained by elimination of insignificant terms with p-value more than 0.05 in the Equation 88.

Equation 87: $Y = 7.80 + 0.24*B - 0.086*A^2$

Equation 88: $Y = 7.80 - 0.064*A + 0.24*B + 0.11*A*B - 0.086*A^2 - 1.250*B^2$

Where, Y = Overall acceptability, A = Temperature, B = Concentration

4.3.5.2 Process optimization for development of red carrot juice concentrate

Optimization is the process of making compromises between the variables, to get a common target. Goal seeking was used to get the best carrot juice concentrate with good nutritional quality and optimum taste. The criteria for goal allotment was based on the functional and sensory properties of the carrot juice concentrate. Goal was set for each independent variable and response before optimization as given Table 4.24. All the independent variables were kept in range based on the results obtained during preliminary experiments so that an optimum product could be obtained with respect to its desirable composition and functional properties. Yield, titratable acidity, ascorbic acid content, total carotenoids, total phenolics, antioxidant activity, non-enzymatic browning, colour, body, flavor and overall acceptability were set in range. Based on the above goals the RSM suggested solutions for optimization (Appendix-IV).

Table 4.24 Goals for optimization of formulation to prepare red carrot juice concentrate

Parameter	Goal	Lower limit	Upper limit
Temperature (°C)	In range	30	60
Concentration (°B)	In range	40	70
Yield (%)	In range	9.37	18.86
Titrateable acidity (as % citric acid)	In range	0.06	0.65
Ascorbic acid (mg/ 100 g)	In range	29.78	51.96
Total carotenoids (mg/ 100 g)	In range	12.06	25.35
Total phenolics (mg GAE/ 100 g)	In range	70.36	212.48
Antioxidant activity (% free radical scavenging activity)	In range	20.18	53.08
Non-enzymatic browning	In range	0.35	0.96
Colour	In range	7.79	8.55
Body	In range	7.34	8.29
Flavour	In range	7.64	8.03
Overall acceptability	In range	7.37	8.09

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Perusal of data in Figure 4.48 indicated that the optimized conditions were temperature 56.27°C and concentration 63.54 per cent at which the desirability of the fit was 0.997, which was quite good. A confirmatory test was conducted for the optimized levels of ingredients for preparation of red carrot juice concentrate and the responses were studied. The predicted values of variables and the result obtained for responses were compared with the observed values using t-test. The significance of difference between predicted values and observed values during preparation of red carrot juice concentrate is given in Table 4.25. No significant difference was observed between predicted values and observed values of the responses. Therefore, it was concluded that these conditions were found suitable preparation of red carrot juice concentrate.

Table 4.25 Predicted and observed values of responses of red carrot juice concentrate

Responses	Predicted value	Observed value	t-test
Temperature (°C)	50.05	50.00	NS
Concentration (°B)	66.27	66.00	NS
Yield (%)	12.05	11.68	NS
Titrateable acidity (as % citric acid)	0.43	0.45	NS
Ascorbic acid (mg/ 100 g)	45.59	45.78	NS
Total carotenoids (mg/ 100 g)	22.16	22.13	NS
Total phenolics (mg GAE/ 100 g)	177.38	181.32	NS
Antioxidant activity (% free radical scavenging activity)	41.87	42.26	NS
Non-enzymatic browning	0.76	0.78	NS
Colour	8.44	8.32	NS
Body	8.17	8.15	NS
Flavour	7.98	7.96	NS
Overall acceptability	7.97	8.03	NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.26 Chemical and sensory characteristics of best rated carrot juice concentrate (black, orange, purple and red)

Characteristic	Black carrot	Orange carrot	Purple carrot	Red carrot
Total soluble solids (°B)	65.88	63.96	64.64	66.27
Total sugars (%)	50.18	48.54	49.40	51.27
Reducing sugars (%)	9.76	10.45	9.13	8.19
Titrateable acidity (as % citric acid)	1.26	0.58	0.97	0.45
Ascorbic acid (mg/ 100 g)	33.85	33.25	30.14	45.78
Pigment content (mg/ 100 g) (Anthocyanins/ Total carotenoids)	1378.16	28.38	1321.46	22.13
Total phenolics (mg GAE/ 100 g)	2490.17	236.26	2402.13	181.32
Antioxidant activity (% free radical scavenging activity)	75.34	29.34	66.18	42.26
Non-enzymatic browning	0.092	0.087	0.079	0.078
Colour	8.32	8.05	8.00	8.12
Body	7.60	7.97	8.20	8.15
Flavour	7.63	8.09	8.12	7.96
Overall acceptability	7.89	8.00	7.96	8.03

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.26 depicts chemical and sensory characteristics of optimized carrot juice concentrates (black, orange, purple and red) at 0 day. The concentrate was further utilized for quality evaluation during storage.

4.3 PACKAGING AND STORAGE OF CARROT JUICE CONCENTRATE (BLACK, ORANGE, PURPLE AND RED)

The data regarding quality changes in carrot juice concentrate (black, orange, purple and red) after packing in glass vials (transparent and amber coloured, Plate 5) and storing for 6 months under ambient and refrigerated condition has been presented in Table 4.27 to Table 4.50.

4.3.1 Total soluble solids

Scrutiny of data presented in Table 4.27 indicates that there was an overall decrease in total soluble solids (TSS) of carrot juice concentrates stored at ambient temperature. There was a significant effect of packaging material (P) on the TSS of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (64.90°B) TSS than that of stored in transparent glass vials (64.64°B). The effect of

A.



B.



Plate. 5: Carrot Juice Concentrates (black, orange, purple and red)
(A. Transparent glass vials and B. Amber coloured glass vials)

storage interval (S) reveals that the TSS of carrot juice concentrates decreased significantly from 65.19 to 64.44°B. The TSS of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value of TSS was observed in red carrot juice concentrate (65.93°B), while, the lowest was observed in orange carrot juice concentrate (63.41°B). The combined effect of storage interval and packaging materials (S×P) on TSS of carrot juice concentrate was found to be significant during storage. The TSS of carrot juice concentrate decreased from 65.19 to 64.26°B and 64.63°B when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (66.02°B) TSS was observed in red carrot juice stored in amber coloured glass vials and lowest (63.16°B) in orange carrot juice concentrate stored in transparent glass vials at the end of storage. The overall effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in TSS of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant.

Table 4.27 Effect of packaging and storage on total soluble solids (°B) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P S T	Transparent glass vials			Mean	Amber coloured glass vials			Mean
	Months				Months			
	0	3	6		0	3	6	
T ₁	65.88	65.32	64.85	65.35	65.88	65.54	65.21	65.54
T ₂	63.96	63.47	63.04	63.16	63.96	63.60	63.42	63.66
T ₃	64.64	64.28	63.73	64.22	64.64	64.41	64.10	64.38
T ₄	66.27	65.83	65.42	65.84	66.27	66.02	65.77	66.02
Mean	65.19	64.48	64.26		65.19	64.89	64.63	
Mean (P)	64.64				64.90			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.05	
					Storage interval (S)		0.06	
T ₁	65.88	65.43	65.03	65.45	Treatment (T)		0.06	
T ₂	63.96	63.04	63.23	63.41	S × P		0.08	
T ₃	64.64	64.35	63.92	64.30	T × P		0.09	
T ₄	66.27	65.93	65.60	65.93	T × S		0.11	
Mean (S)	65.19	64.68	64.44		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.28 shows the TSS of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage at refrigerated conditions. Highest value of TSS was observed in red carrot juice concentrate (66.14°B), while, the lowest was observed in purple carrot juice concentrate (62.83°B). The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. A general decrease in total soluble solids of carrot juice concentrates during storage might be due to the increase in the moisture content resulted due to release of water during non-enzymatic browning reactions in the product (Miranda *et al.* 2014). Similar trends have been reported by Pragma (2018) in carrot juice concentrate.

Table 4.28 Effect of packaging and storage on total soluble solids (°B) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	65.88	65.70	65.54	65.71	65.88	65.75	65.66	65.76
T ₂	63.96	63.81	63.62	63.80	63.96	63.79	63.69	63.81
T ₃	64.64	64.49	64.31	61.15	64.64	64.47	64.44	64.52
T ₄	66.27	66.13	65.94	66.11	66.27	66.18	66.02	66.16
Mean	65.19	62.53	64.85		65.19	65.05	64.95	
Mean (P)	64.19				65.06			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		NS	
T ₁	65.88	65.73	65.60	65.74	Treatment (T)		2.38	
T ₂	63.96	63.80	63.65	63.81	S × P		NS	
T ₃	64.64	59.48	64.38	62.83	T × P		NS	
T ₄	66.27	66.15	65.98	66.14	T × S		NS	
Mean (S)	65.19	63.79	64.90		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.2. Total sugars

Data appended in Table 4.29 reveal that there was an overall decrease in total sugars content of carrot juice concentrates stored at ambient temperature. There was a significant effect of packaging material (P) on the total sugars content of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (48.54%) total sugars content than that of stored in transparent glass vials (47.09%). The effect

of storage interval (S) reveals that the total sugars content of carrot juice concentrates decreased significantly from 49.85 to 46.25 per cent. The total sugars content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of total sugars was observed in red carrot juice concentrate (49.67%), while, the lowest was observed in purple carrot juice concentrate (46.19%). The combined effect of storage interval and packaging materials (S×P) on total sugars content of carrot juice concentrate was found to be significant. The total sugars content of carrot juice concentrate decreased from 49.85 to 45.07 per cent and 47.44 per cent when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (50.08%) total sugars were observed in red carrot juice stored in amber coloured glass vials and lowest (44.33%) in purple carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in total sugars content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be significant.

Table 4.29 Effect of packaging and storage on total sugars (%) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	50.18	47.91	46.06	48.05	50.18	48.38	47.23	48.60
T ₂	48.54	46.32	45.29	46.72	48.54	47.23	46.54	47.44
T ₃	49.40	42.41	41.18	44.33	49.40	47.83	46.94	48.06
T ₄	51.27	48.76	47.74	49.26	51.27	49.92	49.05	50.08
Mean	49.85	46.35	45.07		49.85	48.34	47.44	
Mean (P)	47.09				48.54			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.04	
					Storage interval (S)		0.05	
T ₁	50.18	48.15	46.65	48.32	Treatment (T)		0.06	
T ₂	48.54	46.78	45.92	47.08	S × P		0.07	
T ₃	49.40	45.12	44.06	46.19	T × P		0.09	
T ₄	51.27	49.34	48.40	49.67	T × S		0.11	
Mean (S)	49.85	47.35	46.25		P × S × T		0.15	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.30 shows an overall decrease in total sugars content of carrot juice concentrates stored at refrigerated temperature. There was a significant effect of packaging material (P) on the TSS of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (49.60%) total sugars content than that of stored in transparent glass vials (49.40%). The effect of storage interval (S) reveals that the total sugars content of carrot juice concentrates decreased significantly from 49.85 to 49.25 per cent. The total sugars content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of total sugars was observed in red carrot juice concentrate (50.93%), while, the lowest was observed in orange carrot juice concentrate (48.16%).

Table 4.30 Effect of packaging and storage on total sugars (%) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	50.18	49.61	49.42	49.74	50.18	49.85	49.76	49.93
T ₂	48.54	47.92	47.69	48.05	48.54	48.20	48.08	48.27
T ₃	49.40	48.85	48.68	48.98	49.40	49.13	49.01	49.18
T ₄	51.27	50.74	50.54	50.85	51.27	50.93	50.85	51.02
Mean	49.85	49.28	49.08		49.84	49.53	49.43	
Mean (P)	49.40				49.60			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.04	
					Storage interval (S)		0.05	
T ₁	50.18	49.73	49.59	49.83	Treatment (T)		0.06	
T ₂	48.54	48.06	47.89	48.16	S × P		0.07	
T ₃	49.40	48.99	48.85	49.08	T × P		NS	
T ₄	51.27	50.84	50.70	50.93	T × S		NS	
Mean (S)	49.85	49.40	49.25		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

The combined effect of storage interval and packaging materials (S×P) on total sugars content of carrot juice concentrate was found to be significant. The total sugars content of carrot juice concentrate decreased from 49.85 to 49.08 per cent and 49.43 per cent when stored in transparent and amber coloured glass vials, respectively. However, combined effects of treatments and packaging material (T×P) and treatments and storage interval (T×S) were found

to be non-significant. An overall decrease was observed in total sugars content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant. Total sugars of the carrot juice concentrate decreased significantly during storage period of 6 months. Total sugars get utilized in reaction of aldehydes and ketones with amino compounds and protein. This reaction is independent of the presence of oxygen. Further, caramelization and oxidative changes of polycarbonyl compound might result in decrease in total sugars content (Meyer, 1978). The results were in accordance with Kumar (2018).

4.3.3 Reducing sugars

An appraisal of data (Table 4.31) shows changes in reducing sugars of carrot juice concentrates stored at ambient temperature. There was a significant effect of packaging material (P) on the reducing sugar content of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in transparent glass vials had higher (10.69%) reducing sugars content than that of stored in amber coloured glass vials (10.25%).

Table 4.31 Effect of packaging and storage on reducing sugars (%) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P S T	Transparent glass vials			Mean	Amber coloured glass vials			Mean
	Months				Months			
	0	3	6		0	3	6	
T ₁	9.76	11.08	11.83	10.89	9.76	10.55	11.23	10.51
T ₂	10.45	11.87	12.52	11.61	10.45	11.27	11.74	11.15
T ₃	9.13	10.46	11.16	10.25	9.13	9.90	10.38	9.80
T ₄	8.91	10.28	10.87	10.02	8.91	9.51	10.19	9.54
Mean	9.56	10.92	11.60		9.56	10.31	10.89	
Mean (P)	10.69				10.25			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.05	
					Storage interval (S)		0.06	
T ₁	9.76	10.82	11.53	10.70	Treatment (T)		0.07	
T ₂	10.45	11.57	12.13	11.38	S × P		0.08	
T ₃	9.13	10.18	10.77	10.03	T × P		NS	
T ₄	8.91	9.90	10.53	9.78	T × S		NS	
Mean (S)	9.56	10.62	11.24		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

The effect of storage interval (S) reveals that the reducing sugars content of carrot juice concentrates increased significantly from 9.56 to 11.24 per cent. The reducing sugar content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value of reducing sugars was observed in orange carrot juice concentrate (11.38%), while, the lowest was observed in red carrot juice concentrate (9.78%). The combined effect of storage interval and packaging materials (S×P) on reducing sugars content of carrot juice concentrate was found to be significant. The reducing sugar content of carrot juice concentrate increased from 9.56 to 11.60 and 10.89 per cent when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) was not significant. The combined effect of treatments and storage interval (T×S) was not found to be significant. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant.

Table 4.32 shows changes in reducing sugars content of carrot juice concentrates stored at refrigerated temperature. The effect of storage interval (S) reveals that the reducing sugar content of carrot juice concentrates increased significantly from 9.56 to 9.99 per cent.

Table 4.32 Effect of packaging and storage on reducing sugars (%) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	9.76	10.25	10.63	10.21	9.76	10.05	10.22	10.01
T ₂	10.45	10.92	11.14	10.84	10.45	10.70	10.86	10.67
T ₃	9.13	9.59	9.89	9.54	9.13	9.34	9.47	9.31
T ₄	8.91	8.73	9.06	8.90	8.91	8.44	8.63	8.66
Mean	9.56	9.87	10.18		9.56	9.63	9.80	
Mean (P)	9.87				9.66			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.05	
T ₁	9.76	10.15	10.43	10.11	Treatment (T)		0.06	
T ₂	10.45	10.81	11.00	10.75	S × P		NS	
T ₃	9.13	9.47	9.68	9.43	T × P		NS	
T ₄	8.91	8.59	8.85	8.78	T × S		0.11	
Mean (S)	9.56	9.75	9.99		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

The reducing sugar content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value of reducing sugars was observed in orange carrot juice concentrate (10.75%), while, the lowest was observed in red carrot juice concentrate (8.78%). The combined effect of storage interval and packaging materials (T×S) on reducing sugar content of carrot juice concentrate was found to be significant during storage at refrigerated conditions. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. The increase in reducing sugars might be attributed to inversion of non-reducing sugars to reducing sugars under acidic conditions (Aruna *et al.*, 1997). Similar findings were also reported by Rubina *et al.* (2018) in carrot.

4.3.4 Titratable acidity

As depicted in Table 4.33, effect of storage interval (S) reveals that the titratable acidity of carrot juice concentrates decreased significantly from 0.82 to 0.56 per cent when stored at ambient conditions. The titratable acidity of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value was observed in black carrot juice concentrate (1.13%), while, the lowest was observed in red carrot juice concentrate (0.33%). However, combined effect of packaging material, storage interval and treatments were found to be non-significant. Scrutiny of data presented in Table 4.34, effect of storage interval (S) reveals that the titratable acidity of carrot juice concentrates decreased significantly from 0.82 to 0.72 per cent when stored at refrigerated conditions. The titratable acidity of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value was observed in black carrot juice concentrate (1.21%), while, the lowest was observed in red carrot juice concentrate (0.40%). However, combined effect of packaging material, storage interval and treatments were found to be non-significant. During storage, significant loss in the titratable acidity of carrot juice concentrates (black, orange, purple and red) was recorded. The loss of acid content during storage might be due to their participation in the chemical reactions with sugars and amino acids for the formation of non-enzymatic browning products as well as their utilization in the inversion of non-reducing sugars to reducing sugars. Yahya *et al.* (2019) also observed a similar trend in their results.

Table 4.33 Effect of packaging and storage on titratable acidity (as % citric acid) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	1.26	1.10	0.98	1.11	1.26	1.13	1.04	1.14
T ₂	0.58	0.40	0.31	0.43	0.58	0.46	0.35	0.46
T ₃	0.97	0.76	0.59	0.77	0.97	0.83	0.72	0.84
T ₄	0.45	0.29	0.18	0.31	0.45	0.34	0.27	0.35
Mean	0.82	0.64	0.52		0.82	0.69	0.60	
Mean (P)	0.66				0.70			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.06	
T ₁	1.26	1.12	1.01	1.13	Treatment (T)		0.06	
T ₂	0.58	0.43	0.33	0.45	S × P		NS	
T ₃	0.97	0.80	0.66	0.81	T × P		NS	
T ₄	0.45	0.32	0.23	0.33	T × S		NS	
Mean (S)	0.82	0.66	0.56		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.34 Effect of packaging and storage on titratable acidity (as % citric acid) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	1.26	1.20	1.14	1.20	1.26	1.22	1.19	1.22
T ₂	0.58	0.49	0.46	0.51	0.58	0.53	0.49	0.53
T ₃	0.97	0.90	0.85	0.91	0.97	0.94	0.91	0.94
T ₄	0.45	0.37	0.33	0.38	0.45	0.43	0.39	0.42
Mean	0.82	0.74	0.70		0.82	0.78	0.75	
Mean (P)	0.75				0.78			
T × S interaction Table					CD _(0.05)			
S	0	3	6	Mean (T)	Packaging material (P)			NS
T					Storage interval (S)			0.05
T ₁	1.26	1.21	1.17	1.21	Treatment (T)			0.06
T ₂	0.58	0.51	0.48	0.52	S × P			NS
T ₃	0.97	0.92	0.88	0.92	T × P			NS
T ₄	0.45	0.40	0.36	0.40	T × S			NS
Mean (S)	0.82	0.76	0.72		P × S × T			NS
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.5 Ascorbic acid

Data exhibited in Table 4.35 show that there was a significant effect of packaging material (P) on the ascorbic acid content of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (31.81 mg/ 100 g) ascorbic acid content than that of stored in transparent glass vials (30.01 mg/ 100 g). The effect of storage interval (S) reveals that the ascorbic acid content of carrot juice concentrates decreased significantly from 35.87 to 25.88 mg/ 100 g. The ascorbic acid content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value of ascorbic acid was observed in red carrot juice concentrate (40.73 mg/ 100 g), while, the lowest was observed in purple carrot juice concentrate (25.20 mg/ 100 g). The combined effect of storage interval and packaging materials (S×P) on ascorbic acid content of carrot juice concentrate was found to be significant. The ascorbic acid content of carrot juice concentrate decreased from 35.75 to 23.74 and 28.02 mg/ 100 g when stored in transparent and amber coloured glass vials, respectively.

Table 4.35 Effect of packaging and storage on ascorbic acid (mg/ 100 g) of carrot juice concentrates (black, orange, purple and red) under ambient temperature

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	33.85	28.78	21.15	27.93	33.85	29.76	26.02	29.86
T ₂	33.25	28.13	20.67	27.35	33.25	29.26	25.87	29.46
T ₃	30.14	24.43	18.85	24.81	30.14	25.97	22.18	26.10
T ₄	45.78	39.76	34.27	39.94	45.78	41.69	38.01	41.83
Mean	35.75	30.28	23.74		35.75	31.67	28.02	
Mean (P)	30.01				31.81			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.18	
					Storage interval (S)		0.22	
T ₁	33.82	29.27	23.59	28.89	Treatment (T)		0.25	
T ₂	33.25	28.70	23.27	28.70	S × P		0.31	
T ₃	30.64	25.20	20.52	25.20	T × P		0.36	
T ₄	45.78	40.73	36.14	40.73	T × S		0.44	
Mean (S)	35.87	30.97	25.88		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

However, combined effect of treatments and packaging material (T×P) depicts that highest (41.83 mg/ 100 g) ascorbic acid content was observed in red carrot juice stored in amber coloured glass vials and lowest (24.81 mg/ 100 g) in purple carrot juice concentrate stored in transparent glass vials at the end of storage period. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in ascorbic acid content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant.

Table 4.36 shows that there was a significant effect of packaging material (P) on the ascorbic acid content of carrot juice concentrate during storage at refrigerated conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (34.21 mg/ 100 g) ascorbic acid content than that of stored in transparent glass vials (33.79 mg/ 100 g). The effect of storage interval (S) reveals that the ascorbic acid content of carrot juice concentrates decreased significantly from 35.76 mg/ 100 g to 32.34 mg/ 100 g. The ascorbic acid content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage period. Highest value of ascorbic acid was observed in red carrot juice concentrate (43.93 mg/ 100 g), while, the lowest was observed in purple carrot juice concentrate (28.38 mg/ 100 g). The combined effect of storage interval and packaging materials (S×P) on ascorbic acid content of carrot juice concentrate was found to be significant during storage. The ascorbic acid content of carrot juice concentrate decreased from 35.76 to 31.95 and 32.74 mg/ 100 g when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (44.16 mg/ 100 g) ascorbic acid content was observed in red carrot juice stored in amber coloured glass vials and lowest (28.24 mg/ 100 g) in purple carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in ascorbic acid content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. Ascorbic acid degradation is common during aerobic as well as anaerobic storage. However, rate of aerobic degradation is 100 to 1000 times faster than anaerobic conditions (Fox *et al.*, 1983). In the beginning of storage,

aerobic degradation was observed due to the presence of oxygen, but after some time packaging environment becomes saturated with vapors and oxygen deficient which induces anaerobic degradation (Blasco *et al.*, 2004). Further, it is light as well as heat sensitive and follows first order kinetics thus affected by storage condition and period (Heldman and Singh, 1981). The ascorbic acid might be oxidized to dehydro-ascorbic acid under aerobic conditions, followed by hydrolysis and further oxidation into furfural (Gregory, 1996). The results were in conformity with Bala (1999).

Table 4.36 Effect of packaging and storage on ascorbic acid (mg/ 100 g) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	33.85	31.76	30.07	31.89	33.85	32.45	31.23	32.51
T ₂	33.25	31.18	29.50	31.31	33.25	31.54	30.14	31.64
T ₃	30.14	28.05	26.54	28.24	30.14	28.42	26.98	28.51
T ₄	45.78	43.65	41.67	43.70	45.78	44.11	42.60	44.16
Mean	35.76	33.66	31.95		35.76	34.13	32.74	
Mean (P)	33.79				34.21			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.05	
					Storage interval (S)		0.06	
T ₁	33.85	32.11	30.65	32.20	Treatment (T)		0.07	
T ₂	33.25	31.36	29.82	31.48	S × P		0.08	
T ₃	30.14	28.24	26.76	28.38	T × P		0.10	
T ₄	45.78	43.88	42.14	43.93	T × S		0.12	
Mean (S)	35.76	33.90	32.34		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.6 Pigment content (Anthocyanins/ Total carotenoids)

Table 4.37 shows that there was a significant effect of packaging material (P) on the pigment content of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (683.98 mg/ 100 g) pigment content than that of stored in transparent glass vials (682.33 mg/ 100 g). The effect of storage interval (S) reveals that the pigments content of carrot juice concentrates decreased significantly from 687.53 to 683.50 mg/ 100 g. The pigment content of carrot juice concentrates prepared from different

types of carrot (T) was significantly different at the end of storage period. Highest value of pigment content was observed in black carrot juice concentrate (1375.05 mg/ 100 g), while, the lowest was observed in red carrot juice concentrate (21.22 mg/ 100 g). The combined effect of storage interval and packaging materials (S×P) on pigment content of carrot juice concentrate was found to be significant. The pigment content of carrot juice concentrate decreased from 687.53 to 678.29 and 681.23 mg/ 100 g when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (1373.47 mg/ 100 g) pigment content was observed in black carrot juice stored in amber coloured glass vials and lowest (18.37 mg/ 100 g) in red carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in pigment content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be significant.

Table 4.38 shows that there was a significant effect of packaging material (P) on the pigment content of carrot juice concentrate during storage at refrigerated conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (685.76 mg/ 100 g) pigment content than that of stored in transparent glass vials (685.00 mg/ 100 g). The effect of storage interval (S) reveals that the pigment content of carrot juice concentrates decreased significantly from 687.53 to 683.50 mg/ 100 g. The pigment content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of pigment content was observed in black carrot juice concentrate (1375.05 mg/ 100 g), while, the lowest was observed in red carrot juice concentrate (21.22 mg/ 100 g). The combined effect of storage interval and packaging materials (S×P) on pigment content of carrot juice concentrate was found to be significant during storage. The pigment content of carrot juice concentrate decreased from 687.53 to 682.86 and 684.14 mg/ 100 g when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (1375.50 mg/ 100 g) pigment content was observed in black carrot juice stored in amber coloured glass vials and lowest (20.89 mg/ 100 g) in red carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was

observed in pigment content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be significant. Product stored under refrigerated condition retained more pigments as a result of slower rate of oxidation reaction under low temperature conditions. Muche *et al.* (2018) observed degradation of anthocyanins along with polymeric colour accumulation, brown colour development and haze formation. Polymerization reactions could be due to endogenous enzymes including residual peroxidase activity and residual polyphenol oxidase activity that were not inactivated entirely by pasteurization process. Further, high temperature could trigger this reaction. Another potential mechanism for polymerization could be condensation reactions of anthocyanins with other phenolic compounds such as tannins. Similarly, double bond in carbon chain makes carotenoids susceptible for oxidation and isomerization during food processing and storage. The process gets accelerated in the presence of light, heat, acid and oxygen thus cause loss of colour and biological activity of carotenoids (Rodriguez-Amaya, 1999; Rao and Rao, 2007). Similar trends were reported by Pragya (2018) in black carrot juice concentrate.

Table 4.37 Effect of packaging and storage on pigment content (anthocyanins/ total carotenoids mg/ 100 g) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	1378.16	1369.66	1365.32	1371.05	1378.16	1372.46	1369.80	1373.47
T ₂	28.38	23.47	21.69	24.51	28.38	26.39	24.72	26.49
T ₃	1321.46	1313.98	1310.74	1315.39	1321.46	1315.07	1313.56	1316.69
T ₄	22.13	17.56	15.41	18.37	22.13	18.78	16.85	19.25
Mean	687.53	681.17	678.29		687.53	683.18	681.23	
Mean (P)	682.33				683.98			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.05	
					Storage interval (S)		0.08	
T ₁	1378.16	1374.79	1372.19	1375.05	Treatment (T)		1.25	
T ₂	28.38	27.43	26.67	27.49	S × P		1.12	
T ₃	1321.46	1316.89	1314.92	1317.76	T × P		0.29	
T ₄	22.13	21.33	20.21	21.22	T × S		NS	
Mean (S)	687.53	685.11	683.50		P × S × T		0.25	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.38 Effect of packaging and storage on pigment content (anthocyanins/ total carotenoids mg/ 100 g) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	1378.16	1374.15	1371.46	1374.59	1378.16	1375.43	1372.92	1375.50
T ₂	28.38	27.10	26.34	27.27	28.38	27.75	27.00	27.71
T ₃	1321.46	1316.23	1314.05	1317.25	1321.46	1317.54	1315.79	1318.26
T ₄	22.13	20.97	19.57	20.89	22.13	21.68	20.84	21.55
Mean	687.53	684.61	682.86		687.53	685.60	684.14	
Mean (P)	685.00				685.76			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.07	
					Storage interval (S)		0.09	
T ₁	1378.16	1374.79	1372.19	1375.05	Treatment (T)		0.10	
T ₂	28.38	27.43	26.67	27.49	S × P		0.12	
T ₃	1321.46	1316.89	1314.92	1317.76	T × P		0.14	
T ₄	22.13	21.33	20.21	21.22	T × S		0.18	
Mean (S)	687.53	685.11	683.50		P × S × T		0.25	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.7 Total phenolics

The data in Table 4.39 show that there was a significant effect of packaging material (P) on the total phenolic content of carrot juice concentrate during storage at ambient conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (1274.95 mg GAE/ 100 g) total phenolic content than that of stored in transparent glass vials (1237.22 mg GAE / 100 g). The effect of storage interval (S) reveals that the total phenolic content of carrot juice concentrates decreased significantly from 1327.47 to 1280.82 mg GAE / 100 g. The total phenolic content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of total phenolic was observed in black carrot juice concentrate (2433.24 mg GAE / 100 g), while, the lowest was observed in red carrot juice concentrate (174.17 mg GAE / 100 g). The combined effect of storage interval and packaging materials (S×P) on total phenolic content of carrot juice concentrate was found to be significant during storage. The total phenolic content of carrot juice concentrate decreased from 1327.47 to 1153.15 and 1221.99 mg GAE / 100 g when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P)

depicts that highest (2390.32 mg GAE / 100 g) total phenolic content was observed in black carrot juice stored in amber coloured glass vials and lowest (164.91 mg GAE / 100 g) in red carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in total phenolic content of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non- significant.

Table 4.39 Effect of packaging and storage on total phenolics (mg GAE/ 100 g) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	2490.17	2302.93	2148.40	2313.83	2490.17	2386.26	2294.53	2390.32
T ₂	236.26	216.39	201.31	217.99	236.26	224.87	217.47	226.20
T ₃	2402.13	2241.46	2112.83	2252.14	2402.13	2319.45	2221.34	2314.31
T ₄	181.32	163.34	150.08	164.91	181.32	170.93	154.65	168.967
Mean	1327.47	1231.03	1153.16		1327.47	1275.38	1221.99	
Mean (P)	1237.22				1274.95			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.98	
					Storage interval (S)		1.01	
T ₁	2490.17	2414.12	2395.45	2433.24	Treatment (T)		1.34	
T ₂	236.26	229.66	224.59	230.17	S × P		0.76	
T ₃	2402.13	2378.87	2337.21	2372.73	T × P		0.88	
T ₄	181.32	175.15	166.04	174.17	T × S		0.11	
Mean (S)	1327.47	1299.45	1280.82		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.40 shows that there was a significant effect of packaging material (P) on the total phenolics of carrot juice concentrate during storage at refrigerated conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (1306.51 mg GAE / 100 g) total phenolics than that of stored in transparent glass vials (1298.65 mg GAE / 100 g). The effect of storage interval (S) reveals that the total phenolic content of carrot juice concentrates decreased significantly from 1327.47 to 1280.82 mg GAE / 100 g. The total phenolic content of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of total phenolics was observed in black carrot juice concentrate (2433.24 mg GAE / 100 g), while, the lowest was observed in red carrot juice concentrate (174.17 mg

GAE / 100 g). The combined effect of storage interval and packaging materials (S×P) on total phenolics of carrot juice concentrate was found to be significant during storage. The total phenolics of carrot juice concentrate decreased from 1327.47 to 1272.80 mg GAE / 100 g and 1288.84 mg/ 100 g when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material (T×P) depicts that highest (2438.02 mg GAE / 100 g) total phenolics were observed in black carrot juice stored in amber coloured glass vials and lowest (172.55 mg GAE / 100 g) in red carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval (T×S) was found to be significant. An overall decrease was observed in total phenolics of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be significant. Total phenolics of carrot juice concentrate decreased significantly during storage which might be due to oxidation and hydrolytic degradation of bioactive compounds including phenols (Kotsiou and Tasioula-Margari, 2016). Major degradation of polyphenols can take place even at lower temperatures due to polymerization reactions induced with light (Qu *et al.*, 2012). Similar results were observed by Adiamo *et al.* (2018).

Table 4.40 Effect of packaging and storage on total phenolics (mg GAE/ 100 g) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	2490.17	2406.89	2388.34	2428.47	2490.17	2421.34	2402.55	2438.02
T ₂	236.26	227.64	221.78	228.56	236.26	231.67	227.39	231.77
T ₃	2402.13	2375.28	2317.63	2365.01	2402.13	2382.45	2346.78	2380.45
T ₄	181.32	172.87	163.46	172.55	181.32	177.43	168.62	175.79
Mean	1327.47	1295.67	1272.80		1327.47	1303.22	1288.84	
Mean (P)	1298.65				1306.51			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		1.68	
					Storage interval (S)		2.06	
T ₁	2490.17	2414.12	2395.45	2433.24	Treatment (T)		2.38	
T ₂	236.26	229.66	224.59	230.17	S × P		2.91	
T ₃	2402.13	2378.87	2337.21	2372.73	T × P		3.36	
T ₄	181.32	175.15	166.04	174.17	T × S		4.12	
Mean (S)	1327.47	1299.45	1280.82		P × S × T		5.83	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.8 Antioxidant activity

Data in Table 4.41 elucidate that there was an overall decrease in antioxidant activity of carrot juice concentrate when stored at ambient conditions. There was a significant effect of packaging material (P) on the antioxidant activity of carrot juice concentrate during storage at refrigerated conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (51.95%) antioxidant activity than that of stored in transparent glass vials (51.51%). The effect of storage interval (S) reveals that the antioxidant activity of carrot juice concentrates decreased significantly from 53.28 to 50.26 per cent. The antioxidant activity of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of antioxidant activity was observed in black carrot juice concentrate (73.79%), while, the lowest was observed in orange carrot juice concentrate (28.17%). The combined effect of storage interval and packaging materials (S×P) on antioxidant activity of carrot juice concentrate was found to be significant during storage. The antioxidant activity of carrot juice concentrate decreased from 53.28 to 49.96 and 50.56 per cent when stored in transparent and amber coloured glass vials, respectively.

Table 4.41 Effect of packaging and storage on antioxidant activity (% free radical scavenging activity) of carrot juice concentrates (black, orange, purple and red) under ambient condition

P S T	Transparent glass vials			Mean	Amber coloured glass vials			Mean
	Months				Months			
	0	3	6		0	3	6	
T ₁	75.34	72.96	71.72	73.34	75.34	74.54	72.86	74.25
T ₂	29.34	27.84	26.98	28.05	29.34	28.10	27.43	28.29
T ₃	66.18	64.00	62.47	64.22	66.18	64.58	62.90	64.55
T ₄	42.26	40.32	38.65	40.41	42.26	40.85	39.04	40.72
Mean	53.28	51.28	49.96		53.28	52.02	50.56	
Mean (P)	51.51				51.95			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.04	
					Storage interval (S)		0.05	
T ₁	75.34	73.75	72.29	73.79	Treatment (T)		0.06	
T ₂	29.34	27.97	27.21	28.17	S × P		0.07	
T ₃	66.18	64.29	62.69	64.39	T × P		0.08	
T ₄	42.26	40.59	38.85	40.56	T × S		0.10	
Mean (S)	53.28	51.65	50.26		P × S × T		0.14	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

However, combined effect of treatments and packaging material ($T \times P$) depicts that highest (74.25%) antioxidant activity was observed in black carrot juice stored in amber coloured glass vials and lowest (28.05%) in orange carrot juice concentrate stored in transparent glass vials at the end of storage. The combined effect of treatments and storage interval ($T \times S$) was found to be significant. An overall decrease was observed in antioxidant activity of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be significant.

An appraisal of data in Table 4.42 reveals the changes in antioxidant activity of carrot juice concentrate under refrigerated conditions. There was a significant effect of packaging material (P) on the antioxidant activity of carrot juice concentrate during storage at refrigerated conditions. The carrot juice concentrates stored in amber coloured glass vials had higher (53.03%) antioxidant activity than that of stored in transparent glass vials (52.95%). The effect of storage interval (S) reveals that the antioxidant activity of carrot juice concentrates decreased significantly from 53.28 to 52.74 per cent. The antioxidant activity of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value of antioxidant activity was observed in black carrot juice concentrate (75.10%) while, the lowest was observed in orange carrot juice concentrate (29.05%). The combined effect of storage interval and packaging materials ($S \times P$) on antioxidant activity of carrot juice concentrate was found to be significant during storage. The antioxidant activity of carrot juice concentrate decreased from 53.28 to 52.68 and 52.79 per cent when stored in transparent and amber coloured glass vials, respectively. However, combined effect of treatments and packaging material ($T \times P$) was non-significant. The combined effect of treatments and storage interval ($T \times S$) was found to be significant. An overall decrease was observed in antioxidant activity of all types of carrot juice concentrates during the storage period. The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant. During storage period of 6 months antioxidant activity of carrot juice concentrate decreased significantly which might be due to degradation of its chemical compounds like ascorbic acid, total phenolics, anthocyanins and total carotenoids along with non-enzymatic browning reaction. Ulusoy and Tamer (2019) have also observed same trends in black carrot juice concentrates.

Table 4.42 Effect of packaging and storage on antioxidant activity (% free radical scavenging activity) of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	75.34	75.02	74.85	75.07	75.34	75.12	74.91	75.12
T ₂	29.34	28.96	28.72	29.01	29.34	29.07	28.88	29.10
T ₃	66.18	65.80	65.67	65.88	66.18	65.88	65.70	65.92
T ₄	42.26	41.73	41.48	41.82	42.26	41.95	41.67	41.96
Mean	53.28	52.88	52.68		53.28	53.01	52.79	
Mean (P)	52.95				53.03			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.04	
					Storage interval (S)		0.05	
T ₁	75.34	75.07	74.88	75.10	Treatment (T)		0.06	
T ₂	29.34	29.02	28.80	29.05	S × P		0.07	
T ₃	66.18	65.84	65.69	65.90	T × P		NS	
T ₄	42.26	41.84	41.58	41.89	T × S		0.10	
Mean (S)	53.28	52.94	52.74		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

4.3.9 Non-enzymatic browning

Critical look of data in Table 4.43 shows changes in non-enzymatic browning of carrot juice concentrates stored at ambient temperature. The effect of storage interval (S) reveals that the values for non-enzymatic browning of carrot juice concentrates were same in both transparent and amber coloured glass vials. The non-enzymatic browning of carrot juice concentrates prepared from different types of carrot (T) was significantly different at the end of storage. Highest value for NEB was observed in black carrot juice concentrate (0.10), while, the lowest was observed in purple and red carrot juice concentrates (0.08). The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. Table 4.44 shows changes in non-enzymatic browning of carrot juice concentrates stored at refrigerated conditions. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for NEB was observed in black and orange carrot juice concentrates (0.09), while, the lowest was observed in purple and red carrot juice concentrates (0.08).

Table 4.43 Effect of packaging and storage on non-enzymatic browning of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	0.092	0.097	0.103	0.10	0.092	0.096	0.098	0.10
T ₂	0.087	0.090	0.094	0.09	0.087	0.089	0.091	0.09
T ₃	0.079	0.085	0.089	0.08	0.079	0.082	0.087	0.08
T ₄	0.078	0.084	0.090	0.08	0.078	0.083	0.087	0.08
Mean	0.08	0.09	0.09		0.08	0.09	0.09	
Mean (P)	0.09				0.09			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.01	
T ₁	0.09	0.10	0.10	0.10	Treatment (T)		0.01	
T ₂	0.09	0.09	0.09	0.09	S × P		NS	
T ₃	0.08	0.08	0.09	0.08	T × P		NS	
T ₄	0.08	0.08	0.09	0.08	T × S		NS	
Mean (S)	0.08	0.09	0.09		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

Table 4.44 Effect of packaging and storage on non-enzymatic browning of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	0.092	0.094	0.095	0.09	0.092	0.093	0.094	0.09
T ₂	0.087	0.088	0.090	0.09	0.087	0.087	0.089	0.08
T ₃	0.079	0.080	0.081	0.08	0.079	0.081	0.080	0.08
T ₄	0.078	0.081	0.082	0.08	0.078	0.080	0.081	0.08
Mean	0.08	0.09	0.09		0.08	0.09	0.09	
Mean (P)	0.09				0.09			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		NS	
T ₁	0.09	0.09	0.10	0.09	Treatment (T)		0.01	
T ₂	0.09	0.09	0.09	0.09	S × P		NS	
T ₃	0.08	0.08	0.08	0.08	T × P		NS	
T ₄	0.08	0.08	0.08	0.08	T × S		NS	
Mean (S)	0.08	0.09	0.09		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant. Browning of fruit juice concentrates during storage was result of a non-enzymatic chemical reaction between amino acids and reducing sugars commonly known as Maillard reaction. Hydroxymethylfurfural (HMF), formed in the Maillard reaction and caramelization (pyrolysis of sugar) is the major product which cause browning of food (Arribas-Lorenzo and Morales, 2010). The formation of HMF is accelerated with storage temperature and time. Nie *et al.* (2013) had proposed temperature dependent three sugar-amino acid (glycine) models for Maillard reaction. The mechanism is completely temperature dependent and attributed to selective sugar types, pH and heating time. Similar results have been observed by Bhat *et al.* (2014).

4.3.10 Colour

Data presented in Table 4.45 show changes colour score of carrot juice concentrates stored at ambient conditions. The effect of packaging material on colour scores of carrot juice concentrates was significant when stored at ambient conditions. The colour score of carrot juice concentrate stored in amber coloured glass vials was higher (8.07) than transparent glass vials (8.05). The values of colour score decreased during to storage interval (S). The colour scores of carrot juice concentrate decreased from 8.12 to 7.10 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for colour score was observed in black carrot juice concentrates (8.24), while, the lowest was observed in orange carrot juice concentrates (7.10). The overall combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant. Table 4.46 shows changes in colour score of carrot juice concentrates stored at refrigerated conditions. The values of colour score decreased during to storage period (S). The colour scores of carrot juice concentrate decreased from 8.12 to 8.07 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for colour score was observed in black carrot juice concentrates (8.29), while, the lowest was observed in purple carrot juice concentrates (7.98). The overall combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant.

Table 4.45 Effect of packaging and storage on colour score of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	8.32	8.21	8.17	8.23	8.32	8.24	8.19	8.25
T ₂	8.05	7.98	7.92	7.98	8.05	8.00	7.95	8.00
T ₃	8.00	7.91	7.86	7.92	8.00	7.95	7.88	7.94
T ₄	8.12	8.03	7.98	8.04	8.12	8.06	8.02	8.07
Mean	8.12	8.03	7.98		8.12	8.06	8.01	
Mean (P)	8.05				8.07			
T × S interaction Table					CD _(0.05)			
S	0	3	6	Mean (T)	Packaging material (P)			0.02
T					Storage interval (S)			0.04
T ₁	8.32	8.23	8.18	8.24	Treatment (T)			0.02
T ₂	8.05	7.10	7.94	7.10	S × P			NS
T ₃	8.00	7.93	7.87	7.93	T × P			NS
T ₄	8.12	8.05	8.00	8.06	T × S			NS
Mean (S)	8.12	8.05	7.10		P × S × T			NS
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.46 Effect of packaging and storage on colour score of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	8.32	8.27	8.25	8.28	8.32	8.30	8.28	8.30
T ₂	8.05	8.02	7.98	8.02	8.05	8.03	8.02	8.03
T ₃	8.00	7.97	7.94	7.97	8.00	7.99	7.96	7.98
T ₄	8.12	8.08	8.05	8.08	8.12	8.10	8.07	8.10
Mean	8.12	8.09	8.06		8.12	8.11	8.08	
Mean (P)	8.09				8.10			
T × S interaction Table					CD _(0.05)			
S	0	3	6	Mean (T)	Packaging material (P)		NS	
T					Storage interval (S)		0.02	
T ₁	8.32	8.29	8.27	8.29	Treatment (T)		0.03	
T ₂	8.05	8.03	8.00	8.03	S × P		NS	
T ₃	8.00	7.98	7.95	7.98	T × P		NS	
T ₄	8.12	8.09	8.06	8.09	T × S		NS	
Mean (S)	8.12	8.10	8.07		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

The colour score of carrot juice concentrate exhibited significant decrease during storage which might be due to the loss of natural colour pigment as a result of which panelist gave lower score to the product as compared to initial scores. The decrease in colour score can be attributed due to the development of browning pigments. The non-enzymatic browning of carrot juice concentrate increased during storage which might be due to carbonyl-amino reactions such as reducing sugars with amino acids and oxidation reactions such as conversion of polyphenols into polycarbonyls (Bolin and Steele, 1987). Oikeh *et al.* (2016) also observed similar changes in colour score of citrus juice concentrate.

4.3.11 Body

The data in Table 4.47 show changes body score of carrot juice concentrates stored at ambient conditions. The values of body score decreased due to storage interval (S). The body scores of carrot juice concentrate decreased from 7.98 to 7.85 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage.

Table 4.47 Effect of packaging and storage on body score of carrot juice concentrates (black, orange, purple and red) under ambient condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	7.60	7.52	7.49	7.54	7.60	7.54	7.50	7.55
T ₂	7.97	7.88	7.83	7.89	7.97	7.90	7.86	7.91
T ₃	8.20	8.12	8.06	8.13	8.20	8.14	8.09	8.14
T ₄	8.15	8.07	7.98	8.07	8.15	8.10	8.00	8.08
Mean	7.98	7.90	7.84		7.98	7.92	7.86	
Mean (P)	7.91				7.92			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.02	
T ₁	7.60	7.53	7.50	7.54	Treatment (T)		0.02	
T ₂	7.97	7.89	7.85	7.90	S × P		NS	
T ₃	8.20	8.13	8.08	8.14	T × P		NS	
T ₄	8.15	8.09	7.99	8.08	T × S		NS	
Mean (S)	7.98	7.91	7.85		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Highest value for body score was observed in purple carrot juice concentrates (8.14), while, the lowest was observed in black carrot juice concentrates (7.54). The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant.

Table 4.48 shows changes body score of carrot juice concentrates stored at refrigerated conditions. The values of body score decreased due to storage interval (S). The body scores of carrot juice concentrate decreased from 7.98 to 7.93 during storage period. The body score values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for body score was observed in purple carrot juice concentrates (8.16), while, the lowest was observed in black carrot juice concentrates (7.57). The combined effect of Treatment (T) and packaging material (P) was found to be significant. Highest value (8.19) for body score was recorded in purple carrot juice concentrate stored in amber coloured glass vials and lowest (7.57) was observed in black carrot juice concentrate stored transparent glass vials. The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant.

Table 4.48 Effect of packaging and storage on body score of carrot juice concentrates (black, orange, purple and red) under refrigerated condition

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	7.60	7.57	7.53	7.57	7.60	7.57	7.55	7.57
T ₂	7.97	7.94	7.92	7.94	7.97	7.95	7.93	7.95
T ₃	8.20	8.17	8.15	8.17	8.20	8.19	8.17	8.19
T ₄	8.15	8.11	8.08	8.11	8.15	8.13	8.10	8.13
Mean	7.98	7.95	7.92		7.98	7.96	7.94	
Mean (P)	7.95				7.96			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.02	
T ₁	7.60	7.57	7.54	7.57	Treatment (T)		0.02	
T ₂	7.97	7.95	7.93	7.95	S × P		NS	
T ₃	8.20	8.18	8.16	8.16	T × P		0.03	
T ₄	8.15	8.12	8.09	8.09	T × S		NS	
Mean (S)	7.98	7.95	7.93		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.3.12 Flavour

The perusal of data in Table 4.49 shows changes flavour score of carrot juice concentrates stored at ambient conditions. The values of flavour score decreased due to storage interval (S). The flavour scores of carrot juice concentrate decreased from 7.95 to 7.79 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for flavour score was observed in purple carrot juice concentrates (8.03), while, the lowest was observed in black carrot juice concentrates (7.57). The combined effect of treatment (T) and packaging material (P) was found to be significant. Highest value (8.04) for body score was recorded in purple carrot juice concentrate stored in amber coloured glass vials and lowest (7.56) was observed in black carrot juice concentrate stored in transparent glass vials. The combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant.

Table 4.49 Effect of packaging and storage on flavour score of carrot juice concentrates (black, orange, purple and red) under ambient condition

P S T	Transparent glass vials			Mean	Amber coloured glass vials			Mean
	Months				Months			
	0	3	6		0	3	6	
T ₁	7.63	7.55	7.51	7.56	7.63	7.57	7.52	7.57
T ₂	8.09	7.93	7.88	7.97	8.09	7.96	7.90	7.98
T ₃	8.12	8.00	7.95	8.02	8.12	8.03	7.96	8.04
T ₄	7.96	7.85	7.80	7.87	7.96	7.87	7.83	7.89
Mean	7.95	7.83	7.79		7.95	7.86	7.80	
Mean (P)	7.86				7.87			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		NS	
					Storage interval (S)		0.02	
T ₁	7.63	7.56	7.52	7.57	Treatment (T)		0.02	
T ₂	8.09	7.95	7.89	7.98	S × P		NS	
T ₃	8.12	8.02	7.96	8.03	T × P		0.03	
T ₄	7.96	7.86	7.82	7.88	T × S		NS	
Mean (S)	7.95	7.85	7.79		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.50 shows changes flavour score of carrot juice concentrates stored at refrigerated conditions. The values of flavour score decreased due to storage interval (S). The flavour scores

of carrot juice concentrate decreased from 7.95 to 7.84 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for flavour score was observed in purple carrot juice concentrates (8.06), while, the lowest was observed in black carrot juice concentrates (7.60). The combined effect of Treatment (T) and packaging material (P) was found to be significant. Highest value (8.07) for flavour score was recorded in purple carrot juice concentrate stored in amber coloured glass vials and lowest (7.59) was observed in black carrot juice concentrate stored in transparent glass vials. The combined effect of treatment (T) and storage interval (S) was found to be significant. The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. The flavour score of carrot juice concentrate decreased significantly during storage which could be due to loss of various chemical constituents mainly responsible for the flavour of the product. The loss of sugar and acid blend might also be responsible for change in the flavour for the product as a result of which judges awarded the lower flavour score to the product as compare to the initial score.

Table 4.50 Effect of packaging and storage on flavour score of carrot juice concentrates (black, orange, purple and red) under refrigerated temperature

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	7.63	7.58	7.57	7.59	7.63	7.60	7.58	7.60
T ₂	8.09	8.00	7.95	8.01	8.09	8.01	7.94	8.01
T ₃	8.12	8.06	7.99	8.06	8.12	8.08	8.00	8.07
T ₄	7.96	7.90	7.86	7.91	7.96	7.91	7.86	7.91
Mean	7.95	7.89	7.84		7.95	7.90	7.85	
Mean (P)	7.89				7.90			
T × S interaction Table					CD _(0.05)			
S	0	3	6	Mean (T)	Packaging material (P)			NS
T					Storage interval (S)			0.02
T ₁	7.63	7.59	7.58	7.60	Treatment (T)			0.02
T ₂	8.09	8.01	7.95	8.01	S × P			NS
T ₃	8.12	8.07	7.10	8.06	T × P			0.03
T ₄	7.96	7.91	7.86	7.91	T × S			0.04
Mean (S)	7.95	7.89	7.84		P × S × T			NS
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Further, decrease in flavour score might also be attributing to formation of off flavor compounds in Maillard reaction and reversion reaction. The results were in accordance with Szaloki-Dorka *et al.* (2016).

4.3.13 Overall acceptability

The perusal of data in Table 4.51 shows changes overall acceptability scores of carrot juice concentrates stored at ambient conditions. The effect of packaging material on overall acceptability scores of carrot juice concentrates was significant when stored at ambient conditions. The overall acceptability score of carrot juice concentrate stored in amber coloured glass vials was higher (7.91) than transparent glass vials (7.89). The values of overall acceptability scores decreased due to storage interval (S). The overall acceptability scores of carrot juice concentrate decreased from 7.97 to 7.84 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for overall acceptability score was observed in red carrot juice concentrates (7.96), while, the lowest was observed in black carrot juice concentrates (7.81). The overall combined effect of packaging material, storage interval and treatments ($P \times S \times T$) was found to be non-significant.

Table 4.51 Effect of packaging and storage on overall acceptability score of carrot juice concentrates (black, orange, purple and red) under ambient temperature

P	Transparent glass vials			Mean	Amber coloured glass vials			Mean
S	Months				Months			
T	0	3	6		0	3	6	
T ₁	7.89	7.80	7.68	7.79	7.89	7.82	7.79	7.83
T ₂	8.00	7.91	7.87	7.93	8.00	7.95	7.90	7.95
T ₃	7.96	7.86	7.81	7.88	7.96	7.89	7.85	7.90
T ₄	8.03	7.93	7.90	7.95	8.03	7.96	7.92	7.97
Mean	7.97	7.88	7.82		7.97	7.91	7.87	
Mean (P)	7.89				7.91			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.02	
					Storage interval (S)		0.02	
T ₁	7.89	7.81	7.74	7.81	Treatment (T)		0.02	
T ₂	8.00	7.93	7.89	7.94	S × P		NS	
T ₃	7.96	7.88	7.83	7.89	T × P		NS	
T ₄	8.03	7.95	7.91	7.96	T × S		NS	
Mean (S)	7.97	7.89	7.84		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.52 shows changes overall acceptability scores of carrot juice concentrates stored at refrigerated conditions. The effect of packaging material on overall acceptability scores of carrot juice concentrates was significant when stored at refrigerated conditions. The overall acceptability score of carrot juice concentrate stored in amber coloured glass vials was higher (7.95) than transparent glass vials (7.94). The values of overall acceptability scores decreased due to storage interval (S). The colour scores of carrot juice concentrate decreased from 7.97 to 7.92 during storage period. The values for carrot juice concentrates prepared from different types of carrot (T) were significantly different at the end of storage. Highest value for overall acceptability score was observed in red carrot juice concentrates (8.01), while, the lowest was observed in black carrot juice concentrates (7.87). The combined effect of packaging material, storage interval and treatments (P×S×T) was found to be non-significant. The overall acceptability score of carrot juice concentrate exhibited significant decrease during storage which might be due to reduction in colour, development of quinones and off-flavours. The results were in conformity with Adiamo *et al.* (2018).

Table 4.52 Effect of packaging and storage on overall acceptability score of carrot juice concentrates (black, orange, purple and red) under refrigerated temperature

P S T	Transparent glass vials			Mean	Amber coloured glass vials			Mean
	Months				Months			
	0	3	6		0	3	6	
T ₁	7.89	7.86	7.83	7.86	7.89	7.88	7.85	7.87
T ₂	8.00	7.98	7.95	7.98	8.00	7.97	7.96	7.98
T ₃	7.96	7.93	7.91	7.93	7.96	7.95	7.93	7.95
T ₄	8.03	8.00	7.98	8.00	8.03	8.01	7.98	8.01
Mean	7.97	7.94	7.92		7.97	7.95	7.93	
Mean (P)	7.94				7.95			
T × S interaction Table					CD _(0.05)			
S T	0	3	6	Mean (T)	Packaging material (P)		0.02	
					Storage interval (S)		0.02	
T ₁	7.89	7.87	7.84	7.87	Treatment (T)		0.03	
T ₂	8.00	7.98	7.96	7.98	S × P		NS	
T ₃	7.96	7.94	7.92	7.94	T × P		NS	
T ₄	8.03	8.01	7.98	8.01	T × S		NS	
Mean (S)	7.97	7.95	7.92		P × S × T		NS	
T ₁ : Black carrot juice concentrate, T ₂ : Orange carrot juice concentrate, T ₃ : Purple carrot juice concentrate, T ₄ : Red carrot juice concentrate								

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

As depicted in Table 4.53, carrot juice concentrate packed in glass vials for six months under refrigerated conditions had maximum total sugar (49.40%), titratable acidity (0.75%), ascorbic acid (33.79 mg/ 100 g), pigment content (685.00 mg/ 100 g), total phenolics (1298.65 mg GAE/ 100 g) and antioxidant activity (52.95%) while, the concentrate stored in ambient condition recorded a lower value of total sugars (47.09%), titratable acidity (0.66%), ascorbic acid (30.01 mg/ 100 g), pigment content (682.33 mg/ 100 g) and antioxidant activity (51.51%). The lower TSS (64.19°B), reducing sugar (9.87%) was found in carrot juice concentrate stored under refrigerated condition. After 6 months of storage in glass vials, higher score for colour (8.09), body (7.95), flavour (7.89) and overall acceptability (7.94) was observed in carrot juice concentrate stored under refrigerated condition. However, the concentrate stored under ambient conditions had lower score for colour, body, flavor and overall acceptability i.e. 8.05, 7.91, 7.86 and 7.89, respectively.

Table 4.53 Effect of storage on physico-chemical characteristics of carrot juice concentrate packed in transparent glass vials

Characteristic	Carrot juice concentrate stored under ambient condition	Carrot juice concentrate stored under refrigerated condition	t _{cal}
Total soluble solids (°B)	64.64	64.19	2.61
Total sugars (%)	47.09	49.40	0.64
Reducing sugars (%)	10.69	9.87	1.58
Titratable acidity (as % citric acid)	0.66	0.75	2.23
Ascorbic acid (mg/ 100 g)	30.01	33.79	2.49
Pigment content (mg/ 100 g) (anthocyanins/ Total carotenoids)	682.33	685.00	3.80
Total phenolics (mg GAE/ 100 g)	1237.22	1298.65	2.41
Antioxidant activity (% free radical scavenging activity)	51.51	52.95	1.32
Non-enzymatic browning	0.09	0.09	0.40
Colour	8.05	8.09	1.87
Body	7.91	7.95	0.76
Flavour	7.86	7.89	2.55
Overall acceptability	7.89	7.94	1.73

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

t_{tab} = 2.05 [28 df (at 5% level of significance)]

After 6 months of storage, the higher values for total soluble solids (65.06°B), total sugars (49.60%), titratable acidity (0.78%), ascorbic acid (34.21 mg/ 100 g), pigment content (685.76 mg/ 100 g), total phenolics (1306.51 mg GAE/ 100 g), antioxidant activity (53.03%) in carrot juice concentrate stored in amber coloured glass vials stored under refrigerated conditions. Further, it also had better sensory scores i.e. 8.10, 7.96, 7.90 and 7.95 for colour, body, flavor and overall acceptability. Carrot juice concentrate stored at ambient temperature had lower score for total soluble solids (64.90), total sugars (48.54%), titratable acidity (0.70%), ascorbic acid (31.81 mg/ 100 g), pigment content (683.98 mg/ 100 g), antioxidant activity (51.95%), colour (8.07), body (7.92), flavour (7.87) and overall acceptability (7.91).

Table 4.54 Effect of storage on physico-chemical characteristics of carrot juice concentrate packed in amber coloured vials

Characteristic	Carrot juice concentrate stored under ambient condition	Carrot juice concentrate stored under refrigerated condition	t _{cal}
Total soluble solids (°B)	64.90	65.06	1.98
Total sugars (%)	48.54	49.60	0.51
Reducing sugars (%)	10.25	9.66	1.85
Titratable acidity (as % citric acid)	0.70	0.78	2.46
Ascorbic acid (mg/ 100 g)	31.81	34.21	2.12
Pigment content (mg/ 100 g) (anthocyanins/ Total carotenoids)	683.98	685.76	1.65
Total phenolics (mg GAE/ 100 g)	1274.95	1306.51	1.42
Antioxidant activity (% free radical scavenging activity)	51.95	53.03	0.89
Non-enzymatic browning	0.09	0.09	0.24
Colour	8.07	8.10	1.65
Body	7.92	7.96	0.60
Flavour	7.87	7.90	1.70
Overall acceptability	7.91	7.95	0.98

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

t_{tab} = 2.05 [28 df (at 5% level of significance)]

4.4 UTILIZATION OF CARROT JUICE CONCENTRATE FOR THE DEVELOPMENT OF FUNCTIONAL FOOD PRODUCTS

In this experiment, orange carrot juice concentrate found best among all the treatments was incorporated into the food products (cookies, muffin and cereal bar) to enhance functional

T_0
(Control)



T_1
(5% CJC)



T_2
(10% CJC)



T_3
(15% CJC)



T_4
(20% CJC)



T_5
(25% CJC)



Plate 6: Carrot juice concentrate (CJC) enriched functional cookies

properties. Prepared products were further packed and stored for quality evaluation at different storage intervals.

4.4.1 Cookies

4.4.1.1 Standardization of concentration of orange carrot juice concentrate in cookies preparation

Data on sensory characteristics of different treatments of carrot juice concentrate enriched cookies are given in Table 4.55. It is evident from the data that the maximum colour score (8.20) was given to cookies prepared with the incorporation of 25 per cent carrot juice concentrate i.e. treatment T₅ followed by T₄ and T₃. However, treatment T₃ was found to be best in terms of texture with a score of 8.12 and T₀ (Control) had the lowest texture scores of 7.84. The flavour score of treatment T₃ was awarded with maximum scores (7.98) while minimum scores was reported in T₀ (7.79). The data presented in Table 4.55 revealed that the cookies made with 15 per cent carrot juice concentrate (T₃) had maximum overall acceptability score (8.10) followed by treatment T₂ (7.87) and T₄ (7.86) whereas treatment T₀ had minimum scores (7.75). On the basis of sensory parameters treatment T₃ was adjudged as best among all treatments. Earlier workers, Kumar and Kumar (2011) have used addition of 6 per cent dried carrot pomace in cookies having the highest sensory score.

Table 4.55 Sensory evaluation of carrot juice concentrate enriched functional cookies

Treatment	Colour	Texture	Flavour	Overall acceptability
T ₀ (Control)	7.85	7.84	7.79	7.75
T ₁ (5% CJC)	8.03	7.90	7.83	7.82
T ₂ (10% CJC)	8.09	8.03	7.87	7.87
T ₃ (15% CJC)	8.15	8.12	7.98	8.10
T ₄ (20% CJC)	8.17	8.05	7.85	7.86
T ₅ (25% CJC)	8.20	8.10	7.80	7.79
CD _(0.05)	0.05	0.06	0.08	0.07

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

CJC = Carrot juice concentrate

The physico-chemical analysis of cookies (control) and best rated carrot juice enriched functional cookies has been presented in Table 4.56 and Plate 6. The data showed that treatment

T₁ had higher values for weight (12.40 ± 0.15 g) than carrot juice concentrate incorporated cookies (T₂) which has a value of 12.32 ± 0.10 g. The diameter of 3.87 ± 0.06 and 3.76 ± 0.05 cm was noticed in treatment T₁ and T₂, respectively. Similarly, the thickness of 1.05 ± 0.01 cm was recorded in T₁ whereas, T₂ had 1.01 ± 0.02 cm thickness. The spread ratio and water activity were found to be higher in T₂ (15% CJC) i.e. 3.72 ± 0.05 and 0.44 ± 0.01 , respectively while lower values were noticed in T₁. Further, treatment T₂ exhibited higher moisture content ($4.41 \pm 0.09\%$) while T₁ had lower moisture content of 4.28 ± 0.11 per cent. Similar trends were noticed in ash content where T₂ and T₁ contained 0.85 ± 0.03 and 0.71 ± 0.02 per cent ash, respectively. The maximum amount of protein was noticed in T₂ ($8.40 \pm 0.12\%$) and minimum in T₁ ($8.37 \pm 0.17\%$). The value noted for fat content was higher ($19.43 \pm 0.73\%$) in T₁ as compared to T₂ ($18.14 \pm 0.85\%$). The analysis also revealed a value of 25.10 ± 1.23 and 10.64 ± 0.31 per cent for total and reducing sugars, respectively in treatment T₂.

Table 4.56 Physico-chemical characteristics of cookies (control) and best rated carrot juice concentrate enriched functional cookies

Characteristics	T ₁ (Control)	T ₂ (15% CJC)
Weight (g)	12.40 ± 0.15	12.32 ± 0.10
Diameter (cm)	3.87 ± 0.06	3.76 ± 0.05
Thickness (cm)	1.05 ± 0.01	1.01 ± 0.02
Spread ratio	3.68 ± 0.04	3.72 ± 0.05
Water activity	0.40 ± 0.02	0.44 ± 0.01
Moisture (%)	4.28 ± 0.11	4.41 ± 0.09
Ash (%)	0.71 ± 0.02	0.85 ± 0.03
Protein (%)	8.37 ± 0.17	8.40 ± 0.12
Fat (%)	19.43 ± 0.73	18.14 ± 0.85
Total sugars (%)	23.84 ± 1.45	25.10 ± 1.23
Reducing sugars (%)	9.65 ± 0.26	10.64 ± 0.31
Ascorbic acid (mg/ 100 g)	1.23 ± 0.04	5.12 ± 0.06
Total carotenoids (mg/ 100 g)	0.32 ± 0.01	8.37 ± 0.05
Total phenolic content (mg GAE/ 100 g)	4.21 ± 0.03	15.85 ± 0.08
Antioxidant activity (% free radical scavenging activity)	5.54 ± 0.13	35.69 ± 0.16

CJC = Carrot juice concentrate

However, a lower amount of total sugars ($23.84 \pm 1.45\%$) and reducing sugars ($9.65 \pm 0.26\%$) was observed in T₁. The amount of ascorbic acid present in cookies enriched with 15 per cent carrot juice concentrate was found to be 5.12 ± 0.06 mg/ 100 g while T₁ had 1.23 ± 0.04 mg/ 100 g. Similarly, 8.37 ± 0.05 mg/ 100 g of carotenoids were noticed in T₂ and 0.32 ± 0.01 mg/ 100 g in treatment T₁. As far as total phenols were concerned a higher value of 15.85 ± 0.08 mg GAE/ 100 g was recorded in treatment T₂ whereas an amount of 4.21 ± 0.03 mg/ 100 g was found in T₁. The antioxidant activity was maximum ($35.69 \pm 0.16\%$ free radical scavenging activity) in T₂ and minimum of 5.54 ± 0.13 per cent free radical scavenging activity was observed in treatment T₁ (control). Similar increase in total sugars (13.64 to 16.21%) and decrease in fat content with addition of carrot pulp was reported in carrot pulp fortified lassi was reported by Kaur *et al.* (2019).

4.4.1.2 Storage of cookies

Data pertaining to effect of storage period and condition on physico-chemical and sensory characteristics of cookies (control) along with carrot juice concentrate enriched cookies have been presented in Tables 4.57 to 4.68.

4.4.1.2.1 Protein

Table 4.57 showed a significant difference in protein content of cookies of all the treatments. The effect of storage period indicated a decrease from 8.39 to 8.15 per cent protein during storage of 60 days. The effect of treatments revealed maximum protein content in T₂ (8.29%) and minimum (8.25%) in T₁ during 60 days. The overall effect of storage condition (P) showed that the mean value (8.29%) was higher in refrigerated as compared to ambient conditions (8.25%). The combined effect of treatments, storage period and storage condition were found to be non-significant. The decrease in protein content of cookies might be due to the reaction of protein with carbohydrate, resulting in the destruction of some amino acids and change in the digestibility of the protein by proteolytic enzymes. The decrease in protein content from 9.70 to 9.49 per cent in potato flour-based cookies was reported by Vaishali *et al.* (2020).

Table 4.57 Effect of storage period and temperature on protein (%) content of cookies

P T	S	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
		0 day	30 days	60 days		0 day	30 days	60 days	
	T ₁	8.37	8.21	8.09	8.22	8.37	8.29	8.17	8.28
	T ₂	8.40	8.27	8.13	8.27	8.40	8.32	8.22	8.31
	Mean	8.37	8.25	8.13		8.40	8.30	8.18	
	Mean (P)	8.25				8.29			
		T×S interaction Table				CD _(0.05)			
	T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.05
						Storage condition (P)			0.04
	T ₁	8.39	8.24	8.11	8.25	Treatment (T)			NS
	T ₂	8.39	8.30	8.20	8.29	S×P			NS
	Mean (S)	8.39	8.27	8.15		T×P			NS
						T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies						T×S×P			NS

4.4.1.2.2 Fat

The data in Table 4.58 indicated a significant difference in fat content of cookies in storage period and storage conditions. During storage, the initial mean value decreased from 18.79 to 18.23 per cent among the treatments in fat content. The fat content was found to decrease from an initial mean value of 18.79 to 18.11 and 18.36 per cent in cookies stored in ambient and refrigerated condition, respectively. The effect of storage condition recorded higher fat content (18.61%) in cookies stored under refrigerated conditions as compared to ambient conditions (18.45%). The effect of treatments indicates maximum fat content of 19.19 per cent in T₁ and minimum of 17.88 per cent in T₂ during 60 days of storage. An interaction of treatments, storage intervals and packaging material was also found to be non-significant. The decrease in fat content during storage might be due to reversion or rancidity of fat. The factors which are known to influence the onset of these chemical reactions are temperature, light, oxygen and trace metals. Similar trends of decrease in fat content of wheat and sweet potato cookies were reported by Jemziya and Mahendran (2017).

4.4.1.2.3 Total sugars

Data for total sugars of cookies depicts a non-significant difference among treatments, storage period and conditions (Table 4.59). The effect of treatments indicates maximum total sugars in T₂ (25.33%) and minimum in T₁ (24.05%) during 60 days of storage.

Table 4.58 Effect of storage period and temperature on fat (%) content of cookies

P T \ S	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	19.43	19.10	18.76	19.10	19.43	19.36	19.04	19.28
T ₂	18.14	17.83	17.45	17.81	18.14	18.02	17.68	17.95
Mean	18.79	18.47	18.11		18.79	18.69	18.36	
Mean (P)	18.45				18.61			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS
					Storage condition (P)			NS
T ₁	19.43	19.23	18.90	19.19	Treatment (T)			1.17
T ₂	18.14	17.93	17.57	17.88	S×P			NS
Mean (S)	18.79	18.58	18.23		T×P			NS
					T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS

Table 4.59 Effect of storage period and temperature on total sugars (%) of cookies

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	23.84	24.13	24.45	24.14	23.84	23.97	24.06	23.96
T ₂	25.10	25.45	25.68	25.41	25.10	25.23	25.42	25.25
Mean	24.47	24.79	25.07		24.47	24.60	24.74	
Mean (P)	24.78				24.60			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS
					Storage condition (P)			NS
T ₁	23.84	24.05	24.26	24.05	Treatment (T)			NS
T ₂	25.10	25.34	25.55	25.33	S×P			NS
Mean (S)	24.47	24.70	24.90		T×P			3.41
					T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS

The effect of storage conditions (P) showed the higher mean value in cookies stored at ambient temperature (24.78%) as compared to refrigerated (24.60%) conditions. The combined effect of storage period and storage condition reveals an increase in total sugars of cookies from an initial value of 24.47 to 25.07 per cent in ambient and 24.74 per cent in refrigerated conditions. The combined effect of treatments, storage interval and storage conditions were observed to be non-significant.

4.4.1.2.3 Reducing sugars

Table 4.60 highlights the effect of treatments, storage period and conditions of cookies on the reducing sugars. The cookies showed higher mean value for reducing sugars in ambient (10.40%) than refrigerated condition (10.26%). The overall effect of storage period indicated an increase in mean value of reducing sugars from 10.15 to 10.56 during 60 days of storage. The interaction of treatments, storage period and conditions on reducing sugars was noticed as non-significant. The increase in total sugars could be result of hydrolysis of polysaccharides like pectin, cellulose and starch into simple sugars as reported by Singh and Mathur (1983). Ahmed *et al.* (2008) reported that increase in reducing sugars during storage may be due to acid hydrolysis of non-reducing sugars (sucrose) into glucose and fructose. The results were in conformity with Kumar and Kumar (2011).

4.4.1.2.4 Ascorbic acid

The data in Table 4.61 clearly indicate non-significant difference among storage period and conditions on ascorbic acid content of cookies whereas, significant difference among treatment was noticed. The mean maximum ascorbic acid content of 5.12 per cent was observed in treatment T₂ and minimum of 1.23 per cent in T₁ at 0 day. The overall effect of treatments and storage interval on ascorbic acid content stated that T₂ recorded highest value of 4.96 per cent and lowest value of 1.08 per cent in T₁ during storage. A mean decrease in ascorbic acid content was found from 3.18 to 2.83 per cent during 60 days of storage. The overall effect of storage conditions (P) showed the higher mean value in cookies stored at refrigerated (3.07%) as compared to ambient (2.97%) conditions.

Table 4.60 Effect of storage period and temperature on reducing sugars (%) of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	9.65	9.80	10.16	9.87	9.65	9.72	9.95	9.77	
T ₂	10.64	10.91	11.25	10.93	10.64	10.69	10.88	10.74	
Mean	10.14	10.36	10.71		10.14	10.21	10.42		
Mean (P)	10.40				10.26				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS	
					Storage condition (P)			NS	
T ₁	9.65	9.76	10.06	9.82	Treatment (T)			NS	
T ₂	10.64	10.80	11.07	10.84	S×P			NS	
Mean (S)	10.15	10.28	10.56		T×P			NS	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS	

Table 4.61 Effect of storage period and temperature on ascorbic acid (mg/100 g) of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	1.23	1.05	0.86	1.05	1.23	1.15	0.96	1.11	
T ₂	5.12	4.89	4.65	4.89	5.12	5.09	4.87	5.03	
Mean	3.18	2.97	2.75		3.18	3.12	2.92		
Mean (P)	2.97				3.07				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS	
					Storage condition (P)			NS	
T ₁	1.23	1.10	0.91	1.08	Treatment (T)			0.28	
T ₂	5.12	4.99	4.76	4.96	S×P			NS	
Mean (S)	3.18	3.04	2.83		T×P			NS	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS	

The interaction between treatments, storage interval and conditions were noticed to be non-significant. Cookies showed a significant decrease in the ascorbic acid content during the entire storage period which might be due to its oxidation and direct effect of ambient storage temperature on vitamin content (Clegg and Mortar, 1965). Highest retention of ascorbic acid

content in concentrate under refrigerated condition might be due to slower rate of oxidation reactions at low temperature as compared to ambient conditions. The results were in accordance with Sahni and Shree (2017).

4.4.1.2.5 Total carotenoids

A perusal of data reflects (Table 4.62) a significant difference in carotenoid content of cookies among both the treatments at 0 day. The overall effect of storage condition (P) showed that the mean carotenoids content of cookies was higher in refrigerated (4.21 mg/ 100 g) as compared to ambient (4.15 mg/ 100 g) condition. Further, the mean value for carotenoid content was observed to decrease from 4.35 to 4.01 mg/ 100 g during storage period of 60 days. The maximum and minimum mean value of carotenoids was 8.12 mg/ 100 g in T₂ and 0.24 mg/ 100 g in T₁, respectively. An interaction of treatments, storage intervals and packaging material was found to be non-significant. Similar reports have been given by Hidalgo *et al.* (2010) in pasta, bread and biscuit.

Table 4.62 Effect of storage period and temperature on total carotenoids (mg/ 100 g) content of cookies

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	0.32	0.21	0.13	0.22	0.32	0.27	0.19	0.26
T ₂	8.37	8.05	7.79	8.07	8.37	8.18	7.94	8.16
Mean	4.35	4.13	3.96		4.35	4.23	4.07	
Mean (P)	4.15				4.21			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS
					Storage condition (P)			NS
T ₁	0.32	0.24	0.16	0.24	Treatment (T)			0.56
T ₂	8.37	8.12	7.87	8.12	S×P			NS
Mean (S)	4.35	4.18	4.01		T×P			NS
					T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS

4.4.1.2.6 Total phenolics

Table 4.63 reveals the effect of storage period and storage conditions on total phenolics of cookies. The maximum value of 15.85 mg GAE/ 100 g was noticed in treatment T₂ and minimum of 4.21 mg GAE / 100 g in T₁ at 0 day. It was noticed that the total phenol content of cookies decreased significantly (10.03 to 8.50 mg GAE / 100 g) with the advancement of storage period. The overall effect of storage conditions showed that the total phenolics was recorded to be maximum (9.47 mg GAE / 100 g) in refrigerated and minimum (9.08 mg GAE / 100 g) in ambient conditions during 60 days of storage. The combined effect of treatments, storage period and storage condition were found to be non-significant. The results were in accordance with Formica-Oliveira *et al.* (2017) in carrot functional smoothie.

Table 4.63 Effect of storage period and temperature on total phenols (mg GAE/ 100 g) content of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	4.21	3.56	2.79	3.52	4.21	3.85	3.21	3.76	
T ₂	15.85	14.72	13.34	14.64	15.85	15.03	14.65	15.18	
Mean	10.03	9.14	8.07		10.03	9.44	8.93		
Mean (P)	9.08				9.47				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			NS	
					Storage condition (P)			NS	
T ₁	4.21	3.71	3.00	3.64	Treatment (T)			1.14	
T ₂	15.85	14.88	14.00	14.91	S×P			NS	
Mean (S)	10.03	9.29	8.50		T×P			NS	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS	

4.4.1.2.7 Antioxidant activity

It is apparent from the data in Table 4.64 that there was a significant decrease in antioxidant activity of cookies during storage. Among the two storage conditions, mean value of 19.99 per cent in refrigerated condition was observed to be higher than in ambient condition (19.61%). An interaction of treatments (T) and storage conditions (P) depicts that the mean value

decreased from 20.62 to 18.57 and 19.46 per cent in cookies stored in ambient and refrigerated conditions, respectively. The maximum (34.66%) and minimum (4.94%) mean value of antioxidant activity was observed in T₂ and T₁, respectively. The effect of storage period (S) recorded a decrease from 20.62 to 19.01 per cent in mean values. The combined effect of treatment, storage period and conditions on antioxidant activity was noticed to be non-significant. Similarly, high decreasing trend in antioxidant activity have been reported by Loza *et al.* (2017) in functional cookies prepared with wheat flour, banana flour and sesame seeds.

Table 4.64 Effect of storage period and temperature on antioxidant activity (% free radical scavenging activity) of cookies

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	5.54	4.80	3.94	4.76	5.54	5.01	4.78	5.11
T ₂	35.69	34.45	33.20	34.45	35.69	34.80	34.13	34.87
Mean	20.62	19.63	18.57		20.62	19.91	19.46	
Mean (P)	19.61				19.99			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.81
					Storage condition (P)			NS
T ₁	5.54	4.91	4.36	4.94	Treatment (T)			0.66
T ₂	35.69	34.63	33.67	34.66	S×P			NS
Mean (S)	20.62	19.77	19.01		T×P			NS
					T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS

4.4.1.2.7 Colour

The colour score of cookies showed a significant difference among both the treatments (Table 4.65). Treatment T₂ obtained highest (8.15) colour score while lowest (7.85) was given to T₁ at 0 day. It is evident that there was a significant difference among the treatments, storage period and storage conditions. The mean highest colour score (8.06) was noticed in T₂ and lowest (7.79) in T₁ during 60 days storage. The effect of storage condition (P) reflected the mean colour score of 7.94 in refrigerated and 7.92 at ambient conditions. The overall effect of storage period depicts decrease from 8.00 to 7.86 in mean colour score during storage of 60 days. An interaction of treatments, storage period and storage condition were noticed to be non-significant.

The slight decrease in colour score of cookies might be due to non-enzymatic browning reaction. The results were similar to the studies conducted by Jemziya and Mahendran (2015), who reported changes in organoleptic characteristics of wheat-sweet potato cookies after 12 weeks of storage period.

Table 4.65 Effect of storage period and temperature on color score of cookies

P S T	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	7.85	7.78	7.73	7.79	7.85	7.81	7.75	7.80
T ₂	8.15	8.03	7.96	8.05	8.15	8.10	8.00	8.08
Mean	8.00	7.91	7.84		8.00	7.96	7.87	
Mean (P)	7.92				7.94			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.03
					Storage condition (P)			0.03
T ₁	7.85	7.80	7.74	7.79	Treatment (T)			0.03
T ₂	8.15	8.07	7.98	8.06	S×P			NS
Mean (S)	8.00	7.93	7.86		T×P			NS
					T×S			NS
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale; 9=like extremely, 1=dislike extremely

4.4.1.2.8 Texture

The data (Table 4.66) for texture scores of cookies revealed a significant difference among treatments. The highest score for texture was awarded to the treatment (T₂) with a value of 8.12 and minimum (7.84) in T₁ at 0 day. The data also reveal a significant difference in all the treatments, storage period and condition of cookies during storage of 60 days where the mean maximum texture score was awarded to T₂ (8.03) and minimum to T₁ (7.76). While considering the overall effect of storage condition, the mean highest texture score (7.92) was found at refrigerated and lowest (7.87) at ambient condition. Similar trends were observed by Hidalgo *et al.* (2010) in biscuits.

Table 4.66 Effect of storage period and temperature on texture score of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	7.84	7.75	7.62	7.74	7.84	7.80	7.73	7.79	
T ₂	8.12	8.00	7.91	8.01	8.12	8.05	7.97	8.05	
Mean	7.98	7.88	7.77		7.98	7.93	7.85		
Mean (P)	7.87				7.92				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.04	
					Storage condition (P)			0.03	
T ₁	7.84	7.78	7.67	7.76	Treatment (T)			0.03	
T ₂	8.12	8.03	7.94	8.03	S×P			NS	
Mean (S)	7.98	7.90	7.81		T×P			NS	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS	

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.1.2.8 Flavour

Table 4.67 represents the data regarding the flavour scores of cookies where at 0 day the highest score (7.98) for flavour was recorded in T₂ and lowest (7.79) in T₁. The data indicate significant difference among all the treatments and storage conditions. During 60 days of storage of cookies, mean maximum (7.87) of flavour score was recorded in T₂ and minimum (7.68) in T₁. Further, a decrease in mean flavour score from 7.88 to 7.67 was observed in cookies during 60 days of storage. The storage conditions showed higher flavour score under refrigerated (7.81) as compared to cookies stored under ambient (7.74) conditions. An interaction of treatments, storage period and storage condition were found to be non-significant. Vaishali *et al.* (2020) also recorded a similar trend.

4.4.1.2.8 Overall acceptability

The data regarding effect of storage period and condition on overall acceptability of cookies has been presented in Table 4.68. The highest score (8.10) was awarded to treatment T₂ and lowest (7.75) to T₁ at 0 day. A look at the data also highlights a significant difference among the treatments and storage condition on overall acceptability scores of cookies.

Table 4.67 Effect of storage period and temperature on flavour score of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S		0 day	30 days	60 days		0 day	30 days	60 days	
T	T ₁	7.79	7.65	7.50	7.65	7.79	7.72	7.64	7.72
	T ₂	7.98	7.83	7.71	7.84	7.98	7.90	7.81	7.90
	Mean	7.88	7.74	7.61		7.89	7.81	7.73	
	Mean (P)	7.74				7.81			
T×S interaction Table					CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.03	
					Storage condition (P)			0.03	
T ₁	7.79	7.68	7.57	7.68	Treatment (T)			0.03	
T ₂	7.98	7.87	7.76	7.87	S×P			NS	
Mean (S)	7.88	7.77	7.67		T×P			0.05	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15%) enriched cookies					T×S×P			NS	

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.68 Effect of storage period and temperature on overall acceptability score of cookies

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	7.75	7.67	7.54	7.65	7.75	7.70	7.64	7.70	
T ₂	8.10	7.99	7.81	7.97	8.10	8.00	7.93	8.01	
Mean	7.93	7.83	7.68		7.93	7.85	7.79		
Mean (P)	7.81				7.85				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.04	
					Storage condition (P)			0.04	
T ₁	7.75	7.68	7.59	7.67	Treatment (T)			0.04	
T ₂	8.10	8.00	7.87	7.99	S×P			0.06	
Mean (S)	7.93	7.84	7.73		T×P			NS	
					T×S			NS	
T ₁ : Control cookies, T ₂ : Carrot juice concentrate (15 %) enriched cookies					T×S×P			NS	

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

The mean maximum overall acceptability score of 7.99 was recorded in T₂ and minimum of 7.67 in T₁ during storage of 60 days. The storage condition indicated that maximum (7.85)

overall acceptability score was awarded to cookies stored under refrigerated as compared ambient (7.81) conditions. The overall effect of storage period reveals a decrease in mean overall acceptability score from 7.93 to 7.73. The combined effect of treatments, storage period and condition were found to be non-significant. According to Sanhueza (2007) decrease on overall acceptability of cookies might be due to slight increase in the moisture content due to the permeability of the packaging material. The results are similar to Loza *et al.* (2017).

The mean maximum overall acceptability score of 7.99 was recorded in T₂ and minimum of 7.67 in T₁ during storage of 60 days. The storage condition indicated that maximum (7.85) overall acceptability score was awarded to cookies stored under refrigerated as compared ambient (7.81) conditions. The overall effect of storage period reveals a decrease in mean overall acceptability score from 7.93 to 7.73. The combined effect of treatments, storage period and condition were found to be non-significant. According to Sanhueza (2007) decrease on overall acceptability of cookies might be due to slight increase in the moisture content due to the permeability of the packaging material. The results are similar to Loza *et al.* (2017).

4.4.2 Muffin

4.4.2.1 Standardization of concentration of orange carrot juice concentrate in muffin preparation

Data on sensory characteristics of different treatments of carrot juice concentrate enriched cookies was given in Table 4.69 and Plate 7. It is evident from the data that the maximum colour score (8.00) was recorded by muffin prepared with the incorporation of 15 per cent carrot juice concentrate i.e. treatment T₃ followed by T₄ and T₅. However, treatment T₄ was found to be best in terms of texture with a score of 8.19 and T₀ had the lowest texture scores of 7.96. The flavour of treatment T₃ was awarded with maximum scores (8.27) which was statistically at par with treatment T₄ (8.20) while minimum scores were reported in T₀ (8.00). The data presented in Table 4.69 revealed that the muffin made with 15 per cent carrot juice concentrate (T₃) had maximum overall acceptability score (8.25) whereas, treatment T₀ had minimum scores (8.02). On the basis of sensory scores treatment T₃ (15% carrot juice concentrate) was adjudged best among all treatments.

T_0
(Control)



T_1
(5% CJC)



T_2
(10% CJC)



T_3
(15% CJC)



T_4
(20% CJC)



T_5
(25% CJC)



Plate 7: Carrot juice concentrate (CJC) enriched functional muffin

Table 4.69 Sensory evaluation of carrot juice concentrate enriched functional muffin

Treatment	Color	Texture	Flavour	Overall acceptability
T ₀ (Control)	7.75	7.96	8.00	8.02
T ₁ (5% CJC)	7.90	8.07	8.14	8.14
T ₂ (10% CJC)	7.93	8.11	8.16	8.21
T ₃ (15% CJC)	8.00	8.16	8.27	8.25
T ₄ (20% CJC)	7.97	8.19	8.20	8.21
T ₅ (25% CJC)	7.95	8.12	8.15	8.19
CD _(0.05)	0.05	0.04	0.08	0.03

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

CJC = Carrot juice concentrate

Table 4.70 Physico-chemical characteristics of muffin (control) and best rated carrot juice concentrate enriched functional muffin

Characteristics	T ₁ (Control)	T ₂ (15% CJC)
Weight (g)	37.28 ± 0.24	41.67 ± 0.20
Volume (cc)	85.49 ± 0.76	90.24 ± 0.50
Diameter (cm)	5.40 ± 0.16	6.16 ± 0.12
Thickness (cm)	2.97 ± 0.05	3.17 ± 0.07
Water activity	0.78 ± 0.02	0.81 ± 0.03
Moisture (%)	32.44 ± 0.34	33.36 ± 0.41
Ash (%)	0.58 ± 0.13	0.61 ± 0.17
Protein (%)	7.65 ± 0.78	7.32 ± 0.59
Fat (%)	11.93 ± 0.10	10.84 ± 0.07
Total sugars (%)	17.56 ± 0.04	19.93 ± 0.05
Reducing sugars (%)	6.34 ± 0.08	7.04 ± 0.09
Ascorbic acid (mg/ 100 g)	1.42 ± 0.11	5.76 ± 0.14
Total carotenoids (mg/ 100 g)	2.73 ± 0.04	3.56 ± 0.08
Total phenolics (mg GAE/ 100 g)	6.54 ± 0.19	28.12 ± 0.17
Antioxidant activity (% free radical scavenging activity)	7.12 ± 0.09	39.24 ± 0.04

The physico-chemical analysis of muffin (control) and best rated carrot juice enriched functional muffin is detailed in Table 4.70. The data showed that treatment T₁ had lower weight (37.28 ± 0.24 g) than the carrot juice incorporated muffin (T₂) with a value of 41.67 ± 0.20 g. The diameter of 5.40 ± 0.16 and 6.16 ± 0.05 cm was noticed in treatment T₁ and T₂, respectively. Similarly, the thickness of 2.97 ± 0.05 and 3.17 ± 0.07 cm was recorded in T₁ and T₂, respectively. The water activity was found to be higher in T₂ (15% CJC) with the values of 0.81

± 0.03 while lowest was noticed in T_1 (0.78 ± 0.02). The treatment T_2 exhibited higher moisture content ($33.36 \pm 0.41\%$) whereas T_0 had lower content of 32.44 ± 0.34 per cent moisture. Likewise, ash content was also recorded more in T_2 with a value of 0.61 ± 0.17 per cent and lesser in T_1 ($0.58 \pm 0.13\%$). The amount of protein content was noticed as 7.32 ± 0.59 per cent in T_2 (15% CJC) and 7.65 ± 0.78 per cent in T_1 . The value noted for fat content was higher ($11.93 \pm 0.10\%$) in T_1 while lowest ($10.84 \pm 0.07\%$) in T_2 treatment. The analysis also revealed that the total and reducing sugars were more in T_2 as compared to T_1 with a value of 19.93 ± 0.05 , 7.04 ± 0.09 and 17.56 ± 0.04 and 6.34 ± 0.08 per cent, respectively. The amount of ascorbic acid present in cookies enriched with 15 per cent carrot juice concentrate was found to be 5.76 ± 0.14 mg/ 100 g while T_1 had 1.42 ± 0.11 mg/ 100 g ascorbic acid content. Similarly, 3.56 ± 0.08 mg/ 100 g of carotenoids were noticed in T_2 and 2.73 ± 0.04 mg/ 100 g in treatment T_1 . As far as total phenolics were concerned, a higher value of 28.12 ± 0.17 mg GAE/ 100 g was recorded in treatment T_2 whereas an amount of 6.54 ± 0.19 mg GAE/ 100 g was found in T_1 . The antioxidant activity was maximum ($39.24 \pm 0.04\%$ free radical scavenging activity) in T_2 and minimum of 7.12 ± 0.09 per cent free radical scavenging activity was observed in treatment T_1 (control). Likewise, increase in function characteristics of muffin after incorporation of pumpkin powder was reported by Mala *et al.* (2018).

4.4.2.2 Storage of muffin

Data pertaining to effect of storage period and condition on physico-chemical and sensory characteristics of carrot juice concentrate enriched muffin with control muffin have been presented in Tables 4.71 to 4.82.

4.4.2.2.1 Protein

The storage period (S) and treatment (T) had a significant effect on of the protein content of muffins. The Table 4.71 elucidates that during storage, the highest mean value of 7.59 per cent was observed in control muffin (T_1) and lowest mean value of 7.26 per cent in carrot juice concentrate enriched muffin (T_2). The protein content also varied due to storage condition. High mean value (7.45%) was recorded under refrigerated condition while, a lower value (7.41%) was recorded under ambient condition. The mean protein content decreased from 7.48 to 7.37 per

cent during storage period of 30 days. The changes occurred may be due to denaturation of thermally unstable proteins during storage. A similar decreasing order was noticed by Topkaya and Isik (2019) in pomegranate peel supplemented muffins.

Table 4.71 Effect of storage period and temperature on protein (%) content of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T	S	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁		7.65	7.58	7.50	7.57	7.65	7.61	7.56	7.60
T ₂		7.32	7.24	7.19	7.25	7.32	7.28	7.25	7.28
Mean		7.48	7.41	7.34		7.48	7.44	7.40	
Mean (P)		7.41				7.45			
		T×S interaction Table				CD _(0.05)			
T		0 day	15 days	30 days	Mean (T)	Storage period (S)			0.05
						Storage condition (P)			NS
T ₁		7.65	7.59	7.53	7.59	Treatment (T)			0.04
T ₂		7.32	7.26	7.22	7.26	S×P			NS
Mean (S)		7.48	7.42	7.37		T×P			NS
						T×S			NS
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15 %) enriched muffin						T×S×P			NS

4.4.2.2.2 Fat

The data in the Table 4.72 shows a significant effect of storage conditions and treatments during storage of 30 days. The mean highest value was observed in T₁ (10.99%) and lowest value in T₂ (10.30%) during storage of muffins for 30 days. Storage conditions had a significant effect on fat content of muffins. Highest value was recorded under refrigerated condition (10.88%) and lowest under ambient condition (10.41%). The mean fat content was noticed to decrease from 11.39 to 9.93 per cent during storage of muffins for 30 days. The combined effect of treatments, storage period and storage conditions were observed to be significant. The changes may be due to hydrolysis of triglycerides during storage. These findings follow the results of Pasha *et al.* (2002) and Mushtaq *et al.* (2010).

4.4.2.2.3 Total sugars

While screening the data (Table 4.73) for total sugars of muffins, a significant effect of storage period, storage condition and treatment was recorded.

Table 4.72 Effect of storage period and temperature on fat (%) content of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S		0 day	15 days	30 days		0 day	15 days	30 days	
T	T ₁	11.93	10.68	9.42	10.67	11.93	11.39	10.57	11.30
	T ₂	10.84	10.02	9.57	10.14	10.84	10.42	10.14	10.48
	Mean	11.39	10.35	9.50		11.39	10.90	10.36	
	Mean (P)	10.41				10.88			
T×S interaction Table					CD _(0.05)				
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.11	
					Storage condition (P)			0.09	
T ₁	11.93	11.04	9.99	10.99	Treatment (T)			0.09	
T ₂	10.84	10.22	9.86	10.30	S×P			0.15	
Mean (S)	11.39	10.63	9.93		T×P			0.13	
					T×S			0.15	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			0.22	

Table 4.73 Effect of storage period and temperature on total sugars (%) of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S T		0 day	15 days	30 days		0 day	15 days	30 days	
T ₁		17.56	17.12	16.78	17.15	17.56	17.50	17.43	17.50
T ₂		19.93	19.03	18.12	19.03	19.93	19.84	19.78	19.85
Mean		18.75	18.08	17.45		18.75	18.67	18.61	
Mean (P)		18.09				18.67			
T×S interaction Table						CD _(0.05)			
T		0 day	15 days	30 days	Mean (T)	Storage period (S)			0.06
						Storage condition (P)			0.05
T ₁		17.56	17.31	17.11	17.33	Treatment (T)			0.05
T ₂		19.93	19.44	18.95	19.44	S×P			0.08
Mean (S)		18.75	18.37	18.03		T×P			0.06
						T×S			0.08
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin						T×S×P			0.11

The combined effect of treatments and storage interval shows highest total sugars in T₂ (19.44 %) and lowest in T₁ (17.33 %) during 30 days of storage. The overall effect of storage conditions showed the higher mean value under refrigerated (18.67%) condition and lower under ambient (18.09%) condition. The effect of storage period on total sugars was found to be

significant. The total sugars decreased from 18.75 per cent to 18.03 per cent during the storage period. An interaction of treatments, storage interval and storage conditions were found to be significant. The changes may be due partial hydrolysis of starch during 30 days of storage.

4.4.2.2.4 Reducing sugars

The data in Table 4.74 reflected significant effect of storage period, storage conditions and treatment on reducing sugars of muffin. The highest value was recorded in T₂ (7.12%) and lowest in T₁ (6.42%) during storage. Maximum value of reducing sugars (6.80%) was observed under ambient condition and minimum (6.74%) under refrigerated condition. Further, the mean reducing sugars were observed to increase from 6.69 per cent to 6.85 per cent during storage of 30 days. The combined effects of treatments, storage period and storage conditions were found to be non-significant. Similar results were reported by Singh *et al.* (2017) in eggless muffins.

Table 4.74 Effect of storage period and temperature on reducing sugars (%) of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days	0 day		15 days	30 days		
T ₁	6.34	6.49	6.53	6.45	6.34	6.37	6.45	6.38	
T ₂	7.04	7.15	7.26	7.15	7.04	7.08	7.17	7.10	
Mean	6.69	6.82	6.90		6.69	6.73	6.81		
Mean (P)	6.80				6.74				
	T×S interaction Table				CD _(0.05)				
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.03	
					Storage condition (P)			0.02	
T ₁	6.34	6.43	6.49	6.42	Treatment (T)			0.02	
T ₂	7.04	7.12	7.23	7.12	S×P			0.04	
Mean (S)	6.69	6.77	6.85		T×P			NS	
					T×S			NS	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			NS	

4.4.2.2.5 Ascorbic acid

There was a significant effect of storage period, storage conditions and treatments on the ascorbic acid content of muffins as depicted in Table 4.75. The Table elucidates that during storage the highest mean value of 5.66 mg/ 100 g was observed in T₂ and lowest mean value of

1.35 mg/ 100 g in T₁. A significant effect of storage conditions on ascorbic acid was recorded. More ascorbic acid was retained under refrigerated condition (3.55 mg/ 100 g) and lower under ambient condition (3.45 mg/ 100 g). Further, the mean ascorbic acid decreased from 3.59 to 3.40 mg/ 100 g during storage. The changes occurring in ascorbic acid may be due to oxidation to dehydroascorbic acid followed by the hydrolysis of dehydroascorbic acid to 2, 3-diketogluconic acids.

Table 4.75 Effect of storage period and temperature on ascorbic acid (mg/ 100 g) of muffin

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁	1.42	1.33	1.17	1.31	1.42	1.39	1.35	1.39
T ₂	5.76	5.63	5.40	5.60	5.76	5.72	5.67	5.72
Mean	3.59	3.48	3.29		3.59	3.56	3.51	
Mean (P)	3.45				3.55			
	T×S interaction Table				CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.06
					Storage condition (P)			0.05
T ₁	1.42	1.36	1.26	1.35	Treatment (T)			0.05
T ₂	5.76	5.68	5.54	5.66	S×P			0.08
Mean (S)	3.59	3.52	3.40		T×P			NS
					T×S			NS
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			NS

4.4.2.2.6 Total carotenoids

Significant effect of storage period and storage conditions was observed on the total carotenoids content of muffin as depicted in Table 4.76. The data elucidates that during storage, the highest mean value of 3.23 was observed in T₂ and lowest mean value of 2.59 in T₁. The overall effect of storage conditions recorded the high value (3.06) under refrigerated condition and low value (2.81) under ambient condition. Further, the total carotenoids decreased from 3.15 to 2.70 during storage period. Similar findings were given by Mala *et al.* (2018) in pumpkin powder incorporated muffins.

Table 4.76 Effect of storage period and temperature on total carotenoids (mg/ 100 g) content of muffin

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁	2.73	2.50	2.39	2.54	2.73	2.65	2.51	2.63
T ₂	3.56	2.93	2.74	3.08	3.56	3.42	3.16	3.38
Mean	3.15	2.72	2.57		3.15	3.04	2.84	
Mean (P)	2.81				3.06			
	T×S interaction Table				CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.08
					Storage condition (P)			0.06
T ₁	2.73	2.58	2.45	2.59	Treatment (T)			0.06
T ₂	3.56	3.12	2.95	3.23	S×P			0.11
Mean (S)	3.15	2.88	2.70		T×P			0.09
					T×S			0.11
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			NS

Table 4.77 Effect of storage period and temperature on total phenolics (mg GAE/ 100 g) of muffin

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S T	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁	6.54	6.41	6.28	6.41	6.54	6.49	6.42	17.21
T ₂	28.12	28.02	27.87	8.00	28.12	28.07	28.00	17.27
Mean	17.33	17.22	17.08		17.33	17.28	17.21	
Mean (P)	17.21				17.27			
	T×S interaction Table				CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.06
					Storage condition (P)			0.05
T ₁	6.54	6.45	6.35	6.45	Treatment (T)			0.05
T ₂	28.12	28.05	27.94	28.03	S×P			0.08
Mean (S)	17.33	17.25	17.14		T×P			NS
					T×S			NS
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			NS

4.4.2.2.7 Total phenolics

The Table (4.77) elucidates the effects of storage period, storage conditions and treatment of total phenolics of muffins. The highest value was recorded in T₂ (28.03 mg GAE/ 100 g) and

lowest value was in T₁ (6.45 mg GAE / 100 g) during storage. The overall effect of storage conditions revealed the maximum (17.27 mg GAE / 100 g) retention of total phenolics under refrigerated condition and minimum (17.21 mg GAE / 100 g) under ambient condition. Whereas, the mean total phenols were recorded to decrease from 17.33 to 17.14 mg GAE / 100 g during storage of 30 days. The changes may be due to phenols getting oxidized during storage in the presence of light or other environmental conditions. Similar results were also observed by Kannan and Thirumaran (2001) in their studies.

Table 4.78 Effect of storage period and temperature on antioxidant activity (% free radical scavenging activity) of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days	0 day		15 days	30 days		
T ₁	7.12	7.01	6.93	7.02	7.12	7.07	6.98	7.06	
T ₂	39.24	39.07	38.86	39.06	39.24	39.17	39.04	39.15	
Mean	23.18	23.04	22.90		23.18	23.12	23.01		
Mean (P)	23.04				23.10				
T×S interaction Table					CD _(0.05)				
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.03	
					Storage condition (P)			0.03	
T ₁	7.12	7.04	6.96	7.04	Treatment (T)			0.03	
T ₂	39.24	39.12	38.95	39.10	S×P			0.04	
Mean (S)	23.18	23.08	22.95		T×P			0.04	
					T×S			0.04	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			NS	

4.4.2.2.7 Antioxidant activity

Table 4.78 elucidates the effects of storage period, storage conditions and treatments on antioxidant activity of muffin. The highest value was recorded in T₂ (39.10%) and lowest value was in T₁ (7.04%) during storage. The overall effect of storage conditions revealed maximum (23.10%) retention of antioxidants under refrigerated condition and minimum (23.04%) under ambient condition. Whereas, the mean antioxidant activity was recorded to decrease from 23.18 to 22.95 per cent during storage of 30 days. The combined effect of treatments, storage period and storage conditions were found to be non-significant. The changes occurred may be due to phytochemicals getting oxidized during storage in the presence of light or other environmental

conditions. Similar results were observed by Nagarajaiah *et al.* (2019) in nutritional, antioxidant and sensory properties of value-added muffins.

Table 4.79 Effect of storage period and temperature on color score of muffin

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁	7.75	7.70	7.63	7.69	7.75	7.71	7.66	7.71
T ₂	8.00	7.90	7.79	7.90	8.00	7.94	7.88	7.94
Mean	7.88	7.80	7.71		7.88	7.83	7.77	
Mean (P)	7.80				7.82			
	T×S interaction Table				CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)		0.04	
					Storage condition (P)		NS	
T ₁	7.75	7.71	7.65	7.70	Treatment (T)		0.04	
T ₂	8.00	7.92	7.84	7.92	S×P		NS	
Mean (S)	7.88	7.81	7.74		T×P		NS	
					T×S		NS	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P		NS	

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.2.2.8 Colour

The data recorded for effect of storage on color scores of muffin during storage are given in Table 4.79. The data show that there was a significant effect of the treatments and storage period. The mean highest color score was recorded in T₂ (7.92) and lowest in T₁ (7.70) during 30 days of storage. The effect of storage conditions revealed the mean color score was more under refrigerated (7.82) as compared to ambient (7.80) condition. The overall effect of color score decreased from 7.88 to 7.74 during 30 days of storage. The combined effect of treatments, storage conditions and storage period were found to be non-significant. The decrease in color score may be due to non-enzymatic oxidation process. Bartolozzo *et al.* (2015) also reported similar results in triticale-based edible coated muffins.

4.4.2.2.9 Texture

Table 4.80 shows a significant effect of storage period, treatments and storage condition on texture scores of muffins during storage of 30 days. The mean highest value was observed in

T₂ (8.07) as compared to T₁ (7.80). While observing the overall effect of storage condition, the mean lowest texture score was found under refrigerated condition (7.88) and highest under ambient condition (8.00). Further, there was a decrease in mean texture score from 8.06 to 7.78 during storage of 30 days. The combined effect of treatment, storage conditions and storage period were found to be significant. The decrease in texture scores during storage might be due to loss of moisture by muffins.

Table 4.80 Effect of storage period and temperature on texture score of muffin

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	15 days	30 days		0 day	15 days	30 days	
T ₁	7.96	7.90	7.84	7.90	7.96	7.87	7.28	7.70
T ₂	8.16	8.10	8.02	8.09	8.16	8.02	7.97	8.05
Mean	8.06	8.00	7.93		8.06	7.95	7.63	
Mean (P)	8.00				7.88			
	T×S interaction Table				CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.05
					Storage condition (P)			0.04
T ₁	7.96	7.89	7.56	7.80	Treatment (T)			0.04
T ₂	8.16	8.06	8.00	8.07	S×P			0.08
Mean (S)	8.06	7.97	7.78		T×P			0.06
					T×S			0.08
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin					T×S×P			0.12

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.2.2.10 Flavour

The data showing the effect of storage on flavour scores of muffin is given in Table 4.81. The data designate significant effect of treatment and storage period on flavor score of muffins during 30 days of storage. The mean maximum flavour score was found to be highest in treatment T₂ (8.21) and lowest in treatment T₁ (7.93) during 30 days of storage. The maximum flavour score was noticed under refrigerated (8.09) condition and minimum under ambient (8.05) condition. The combined effect of treatment, storage period and storage conditions were found to be non-significant. The decreasing trend in flavour scores may be due to oxidation of compounds and due to oxidation of unsaturated free fatty acids which causes rancidity. The data is in accordance with the results of Sharma *et al.* (2016).

Table 4.81 Effect of storage period and temperature on flavour score of muffin

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S		0 day	15 days	30 days		0 day	15 days	30 days	
T	T ₁	8.00	7.90	7.82	7.91	8.00	7.95	7.90	8.14
	T ₂	8.27	8.21	8.12	8.20	8.27	8.23	8.18	8.09
	Mean	8.14	8.06	7.97		8.14	8.09	8.04	
	Mean (P)	8.05				8.09			
T×S interaction Table						CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.05	
					Storage condition (P)			NS	
T ₁	8.00	7.93	7.86	7.93	Treatment (T)			0.04	
T ₂	8.27	8.22	8.15	8.21	S×P			NS	
Mean (S)	8.13	8.07	8.01		T×P			NS	
					T×S			NS	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin						T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

Table 4.82 Effect of storage period and temperature on overall acceptability score of muffin

T \ P	Ambient storage (Days)				Mean	Refrigerated storage (Days)			Mean
	0 day	15 days	30 days	0 day		15 days	30 days		
T ₁	8.02	7.80	7.69	7.84	8.02	7.98	7.95	7.98	
T ₂	8.25	8.15	8.02	8.14	8.25	8.21	8.16	8.21	
Mean	8.14	7.98	7.86		8.14	8.10	8.06		
Mean (P)	7.99					8.10			
	T×S interaction Table					CD _(0.05)			
T	0 day	15 days	30 days	Mean (T)	Storage period (S)			0.06	
					Storage condition (P)			0.05	
T ₁	8.02	7.89	7.82	7.91	Treatment (T)			0.05	
T ₂	8.25	8.18	8.09	8.17	S×P			0.08	
Mean (S)	8.14	8.04	7.96		T×P			NS	
					T×S			NS	
T ₁ : Control muffin, T ₂ : Carrot juice concentrate (15%) enriched muffin						T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.2.2.11 Overall acceptability

The data (Table 4.82) show the effect of storage period, treatments and storage conditions on overall acceptability scores of muffins. The mean highest overall acceptability score of 8.17

was observed in T₂ and lowest overall acceptability score of 7.91 was observed in T₁ during storage of 30 days of muffins. The overall effect of storage condition was recorded maximum overall acceptability score (8.10) under refrigerated condition and minimum (7.99) under ambient condition. The combined effect of treatment, storage period and storage conditions were found to be non-significant. Nagarajaiah *et al.* (2019) have found similar results in their studies.

4.4.3 Cereal bar

4.4.3.1 Standardization of concentration of orange carrot juice concentrate in cereal bar preparation

Data on sensory characteristics of different treatments of carrot juice concentrate enriched cereal bar has been given in Table 4.83 and Plate 8. It is evident from the data that the maximum colour score (8.37) was recorded by cereal bar prepared with the incorporation of 20 per cent carrot juice concentrate i.e. treatment T₄ followed by T₅ and T₃. However, treatment T₄ was found to be best in terms of texture with a score of 8.29 and T₀ had the lowest texture scores of 7.83. The flavour of treatment T₄ was awarded with maximum scores (8.18) while minimum scores were reported in T₀ (7.76). The data presented in Table 4.83 revealed that the cereal bar made with 20 per cent carrot juice concentrate (T₄) had maximum overall acceptability score (8.21) whereas, treatment T₀ had minimum scores (7.80). On the basis of sensory scores, treatment T₄ (20% carrot juice concentrate) was adjudged best among all treatments. The results were in accordance with Yadav and Bhatnagar (2015) who optimized 30 per cent incorporation of corn syrup and honey in development of ready to eat cereal bar.

Table 4.83 Sensory evaluation of carrot juice concentrate enriched functional cereal bar

Treatment	Color	Texture	Flavour	Overall acceptability
T ₀ (Control)	7.78	7.83	7.76	7.80
T ₁ (5% CJC)	8.13	7.91	7.85	7.92
T ₂ (10% CJC)	8.17	8.08	7.92	7.98
T ₃ (15% CJC)	8.28	8.20	8.07	8.15
T ₄ (20% CJC)	8.37	8.29	8.18	8.21
T ₅ (25% CJC)	8.32	8.22	8.09	8.17
CD _(0.05)	0.07	0.06	0.08	0.02

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

CJC= Carrot juice concentrate

T_0
(Control)



T_1
(5% CJC)



T_2
(10% CJC)



T_3
(15% CJC)



T_4
(20% CJC)



T_5
(25% CJC)



Plate 8: Carrot juice concentrate (CJC) enriched functional cereal bar

The physico-chemical analysis of cereal bar (control) and best rated carrot juice enriched functional cereal bar is detailed in Table 4.84. The data showed that treatment T₁ had higher total soluble solids (32.00⁰B) as compared to treatment T₂ (30.50⁰B). The treatment T₂ exhibited higher moisture content (19.56 ± 0.02%) whereas T₁ had lower content of 18.07 ± 0.05 per cent moisture. Likewise, ash content was also recorded more in T₂ with a value of 1.82 ± 0.01 per cent and lesser in T₁ containing 1.78 ± 0.02 per cent. The amount of protein content was noticed maximum (19.78 ± 0.25%) in T₂ (15% CJC) and minimum (19.65 ± 0.38%) in T₁. The value noted for fat content was higher (26.43 ± 0.87 %) in T₁ while lowest (26.40 ± 0.69%) in T₂ treatment. The analysis also revealed total and reducing sugars content of 15.26, 16.34, 2.49 and 2.35 per cent in T₁ and T₂, respectively. The amount of ascorbic acid present in cereal bar enriched with carrot juice concentrate was found to be maximum in T₂ with a value of 8.64 ± 0.04 mg/ 100 g while minimum (4.02 ± 0.03 mg/ 100g) in T₁. Similarly, 7.58 ± 0.03 mg/ 100 g of carotenoids were noticed in T₂ and 0.52 ± 0.01 mg/ 100 g in treatment T₁. As far as total phenolics are concerned, a higher value of 24.76 ± 0.16 mg/ 100g was recorded in treatment T₂ whereas an amount of 7.68 ± 0.07 mg/ 100 g was found in T₁. The antioxidant activity was maximum (47.26 ± 0.87 % free radical scavenging activity) in T₂ and minimum of 23.86 ± 0.54 per cent free radical scavenging activity was observed in treatment T₁ (control).

Table 4.84 Physico-chemical attributes of cereal bar (control) and best rated carrot juice concentrate enriched functional cereal bar

Characteristics	T ₁ (Control)	T ₂ (20% CJC)
TSS (⁰ B)	32.00 ± 0.15	30.50 ± 0.10
Moisture (%)	18.07 ± 0.05	19.56 ± 0.02
Ash (%)	1.78 ± 0.02	1.82 ± 0.01
Protein (%)	19.65 ± 0.38	19.78 ± 0.25
Fat (%)	26.43 ± 0.87	26.40 ± 0.69
Total sugars (%)	15.26 ± 1.10	16.34 ± 0.95
Reducing sugars (%)	2.49 ± 0.09	2.35 ± 0.05
Ascorbic acid (mg/ 100 g)	4.02 ± 0.03	8.64 ± 0.04
Total carotenoids (mg/ 100 g)	0.52 ± 0.01	7.58 ± 0.03
Total phenolics (mg GAE/ 100 g)	7.68 ± 0.07	24.76 ± 0.16
Antioxidant activity (% free radical scavenging activity)	23.86 ± 0.54	47.26 ± 0.87

4.4.3.2 Storage of cereal bar

Data pertaining to effect of storage period and condition on physico-chemical and sensory characteristics of carrot juice concentrate enriched cereal bar with control cereal bar have been presented in Tables 4.85 to 4.96.

4.4.3.2.1 Protein

Data appended in Table 4.85 reveal that the protein content of cereal bar decreased during the entire storage period. The overall effect of storage period (S) reveal that the protein content of cereal bars decreased from 19.72 to 19.37 per cent during storage. Further, while comparing the overall effect of storage conditions (P), it was observed that there was a significant difference between protein content of cereal bar during storage under refrigerated conditions. The overall effect of treatments (T) indicate that higher (19.62%) protein content was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (19.48%) at the end of storage. The interaction of treatments, storage intervals and storage conditions were found to be non-significant.

Table 4.85 Effect of storage period and temperature on protein (%) content of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T	S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁		19.65	19.46	19.17	19.43	19.65	19.51	19.42	19.53
T ₂		19.78	19.61	19.39	19.59	19.78	19.66	19.5	19.65
Mean		19.72	19.54	19.28		19.72	19.59	19.46	
Mean (P)		19.51				19.59			
		T×S interaction Table				CD _(0.05)			
T		0 day	30 days	60 days	Mean (T)	Storage period (S)			0.07
						Storage condition (P)			0.09
T ₁		19.65	19.49	19.30	19.48	Treatment (T)			0.07
T ₂		19.78	19.64	19.45	19.62	S×P			NS
Mean (S)		19.72	19.56	19.37		T×P			NS
						T×S			NS
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar						T×S×P			NS

4.4.3.2.2 Fat

Data appended in Table 4.86 reveal that the fat content of cereal bar decreased during the entire storage period. The overall effect of storage period (S) reveal that the fat content of cereal bars decreased from 26.42 to 25.29 per cent during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that more (26.34%) fat was retained under refrigerated storage as compared to ambient storage conditions (25.42%). The overall effect of treatments (T) on fat content of cereal bar was non-significant. The combined effect of storage period and storage conditions (S×P) shows that fat content decreased from 26.42 to 24.30 and 26.45 per cent under ambient storage conditions during entire storage period. The combined effect of treatments and storage conditions (T×P) and combined effect of treatments and storage period (T×S) on fat content of cereal bar was found to be non-significant during storage. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on fat content of cereal bars was also found to be non-significant.

Table 4.86 Effect of storage period and temperature on fat (%) content of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	26.43	25.56	24.20	25.40	26.43	26.36	26.30	26.36	
T ₂	26.40	25.51	24.39	25.43	26.40	26.31	26.26	26.32	
Mean	26.42	25.54	24.30		26.42	26.34	26.45		
Mean (P)	25.42				26.34				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.07	
					Storage condition (P)			0.09	
T ₁	26.43	25.96	25.25	25.88	Treatment (T)			NS	
T ₂	26.40	25.91	25.33	25.88	S×P			0.12	
Mean (S)	26.42	25.94	25.29		T×P			NS	
					T×S			NS	
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS	

4.4.3.2.3 Total sugars

Data appended in Table 4.87 reveal that the total sugar content of cereal bar decreased during the entire storage period. The overall effect of storage period (S) reveal that the total sugars of cereal bars decreased from 15.80 to 14.90 per cent during storage. Further, while

comparing the overall effect of storage conditions (P) it was observed that more (15.59%) total sugars were retained under refrigerated storage as compared to ambient storage conditions (15.18%). The overall effect of treatments (T) indicate that higher (15.94%) total sugar content was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (14.83 %) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that total sugars decreased from 15.80 to 14.43 and 15.37 per cent under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) depicts that higher (16.14%) total sugar content was found in cereal bars containing 20 per cent carrot juice concentrate under refrigerated storage conditions and lower (14.62%) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period (T×S) is non-significant. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on total sugars of cereal bars was also found to be non-significant.

Table 4.87 Effect of storage period and temperature on total sugars (%) of cereal bar

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	15.26	14.78	13.82	14.62	15.26	15.04	14.83	15.04
T ₂	16.34	15.85	15.04	15.74	16.34	16.17	15.91	16.14
Mean	15.80	15.32	14.43		15.80	15.61	15.37	
Mean (P)	15.18				15.59			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.09
					Storage condition (P)			0.11
T ₁	15.26	14.91	14.33	14.83	Treatment (T)			0.09
T ₂	16.34	16.01	15.48	15.94	S×P			0.15
Mean (S)	15.80	15.46	14.90		T×P			0.12
					T×S			NS
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS

4.4.3.2.4 Reducing sugars

Data appended in Table 4.88 reveal a significant effect of storage period, storage condition and treatment on reducing sugars of cereal bar. The overall effect of storage period (S)

reveal that the reducing sugars content of cereal bars decreased from 2.42 to 1.95 per cent during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that more (2.25%) reducing sugars were observed under refrigerated storage as compared to ambient storage conditions (2.10%). The overall effect of treatments (T) indicate that higher (2.22%) reducing sugars content was present in control cereal than cereal bars containing 20 per cent carrot juice concentrate (2.13%) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that reducing sugars content decreased from 2.42 to 1.80 and 2.10 per cent under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) and combined effect of treatments and storage period (T×S) have no significant effect on reducing sugars during storage. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on reducing sugars content of cereal bars was found to be non-significant.

Table 4.88 Effect of storage period and temperature on reducing sugars (%) of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T	S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁		2.49	2.14	1.82	2.15	2.49	2.25	2.13	2.29
T ₂		2.35	2.03	1.79	2.05	2.35	2.18	2.07	2.20
Mean		2.42	2.09	1.80		2.42	2.22	2.10	
Mean (P)		2.10				2.25			
		T×S interaction Table				CD _(0.05)			
T		0 day	30 days	60 days	Mean (T)	Storage period (S)			0.08
						Storage condition (P)			0.10
T ₁		2.49	2.20	1.98	2.22	Treatment (T)			0.07
T ₂		2.35	2.11	1.93	2.13	S×P			0.14
Mean (S)		2.42	2.15	1.95		T×P			NS
						T×S			NS
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar						T×S×P			NS

4.4.3.2.5 Ascorbic acid

Data appended in Table 4.89 reveal a significant effect of storage period, storage condition and treatment on ascorbic acid content of cereal bar. The overall effect of storage period (S) reveal that the ascorbic acid content of cereal bars decreased from 6.33 to 5.81 mg/

100 g during storage. Further, while comparing the overall effect of storage conditions (P), it was observed that more (6.25 mg/ 100 g) ascorbic acid was retained under refrigerated storage as compared to ambient storage conditions (5.91 mg/ 100 g). The overall effect of treatments (T) indicate that higher (8.34 mg/ 100 g) ascorbic acid content was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (3.82 mg/ 100 g) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that ascorbic acid content decreased from 6.33 to 5.45 and 6.17 mg/ 100 g under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) depicts that higher (8.57 mg/ 100 g) ascorbic acid content was found in cereal bars containing 20 per cent carrot juice concentrate under refrigerated storage conditions and lower (3.69 mg/ 100 g) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period (T×S) reveals that there was a gradual decrease in ascorbic acid content from 8.64 to 8.00 and 4.02 to 3.10 per mg/ 100 g in cereal bars containing 20 per cent carrot juice concentrate and control cereal bars, respectively. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on ascorbic acid content of cereal bars was found to be non-significant.

Table 4.89 Effect of storage period and temperature on ascorbic acid (mg/ 100 g) of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	4.02	3.67	3.38	3.69	4.02	3.96	3.84	3.94	
T ₂	8.64	8.21	7.51	8.12	8.64	8.57	8.49	8.57	
Mean	6.33	5.94	5.45		6.33	6.27	6.17		
Mean (P)	5.91				6.25				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.08	
					Storage condition (P)			0.10	
T ₁	4.02	3.82	3.10	3.82	Treatment (T)			0.03	
T ₂	8.64	8.39	8.00	8.34	S×P			0.19	
Mean (S)	6.33	6.10	5.81		T×P			0.02	
					T×S			0.05	
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS	

4.4.3.2.6 Total carotenoids

Data appended in Table 4.90 reveal that the storage period and storage conditions have significant effect on carotenoids content of cereal bar. The overall effect of storage period (S) has no significant effect on carotenoids content of cereal bar. The overall effect of treatments (T) indicate that higher (7.40 mg/ 100 g) carotenoids content was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (0.42 mg/ 100 g) initially and at the end of storage. The combined effect of storage period and storage conditions (S×P) was reported to be non-significant. However, combined effect of treatments and storage conditions (T×P) depicts that higher (7.44 mg/ 100 g) carotenoids content was found in cereal bars containing 20 per cent carrot juice concentrate and lower (0.40 mg/ 100 g) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period (T×S) reveals that there was a gradual decrease in carotenoids content from 7.65 to 7.20 and 0.52 to 0.32 mg/ 100 g in cereal bars containing 20 per cent carrot juice concentrate and control cereal bars, respectively. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on total carotenoids of cereal bars was found to be non-significant.

Table 4.90 Effect of storage period and temperature on total carotenoids (mg/ 100 g) content of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	0.52	0.38	0.30	0.40	0.52	0.47	0.35	0.45	
T ₂	7.58	7.40	7.27	7.44	7.58	7.29	7.14	7.36	
Mean	4.09	3.89	3.78		4.09	3.88	3.74		
Mean (P)	3.92				3.90				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)		NS		
					Storage condition (P)		0.07		
T ₁	0.52	0.43	0.32	0.42	Treatment (T)		0.06		
T ₂	7.65	7.35	7.20	7.40	S×P		NS		
Mean (S)	4.09	3.89	3.76		T×P		0.08		
					T×S		0.10		
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS	

4.4.3.2.7 Total phenolics

Data appended in Table 4.91 reveal that the total phenols content of cereal bar decreased during the entire storage period. The overall effect of storage period (S) reveals that the total phenols content of cereal bars decreased from 16.22 to 13.42 mg/ 100 g during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that more (15.49 mg/ 100 g) total phenols were retained under refrigerated storage as compared to ambient storage conditions (13.92 mg/ 100 g). The overall effect of treatments (T) indicate that higher (23.07 mg/ 100 g) total phenols content was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (6.35 mg/ 100 g) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that total phenols content decreased from 16.22 to 11.93 and 14.91 mg/ 100 g under ambient and refrigerated storage conditions, respectively, during entire storage period.

Table 4.91 Effect of storage period and temperature on total phenolics (mg GAE/ 100 g) content of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
T ₁	7.68	5.87	4.24	5.93	7.68	6.57	6.03	6.76	
T ₂	24.76	21.35	19.61	21.91	24.76	24.12	23.79	24.22	
Mean	16.22	13.61	11.93		16.22	15.35	14.91		
Mean (P)	13.92				15.49				
	T×S interaction Table				CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.10	
					Storage condition (P)			0.12	
T ₁	7.68	6.22	5.14	6.35	Treatment (T)			0.09	
T ₂	24.76	22.74	21.70	23.07	S×P			0.17	
Mean (S)	16.22	14.48	13.42		T×P			0.14	
					T×S			0.17	
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			0.24	

However, combined effect of treatments and storage conditions (T×P) depicts that higher (24.22 mg/ 100 g) total phenols content was found in cereal bars containing 20 per cent carrot juice concentrate under refrigerated storage conditions and lower (5.93 mg/ 100 g) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period

(T×S) reveals that there was a gradual decrease in total phenols content from 24.76 to 21.70 and 7.68 to 5.14 mg/ 100 g in cereal bars containing 20 per cent carrot juice concentrate and control cereal bars, respectively. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on total phenols content of cereal bars was found to have a significant effect in cereal bars.

Table 4.92 Effect of storage period and temperature on antioxidant activity (% free radical scavenging activity) of cereal bar

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	23.86	20.65	18.24	20.92	23.86	22.92	21.56	22.78
T ₂	47.26	43.87	40.96	44.03	47.26	46.38	45.15	46.26
Mean	35.56	32.26	29.60		35.56	34.65	33.36	
Mean (P)	32.47				34.52			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)		0.09	
					Storage condition (P)		0.11	
T ₁	23.86	21.79	19.90	21.85	Treatment (T)		0.09	
T ₂	47.26	45.13	43.06	45.15	S×P		0.16	
Mean (S)	35.56	33.46	31.48		T×P		0.13	
					T×S		NS	
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			0.23

4.4.3.2.8 Antioxidant activity

The overall effect of storage period (S) reveals that the antioxidant activity of cereal bars decreased from 35.56 to 31.48 per cent during storage (Table 4.92). Further, while comparing the overall effect of storage conditions (P) it was observed that more (34.52%) antioxidant activity was retained under refrigerated storage as compared to ambient storage conditions (32.47%). The overall effect of treatments (T) indicate that higher (45.15%) antioxidant activity was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (21.85%) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that the antioxidant activity decreased from 35.56 to 29.60 and 33.36 per cent under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) depicts that higher (46.26%) antioxidant

activity was found in cereal bars containing 20 per cent carrot juice concentrate under refrigerated storage conditions and lower (20.92%) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period (T×S) revealed no significant effect on antioxidant activity in cereal bars containing 20 per cent carrot juice concentrate and control cereal bars. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on antioxidant activity of cereal bars was found to be significant.

4.4.3.2.9 Colour

Table 4.93 shows the effect of storage period and temperature on color score of cereal bar. The overall effect of storage period (S) on color score of cereal bars was found to be non-significant. Further, while comparing the overall effect of storage conditions (P), it was observed that there was no significant difference between color scores of cereal bars under refrigerated and ambient storage conditions. The overall effects of treatments (T) indicate that cereal bar containing 20 per cent carrot juice concentrate had higher (8.33) color score than control cereal bar (7.74). The effects of interactions between storage period, storage condition and treatments were found to be non- significant.

Table 4.93 Effect of storage period and temperature on color score of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
S T		0 day	30 days	60 days		0 day	30 days	60 days	
T ₁		7.78	7.73	7.70	7.74	7.78	7.75	7.71	7.75
T ₂		8.37	8.31	8.28	8.32	8.37	8.35	8.31	8.34
Mean		8.08	8.02	7.99		8.08	8.05	8.01	
Mean (P)		8.03				8.05			
		T×S interaction Table				CD _(0.05)			
T		0 day	30 days	60 days	Mean (T)	Storage period (S)			NS
						Storage condition (P)			0.04
T ₁		7.78	7.74	7.71	7.74	Treatment (T)			0.03
T ₂		8.37	8.33	8.30	8.33	S×P			NS
Mean (S)		8.08	8.03	8.00		T×P			NS
						T×S			NS
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar						T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.3.2.10 Texture

Data appended in Table 4.94 show the effects of storage period, storage condition and treatment on texture score of cereal bar. The overall effect of storage period (S) reveals that the texture score of cereal bars decreased from 8.06 to 7.65 during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that cereal bar kept under refrigerated storage had higher (7.89) texture score than cereal bar under ambient storage condition (7.82). The overall effect of treatments (T) indicates that cereal bar containing 20 per cent carrot juice concentrate had higher (8.05) texture score than control cereal bar (7.67). The combined effect of storage period and storage conditions (S×P) shows that texture score decreased from 8.06 to 7.56 and 7.73 under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) depicts that highest texture score was observed in cereal bar containing 20 per cent carrot juice concentrate stored at refrigerated condition (8.06) and lowest (7.61) was found in control cereal bar stored under ambient storage. Further, combined effect of treatments and storage period (T×S) showed no significant effect on texture score of cereal bar. The combined effect of storage conditions, storage period and treatment (P×S×T) on texture score of cereal bar was also found to be non-significant.

Table 4.94 Effect of storage period and temperature on texture score of cereal bar

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	7.83	7.61	7.38	7.61	7.83	7.76	7.58	7.72
T ₂	8.29	8.08	7.75	8.04	8.29	8.02	7.87	8.06
Mean	8.06	7.85	7.56		8.06	7.89	7.73	
Mean (P)	7.82				7.89			
	T×S interaction Table				CD (0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.04
					Storage condition (P)			0.05
T ₁	7.83	7.69	7.48	7.67	Treatment (T)			0.04
T ₂	8.29	8.05	7.81	8.05	S×P			0.08
Mean (S)	8.06	7.87	7.65		T×P			0.06
					T×S			NS
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.3.2.11 Flavour

Data appended in Table 4.95 reveal the effect of storage period, storage condition and treatment on flavour scores of cereal bar. The overall effect of storage period (S) reveals that the flavour score of cereal bars decreased from 7.97 to 7.84 during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that higher (7.93) texture score was retained under refrigerated storage as compared to ambient storage conditions (7.88). The overall effect of treatments (T) indicate that higher (8.09) texture score was present in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (7.72) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows that texture score decreased from 7.97 to 7.79 and 7.89 under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of treatments and storage conditions (T×P) had no significant effect on flavour scores of cereal bar. Further, combined effect of treatments and storage period (T×S) reveals that there was a gradual decrease in texture score from 8.18 to 8.00 and 7.76 to 7.67 in cereal bars containing 20 per cent carrot juice concentrate and control cereal bars, respectively. The combined overall effect of storage conditions, storage period and treatment (S×P×T) on flavor score of cereal bars was found to be non-significant.

Table 4.95 Effect of storage period and temperature on flavour score of cereal bar

P	Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days		0 day	30 days	60 days	
T ₁	7.76	7.72	7.65	7.71	7.76	7.75	7.70	7.74
T ₂	8.18	8.05	7.94	8.06	8.18	8.13	8.07	8.13
Mean	7.97	7.89	7.79		7.97	7.94	7.89	
Mean (P)	7.88				7.93			
	T×S interaction Table				CD _(0.05)			
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.03
					Storage condition (P)			0.03
T ₁	7.76	7.74	7.67	7.72	Treatment (T)			0.02
T ₂	8.18	8.09	8.00	8.09	S×P			0.05
Mean (S)	7.97	7.91	7.84		T×P			NS
					T×S			0.05
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			NS

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.4.3.2.12 Overall acceptability

Data appended in Table 4.96 reveal the effect of storage period, storage condition and treatment on overall acceptability of cereal bar. The overall effect of storage period (S) reveals that the overall acceptability score of cereal bars decreased from 7.99 to 7.68 during storage. Further, while comparing the overall effect of storage conditions (P) it was observed that higher (7.88) overall acceptability score was retained under refrigerated storage as compared to ambient storage conditions (7.81). The overall effect of treatments (T) indicate that higher (8.02) overall acceptability score in cereal bars containing 20 per cent carrot juice concentrate than control cereal bars (7.66) at the end of storage. The combined effect of storage period and storage conditions (S×P) shows no significant effect under ambient and refrigerated storage conditions during entire storage period. However, combined effect of treatments and storage conditions (T×P) depicts that higher (8.02) overall acceptability score was found in cereal bars containing 20 per cent carrot juice concentrate under refrigerated storage conditions as well as ambient storage condition and lower (7.60) in control cereal bars under ambient conditions. Further, combined effect of treatments and storage period (T×S) shows no significant effect on overall acceptability score of cereal bar. The combined overall effect of storage conditions, storage period and treatment (P×S×T) overall acceptability score of cereal bars was found to be significant.

Table 4.96 Effect of storage period and temperature on overall acceptability score of cereal bar

P		Ambient storage (Days)			Mean	Refrigerated storage (Days)			Mean
T \ S	0 day	30 days	60 days	0 day		30 days	60 days		
	T ₁	7.80	7.62	7.37	7.80	7.74	7.65		
	T ₂	8.18	8.03	7.86	8.18	8.05	7.83		
	Mean	7.99	7.83	7.61	7.99	7.90	7.74		
	Mean (P)	7.81			7.88				
T×S interaction Table					CD _(0.05)				
T	0 day	30 days	60 days	Mean (T)	Storage period (S)			0.05	
					Storage condition (P)			0.06	
T ₁	7.80	7.68	7.51	7.66	Treatment (T)			0.04	
T ₂	8.18	8.04	7.85	8.02	S×P			NS	
Mean (S)	7.99	7.86	7.68		T×P			0.06	
					T×S			NS	
T ₁ : Control cereal bar, T ₂ : Carrot juice concentrate (20%) enriched cereal bar					T×S×P			0.11	

*Sensory evaluation on 9-point Hedonic scale: 9=like extremely, 1=dislike extremely

4.5 EFFECT OF STORAGE ON MICROBIAL LOAD OF PRODUCTS

Microbial analysis of carrot juice concentrates and carrot juice concentrate enriched functional products shows growth of bacterial colonies after their respective storage period which was comparatively more at ambient condition than refrigerated condition. However, the growth of bacterial colonies was within the safe limits as prescribed by FSSAI. Therefore, the products were in good condition and fit for consumption after storage both at ambient and refrigerated temperatures. Frazier and Westhoff (2013) reported that both high acidity and sugar content in fruit and vegetable concentrates, favour the growth of limited type of microorganisms viz., yeast and bacteria (*Leuconostoc spp* and *Lactobacillus spp*). The viable microbial count of such products could also be attributed to the presence of spores which might have not been killed (Woodroof and Luh, 1986). Since, the yeast and lactic acid bacteria, as described are generally considered as non-pathogenic and hence the products could be considered as safe for consumption up to their respective storage periods.

4.6 COST OF PRODUCTION

Cost incurred in the preparation of carrot juice concentrate and carrot juice enriched functional cookies, muffin and cereal bar was calculated by taking into consideration the cost of all the inputs along with the processing cost. The comparative costs of production of carrot juice concentrate from four types of carrot have been presented in Table 4.97. The cost of carrot juice concentrate production was Rs 290.55, Rs 373.46, Rs 260.85 and Rs 277.52 per litre for black, orange, purple and red carrot, respectively.

As depicted in Table 4.98, the cost of production of carrot juice concentrate enriched cookies was higher (Rs 10.22/ 100 g) than control cookies (Rs 6.93/ 100 g). Further, the preparation cost for carrot juice enriched functional muffin and cereal bar was 8.46 and 29.24 (Rs/ 100 g) while cost of control muffin and cereal bar was 5.90 and 29.30 (Rs/ 100 g), respectively (Table 4.99 and 4.100). Higher cost of production in carrot juice concentrate incorporated samples might be due to the higher price of concentrate as compared to other ingredients. However, all the products were cost effective and nutritionally appreciable.

Table 4.97 Cost of production of carrot juice concentrate (black, orange, purple and red)

Particular	Rate (Rs)	Quantity	Black carrot		Orange carrot		Purple carrot		Red carrot	
			Yield	Amount (Rs)	Yield (%)	Amount (Rs)	Yield (%)	Amount (Rs)	Yield (%)	Amount (Rs)
Carrot	20/ kg	100 kg	-	2000.00	-	2000.00	-	2000.00	-	2000.00
Citric acid	400/ kg	45.00 g	-	18.00	-	-	-	18.00	-	-
Depreciation on machinery	@ 10 %	-	-	-		200.00	-	-	-	200.00
Carrot juice	-		65.30 L	2018.00	52.90 L	2200.00	66.60 L	2018.00	72.40 L	2200.00
Processing cost	@ 10 %	-	-	201.80	-	220.00	-	201.80	-	220.00
Total cost of production of the concentrate (63.96 – 66.27°B)	-	-	7.64 L	2219.80	6.48 L	2420.00	8.51 L	2219.80	8.72 L	2420.00
Cost of concentrate/ L	-	-	-	290.55	-	373.46	-	260.85	-	277.52

Table 4.98 Cost of production of cookies

Particular	Rate (Rs)	T ₁ : Control cookies		T ₂ : Carrot juice concentrate (15%) enriched cookies	
		Quantity	Amount (Rs)	Quantity	Amount (Rs)
Wheat flour	25/ kg	100.00 g	2.50	100.00 g	2.50
Carrot juice concentrate	373.46/ L	-	-	15.00 mL	5.60
Vegetable oil	95/ L	40.00 mL	3.80	40.00 mL	3.80
Sugar powder	40/ kg	35.00 g	1.40	25.00 g	1.00
Skim milk powder	25/ 100 g	10.00 g	2.50	10.00 g	2.50
Baking powder	21/ 100 g	1.00 g	0.21	1.00 g	0.21
Salt	20/ kg	1.00 g	0.02	1.00 g	0.02
Total	-	-	10.43	-	15.81
Processing cost	@ 10 %	-	1.04	-	1.58
Packaging material	0.5/ piece	2 pieces	1.00	2 pieces	1.00
Total cost (180 g)	-	-	12.47	-	18.39
Total Cost (100 g)	-	-	6.93	-	10.22

Table 4.99 Cost of production of muffin

Particular	Rate (Rs)	T ₁ : Control muffin		T ₂ : Carrot juice concentrate (15%) enriched muffin	
		Quantity	Amount (Rs)	Quantity	Amount (Rs)
Wheat flour	25/ kg	100.00 g	2.50	100.00 g	2.50
Carrot juice concentrate	373.46/ L	-	-	15.00 mL	5.60
Vegetable oil	95/ L	8.00 mL	0.76	8.00 mL	0.76
Sugar powder	40/ kg	54.00 g	2.16	45.00 g	1.80
Milk	40/ L	80.00 mL	3.20	65.00 mL	2.60
Baking powder	21/ 100 g	5.00 g	1.05	5.00 g	1.05
Baking soda	20/ 100 g	0.75 g	0.15	0.75 g	0.15
Total	-	-	9.82	-	14.46
Processing cost	@ 10 %	-	0.98	-	1.45
Packaging material	0.50/ piece	2 pieces	1.00	1 piece	1.00
Total cost (200 g)	-	-	11.80	-	16.91
Total Cost (100 g)	-	-	5.90	-	8.46

Table 4.100 Cost of production of cereal bar

Particular	Rate (Rs)	T ₁ : Control cereal bar		T ₂ : Carrot juice concentrate (20%) enriched cereal bar	
		Quantity	Amount (Rs)	Quantity	Amount (Rs)
Oat	180/ kg	100.00 g	18.00	7100.00 g	18.00
Carrot juice concentrate	373.46/ L	-	-	20.00 mL	7.47
Honey	200/ 600 mL	50.00 mL	16.67	30 mL	10.00
Peanut	46/ 200 g	100.00 g	23.00	100.00 g	23.00
Total	-	-	57.67	-	58.47
Processing cost	@ 10 %	-	5.77	-	5.85
Packaging material	0.5/ piece	2 pieces	1.00	2 pieces	1.00
Total cost (220 g)	-	-	64.44	-	64.32
Total Cost (100 g)	-	-	29.30	-	29.24

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled **“Carrot juice concentrate production and utilization”** was carried out in the Department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2017-2020. To accomplish this study, carrot roots (black, orange, purple and red) were procured from Department of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh and were brought to the Department of Food Science and Technology where they were analyzed for various physico-chemical parameters. The carrot roots prior to juice extraction were subjected to blanching (water, steam, acidified water, ultrasound assisted and microwave assisted) and enzymatic treatments (Pectinase, Cellulase and Pectinase + Cellulase) for enhancing the juice yield. The extracted juice was hot filled into pre-sterilized glass bottles and stored for further use. Further, different combinations of temperature and concentration were laid by Response Surface Methodology (RSM) for the development of carrot juice concentrates (black, orange, purple and red). The concentrates prepared by different runs were analyzed for various responses. On the basis of these responses, best treatment was selected for each type of carrot juice concentrate (black, orange, purple and red) which was further packed in transparent and amber coloured glass vials and stored at ambient (10.2 - 28.3°C) and refrigerated (4 - 7°C) condition for a period of 6 months. Changes in the quality characteristics like chemical and sensory attributes were recorded at different storage intervals (0, 3 and 6 months). The orange carrot juice concentrate was further utilized in the preparation of functionally enriched cookies, muffins and cereal bar. The amount of carrot juice concentrate (0, 5, 10, 15, 20 and 25%) was optimized on the basis of sensory evaluation. The best rated product along with control was further packed in polyethylene pouches and stored at ambient and refrigerated conditions. The products were further analyzed for various quality attributes at different storage intervals (0, 30 and 60 days for cookies and cereal bar and 0, 15 and 30 days for muffin). Cost of production of the best rated products was also calculated to see their economic feasibility. The results of the study on various aspects of product preparation and storage are summarized as under:

1. The data on physico-chemical characteristics of different types of carrot (black, orange, purple and red) indicated that maximum root weight and length was reported in red carrot whereas, maximum diameter was noted in orange carrot. Further, red carrot had maximum value for total soluble solids, reducing sugars and total sugars followed by black carrot, purple carrot and orange carrot. Maximum titratable acidity and minimum pH was found in black carrot roots. The fibre and pectin content was highest in orange carrot and lowest in black carrot. Black carrot had maximum antioxidant activity (80.25%) which might be due to presence of high anthocyanins (249.32 mg/ 100 g) and total phenolics (290.63 mg GAE/ 100 g).
2. In total, 42 treatment combinations were tried to standardize the blanching method and time in each type of carrot for the extraction of juice. In black carrot, juice extracted after 4 min of acidified water blanching of whole carrot was selected as best treatment on the basis of juice yield (65.30%), anthocyanin content (185.76 mg/ 100 g), total phenolics (93.50 mg GAE/ 100 g) and antioxidant activity (68.98%). However, in orange carrot, ultrasound assisted blanched whole carrot (5 min) had better juice yield (52.90%) as compared to rest of the treatments. Likewise, acidified water blanched whole carrot for 3 min (juice yield 66.60%) and ultrasound assisted whole carrot for 4 min (juice yield 72.40%) were recorded as best treatments in purple carrot and red carrot, respectively.
3. For comparing different enzymes, concentration and time of application, 21 treatments were applied to each type of carrot. The juice extracted was analyzed for various chemical parameters. Cellulase @ 0.1 per cent applied for 120 min had the maximum juice yield of 57.10 per cent in black carrot. Similarly, in orange carrot, 0.3 percent Cellulase for 90 min was found to be the best treatment. Further, Cellulase @ 0.1 and 0.3 per cent for 90 and 120 min was optimized for juice extraction in purple carrot and red carrot, respectively. The temperature was kept constant at 50°C.
4. Further, carrot juice concentrates (black, orange, purple and red) were prepared according to treatments/ run designed by Response Surface Methodology (RSM). The responses measured were yield, total sugars, reducing sugars, titratable acidity, ascorbic acid, total carotenoids, anthocyanins, total phenolics, antioxidant activity, non-enzymatic browning

and sensory parameters i.e. colour, body, flavor and overall acceptability. On the basis of these responses, the process parameters were optimized.

5. The best carrot juice concentrates (black, orange, purple and red) were packed in transparent and amber coloured glass vials which were then stored in ambient (10.2 - 28.3°C) and refrigerated conditions (4 - 7°C) for quality evaluation at an interval of 0, 3 and 6 months.
6. During storage, the carrot juice concentrates experienced slight decrease in total soluble solids, total sugars, titratable acidity, ascorbic acid, total carotenoids, anthocyanins, total phenolics and antioxidant activity whereas, increase in reducing sugars and non-enzymatic browning up to 6 months of storage period was recorded. Although, the sensory quality of juice concentrate decreased during storage, yet the concentrate had sensory score within acceptable range. The changes in various quality attributes of carrot juice concentrate stored at ambient temperature were observed to be slightly higher as compared to refrigerated storage condition.
7. The best rated orange carrot juice concentrate was further utilized for the preparation of functionally enriched food products. In carrot juice concentrate enriched cookies, 15 per cent carrot juice concentrate was optimized on the basis of sensory evaluation. Further, these carrot juice concentrate enriched cookies had higher amount of total carotenoids (8.37 mg/ 100 g), total phenols (15.85 mg GAE/ 100 g) and antioxidant activity (35.69%) as compare to control cookies.
8. In the case of functionally enriched muffins, 15 per cent carrot juice concentrate was declared as best on the basis of colour, texture, flavor and overall acceptability score. The best rated treatment was further reported to contain 5.76 mg/ 100 g ascorbic acid, 28.12 mg GAE/ 100 g total phenolics and 39.24 per cent antioxidant activity as compared to control muffins which had 1.42 mg/ 100 g, 6.54 mg GAE/ 100 g and 7.12 per cent ascorbic acid, total phenolics and antioxidant activity, respectively.
9. In cereal bar, treatment with 20 per cent carrot juice concentrate was adjudged the best by panelists in term of sensory score and hence was optimized for the preparation of functionally enriched cereal bar. Organoleptically best rated cereal bar contained 7.58

mg/ 100 g total carotenoids, 24.76 mg GAE/ 100 g and 47.26 per cent antioxidant activity.

10. The concentrate enriched food products i.e. cookies, muffin and cereal bar could be stored safely in polyethylene pouches under ambient (27.1 - 29.1°C) and refrigerated condition (4 - 7°C) for a period of 60, 30 and 60 days, respectively with minimum changes in chemical and sensory attributes. However, comparatively fewer changes in products stored under refrigerated conditions were observed as compared to the products stored under ambient temperature.
11. The cost of production of various products was calculated on the basis of current market price of all the ingredients. The cost of production was 290.55, 373.46, 260.85 and 277.52 (Rs/ L) for black, orange, purple and red carrot juice concentrate, respectively. Further, price of functionally enriched cookies, muffin and cereal bar was 10.22, 8.46 and 29.24 rupees per 100 g, respectively. However, a lower cost of production for control (without addition of carrot juice concentrate) samples i.e. 6.93 and 5.90 Rupees per 100 g was calculated for cookies and muffin, respectively.

On the basis of above summary, it is concluded that in the present investigation, 4 different types of carrots (black, orange, purple and red) were evaluated for the preparation of carrot juice concentrate and its further utilization in formulation of functionally enriched food products. Among these carrot roots, black carrot was found to have the highest anthocyanins, total phenolics and antioxidant activity. Further, optimization of blanching method and time was done for each type of carrot. The best method was selected on the basis of juice yield and quality. Likewise, type of enzyme, concentration and time of application was finalized for the extraction of carrot juice. Further, the juice concentrates were successfully prepared in rotary vacuum evaporator following different temperature and concentration combinations designed by Response Surface Methodology (RSM). The prepared carrot juice concentrates were subjected to storage and it was found that these could be stored safely up to 6 months under both ambient and refrigerated conditions in both packaging materials (transparent and amber coloured glass vials) with minimum changes in quality attributes. To ascertain the utilization of concentrates in bakery products enriched with functional food products, cookies and muffin prepared with 15 per cent orange carrot juice concentrate were adjudged the best on the basis of sensory characteristics.

Similarly, cereal bar with 20 per cent carrot juice concentrate was optimized as the best. The functionally enriched bakery products contained higher amount of ascorbic acid, total carotenoids, total phenolics as well as antioxidant activity. These food products could be stored successfully in polyethylene pouches at ambient and refrigerated temperature for a period of 30 days (muffin) and 60 days (cookies and cereal bar). Overall, it is concluded that carrot available in plenty in winter season at a reasonable cost, the juice can successfully be converted to carrot juice concentrates and substantially be incorporated for the enrichment of bakery food products. The cost of production of concentrates and functionally enriched food products was comparable to the cost of similar products in the market.

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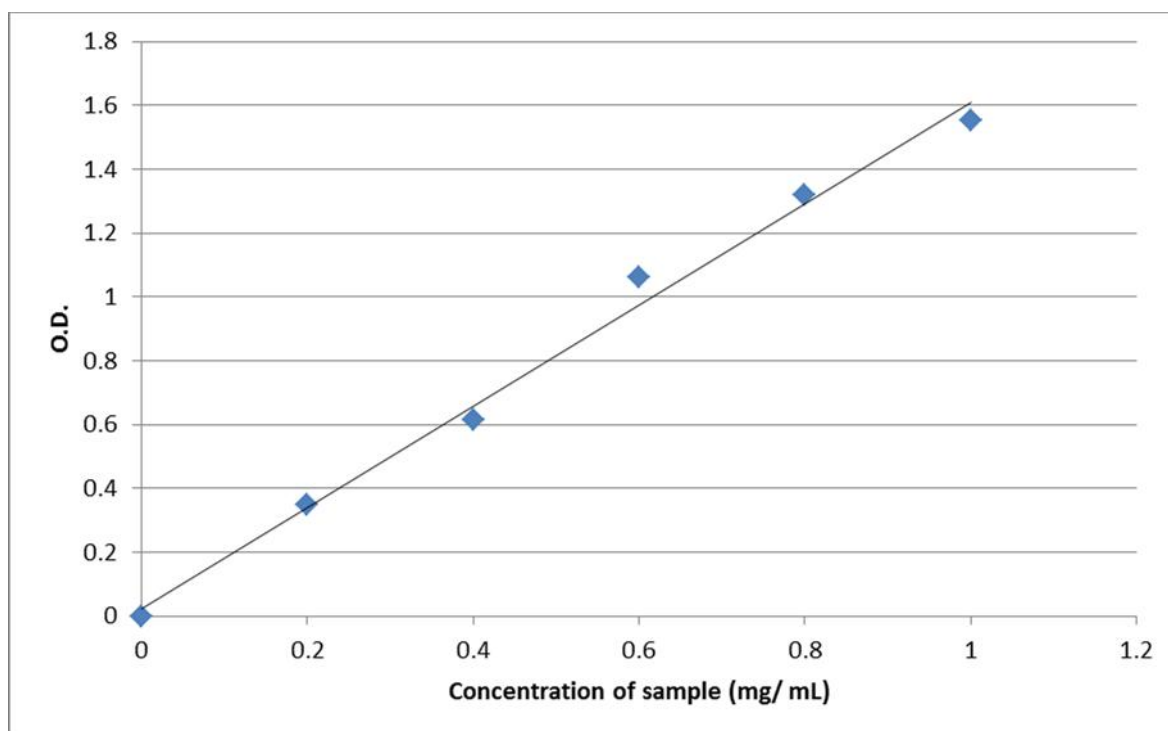
APPENDIX - I

AMBIENT TEMPERATURE AND RELATIVE HUMIDITY DATA RECORDED IN THE LABORATORY DURING THE PERIOD OF STOORAGE STUDY (2019-2020)

Month	Temperature (° C)		Mean	Relative Humidity (%)
	Maximum	Minimum		
January, 2019	17.1	3.4	10.2	50
February, 2019	19.6	6.7	13.1	51
March, 2019	21.4	8.1	14.8	47
April, 2019	25.4	15.9	20.7	51
May, 2019	31.3	19.7	25.5	42
June, 2019	35.7	20.2	27.9	46
July, 2019	31.6	24.7	28.2	66
August, 2019	31.9	24.6	28.3	65
September, 2019	30.6	22.8	26.7	67
October, 2019	27.2	19.8	23.5	59
November, 2019	21.1	14.9	18.0	57
December, 2019	16.5	12.4	14.5	59
January, 2020	18.3	4.2	11.3	65
February, 2020	23.5	7.2	15.4	57
March, 2020	24.4	7.8	16.1	58
April, 2020	23.8	16.7	20.3	49
May, 2020	25.3	22.2	23.7	50
June, 2020	32.9	21.5	27.2	57
July, 2020	32.3	25.8	29.1	63
August, 2020	30.8	23.3	27.1	67
September, 2020	31.6	24.3	27.9	59
October, 2020	28.2	16.6	22.4	48
November, 2020	23.1	13.8	18.4	52
December, 2020	16.8	10.1	13.5	44

APPENDIX - II

STANDARD CURVE OF GALLIC ACID



APPENDIX - III

HEDONIC RATING TEST EVALUATION FOR SENSORY QUALITY

NAME: _____

Date: _____

PRODUCT: _____

Please evaluate the following samples as per the standard scale.

Parameters Treatments	Colour	Body	Taste	Aroma	Overall acceptability

Nine-point Hedonic scale

9 = Like extremely

8 = Like very much

7 = Like moderately

6 = Like slightly

5 = Neither like nor dislike

4 = Dislike slightly

3 = Dislike moderately

2 = Dislike very much

1 = Dislike extremely

Signature of Evaluator

APPENDIX - IV

ANOVA: Effect of blanching method and time on the chemical properties of extracted black carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titratable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	41	4.90	3.87	0.02	0.11	0.01	1.21	0.03	3.98	0.09	0.11	1.00	0.98
Error	84	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.08	0.01	0.02	0.02	0.01

ANOVA: Effect of blanching method and time on the chemical properties of extracted orange carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titratable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	41	3.90	6.90	0.98	3.21	2.12	11.90	5.67	0.89	2.43	1.76	2.90	2.45
Error	84	0.01	0.11	0.02	0.03	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.02

ANOVA: Effect of blanching method and time on the chemical properties of extracted purple carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titratable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	41	7.65	3.76	1.09	2.34	0.98	0.87	1.32	0.87	1.34	0.09	0.2	0.78
Error	84	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01

ANOVA: Effect of blanching method and time on the chemical properties of extracted red carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titratable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	41	5.87	4.32	1.12	0.87	0.56	1.12	2.23	8.09	2.34	0.34	0.43	0.55
Error	84	0.01	0.02	0.01	0.02	0.01	0.11	0.34	0.98	0.02	0.01	0.02	0.01

ANOVA: Effect of enzymatic treatment, concentration and time on the chemical properties of extracted black carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	26	22.23	48.03	13.42	2.51	4.97	0.58	2.52	0.45	24.02	2.46	1.45	1.98
Error	54	0.01	1.23	0.29	0.48	0.25	0.02	0.01	0.01	0.01	0.01	0.02	0.02

ANOVA: Effect of enzymatic treatment, concentration and time on the chemical properties of extracted orange carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	26	1.51	4.98	1.38	11.98	19.34	16.01	15.13	2.27	22.80	11.09	14.76	15.46
Error	54	0.03	1.12	0.06	0.76	2.89	0.02	0.98	0.01	0.23	0.45	0.01	0.02

ANOVA: Effect of enzymatic treatment, concentration and time on the chemical properties of extracted purple carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	26	37.12	87.90	21.78	56.90	48.85	8.30	4.26	3.09	10.56	6.10	17.23	8.49
Error	54	0.55	0.72	0.04	0.18	0.03	0.26	0.02	0.01	0.03	0.01	0.12	0.02

ANOVA: Effect of enzymatic treatment, concentration and time on the chemical properties of extracted red carrot juice

Source of variation	Degrees of freedom	Mean sum of squares											
		Yield (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Titrateable acidity (as % citric acid)	Fibre (%)	Pectin (%)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non-enzymatic browning
Treatment (T)	26	7.75	3.38	2.99	0.76	1.30	1.34	7.64	5.98	7.78	0.16	0.98	13.30
Error	54	0.14	0.27	0.02	0.07	0.01	0.02	0.75	0.15	0.01	0.02	0.14	0.01

Solutions for optimization of formulation to prepare black carrot juice concentrate by Response Surface Methodology (RSM)

Solutions													
Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	39.74	50.75	14.88	1.04	25.56	1057.81	1908.09	59.21	0.80	8.08	7.43	7.49	7.75
2	37.09	61.94	12.62	1.25	31.05	1289.82	2332.99	71.77	1.00	8.02	7.42	7.47	7.76
3	34.81	61.80	12.68	1.24	31.06	1287.66	2329.75	71.86	1.02	7.99	7.41	7.45	7.74
4	35.60	60.09	12.97	1.21	30.21	1252.07	2265.00	69.88	0.97	8.02	7.41	7.46	7.74
5	33.42	44.64	16.23	0.92	22.72	935.62	1675.83	53.54	0.81	7.98	7.39	7.41	7.64
6	37.40	64.52	12.18	1.30	32.28	1343.08	2428.55	74.62	1.05	8.00	7.43	7.48	7.77
7	48.09	44.33	16.69	0.92	22.10	922.25	1663.19	51.35	0.71	8.06	7.49	7.55	7.79
8	34.62	62.05	12.64	1.25	31.19	1292.85	2339.21	72.16	1.03	7.99	7.41	7.45	7.73
9	33.87	44.08	16.38	0.91	22.44	923.82	1653.31	52.89	0.80	7.98	7.39	7.41	7.64
10	37.30	68.43	11.58	1.37	34.16	1423.86	2572.07	79.05	1.16	7.94	7.43	7.48	7.77
11	30.85	66.75	12.01	1.32	33.55	1390.52	2517.38	77.79	1.19	7.87	7.39	7.41	7.70
12	42.79	58.98	13.13	1.20	29.39	1227.63	2221.94	67.88	0.88	8.09	7.46	7.53	7.80
13	45.94	67.92	11.44	1.38	33.46	1414.00	2556.50	77.70	1.05	8.02	7.50	7.56	7.82
14	30.04	64.48	12.36	1.28	32.47	1344.50	2435.81	75.35	1.14	7.89	7.39	7.39	7.68
15	38.92	56.81	13.57	1.16	28.52	1183.48	2139.90	65.91	0.88	8.07	7.43	7.49	7.77
16	50.93	65.88	11.72	1.35	32.16	1372.96	2489.71	74.94	0.96	8.05	7.54	7.59	7.82
17	32.20	55.56	13.84	1.12	28.09	1160.46	2098.54	65.31	0.93	7.99	7.39	7.41	7.68
18	55.94	56.05	13.82	1.15	27.16	1168.60	2134.25	63.36	0.75	8.09	7.58	7.61	7.82
19	49.13	63.12	12.27	1.29	30.99	1314.58	2384.00	71.94	0.91	8.08	7.52	7.58	7.83
20	36.26	52.28	14.51	1.07	26.41	1091.00	1968.84	61.29	0.84	8.05	7.41	7.45	7.72

Solutions for optimization of formulation to prepare orange carrot juice concentrate by Response Surface Methodology (RSM)

Solutions													
Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	39.29	64.11	12.58	0.59	33.84	27.30	236.84	29.80	0.68	8.13	7.82	8.13	8.10
2	34.71	50.03	15.14	0.34	26.90	22.78	196.79	19.32	0.49	8.04	7.47	8.02	7.92
3	40.78	49.22	15.32	0.33	26.74	22.74	192.74	18.42	0.56	8.01	7.60	8.02	7.90
4	54.46	54.12	14.15	0.44	28.74	24.92	204.49	20.90	0.82	7.97	7.76	8.05	7.88
5	52.78	47.62	15.62	0.32	25.50	23.02	185.60	17.79	0.76	7.86	7.64	7.99	7.77
6	54.58	42.31	16.92	0.23	22.35	21.82	170.31	16.70	0.76	7.65	7.51	7.93	7.64
7	49.02	66.96	11.96	0.65	34.96	28.51	244.91	31.97	0.81	8.05	8.01	8.16	8.16
8	30.47	48.30	15.47	0.30	25.62	22.18	193.59	19.01	0.42	7.99	7.31	8.00	7.89
9	33.65	64.28	12.62	0.58	33.60	27.31	238.38	30.87	0.64	8.12	7.66	8.13	8.07
10	37.77	50.08	15.14	0.34	27.10	22.88	196.00	19.05	0.53	8.04	7.55	8.02	7.92
11	43.13	63.91	12.56	0.59	33.82	27.32	235.69	29.15	0.72	8.12	7.89	8.14	8.11
12	37.24	48.88	15.39	0.32	26.44	22.51	192.82	18.51	0.51	8.01	7.52	8.01	7.91
13	48.15	65.54	12.20	0.62	34.41	28.01	240.38	30.46	0.79	8.07	7.98	8.15	8.13
14	39.54	58.65	13.48	0.49	31.41	25.54	220.25	24.61	0.63	8.14	7.73	8.10	8.03
15	33.99	46.89	15.80	0.28	25.17	21.84	188.51	17.97	0.45	7.96	7.40	7.99	7.88
16	55.78	48.26	15.43	0.34	25.57	23.43	187.02	18.22	0.82	7.83	7.63	7.99	7.74
17	42.70	50.96	14.95	0.37	27.67	23.32	197.17	19.17	0.61	8.04	7.66	8.03	7.92
18	34.65	43.56	16.57	0.23	23.35	20.91	179.39	16.82	0.42	7.86	7.37	7.96	7.85
19	35.57	62.24	12.91	0.55	32.85	26.63	231.80	28.42	0.63	8.14	7.69	8.12	8.06
20	42.41	41.57	17.12	0.20	22.48	20.72	171.43	16.07	0.52	7.77	7.49	7.94	7.78

Solutions for optimization of formulation to prepare purple carrot juice concentrate by Response Surface Methodology (RSM)

							Solutions						
Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Anthocyanins (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	49.08	41.20	18.48	0.48	18.87	829.15	1486.92	40.37	0.63	7.72	7.59	7.92	7.70
2	58.82	67.11	12.26	1.00	30.37	1375.71	2504.11	68.24	0.86	7.99	8.26	8.17	7.99
3	34.56	43.02	17.53	0.51	20.23	873.93	1556.99	44.17	0.72	7.60	7.58	7.76	7.57
4	56.69	68.95	11.94	1.03	31.43	1413.05	2564.34	70.54	0.92	7.99	8.33	8.17	8.05
5	56.38	64.64	12.78	0.95	29.46	1322.13	2404.59	65.56	0.82	8.00	8.19	8.15	7.98
6	33.62	64.21	13.18	0.90	30.58	1309.92	2366.33	67.13	1.02	7.62	7.93	7.89	7.82
7	48.27	48.45	16.46	0.62	22.40	980.81	1770.89	48.23	0.65	7.86	7.76	7.99	7.78
8	46.22	66.62	12.53	0.98	31.16	1359.41	2455.21	68.65	0.94	7.92	8.21	8.10	8.03
9	33.43	46.72	16.61	0.58	22.07	950.75	1703.29	48.19	0.75	7.61	7.62	7.77	7.59
10	37.39	53.42	15.14	0.71	25.25	1086.65	1957.90	54.86	0.77	7.76	7.80	7.89	7.74
11	47.26	66.81	12.48	0.98	31.18	1363.68	2463.65	68.78	0.94	7.93	8.23	8.11	8.04
12	49.36	50.07	16.07	0.66	23.11	1014.53	1835.33	49.87	0.65	7.88	7.80	8.01	7.80
13	52.09	60.83	13.59	0.87	28.03	1240.17	2250.77	61.56	0.77	7.98	8.09	8.11	7.94
14	33.40	44.75	17.07	0.55	21.10	910.32	1626.44	46.13	0.74	7.59	7.59	7.75	7.57
15	32.15	64.48	13.17	0.90	30.75	1315.91	2378.25	67.59	1.04	7.57	7.90	7.86	7.79
16	52.21	45.14	17.47	0.56	20.58	911.24	1648.45	44.21	0.62	7.80	7.66	7.98	7.73
17	52.33	54.62	15.00	0.75	25.08	1110.00	2016.15	54.57	0.68	7.94	7.91	8.07	7.85
18	55.94	56.05	13.82	1.15	27.16	1168.60	2134.25	63.36	0.75	8.09	7.58	7.61	7.82
19	49.13	63.12	12.27	1.29	30.99	1314.58	2384.00	71.94	0.91	8.08	7.52	7.58	7.83
20	36.26	52.28	14.51	1.07	26.41	1091.00	1968.84	61.29	0.84	8.05	7.41	7.45	7.72

Solutions for optimization of formulation to prepare red carrot juice concentrate by Response Surface Methodology (RSM)

							Solutions						
Number/ Run	Temperature (°C)	Concentration (°B)	Yield (%)	Titrateable acidity (as % citric acid)	Ascorbic acid (mg/ 100 g)	Total carotenoids (mg/ 100 g)	Total phenolics (mg GAE/ 100 g)	Antioxidant activity (% free radical scavenging activity)	Non- enzymatic browning	Colour	Body	Flavour	Overall acceptability
1	50.05	66.27	12.05	0.43	45.59	22.16	177.38	41.87	0.76	8.44	8.18	7.98	7.97
2	34.27	50.22	15.16	0.19	38.34	15.97	129.51	29.12	0.44	8.43	7.63	7.85	7.75
3	37.72	68.29	11.69	0.47	47.83	22.25	185.46	45.04	0.65	8.47	8.02	7.99	7.97
4	34.94	52.43	14.81	0.21	39.48	16.77	136.04	30.72	0.47	8.47	7.69	7.87	7.78
5	35.12	43.95	16.25	0.13	35.25	14.04	111.34	25.43	0.39	8.27	7.56	7.79	7.68
6	54.7	62.04	12.65	0.37	43.03	21.04	161.77	37.48	0.80	8.41	8.09	7.95	7.87
7	42.38	56.04	14.38	0.24	41.21	18.60	146.38	33.58	0.60	8.50	7.91	7.91	7.82
8	30.49	57.25	13.56	0.30	41.97	17.91	150.14	34.28	0.47	8.51	7.61	7.90	7.80
9	52.45	58.01	13.66	0.28	41.46	19.80	149.69	34.53	0.75	8.43	8.02	7.92	7.80
10	50.29	64.26	12.48	0.39	44.59	21.56	170.71	39.97	0.75	8.46	8.14	7.97	7.94
11	31.78	60.38	13.05	0.34	43.70	19.11	159.86	37.15	0.52	8.52	7.71	7.93	7.84
12	37.67	41.85	16.70	0.11	34.38	13.69	105.10	24.66	0.41	8.19	7.58	7.77	7.65
13	30.2	60.15	12.96	0.35	43.57	18.88	158.89	36.87	0.50	8.51	7.64	7.92	7.83
14	57.3	64.05	11.95	0.42	43.58	21.68	167.22	38.81	0.85	8.36	8.11	7.96	7.88
15	56.77	41.82	16.16	0.13	34.43	15.54	97.43	25.34	0.75	7.98	7.65	7.75	7.41
16	45.61	66.59	12.14	0.43	46.25	22.10	179.47	42.69	0.72	8.47	8.14	7.99	7.98
17	34.03	43.41	16.26	0.13	34.93	13.72	109.87	25.02	0.37	8.25	7.52	7.79	7.68
18	36.65	58.27	13.79	0.28	42.50	18.85	153.72	35.38	0.55	8.53	7.83	7.92	7.85
19	37.82	55.78	14.33	0.24	41.19	18.14	146.06	33.36	0.54	8.51	7.82	7.90	7.82
20	47.65	62.99	12.88	0.36	44.25	21.07	167.30	39.09	0.71	8.49	8.10	7.96	7.92

ANOVA: Effect of packaging and storage on chemical characteristics of carrot juice concentrate at ambient condition

Source of variation	Degrees of freedom	TSS	Total sugars	Reducing sugars	Acidity	Ascorbic acid	Pigment content	Total phenolics	Antioxidant activity	Non-enzymatic browning
Packaging material (P)	1	1.28	38.07	0.03	0.03	58.59	9.80	1.12	3.51	0.01
Storage interval (S)	2	3.51	81.48	0.04	0.41	599.41	34.90	4.59	4.97	0.01
Treatment (T)	3	23.30	41.21	0.05	2.01	837.46	12.09	9.79	0.98	0.02
P × S	2	0.27	9.72	0.03	0.02	31.78	2.34	5.98	9.97	0.09
P × T	3	0.09	10.38	0.04	0.03	0.58	7.89	4.87	0.43	0.04
S × T	6	0.15	2.99	0.57	0.09	0.55	3.45	3.90	0.62	0.01
P × S × T	6	0.12	2.62	0.080	0.01	0.62	0.98	2.78	0.13	0.02
Error	48	0.01	0.08	0.02	0.03	0.14	1.09	9.80	0.08	0.01

ANOVA: Effect of packaging and storage on chemical characteristics of carrot juice concentrate at refrigerated condition

Source of variation	Degrees of freedom	TSS	Total sugars	Reducing sugars	Acidity	Ascorbic acid	Pigment content	Total phenolics	Antioxidant activity	Non-enzymatic browning
Packaging material (P)	1	13.60	0.65	0.77	0.16	3.18	13.78	0.97	0.11	0.02
Storage interval (S)	2	13.07	2.26	1.08	0.55	70.10	89.09	1.76	1.81	0.02
Treatment (T)	3	44.37	24.78	13.09	2.48	839.07	13.41	3.37	0.03	0.05
P × S	2	12.20	0.21	0.22	0.04	0.94	8.90	5.80	9.79	0.01
P × T	3	12.66	0.018	0.05	0.01	0.10	7.44	2.34	0.13	0.08
S × T	6	12.32	0.01	0.23	0.02	0.06	13.87	1.67	0.01	0.02
P × S × T	6	12.51	0.06	0.02	0.03	0.03	3.02	0.85	0.07	0.01
Error	48	12.62	0.07	0.09	0.05	0.10	18.14	6.81	0.23	0.01

ANOVA: Effect of packaging and storage on sensory characteristics of carrot juice concentrate at ambient condition

Source of variation	Degrees of freedom	Colour	Body	Flavour	Overall acceptability
Replication	2	0.07	0.03	0.04	0.15
Packaging material (P)	1	0.09	0.99	0.03	0.10
Storage interval (S)	2	0.20	1.23	0.76	0.06
Treatment (T)	3	0.32	0.02	0.01	0.24
P × S	2	0.01	0.01	0.02	0.01
P × T	3	0.01	0.01	0.09	0.02
S × T	6	0.01	0.02	0.05	0.08
P × S × T	6	0.02	0.01	0.01	0.50
Error	46	0.01	0.01	0.02	0.01

ANOVA: Effect of packaging and storage on sensory characteristics of carrot juice concentrate at refrigerated condition

Source of variation	Degrees of freedom	Colour	Body	Flavour	Overall acceptability
Replication	2	0.05	0.02	0.55	0.01
Packaging material (P)	1	0.17	0.16	0.08	0.12
Storage interval (S)	2	0.01	0.01	0.32	0.10
Treatment (T)	3	0.32	0.04	0.01	0.64
P × S	2	0.01	0.12	0.02	0.01
P × T	3	0.02	0.34	0.29	0.01
S × T	6	0.34	0.22	0.02	0.21
P × S × T	6	0.10	0.01	0.01	0.02
Error	46	0.23	0.02	0.65	0.01

ANNOVA: Sensory evaluation of cookies

Source of variation	Degrees of freedom	Mean sum of squares			
		Colour	Body	Flavour	Overall acceptability
Replication	2	0.67	0.54	0.32	0.43
Treatment (T)	5	0.17	0.15	0.11	0.19
Error	10	0.08	0.01	0.02	0.01

ANOVA: Effect of packaging and storage on chemical characteristics of cookies

Source of variation	Degrees of freedom	Protein	Fat	Total sugars	Reducing sugars	Ascorbic acid	Total carotenoids	Total phenolics	Antioxidant activity
Storage period (S)	1	0.21	0.19	0.228	0.22	0.29	3.78	45.20	0.01
Storage condition (P)	2	0.61	0.01	0.02	1.34	0.77	1.89	209.25	0.01
Packaging (T)	1	0.06	0.15	0.61	0.96	0.12	2.89	11.57	0.07
P × S	2	0.15	0.08	0.59	0.29	0.54	2.23	4.87	0.08
P × T	1	0.01	0.52	0.01	0.02	0.27	3.67	0.71	0.01
S × T	2	0.02	0.07	0.06	0.71	0.28	1.98	0.19	0.12
P × S × T	2	0.04	0.19	0.01	0.23	0.19	0.56	0.02	0.01
Error	24	0.02	0.10	0.20	0.17	0.04	1.90	0.01	0.02

ANOVA: Effect of packaging and storage on sensory characteristics of cookies

Source of variation	Degrees of freedom	Colour	Body	Flavour	Overall acceptability
Replication	2	0.06	0.29	0.10	0.16
Storage condition (P)	1	3.71	0.12	1.34	0.30
Storage period (S)	2	3.08	0.69	3.30	1.83
Packaging (T)	1	0.18	0.04	0.05	0.16
P × S	2	1.03	0.04	0.38	0.08
P × T	1	0.03	0.00	0.06	0.02
S × T	2	0.05	0.01	0.02	0.04
P × S × T	2	0.01	0.00	0.03	0.01
Error	22	0.04	0.02	0.04	0.03

ANNOVA: Sensory evaluation of muffin

Source of variation	Degrees of freedom	Mean sum of squares			
		Colour	Body	Flavour	Overall acceptability
Replication	2	0.04	0.05	0.12	0.13
Treatment (T)	5	0.34	0.12	0.09	0.03
Error	10	0.01	0.02	0.03	0.01

ANOVA: Effect of packaging and storage on chemical characteristics of muffin

Source of variation	Degrees of freedom	Protein	Fat	Total sugars	Reducing sugars	Ascorbic acid	Total carotenoids	Total phenolics	Antioxidant activity
Storage condition (P)	1	0.37	0.39	0.11	0.24	0.38	3.67	45.90	0.65
Storage period (S)	2	0.80	1.06	0.91	0.31	3.90	1.66	23.20	0.54
Packaging (T)	1	0.17	0.021	0.76	0.29	0.98	2.01	12.42	0.89
P × S	2	0.53	0.12	0.34	0.67	0.155	4.78	9.31	9.80
P × T	1	0.14	0.13	0.19	0.12	0.04	0.02	0.59	3.21
S × T	2	0.87	0.08	0.03	0.11	0.05	0.74	0.16	1.21
P × S × T	2	0.40	0.98	0.12	0.67	0.16	0.01	0.34	0.89
Error	24	0.01	0.03	0.01	0.23	0.01	0.06	3.90	0.02

ANOVA: Effect of packaging and storage on sensory characteristics of muffin

Source of variation	Degrees of freedom	Colour	Body	Flavour	Overall acceptability
Replication	2	0.29	0.10	0.16	0.29
Storage condition (P)	1	0.12	1.34	0.30	0.12
Storage period (S)	2	0.69	3.30	1.83	0.69
Packaging (T)	1	0.04	0.05	0.16	0.04
$P \times S$	2	0.04	0.38	0.08	0.04
$P \times T$	1	0.00	0.06	0.02	0.00
$S \times T$	2	0.01	0.02	0.04	0.01
$P \times S \times T$	2	0.00	0.03	0.01	0.00
Error	22	0.02	0.04	0.03	0.02

ANNOVA: Sensory evaluation of cereal bar

Source of variation	Degrees of freedom	Mean sum of squares			
		Colour	Body	Flavour	Overall acceptability
Replication	2	1.45	1.88	3.25	4.50
Treatment (T)	5	0.34	0.78	0.34	0.22
Error	10	0.05	0.05	0.02	0.01

ANOVA: Effect of packaging and storage on chemical characteristics of cereal bar

Source of variation	Degrees of freedom	Protein	Fat	Total sugars	Reducing sugars	Ascorbic acid	Total carotenoids	Total phenolics	Antioxidant activity
Storage condition (P)	1	0.37	0.32	0.11	14.42	0.18	18.69	0.41	0.98
Storage period (S)	2	0.64	0.09	0.15	39.98	0.09	16.90	0.20	2.10
Packaging (T)	1	0.04	0.08	0.95	0.40	3.56	10.78	0.91	0.01
P × S	2	0.06	0.76	0.74	5.43	0.20	0.76	0.80	2.13
P × T	1	0.41	0.32	0.34	0.07	0.19	0.02	0.74	1.45
S × T	2	0.16	0.03	0.08	0.09	0.02	0.18	0.04	0.01
P × S × T	2	0.91	0.02	0.32	0.13	0.73	0.01	0.01	0.01
Error	24	0.76	0.72	0.01	0.03	0.06	0.21	0.01	0.02

ANOVA: Effect of packaging and storage on sensory characteristics of cereal bar

Source of variation	Degrees of freedom	Colour	Body	Flavour	Overall acceptability
Replications	2	0.25	0.25	0.11	0.16
Storage condition (P)	1	0.24	0.14	0.36	0.30
Storage period (S)	2	0.74	0.70	0.86	1.83
Packaging (T)	1	0.08	0.08	0.09	0.16
P × S	2	0.07	0.04	0.09	0.08
P × T	1	0.01	0.01	0.00	0.02
S × T	2	0.00	0.02	0.02	0.04
P × S × T	2	0.00	0.00	0.01	0.01
Error	22	0.04	0.03	0.02	0.03

Department of Food Science and Technology
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Title of Thesis : **Carrot juice concentrate production and utilization**
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ABSTRACT

The present investigations involving evaluation of four types of carrot for juice concentrate production and its further utilization in food products was conducted during 2017-20 in the Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Solan. Carrot is a widely consumed vegetable throughout the world and is known for its high antioxidant properties due to the presence of bioactive compounds like total carotenoids, anthocyanins and total phenolics. Out of various pre-treatments tried for enhancement of juice yield, acidified water blanching in black and purple carrot for 4 min and 3 min, respectively was optimized. Whereas, ultrasound assisted blanching for 5 min before extraction of juice in orange and red carrot was found to be the best. Further, carrot juice concentrates were developed by Response Surface Methodology (RSM) with different temperature-concentration combinations in rotary vacuum evaporator. The prepared black carrot juice concentrates (53.2°C and 65.68°B) had maximum anthocyanins, total phenolics and antioxidant activity of 1378.16 mg/ 100 g, 2490.17 mg GAE/ 100 g and 75.34 per cent free radical scavenging activity, respectively. The optimized concentrates were packed in transparent and amber colour glass vials and analyzed for various chemical and sensory attributes during storage. Though concentrates experienced marginal changes in quality attributes, yet remained shelf-stable during the storage period of 6 months at ambient and refrigerated temperature. The concentrate was further utilized for the nutritional enrichment of bakery food products. On the basis of sensory evaluation, 15 per cent incorporation of orange carrot juice concentrate in cookies and muffin and 20 per cent in cereal bar was found to be the best combination. Further, the developed bakery products had better taste, palatability, medicinal and nutritive value. Moreover, cookies and cereal bar retaining acceptable quality could be stored for 60 days and muffin for 30 days in polyethylene pouches at both ambient and refrigerated temperatures. The cost of production of all products was comparable to the cost of similar products in the market. Therefore, it is recommended that the carrot available in winter months at reasonable price could successfully be utilized for the development of juice concentrate at commercial scale and further making the concentrate available to the ancillary food industry for its use in bakery products for nutritional, natural colour and antioxidants enrichment.

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