

**EFFECT OF PACKAGING MATERIAL AND STORAGE CONDITIONS
ON SHELF LIFE AND QUALITY OF DRIED GINGER**

Thesis

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

**MASTER OF TECHNOLOGY
in
PROCESSING AND FOOD ENGINEERING
(Minor Subject: Computer Science and Engineering)**

By

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CERTIFICATE – I

This is to certify that the thesis entitled, “**Effect of packaging material and storage conditions on shelf life and quality of dried ginger**”, submitted for the degree of **M. Tech.** in the subject of **Processing and Food Engineering** (Minor subject: **Computer Science and Engineering**) of the Punjab Agricultural University, Ludhiana is a bonafide research work carried out by **Jasmeen Kaur (L-2009-AE-140-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE – II

This is to certify that the thesis entitled, “**Effect of packaging material and storage conditions on shelf life and quality of dried ginger**”, submitted by **Jasmeen Kaur (L-2009-AE-140-M)** to the Punjab Agricultural University in partial fulfilment of the requirements for the degree of **M. Tech.** in the subject of **Processing and Food Engineering** (Minor subject: **Computer Science and Engineering**) has been approved by the student’s Advisory Committee along with Head of the Department after an oral examination on the same.

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ABSTRACT

The study on the effect of packaging material and storage conditions on shelf life of dried ginger was undertaken to select the suitable package material for extending the shelf-life of dried ginger based on physico-chemical quality and sensory evaluation. The ginger was peeled, cut and dried into three physical forms i.e. dried ginger flakes, dried rhizome and ginger powder and packaged in HDPE films, laminated aluminium films, PET containers and glass containers. These dried and packaged samples were stored under ambient conditions and refrigerated temperature ($3\pm 0.5^{\circ}\text{C}$). The analysis was carried out to estimate the quality and shelf-life of the stored dried ginger during whole storage period of four months. The parameters evaluated were colour change in terms of L value, chroma & hue angle, volatile oil (%), flavor (hedonic scale), shrinkage/swelling, weight change (g) and moisture content (% wb). Weight change (g) and moisture content (% wb) increased whereas colour change in terms of L value, chroma, lightness, flavour and volatile oil were decreased during storage period. Shrinkage/Swelling remained almost same during the storage period. Based on these physico-chemical quality parameters and sensory evaluation, it was found that the best physical form was powder followed by flakes and rhizome. Glass containers was the best packaging material followed by laminated aluminium films, HDPE films and PET containers for extending the shelf-life and maintaining the quality of dried ginger upto 4 months. Refrigerated conditions were observed as the better storage conditions than the room temperature. The statistical analysis was also done to check the significance of different packaging materials used under different storage conditions.

Keywords: Packaging material, refrigeration, ginger powder, glass containers, HDPE, laminated aluminium films, dried ginger, storage period.

Signature of Major Advisor

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ਸਾਰੰਸ਼

ਪੈਕੇਜਿੰਗ ਵਸਤੂ ਤੇ ਸਟੋਰੇਜ ਹਾਲਾਤ ਦਾ ਸੁੱਕੇ ਹੋਏ ਅਧਰਕ ਦੀ ਸੈਲਫ ਲਾਈਫ ਅਤੇ ਕੁਆਲਟੀ ਤੇ ਅਸਰ ਦੇਖਣ ਲਈ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ ਤਾਂ ਕਿ ਕੁਆਲਟੀ ਦੇ ਆਧਾਰ ਤੇ ਪੈਕੇਜਿੰਗ ਵਸਤੂ ਦੀ ਸਹੀ ਚੋਣ ਕੀਤੀ ਜਾ ਸਕੇ। ਅਧਰਕ ਨੂੰ ਛਿਲਿਆ, ਕੱਟਿਆ ਤੇ ਸੁਕਾਇਆ ਗਿਆ ਤਿੰਨ ਤਰ੍ਹਾਂ ਦੇ ਰੂਪ ਵਿੱਚ-ਸੁੱਕਿਆ ਹੋਇਆ ਅਧਰਕ ਫਲੇਕ, ਸੁੱਕਿਆ ਹੋਇਆ ਪੂਰਾ ਅਧਰਕ ਅਤੇ ਅਧਰਕ ਦਾ ਪਾਊਡਰ। ਫੇਰ ਇਨ੍ਹਾਂ ਨੂੰ ਅਲੱਗ-ਅਲੱਗ ਪੈਕੇਜਿੰਗ ਲਫਾਫਿਆਂ (ਐਚ.ਡੀ.ਪੀ.ਈ. ਤੇ ਲੈਮੀਨੇਟਿਡ ਅਲਮੀਨਿਅਮ) ਅਤੇ ਪੈਕੇਜਿੰਗ ਡੱਬੀਆਂ (ਪੀ.ਈ.ਟੀ. ਤੇ ਗਲਾਸ) ਵਿੱਚ ਪੈਕ ਕੀਤਾ ਗਿਆ। ਇਹ ਪੈਕਟ ਆਮ ਤਾਪਮਾਨ ਤੇ ਘੱਟ ਤਾਪਮਾਨ (3 ± 0.5) ਤੇ 4 ਮਹੀਨਿਆਂ ਲਈ ਸਟੋਰ ਕੀਤਾ ਗਿਆ। ਸਟੋਰ ਕੀਤੇ ਨਮੂਨਿਆਂ ਦਾ ਕੁਆਲਟੀ ਅਤੇ ਸੈਲਫ ਲਾਈਫ ਦਾ ਪਤਾ ਕਰਨ ਲਈ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ। ਜਾਂਚੇ ਗਏ ਗੁਣਕ ਸਨ-ਰੰਗ ਵਿੱਚ ਬਦਲਾਅ, ਵੋਲਾਟਾਈਲ ਤੇਲ (%), ਮਨੁੱਖੀ ਇੰਦਰੀਆਂ ਦੁਆਰਾ ਮੁੱਲ ਅੰਕਣ, ਸਿਕੁੜਨ/ਸੋਜ ਵਿੱਚ ਬਦਲਾਅ, ਭਾਰ ਵਿੱਚ ਬਦਲਾਅ ਤੇ ਨਮੀ ਸੰਤੋਖ (%)। ਸਟੋਰੇਜ ਸਮੇਂ ਦੌਰਾਨ ਭਾਰ ਵਿੱਚ ਬਦਲਾਅ ਤੇ ਨਮੀ ਸੰਤੋਖ (%) ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ ਜਦਕਿ ਰੰਗ ਵਿੱਚ ਬਦਲਾਅ, ਫਲੇਵਰ ਤੇ ਵੋਲਾਟਾਈਲ ਤੇਲ ਵਿੱਚ ਕਮੀ ਆਈ। ਸਿਕੁੜਨ/ਸੋਜ ਵਿੱਚ ਬਦਲਾਅ ਤਕਰੀਬਨ ਸਾਰੇ ਸਟੋਰੇਜ ਸਮੇਂ ਦੌਰਾਨ ਇੱਕ ਜਿਹਾ ਹੀ ਰਿਹਾ। ਇਨ੍ਹਾਂ ਕੁਆਲਟੀ ਅਤੇ ਮਨੁੱਖੀ ਇੰਦਰੀਆਂ ਦੁਆਰਾ ਮੁੱਲ ਅੰਕਣ ਦੇ ਆਧਾਰ ਤੇ ਇਹ ਨਤੀਜਾ ਸਾਹਮਣੇ ਆਇਆ ਕਿ ਸਭ ਤੋਂ ਵਧੀਆਂ ਅਧਰਕ ਦਾ ਰੂਪ ਸੀ ਪਾਊਡਰ ਤੇ ਉਸਤੋਂ ਬਾਦ ਸੁੱਕਿਆ ਹੋਇਆ ਅਧਰਕ ਫਲੇਕ ਤੇ ਸੁੱਕਿਆ ਹੋਇਆ ਪੂਰਾ ਅਧਰਕ। ਗਲਾਸ ਡੱਬੀਆਂ ਸਭ ਤੋਂ ਵਧੀਆਂ ਪੈਕੇਜਿੰਗ ਪਦਾਰਥ ਸੀ ਤੇ ਉਸਤੋਂ ਬਾਦ ਲੈਮੀਨੇਟਿਡ ਅਲਮੀਨਿਅਮ ਤੇ ਐਚ.ਡੀ.ਪੀ.ਈ. ਲਫਾਫੇ ਅਤੇ ਅੰਤ ਵਿੱਚ ਪੀ.ਈ.ਟੀ. ਡੱਬੀਆਂ। ਘੱਟ ਤਾਪਮਾਨ ਆਮ ਤਾਪਮਾਨ ਨਾਲੋਂ ਵਧੀਆ ਸਾਬਿਤ ਹੋਇਆ। ਅੰਕੜਾ ਅਧਿਐਨ ਦੇ ਆਧਾਰ ਤੇ ਵੀ ਪੈਕੇਜਿੰਗ ਵਸਤੂ ਤੇ ਸਟੋਰੇਜ ਹਾਲਾਤ ਦਾ ਸੁੱਕੇ ਅਧਰਕ ਦੀ ਸੈਲਫ ਲਾਈਫ ਤੇ ਅਸਰ ਦੀ ਮਹੱਤਤਾ ਦੇਖੀ ਗਈ।

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LIST OF ABBREVIATIONS

HDPE	High Density Polyethylene
Lam Al.	Laminated Aluminium
LA NF	Laminated Aluminium Nitrogen Flushed
°C	Degree Celsius
Fig	Figure
g	Gram
ml	Milli litre
i.e.	That is
Refrg.	Refrigeration
Kg	Kilogram
wb	Wet basis
MAP	Modified atmosphere packaging
mg	Milligram
CO₂	Carbon dioxide
%	Percent
RH	Relative humidity
Viz.	Videlicet (namely)

CHAPTER I

INTRODUCTION

Indian spices include a variety of spices and herbs grown across the Indian subcontinent (South Asia). Spices, the aromatic vegetable materials are used to flavour and season foods. Many of these spices possess medicinal properties and have profound effect on human health. Ginger is a tuber that is consumed whole as a delicacy, medicine or spice. It is the rhizome of the plant *Zingiber officinale*. It lends its name to its genus and family (Zingiberaceae). There are many varieties of ginger root. The most sought-after has a light brown skin, with creamy yellow to light green flesh. Ginger comes in many forms including fresh, dried, pickled, preserved and powdered or ground. The production of ginger in India is 717.43 thousand tones with an area of 124558 hectares (Anon 2009).

Ginger is rich in a number of nutrients. It has proteins, essential fats and vitamins B and C. It is rich in antioxidants. Pungency is an important quality characteristic of ginger. The rhizome has been valued for this since antiquity (Denniff and Whiting 1976). The main pungent principles of ginger rhizome are gingerol homologues and their dehydrated products—shogaol homologues, which may result from thermal process or long-term storage (Purseglove 1972). Ginger, onion and garlic are important spices in the world trade and are widely used as condiments in the every cooking in several countries. Onion and garlic are important allium spices, known for their therapeutic uses and as flavouring agents. Ginger, the rhizome of *Zingiber* spices, has long been used both in medicine and as a spice (Sagar and Kumar 2009). Ginger is currently processed into ginger powder, oleoresin and oil, respectively (Govindarajan 1982; Okwuowulu 2005). Ginger is commonly used as a spice and a medicinal plant (Afzal *et al* 2001; Chrubasik *et al* 2005).

Fresh spices are perishable in nature and get spoiled due to improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes, chemical reactions and structural changes during storage. Drying is the most common way to preserve agricultural products. It usually refers to the removal of water from a substance using some energy source (Allen,1960). It is well known that the quality is strongly affected by drying methods and drying process. In the drying of ginger, the water is evaporated from the freshly harvested ginger rhizome to moisture content close to that of its storage environment (Rao, 1986). For the prevention of crop from deterioration and for increasing its shelf life, various preservation methods are employed. A major goal of food processing is to convert perishable commodities

into stable products that can be stored for extended periods thereby reducing losses and making them available at the time of shortage and off-season use and for places which are far away from production site. Processing can change foods into new or more usable forms and make them more convenient to prepare. Several processing technologies have been employed on industrial scale to preserve food products. These include canning, refrigeration, controlled atmosphere storage, dehydration, chemical treatment and use of subatomic particles. Product drying is an integral part of production, handling, storage and utilization chain (Cenkowski *et al* 1993). Drying is the process of removal of moisture from grain mass to a safe level of moisture content for preservation of quantity, quality, nutritive value and viability. Drying is one of the oldest methods of preserving food. Dried foods can be stored for long periods without deterioration. The principle reasons for this are that the micro-organisms which cause food spoilage and decay are unable to grow and multiply in the absence of sufficient water and many of enzymes which promote undesired changes in the chemical composition of the food cannot function without water. Product is dried whenever high moisture content poses a threat to its safe storage. Product can be dried using near-ambient or higher temperature air in drying systems, commonly referred to as dryers. It brings about substantial reduction in weight and volume; thereby lowering packaging, transportation and storage costs and enables storability of the product under ambient temperatures. Drying is the most energy-consuming and the least understood unit operation, consisting of a simultaneous heat and mass transfer process (Sun and Woods 1997). The importance of drying farm produce is increasing. Drying permits the farmer to secure a greater economic return for their produce, as early harvest (at high moisture content) minimizes field damage and shattering loss. Long-period storage without product deterioration is possible. Viability of seeds is maintained over long period. Products with greater economic value are produced. Waste products can be converted to useful products. The transportation and storage losses are reduced since the quality of grains is the best.

Free flowing difficulty and caking are common problems in powders due to moisture exchange between food product and its surrounding atmosphere. These changes can be controlled after providing adequate packaging. The ginger must be stored in a cool, dry and good ventilated room. Fresh, unpeeled root should be wrapped in paper towels, placed in a plastic bag and refrigerated up to three weeks. It can also be tightly wrapped and frozen up to two months. Dried ginger should be kept in a cool, dark space in an airtight container. Processing and storage conditions have impact on the physicochemical properties of food and food components (Niba 2003).

Food packaging is rooted in man's advancement in the production and processing of foods. In the 1960s and 1970s, most of the major packaging accomplishments involved the development of plastic jars, bottles, tubs, and films from polyolefins, polyvinyl, polyethylene, vinylidene, vinyl chloride, surlyn, and nylon. (Sacharow *et al* 1970) From a historical perspective, humans have struggled to develop means to provide protection from the ravages of time and environment for natural and manufactured products. Food packaging exists because it performs four basic functions: protection, containment, information, and utility of use (Kelsey 1989).

Packaging can directly prevent the development of light-induced off-flavour by protecting the product from both light and oxygen (Schröder 1982; Skibsted 2000; Vassila *et al* 2002). MAP costs twice as much as vacuum packaging because it requires special packaging material and gases (Reddy *et al* 1992). The elimination of O₂ from the packaging and the introduction of different concentrations of CO₂ and N₂, together with adequate refrigeration, inhibits the growth of aerobic micro-organisms, proteolytic bacteria, yeasts and fungi (Swiderski *et al* 1997). Vacuum and MAP have certain advantages over other more traditional methods since such practices increase the shelf-life of raw vegetables by 50–400% by reducing respiration and ethylene production, delaying ripening and softening and reducing chlorophyll degradation, while at the same time maintaining organoleptic characteristics (taste, aroma, texture) (Francis *et al* 1999). Since ginger is a very important spice and little work has been reported on drying of ginger into various physical forms and its subsequent storage and packaging in different packaging materials, a need was felt to study the effect of packaging material and storage conditions on quality and shelf life of dried ginger.

Keeping in view the above aspects, the present study was carried out with the following objectives:

1. To study the change in the quality parameters of dried ginger under different packaging and storage conditions.
2. To select the best packaging material and storage conditions for improving the shelf life of dried ginger.

CHAPTER II

REVIEW OF LITERATURE

The present study was undertaken to study the effect of packaging material and storage conditions on shelf life of dried ginger in order to select the most suitable packaging material based on physico-chemical quality and sensory evaluation. The various relevant parameters that influence the quality of end product were taken into consideration while reviewing the literature. The literature has been reviewed as below under the following heads:-

- (i) Ginger
- (ii) Volatile oil
- (iii) Colour change
- (iv) Drying
- (v) Flavour changes
- (vi) Modified atmosphere packaging
- (vii) Packaging material
- (viii) Storage
- (ix) Weight change

2.1 Ginger

Mukherjee *et al* (1995) studied the shelf-life enhancement of fresh ginger rhizomes at ambient temperatures by combination of gamma-irradiation, biocontrol and closed polyethylene bag storage. Storage in closed polyethylene bags reduced weight loss but increased sprouting and rooting, which could be prevented by gamma irradiation to 60 Gy. Rotting caused by *Sclerotium rolfsii* was, however, a major cause of spoilage during extended storage.

Mishra *et al* (2004) studied the shelf-Life extension of fresh ginger (*Zingiber officinale*) by gamma Irradiation. Gamma irradiation was found to extend the shelf life of farm fresh ginger. A 5-kGy radiation dose and 10 °C storage temperature were found to keep peeled ginger samples microbe free and acceptable until 70 d of storage, whereas non irradiated (control) peeled ginger spoiled within 40 d under similar storage conditions.

Jolad *et al* (2005) determined commercially processed dry ginger (*Zingiber officinale*): Composition and effects on LPS-stimulated PGE₂ production. Using techniques previously employed to identify ginger constituents in fresh organically grown Hawaiian white and yellow ginger varieties, partially purified fractions derived from the silica gel column chromatography and HPLC of a

methylene chloride extract of commercially processed dry ginger, *Zingiber officinale* Roscoe, Zingiberaceae, which demonstrated remarkable anti-inflammatory activity, were investigated by gas chromatography-mass spectrometry.

Kim and Lee (2006) studied the changes in some quality factors of frozen ginger as affected by the freezing storage conditions. The effects of types of ginger root, the freezing storage temperature and time on quality factors associated with color, off-odor and acceptability of frozen ginger were evaluated to establish the freezing storage conditions of ginger roots. The quality of the ginger was determined at the following times and storage temperatures: the ginger stored at -5°C , -20°C , and -40°C was sampled at 30-day intervals for 4 months, at 90-day intervals for 12 months, and at 120-day intervals for 16 months, respectively. The content of free sugars, free amino acids (FAAs), unsaturated fatty acids (FUFAs) and volatile compounds noticeably decreased during the storage period, while the total color difference (ΔE) increased, and the temperature effect was significant. The changes in these compounds were generally less in the whole ginger samples. The increase of ΔE with decreases of free sugars, FAAs and sensory color indicated the discoloration of frozen ginger was due to the browning reaction. The sensory off-odor and overall preference scores showed that whole ginger could be stored for 2 or 9 months at -5 or -20°C , respectively, maintaining a good overall quality.

Stoilova *et al* (2007) evaluated the antioxidant activity of a ginger extract (*Zingiber officinale*). The antioxidant effect and the total phenols of ginger extract were studied. The antioxidant activity in a linoleic acid/water emulsion system was highest at 37°C – 73.2%, and 71.6% when the formation of conjugated dienes was inhibited. At 80°C the antioxidant activity at the highest concentration of a ginger extract was less efficient: 65.7% for conjugated dienes formation and 68.2% for TBARS. The ginger extract inhibited the hydroxyl radicals 79.6% at 37°C and 74.8% at 80°C , which showed a higher antioxidant activity than quercetin.

Ali *et al* (2008) studied some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): A review of recent research. Ginger (*Zingiber officinale* Roscoe, Zingiberaceae) is a medicinal plant that has been widely used in Chinese, Ayurvedic and Tibb- Unani herbal medicines all over the world, since antiquity, for a wide array of unrelated ailments that include arthritis, rheumatism, sprains, muscular aches, pains, sore throats, cramps, constipation, indigestion, vomiting, hypertension, dementia, fever, infectious diseases and helminthiasis. This article aims at reviewing the most salient recent reports on these investigations.

Abraham *et al* (2010) studied the effect of dried ginger powder, fennel powder, cumin powder and fresh ginger extract addition on supari from aonla (*Emblica officinalis* Gaertn). This work was carried out to study the nutraceutical and biochemical properties of value added supari from

aonla (*Embllica officinalis* Gaertn). The percentage composition of total phenol content and tannin content seems to increase after Osmotic dehydration and drying in all the treated samples. While, it was found that, titrable acidity and ascorbic acid content decreased. Sensory evaluation and microbiological analysis was also carried out for the samples.

Zhao *et al* (2010) studied the surface characterization of ginger powder examined by X-ray photoelectron spectroscopy and scanning electron microscopy. The results show that the color differences are greater for superfine ground ginger than for conventional comminuted ones; the values of crude fibre, neutral detergent fiber (NDF) and acid detergent fiber (ADF) decrease with decreasing ginger particle size.

2.2 Volatile oil

Zhang *et al* (1994) evaluated that gingerol decreases after processing and storage of ginger. Fresh cooked ginger and processed ginger products were extracted with methanol and analyzed by HPLC to study changes in the levels of [6]-, [8]-, and [10]-gingerols after the products had been cooked and processed, and during storage of the products. Cooking and processing of paste and senbei decreased gingerol levels, but blanching and freeze-drying had no effect. Gingerols in all products degraded gradually with storage. Ginger powder had a lower degradation rate than the paste stored at 4°C. Likewise, ginger senbei was more stable than ginger powder stored at room temperature ($\cong 23^{\circ}\text{C}$).

Zarate and Yeoman (1996) evaluated the changes in the amounts of [6]gingerol and derivatives during a culture cycle of ginger, *Zingiber officinale*. The accumulation of [6]gingerol and [6]shogaol (phenolic pungent principles of ginger) was much higher in culture systems of *Zingiber officinale* where morphological differentiation was apparent. Cultures grown on a callus-inducing medium also accumulated these metabolites but to a lesser extent.

Variyar *et al* (1997) studied the effect of γ -irradiation on the volatile oil constituents of fresh ginger (*zingiber officinale*) rhizome. Major compounds present in these oils were identified by GLC and GC/MS analysis. Zingiberin, β -sesquiphellandrene and ar-curcumene were the major compounds identified with zingiberin accounting for 40% of the essential oil. γ -irradiation at a dose of 60Gy did not bring about any detectable qualitative and quantitative changes in the aroma constituents of the spice immediately after irradiation.

Schwertner and Rios (2007) evaluated the High-performance liquid chromatographic analysis of 6-gingerol, 8-gingerol, 10-gingerol, and 6-shogaol in ginger-containing dietary supplements, spices, teas, and beverages. The recoveries of 6-, 8-, and 10-gingerol, and 6-shogaol from the ginger dietary supplements and ginger-containing products were 94.7 ± 4.1 , 93.6 ± 3.4 , 94.9 ± 4.0 , $97.1\pm 3.8\%$, respectively. The within-day coefficients of variation for 6-gingerol, 6-shogaol, 8-gingerol, and 10-

gingerol standards at 50.0 g/mL were 2.54, 2.38, 2.55, and 2.31%, respectively. The variation (CV's) in the 6-gingerol, 6-shogaol, 8-gingerol, and 10-gingerol concentrations of nine different ginger root dietary supplements were 115.2, 45.7, 72.3, and 141.7%, respectively. The gingerol composition of various ginger-containing spices, teas, and beverages also were found to vary widely.

Toure and Xiaoming (2007) conducted a study on the gas chromatographic analysis of volatile components of Guinean and Chinese ginger oils (*Zingiber officinale*) extracted by steam distillation. The results showed that more than 90 components were separated of Guinean and Chinese ginger, respectively were tentatively identified. The components accounted for about 93.57 and 89.55% of the total relative content for Guinean and Chinese ginger, respectively. Zingiberene (19.89 and 31.1%) was the most abundant compound identified for Guinean and Chinese ginger. The major effects of the steam distillation process are increase in terpene hydrocarbons and monoterpene alcohols.

Cheng-Lun *et al* (2008) carried out research on the extracting and anti-oxidation dynamic characteristics of ginger oleoresin. The pore diameter distribution and specific surface area of ginger residue have been measured by ASAP2010 Physical Adsorption Instrument. The micro pore volume is 43%, and medium pore volume is 47%. An improved purifying condition on oleoresin is 50°C, solid/liquid ratio 1:3 and extraction time is 1.5 h.

Singh *et al* (2008) studied the chemistry, antioxidant and antimicrobial investigations on essential oil and oleoresins of *Zingiber officinale*. The essential oil and oleoresins (ethanol, methanol, CCl₄ and isooctane) of *Zingiber officinale* were extracted respectively by hydrodistillation and Soxhlet methods and subjected to GC-MS analysis. Geranial (25.9%) was the major component in essential oil; eugenol (49.8%) in ethanol oleoresin, while in the other three oleoresins, zingerone was the major component (33.6%, 33.3% and 30.5% for, methanol, CCl₄ and isooctane oleoresins, respectively). For other tested fungi and bacteriae, the essential oil and all oleoresins showed good to moderate inhibitory effects. Though, both essential oil and oleoresins were found to be effective, essential oil was found to be better than the oleoresins.

Szumny *et al* (2010) observed the composition of rosemary essential oil (*Rosmarinus officinalis*) as affected by drying method. Thirty-four compounds were tentatively identified, with α -pinene, bornyl acetate, camphene and 1,8-cineole being the major components. The total volatiles concentration of fresh rosemary (135 g kg⁻¹) decreased considerably during both convective (CD) (87.2 g kg⁻¹) and vacuum-microwave (VMD) (61.9 g kg⁻¹). convective pre-drying and VM finish-drying (CPD-VMFD) was the best option for drying rosemary because the time required was relatively short (30 min), and the aroma quality was good according to both instrumental (100 g kg⁻¹) and sensory analyses.

Pawar *et al* (2011) determined the RP-HPLC analysis of phenolic antioxidant compound 6-gingerol from different ginger cultivars. The quantities of phenolic compound 6-gingerol was determined with reverse phase high performance liquid chromatography (RP-HPLC) which was ranging from 0.1% to 0.2%. The antioxidant capacity was determined using DPPH (1,1-diphenyl-2-picrylhydrazyl) and FRAP (ferric-reducing antioxidant power) assays. The rhizome of Rajasthan and Rio De Janero cultivars were good sources for these compounds among the cultivars examined.

Sivasothy *et al* (2011) evaluated the essential oils of *Zingiber officinale* var. *rubrum* Theilade and their antibacterial activities. Forty-six constituents were identified in the leaf oil, while 54 were identified in the oil from the rhizomes. The leaf oil was clearly dominated by β -caryophyllene (31.7%), while the oil from the rhizomes was predominantly monoterpenoid, with camphene (14.5%), geranial (14.3%), and geranyl acetate (13.7%) the three most abundant constituents.

Zhan *et al* (2011) studied the preparative separation and purification of gingerols from ginger (*Zingiber officinale* Roscoe) by high-speed counter-current chromatography. The experiment yielded 30.2 mg of 6-gingerol, 40.5 mg of 8-gingerol, 50.5 mg of 10-gingerol from 200 mg of crude extract in one-step separation. And the purity of these compounds was 99.9%, 99.9% and 99.2%, respectively, as determined by high-performance liquid chromatography (HPLC). Their structures were identified by gas chromatography–mass spectrometry (GC/MS) and ¹H, ¹³C nuclear magnetic resonance (NMR).

2.3 Colour change

Gangwar (1972) stated that the change in colour from green to light yellow as well as softening of fruits at maturity gave an indication that the decomposition of chlorophyll and dissolution of cell wall cementing material began with start of maturity. Hence, the extent of firmness and the change in colour of fruit at full maturity may be used as a field method to judge the appropriate time of their picking.

Jowitt *et al* (1987) stated that in the objective measure the colour of a sample means locate the co-ordinates in colour space which represent that particular sample. The response of the human eye was standardized in 1931 and led to what is known as the CIE system (Commission International d'Enclairage), which was rapidly adopted world-wide. Many colour solids have been developed to encompass the range of colors discernible to the human eye. Two are possibly better known than the others. They are the CIE XYZ solid and the Judd-Hunter Lab solid.

Brackett (1990) studied the overall sensory quality, colour changes and surface pH of bell pepper were monitored. Shrink wrapped (SW) peppers developed higher populations of total aerobic microorganisms, yeast, moulds and enterobacteriaceae than did cardboard packing peppers but populations of other groups of micro-organisms were similar. Colour and surface pH of peppers did

not differ in any of the treatments. SW and sealed in GP peppers remained unspoiled for at least 6 weeks, whereas CN peppers spoiled in 3 weeks.

Patel *et al* (1993) reported that initially, the guava fruits were greenish, but subsequently on gradual ripening, they turned greenish-yellow, yellow, yellowish-brown and finally brownish during storage.

Meir *et al* (1995) have found pre-storage holding of peppers packed in perforated bags for 2 days at 25°C resulted in full red colour developed at the end of a 12 day storage period without loss of firmness and quality.

Manzano *et al* (1997) carried out experiments on coating waxes on Haden mangoes. Mangoes were wax treated and stored at 12, 18 or 25°C for upto 20 days. The 'L' and chroma values were higher in treated fruits than in control fruits. Hue values remained close to zero throughout storage. Ethylene application and waxing resulted in good colour and uniform ripening after 20 days of storage at 12 or 18°C.

Baskaran *et al* (2002) measured the colour of avocado peel and pulp initially and at the end of storage period using UV/visible recording spectrophotometer at wavelength ranging from 360 to 800 nm and expressed as Hunter colour values 'L', 'a' and 'b'. Both peel and pulp values of waxed fruits under MAP condition stored at $8 \pm 2^\circ\text{C}$ at initial stage and upto a period of 22 days showed that there was no softening of the fruits. The change in colour and ripening correlated with the steady increase in the rate of respiration reaching a peak on the 32nd day.

Keditsu *et al* (2003) found that the fruits from polythene bag, KMnO_4 + polythene bag and 0-1°C treatments recorded minimum colour development whereas, fruits stored at room temperature showed maximum colour development during entire storage. The slow colour development in polythene and KMnO_4 + polythene bag treatments was indicative of reduced rate of metabolic changes within the fruits or it may be attributed to higher accumulation of CO_2 concentration and depletion of O_2 level around the fruit.

Thakur (2008) studied the drying kinetics and evaluated physical quality of green peas. Fresh and blanched green peas were dried at 55, 60 and 65°C in a tray dryer with loading of 5 kg/m². Four statistical models, which are semi-theoretical and/or empirical have been investigated. The colour change of peas during drying at different air temperature followed first order reaction kinetics with a rate constant of 0.206 and 0.271/°C for blanched and unblanched samples, respectively.

Paksi *et al* (2010) studied the changes in colour and antioxidants during vine and postharvest ripening of tomato fruit. Detached tomato fruit stored at 15°C and 30°C, and vine ripened fruit were studied to characterise ripening by Hue (°) index of the CIELab colour system, which is strongly influenced by ripening. Colour changes of fruit stored at 15°C and

vine ripened fruit showed significant differences compared to fruit stored at 30°C.

2.4 Drying

McMinn and Magee (1999) studied the principles, methods and applications of the convective drying of foodstuffs. During the drying process, a multiphase system undergoes simultaneous physical and structural modifications. Therefore, for accurate interpretation of this coupled heat and mass transport operation, moisture transport characteristics and physical property data is essential.

Straatsma *et al* (1999) evaluated spray drying of food products: 2. Prediction of insolubility index. It was proven possible to achieve a good fit between the calculated values of the insolubility index obtained from an idealised model and the values obtained experimentally. This method is also suitable for other food products. The kinetic model can be used as a submodel for drying simulation models that describe the behaviour of the individual particles during spray drying. The combination of these models is an effective tool in giving indications of how to adapt industrial dryers to reduce the insolubility of the powder and get a better product quality.

Doymaz and Pala (2002) studied the theoretical and experimental study of the drying kinetics of red peppers under different pretreatment and air drying conditions. Our results indicated that pretreated peppers dried faster and had higher Hunter L (lightness), Δa (redness) and Δb (yellowness) values than the untreated and dried peppers. 2% ethyl oleate and 5% K_2CO_3 solution was found to be the most effective dipping solution that provided for whole peppers dried at 50°C, and yielded best color quality. Drying curves of sliced peppers were obtained using the Page and exponential equations. Comparing the r^2 values of both equations, it was concluded that the Page equation represents drying characteristics better than the exponential equation.

Hu *et al* (2006) studied the drying of edamames by hot air and vacuum microwave combination. The characteristics of hot air and vacuum microwave drying were compared using edamame as the raw material, and an optimized combination drying process was then established thereof so as to achieve increased drying rate and enhanced product quality. Edamame was subjected to 70°C hot air drying for 20 min, and then microwave dried at power intensity 9.33 W/g for 15 min under -95 kPa (gauge pressure). The optimized combination drying process exhibited significantly shortened drying time as compared with conventional hot air drying, and greatly decreased mass loads on the vacuum microwave dryer.

Swami *et al* (2007) studied the convective hot air drying and quality characteristics of bori: A traditional Indian nugget prepared from black gram pulse batter. Drying characteristics of bori nuggets, an Indian traditional food, prepared from black gram batter were studied using hot air temperature of 30, 50 and 70°C and air flow rates of 0.6, 1.0 and 1.4 m/s. The drying constants

obtained from Lewis equation decreased from 0.457 to 0.139, 0.514 to 0.324 and 0.735 to 0.487 ($r \geq 0.975$; $MSE \leq 0.0082$) for 30, 50 and 70°C, respectively, while the air velocity decreased from 1.4 to 0.6 m/s in each case.

Doymaz (2007) studied the air-drying characteristics of tomatoes. The drying characteristics of tomatoes were investigated at 55, 60, 65 and 70°C with air flow rate of 1.5 m/s. Also, drying of raw tomatoes was taken as a control. During the experiments, tomatoes were dried to the final moisture content of 11% from 94.5% (w.b.) It has been found that pre-treatment and air temperature affect the course and rate of drying. The experimental data were fitted to two drying models: Henderson and Pabis, and Page models. The models were compared using the coefficient of determination and reduced chi-square. The Page model best described the drying curve of tomatoes. A diffusion model was used to describe the moisture transfer and the effective diffusivity at each temperature was determined. The temperature dependence of the diffusivity coefficient was also described by the Arrhenius type relationship.

Orikasa *et al* (2008) determined the drying characteristics of kiwifruit during hot air drying. Drying characteristics and L-ascorbic acid changes of a kiwifruit slice (10 mm) were investigated during hot air drying at four temperatures ranging from 40 to 70°C. A relationship between hardening of the sample surface and the drying rate was also investigated. An Arrhenius-type equation was used to relate the diffusion coefficient of kiwifruit to temperature, and the activation energy of kiwifruit for hot air drying was estimated. In addition, it was estimated that the drying rate of kiwifruit might increase by avoiding hardening of the sample surface. In order to examine the nutrient changes in kiwifruit during hot air drying, a first-order rate equation was applied to the changes in the decomposition of L-ascorbic acid contents during drying.

Therdthai and Zhou (2009) evaluated the characterization of microwave vacuum drying and hot air drying of mint leaves (*Mentha cordifolia* Opiz ex Fresen). Mint (*Mentha cordifolia* Opiz ex Fresen) was subjected to microwave vacuum drying and hot air drying, respectively. Lewis's, Page's and Fick's models were used to describe drying kinetics under various drying conditions. The microwave vacuum drying could reduce drying time of mint leaves by 85–90%, compared with the hot air drying. In addition, color change during drying was investigated. Lightness, greenness and yellowness of the microwave vacuum dried mint leaves were higher than those of the hot air dried mint leaves. From scanning electron micrographs, the microwave vacuum dried mint leaves had a more porous and uniform structure than the hot air dried ones.

Vega-Gálvez *et al* (2009) determined the effect of air-drying temperature on physico-chemical properties, antioxidant capacity, colour and total phenolic content of red pepper (*Capsicum annuum*, L. var. Hungarian). The rehydration ratio decreased with temperature and the maximum

water holding capacity was achieved at 50°C. Both vitamin C content and the total phenolic content decreased as air-drying temperature decreased. The radical scavenging activity showed higher antioxidant activity at high temperatures (i.e. 80 and 90°C) rather than at low temperatures (i.e. 50, 60 and 70°C). Chromatic parameters (L^* , a^* , b^* , C^* and H°), non-enzymatic browning compounds and extractable colour were affected by drying temperature, which contributed to the discolouring of pepper during this process.

Phoungchandang and Saentaweesuk (2010) determined the effect of two stage, tray and heat pump assisted-dehumidified drying on drying characteristics and qualities of dried ginger. Desorption isotherms for sliced gingers have been measured. Tray and heat pump dehumidified drying incorporated by single and two stage drying were conducted. It was found that the modified Page model was the most effective. The drying constant was fitted to drying air temperature using the Arrhenius model. Effective moisture diffusivities were determined using the drying data. The heat pump dehumidified drying incorporated by the two stage drying could reduce the drying time at 40 °C by 59.32% and increase 6-gingerol content by 6%. Quality evaluation by 6-gingerol content, rehydration ratio and ΔE^* showed the best quality for dried sliced gingers in the heat pump dehumidified drying incorporated by the two stage drying at 40°C.

2.5 Flavour changes

Freeman and Whenham (1976) studied the effect of overwinter storage at three temperatures on the flavour intensity of dry bulb onions. Flavour intensity increased progressively with length of storage to about 190 days and was usually followed by a steep downturn to 240 days' storage. These changes have been interpreted in terms of incidence of sprouting and changes of respiration rates.

Petersen *et al* (1998) compared the normal and accelerated storage of commercial orange juice changes in flavor and content of volatile compounds. Sensory quality, content of aroma compounds and colour were measured. Significant changes were seen in all three parameters, and the pattern of changes in both sensory quality and in content of aroma compounds were practically identical during normal and accelerated storage, except for the time span: the changes in quality after 6 months at 20%’ corresponded to the changes after 13 days at 40°C and after 5 days at 50°C. Quality changes during storage for half a year can therefore be predicted by 1-2 weeks’ accelerated storage. Furthermore, from partial least squares (PLS)-regression of sensory quality on content of 11 aroma compounds it was found that a trained panel’s average score of orange taste, orange odour, oxidized taste, oxidized odour and bitterness could be predicted with a high degree of certainty from measurement of the 11 aroma compounds.

Valero *et al* (2001) studied the changes in flavour and volatile components during storage of whole and skimmed UHT milk. Six batches of commercial UHT milk, submitted to direct treatment, three whole and the other three skimmed milk, were stored at $25\pm 2^{\circ}\text{C}$ for 4 months. Non-casein nitrogen (NCN) increased during storage; the increase was greater in skimmed milk samples. Sensory characteristics were slightly better in the whole samples, although the scores decreased for both groups in the third month. Quantification of about 40 volatile components in whole milks showed no changes until 90 days (the legal shelf-life in Spain); the main change was the increase of methyl ketones.

Oirschot *et al* (2003) studied the sensory characteristics of five sweet potato cultivars and their changes during storage under tropical conditions. A principal component analysis (PCA) revealed two principal components (PC1 and PC2) explaining in total 68% of the variation. PC1 explained 52% and correlated with textural properties, and PC2 explained 16% of the variation and correlated with flavour components. The results suggest that differences between sweet potato cultivars are mainly determined by textural components. Storage had most effect on the sweet and chestnutty characteristics, and did not affect the texture characteristics. Overall the changes during storage were less significant than the differences between the cultivars.

Abegaz *et al* (2004) studied the role of moisture in flavor changes of model peanut confections during storage. Peanut pastes with 2 g $\text{H}_2\text{O}/100$ g and 5 g $\text{H}_2\text{O}/100$ g added moisture had lower ‘roasted peanutty’ intensity and lower pyrazine concentrations than those samples without added moisture. Samples with 2 g $\text{H}_2\text{O}/100$ g and 5 g $\text{H}_2\text{O}/100$ g added moisture had lower PV as well as lower hexanal and heptanal concentrations. Significant positive correlations were observed between pyrazine concentrations and ‘roasted peanutty’ flavor.

Rhee *et al* (2005) compared the flavor changes in cooked–refrigerated beef, pork and chicken meat patties. The rate of decline in species-specific natural meat flavor intensity and the rate of increase in “cardboard” (CBD) flavor intensity during the first half of the 6-day storage were fastest for beef, while such decline and increase during the entire storage period were slowest for chicken B. It was concluded that, while flavor deterioration can occur in cooked–stored meats from all the species, quantitative or the magnitude of differences between species would depend on muscle types and sensory terms/method used.

Chen *et al* (2006) studied the changes in the volatile compounds and chemical and physical properties of Yali pear (*Pyrus bertschneideri* Reld) during storage. By using GC-olfactometry, it was demonstrated that the volatile compounds from solidphase microextraction (SPME) were responsible for the aroma of Yali pear. Fructose was the dominant sugar, followed by glucose and sucrose. With increasing storage time, sucrose levels decreased, however fructose and glucose levels did not

changed remarkably. There was a slight decrease in flesh firmness during storage. The general soluble solids concentration, slightly decreased after 5 months storage. Some aroma volatile components increased during storage, while others decreased, especially the esters. The organic acids and phenolic acids also changed. Yali pear flavor was affected by changes in the levels of volatile compounds, and chemical and physical properties.

Karatapanis *et al* (2006) studied the changes in flavour volatiles of whole pasteurized milk as affected by packaging material and storage time. Two distinct patterns of milk flavor deterioration were observed. In light-exposed samples, a light-induced oxidation mechanism prevailed while in light-protected samples, an autoxidation mechanism was apparent. Under both conditions, the concentration of selected odorous compounds increased with storage time. Microbiological data correlated poorly with both sensory and GC/MS data. Sensory data correlated well with selected volatile compounds pointing to dimethyl disulphide, pentanal, hexanal and heptanal as potential markers of fresh milk quality. Based on sensory analysis, the optimal shelf life of the whole pasteurized milk used in this study was approximately 5 days.

Sahan *et al* (2008) determined the physical, chemical and flavour quality of non-fat yogurt as affected by a b-glucan hydrocolloidal composite during storage. In this study, a possible use of b-glucan hydrocolloidal composite as a fat replacer in the manufacture of non-fat yogurts was investigated. Fat and protein contents of the experimental yogurts were identical, while ash content differed. Addition of b-glucan composite did not show a significant change of pH, titratable acidity, acetaldehyde, volatile fatty acids and tyrosine contents at any storage time. Titratable acidity and tyrosine content increased significantly throughout storage. Gel firmness and water-holding capacity in the yogurts were not influenced by addition of b-glucan composite, but these variables decreased with storage time. Addition of b-glucan composite and storage time caused a decrease in whey separation. Viscosity values in the yogurts increased by addition of b-glucan composite and storage time. Sensory results indicated a preference for control yogurts; however, use of low levels of b-glucan composite in the production of non-fat yogurt gave satisfactory sensory scores.

Edelenbos *et al* (2010) studied the effects of minimal processing and packaging on volatile compounds and other sensory aspects in carrots. Several studies demonstrate that volatile terpenes play a major role for the aroma and flavour perception of carrots. Carrots were minimally processed and packaged and then analysed for volatile constituents by dynamic headspace sampling. The total terpene content decreased by 59%. Washing in water after cutting and then spin-drying further reduced the volatile content, especially the sesquiterpenes. Flavour intensity, carrot flavour, sweetness and juiciness were significantly lower in the cut, washed and spin-dried product as compared to the cut and spin-dried product. In contrast, minimally processed carrots packaged in non-perforated film

only lost around 70% of the initial terpene content. These findings indicate that gentle processing and optimal packaging technology are essential factors to provide consumers with minimally processed carrot with high terpene flavour quality.

Aguiló-Aguayo *et al* (2010) studied the changes on flavor compounds throughout cold storage of watermelon juice processed by high-intensity pulsed electric fields or heat. HIPEF processing not only induced a rise (roughly 20%) in the concentrations of hexanal, (E)-2-nonenal, nonanal, 6-methyl-5-hepten-2-one and geranylacetone but also achieved less reductions on the retention of volatiles than the thermal treatment at 90°C for 60 s. In contrast, the content of (Z)-6-nonenal, 1-nonanol and (Z)-3-nonen-1-ol in the untreated and processed juices remained unchanged after processing. Despite the decrease in overall flavor compounds observed during storage irrespective of the treatment applied, HIPEF-treated juices showed better flavor retention than heat-treated samples for at least 21 days of storage.

Chin *et al* (2010) studied the effect of thermal processing and storage condition on the flavour stability of spray-dried durian powder. Stability of key odour volatiles (propanethiol, ethyl propanoate, ethyl 2-methylbutanoate and diethyl disulfide) from spray-dried durian powder that was subjected to accelerated storage were analysed quantitatively using headspace solid phase microextraction coupled to fast gas chromatography–mass spectrometry. The type of drying aids incorporated significantly influenced volatiles retention in the powder product. The addition of gum Arabic resulted in higher retention of volatiles in the durian powder as compared to maltodextrin and N-Lok starches. Volatiles that remained in the powder ranged from 57% to 76% of the original concentration. Volatile composition of the powder product was altered with only two aldehydes included 2- and 3-methyl butanal and no off-flavour volatile was detected throughout the storage. The rates of volatiles release from the spray-dried powder under accelerated storage condition increased markedly at higher relative humidity.

Aguiló-Aguayo *et al* (2010) studied the volatile compounds and changes in flavour-related enzymes during cold storage of high-intensity pulsed electric field and heat-processed tomato juices. HIPEF-treated juice exhibited higher levels of compounds contributing to tomato aroma than untreated and heat-treated juices throughout storage. Thus HIPEF processing can preserve flavour quality and stability of tomato juice compared with conventional thermal treatments.

Schindler *et al* (2010) studied the aroma development in high pressure treated beef and chicken meat compared to raw and heat treated. Vacuum-packed beef meat with a smaller fraction of unsaturated fatty acids showed better oxidative stability during 14 days of cold storage, as shown by a low steady-state level of hydroperoxide values, than vacuum-packed chicken meat. Overall, beef meat contained less volatiles and in lower abundance (factor of 5) compared to chicken meat. Lipid

oxidation was significantly accelerated during 24 h of cold storage in both cooked chicken and beef when exposed to oxygen, while the pressurised and oxygen-exposed chicken and beef meat remained stable. Pressure treatment of beef and chicken did not induce severe changes of their raw aroma profiles.

Jensen *et al* (2011) evaluated chemical changes in wheat pan bread during storage and how it affects the sensory perception of aroma, flavour, and taste. Fresh wheat bread had a higher concentration of the fermentation products 2,3-butandione and 3- hydroxy-2-butanone and the Strecker aldehydes 2- and 3-methylbutanal. Bread stored 2 and 3 weeks generally had a higher content of secondary lipid oxidation products than the more fresh samples. The total content of soluble phenolic acids stayed unchanged during storage. Most sensory attributes could be directly related to changes in the chemical composition of volatiles. The formation of off-flavours in bread could be related to the formation of secondary lipid oxidation products together with decreasing levels of compounds from Maillard reactions.

Balestra *et al* (2011) studied the evaluation of antioxidant, rheological and sensorial properties of wheat flour dough and bread containing ginger powder. The effects of addition of ginger powder (0, 3, 4.5 and 6%) in formulation were examined in order to obtain an antioxidant-enriched bread with good physico chemical and sensorial properties. The rheological properties of doughs were evaluated using dynamic rheological measurements. Physical properties, total phenolics content (TPC- Folin-Ciocalteu method), radical scavenging activity (RSA- DPPH assay) and sensory analysis (hedonic test) of the supplemented bread were determined. Among the studied samples, bread with 3% of ginger powder showed good rheological characteristics and doubled anti-oxidant content compared to the control bread and the highest sensorial acceptability.

2.6 Modified atmosphere packaging

Jayasingh *et al* (2001) studied the evaluation of carbon monoxide treatment in modified atmosphere packaging or vacuum packaging to increase color stability of fresh beef. Our goal was to obtain > 21 days red color stability for carbon monoxide (CO)-treated beef steaks in vacuum packaging (VP). In preliminary tests, pretreatment for 24 h in a 5% CO modified atmosphere package (MAP) was needed to maintain redness after re-packaging in VP. Pressure pretreatment with 5% CO for 2 h developed redness, but was impractical for large-scale application. Color stability and microbial load were then compared after treatment of steaks in 5% CO-MAP for 24 h, then VP; 100% COMAP for 1 h, then VP; steaks and ground beef in 0.5% CO-MAP; and steaks and ground beef in polyvinyl chloride (PVC) wrap. Steaks remained red for 5, 6, 8 and <1-week storage at 2°C, respectively. Steaks microbial load exceeded spoilage levels (>10⁶cfu/ cm²) at 5, 6, 7 and <2-weeks,

respectively. Thus, extended color stability in VP was achieved by pretreatment with 5% CO for 24 h or 100% CO for 1 h.

Skandamis and Nychas (2002) determined the preservation of fresh meat with active and modified atmosphere packaging conditions. It was found that the extension of shelf life of meat samples depended on the packaging conditions and augmented in the order: air < vacuum pack < 40% CO₂/30% N₂/30% O₂ < 80% CO₂/ 20% air < 100% CO₂. Longer shelf life was observed in samples supplemented with the volatile compounds of oregano essential oil and stored under the same packaging conditions mentioned above. The effect of essential oil volatile compounds was even more pronounced on the physicochemical changes of meat samples caused by microbial association.

Murcia *et al* (2003) studied extending the shelf-life and proximate composition stability of ready to eat foods in vacuum or modified atmosphere packaging. The stability of the proximate composition (moisture, proteins, lipids and ash) and the microbiological state of cooked 'ready to eat' foods in vacuum or modified atmosphere packaging were examined and compared with conventionally packaged (in air) foods. The study was carried out for 7 and 29 days, during which time the food products were stored at 3°C. Vacuum or modified atmosphere packaging were effective for prolonging the shelf-life of the studied products up to 29 days with minimal changes in the proximate composition. Aerobic mesophilic, psychrotrophic microorganisms, and yeasts and moulds increased with time regardless of packaging type but more rapidly under conventional packaging.

García-Esteban *et al* (2004) compared modified atmosphere packaging and vacuum packaging for long period storage of dry-cured ham: effects on colour, texture and microbiological quality. Lightness was found to be more stable when samples were stored with 20% CO₂ and 80% N₂ without statistical differences between vacuum and 100% N₂. A slight whiteness was observed in the vacuum packed samples. Yellowness increased during time in vacuum packed samples, although no differences were found among the three conditions at the end of the study. Redness values were not affected by time or by the packaging system. With regard to texture, values found for all samples were within the normal range for this type of products, although it was observed that modified atmosphere packaging preserved samples better from hardening than vacuum packaging. No safety problems were detected in relation to the microbial quality in any case. In general, no clear differences were found among the three packaging systems for colour, texture and microbial quality in the storage conditions studied.

Chapon *et al* (2004) studied a modified atmosphere system using a nitrogen generator. The generation of a stable modified atmosphere using a commercial oxygen scrubber (or N₂ generator), designed to store and transport palletised fruit and vegetables, was investigated. The two main advantages of the system compared with conventional MAP are the possibility of generating any

equilibrated atmosphere such as O₂ plus CO₂ equal to or less than 21 kPa, and of enabling a manual correction if the storage temperature changes. The system is easy to handle (at stable temperatures) and does not involve any probes or fragile parts.

Akbudak and Eris (2004) studied the physical and chemical changes in peaches and nectarines during the modified atmosphere storage. Peach (“Flavorcrest” and “Red Top”) and nectarine (“Fantasia” and “Fairlane”) cultivars were stored in modified atmosphere packaging (MAP) by using 30 lm PP (polypropylene) and 45 lm PE (polyethylene) plastic bags at 0°C temperature and 90% relative humidity in the same conditions in three different years. PP gave the best result for MAP of peaches while PE gave the best result for MAP of nectarines. Peach “Flavorcrest” and nectarine “Fantasia” could be stored for 30–45 days using PP and PE, respectively. Peach “Red Top” and nectarine “Fairlane” stored successfully for up to 45 days using the same cover materials. Peach and nectarine cultivars had a shelf life of 10 days after these storage periods.

Santos *et al* (2005) evaluated the microbiological and sensory changes in “Morcilla de Burgos” preserved in air, vacuum and modified atmosphere packaging. In air-stored “morcilla” a significant increase in all microbial groups was observed during storage. A decrease in pH was noticed in MAP and in vacuum packaged “morcilla” (pH 4.73) during storage. At the same time, lactic acid bacteria (LAB) becomes the predominant species in all these packaged samples. The rest of the microbiota did not grow during storage. In “morcilla” packed with 50% and 80% of CO₂, counts of pseudomonads and enterobacteria were lower than found in the vacuum packs. Sensory analysis showed that shelf-life of “morcilla” stored in air did not exceed 17 days, while samples packed under vacuum and with 30% CO₂ were acceptable until 22 days of storage. “Morcillas” packaged with 50% and 80% CO₂ were sensorially acceptable for 32 days.

Summon *et al* (2006) studied the effect of vacuum-packaging storage on the quality level of ripened sausages. To investigate the influence of vacuum-packaging on both the sensory properties and the degradation level of their lipid fraction, some ripened sausages (30 days) were further stored for 40 days under vacuum-packaging and compared to sausages kept unpackaged for the same period of time. The same kind of sausages was used in both the trials. As for the sensory properties, after storage the unpackaged sausages showed significantly higher mean scores of red intensity and global flavour than vacuum-packed ones ($p < 0.01$ and $p < 0.05$, respectively) indicating a brighter red colour of meat and a greater overall appreciation by the panelists. The oxidative degradation of the fatty fraction, measured by the combined use of conventional (determination of peroxide value and TBA test) and nonconventional techniques (HPSEC analysis of the polar compounds of the lipid

fraction) showed significant increases during storage for both the storage conditions considered but no significant differences were found between packaged and unpackaged sausages.

Manju *et al* (2007) studied the effects of sodium acetate dip treatment and vacuum-packaging on chemical, microbiological, textural and sensory changes of Pearlsplit (*Etroplus suratensis*) during chill storage. Air packed samples were found to have a shelf life of about 8 days; vacuum- packed samples were found to be acceptable up to 10 days, whereas sodium acetate-treated vacuum packed samples were found to be acceptable up to 15 days. Thus, vacuum-packaging, in combination with sodium acetate, was found to delay the spoilage, thereby significantly extending the shelf life of Pearlsplit at refrigeration temperatures.

Mahajan and Goswami (2007) studied the use of liquid nitrogen in CA storage: Theoretical analysis and experimental validation. The present study establishes a relationship for predicting the amount of LN₂ required for reducing O₂ concentration in the CA storage. Simulations were carried out for predicting the amount of LN₂ required for flushing at different conditions such as purity level of LN₂, O₂ set point of the CA storage and flow rate of LN₂. The simulation results were validated using the laboratory scale CA storage system having a storage capacity that could hold 10 kg of apples.

Nasar-Abbas *et al* (2008) studied that nitrogen retards and oxygen accelerates colour darkening in faba bean (*Vicia faba* L.) during storage. It was observed that relative to controls, nitrogen was effective in reducing colour darkening by an appreciable level, whereas storage in oxygen accelerated the colour darkening process. Ethylene had some effect whereas the other MAP treatments were ineffective in reducing colour darkening in faba beans. Flushing with N₂, which reduced colour darkening and tannin losses, would be useful in maintaining quality and improving market opportunities and acceptance during long-term storage of faba beans.

Parra *et al* (2010) determined the modified atmosphere packaging and vacuum packaging for long period chilled storage of dry-cured Iberian ham. A loss of intensity of red colour (a*-values) was observed during storage in ham slices (P < 0.05). Slices of ham packed in 40%CO₂ (60/40) and 30%CO₂ (70/30) showed lower a*-values than the rest of the batches after 60 days (P < 0.05), though differences were not evident after 120 days (P > 0.05). TBARs values showed an upward trend during the storage of packaged slices (P < 0.05). Vacuum-packed slices showed the lowest TBARs values and those packed with 40%CO₂, the highest. Sensory attributes did not vary significantly (P > 0.05) throughout storage under refrigeration and packed either in vacuum or in modified atmospheres. No safety problems were detected in relation to the microbial quality in any case.

Mexis and Kontominas (2010) observed the effect of oxygen absorber, nitrogen flushing, packaging material oxygen transmission rate and storage conditions on quality retention of raw whole

unpeeled almond kernels (*Prunus dulcis*) Polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) increased with a parallel decrease of monounsaturated fatty acids (MFA) after 12 months of storage in all treatments. Likewise, volatile compounds such as aldehydes, ketones, alcohols, alkanes and aromatic hydrocarbons increased indicating enhanced lipid oxidation. Color was the parameter least affected. Use of the oxygen absorber provided a shelf life of at least 12 months for all samples irrespective of container oxygen barrier, lighting conditions and storage temperature.

2.7 Packaging material

Zhang *et al* (2001) studied on preservation of two cultivars of grapes at controlled temperature. Biochemical changes of grapes during controlled temperature (CT, 0°C) preservation were monitored in practice. The change of soluble solids content, reductive sugar content, total acid content, respiratory activity and pressure resistance during the storage test were studied. The results showed that the changes of grapes during 60 days of CT (0°C) preservation were small, and there is not any distinctive difference in texture and flavour between tested grapes and fresh grapes. CT (0°C) preservation can be seen as a preferable method.

Catherine Nettles Cutter (2002) studied a review on microbial control by packaging. Packaging materials have been developed specifically to prevent the deterioration of foods resulting from exposure to air, moisture, or pH changes associated with the food or the surrounding atmosphere. Both flexible and rigid packaging materials, alone or in combination with other preservation methods, have been developed to offer the necessary barrier, inactivation, and containment properties required for successful food packaging.

Aguayo *et al* (2003) evaluated quality improvement of fresh-cut tomato under active and passive Modified Atmosphere Packaging. Changes in microbial counts and sensorial and chemical quality attributes of fresh-cut tomato were evaluated at harvest and after 14 days of storage. The levels of C₂H₄ accumulating under passive MAP (12 ppm) were double the levels reached under both active MAP treatments. Compared with control, MAP reduced total microbial counts. Based on the sensorial quality evaluation, control tomato slices were unsuitable for consumption. Meanwhile slices under all MAP treatments kept a good visual appearance, overall quality and texture, and although only a fair flavour rating was found, they were acceptable for commercial purposes.

Hong and Kim (2004) determined the effect of packaging treatment on the storage quality of minimally processed bunched onions. Five different packaging treatments, including two passive modified atmosphere packaging (MAP), two active MAP and a moderate vacuum packaging (MVP), were used for MP bunched onions. Various sealed-packaging treatments did not significantly influence changes in colour of white stem and green leaf tissues, flesh weight loss and

microbiological populations including mesophiles, psychrotrophs and lactic acid bacteria. However, sensory attributes and disease incidence were affected by packaging type. MVP with a gas-permeable plastic film retained better quality bunched onions, with reduced microbial decay and visual sensory aspects, as compared with the other packages.

Waskar and Gaikwad (2004) determined the packaging and storage studies on pomegranate, kokum and mango based blend. It was found that total soluble solids and total sugars of the resultant blend were found to have increased during storage under different storage conditions irrespective of packaging containers, but slight decrease was noticed in acidity. The total anthocyanin content of this blend was found to have decreased during storage irrespective of storage conditions and packaging containers but the rate of degradation of anthocyanin content was found to be the highest during storage at ambient temperature. This blend when packed in glass was found to be acceptable upto 150 days in cool storage, 120 days in cool chamber and upto 90 days at ambient temperature.

Ibrahim *et al* (2005) observed the effects of packaging films on the physical characteristics and sensory aspects of shredded cabbage at different storage conditions. Generally, in almost all the analyses done, the quality of the minimally processed (MP) shredded cabbage deteriorated with increase in storage time. Among all the packaging films used, it was found that polypropylene (PP) could extend the shelf life of the MP shredded cabbage almost up to 3 weeks with minimum colour change, reduction in weight loss and deterioration in sensory properties and marginally low changes in other parameters tested. PVC cling wrap (control) was found to be the least effective packaging film. Samples in vacuum packaging showed no significant difference with those in non-vacuum packaging in almost all the parameters tested for all the different packaging films used.

Karatapanis *et al* (2006) studied the changes in flavour volatiles of whole pasteurized milk as affected by packaging material and storage time. In light-exposed samples, a light-induced oxidation mechanism prevailed while in light-protected samples, an autoxidation mechanism was apparent. Under both conditions, the concentration of selected odorous compounds increased with storage time. Microbiological data correlated poorly with both sensory and GC/MS data. Sensory data correlated well with selected volatile. Based on sensory analysis, the optimal shelf life of the whole pasteurized milk used in this study was approximately 5 days.

Sulochanamma *et al* (2008) evaluated the storage characteristics of large cardamom (*amomum Subulatum Roxb*) and seeds in different packages. Capsules packed in unlined high density polyethylene (HDPE) woven sack material, polypropylene (PP) and ethylene terephthalate/polyethylene (PET/ PE) and stored under humid condition registered high moisture pick up. Loss in volatile oil was appreciable under dry condition in unlined woven sack. Under normal storage condition, capsules packed in PP and PET/PE registered marginal change in moisture

and volatile oil contents. Also retention of major flavour component 1, 8 cineol, which contributes to 84.3% of volatile oil, was in the range of 93.9-97.4%. Seeds packed in PET, glass and HDPE jars and foil laminate exhibited 15-30% loss in volatile oil over a period of 240 days under normal storage condition and moisture content was within the maximum permissible limit.

Saint-Eve *et al* (2008) studied the quality changes in yogurt during storage in different packaging materials. Regardless of the packaging type, complex viscosity and thickness perception increased during storage due to exopolysaccharide production, whereas the pH of yogurts decreased. Packaging type had a greater impact on 0%-fat yogurts than on 4%-fat yogurts for both sensory and physicochemical characteristics. During storage, 0%-fat yogurt conditioned in glass displayed the lowest aroma quantity decrease of the three types of packaging, in accordance with the olfactory properties. However, between the two polymer types, polystyrene packaging seemed to be preferable for limiting aroma compound losses and subsequent fruity note intensities, and for avoiding the development of odour and aroma defects. Less significant packaging effect was observed for 4%-fat yogurts.

Singh *et al* (2008) evaluated the quality and shelf-life of strawberry fruits in different packages during storage. Weight and decay losses were minimum in fruits treated with CaCl_2 (2%) in high density polyethylene crates. Total soluble solids and acidity decreased during storage in all the treatments; decrease being least in fruits packed in perforated HDPE crates/PET punnets treated with CaCl_2 (2%). Irrespective of treatments maximum amount of ascorbic acid and anthocyanin responsible for redness of strawberry were found on 6th day of storage in fruits packed in HDPE crates, treated with $\text{Ca}(\text{NO}_3)_2$ (1.5%). Shelf-life of strawberry fruits was 6 days when treated with CaCl_2 (2%) and packed in HDPE crates.

Rizzo and Muratore (2009) evaluated the effects of packaging on shelf life of fresh celery. Celery could be sold in a wide range of presentations, from without any kind of packaging until 'ready to eat'. The results showed that colour intensity and firmness decreased during storage; weight loss in antifogging additive (AF) packed celery was lower than 3%. Tiny accumulations of condensate in AF didn't reduce shelf life, so it may be considered the most suitable packaging material for extending shelf life of celery stalks.

Dhall *et al* (2010) studied the effect of packaging on storage life and quality of cauliflower stored at low temperature. Cauliflower curds individual packed in high density polyethylene bags (20 μm) with perforation (6 holes/bag) can be stored up to 21 days at $0 \pm 1^\circ\text{C}$ and 90–95% RH with maximum retention of white colour of curd, minimum spoilage, weight and firmness loss and good sensory quality attributes. The use of cling wrap films should be avoided as this leads to accumulation of excessive moisture resulting in huge spoilage loss.

2.8 Storage

Andrich and Fiorentini (1986) determined the effects of controlled atmosphere on the storage of new apricot cultivars. "The storage in refrigerated (0-0.5°C) and controlled atmospheres (5% O₂ and 0-7.5% CO₂) of fruit belonging to two new late-ripening cultivars of apricots (ICAPI-17-COL and ICAPI-30-COL) has been studied to determine their storability and to examine the effect of the CO₂ level on weight decrease, firmness, total titratable acidity (TTA), pH, refractometric degree (RD) and physiological and pathological changes. Both cultivars, but particularly ICAPI-30-COL, proved suitable to store for up to 3 weeks under controlled conditions. Only for ICAPI-30-COL did the development during storage of some ripening parameters (firmness, TTA, pH and RD) seem to be related to CO₂ concentration, showing the importance of varietal influence.

Pandey *et al* (1999) evaluated the physico-chemical changes during storage in kiwi fruit. It was observed that the fruit pH showed significant decline during the first 20 days. Thereafter, it increased sharply up to 40 days in fruits of all the cultivars. The levels of non-reducing sugars were slightly decreased in fruits of Bruno and Abbot up to 10 days and thereafter increased. The TSS sharply increased up to 20 days and after that slowly decreased throughout the storage period in all the cultivars. The levels of total sugars and ascorbic acid content increased during first 10 days. Thereafter slightly decreased up to 20 days and again sharply increased in all the cultivars.

Niba (2003) studied the effect of storage period and temperature on resistant starch and b-glucan content in cornbread. b-Glucan levels increased with storage. Starch damage percentage decreased with storage up to 4 days. These changes may be due to structural modification of components during storage.

Akbudak and Eris (2004) evaluated physical and chemical changes in peaches and nectarines during the modified atmosphere storage. Polypropylene (PP) gave the best result for MAP of peaches while polyethylene (PE) gave the best result for MAP of nectarines. Peach "Flavorcrest" and nectarine "Fantasia" could be stored for 30–45 days using PP and PE, respectively. Peach "Red Top" and nectarine "Fairlane" stored successfully for up to 45 days using the same cover materials. Peach and nectarine cultivars had a shelf life of 10days after these storage periods.

Vázquez-Barrios *et al* (2006) studied and predicted quality changes in garlic cv. Perla (*Allium sativum* L.) stored at different temperatures. The weight loss and internal sprouting index had a negative correlation on the subjective firmness, penetration resistance, and hue of the cloves. Storage at 5°C, 20°C, and RT induced sprouting, and subsequent growth had an effect on a loss of firmness and color. Complete sprouting (>100%) induced a weight loss of 9–11% at these temperatures. In order to maintain an adequate safety margin for marketing, we propose an internal sprouting index of 50% to determining the effective shelf life of garlic cv. 'Perla'. In accordance with

this criterion and in conditions studying, shelf life at 0°C was 155 days; at 5°C and RT it was 80 days; and at 20°C it was 60 days. These results lead us to conclude that it is possible to estimate the shelf life of garlic using the internal sprouting index.

Silip and Hajar (2007) evaluated relationship between precooling, storage temperature and storage duration to the quality characteristics of guava (*Psidium guajava* L. Cv. Kampuchea). The results indicated that cooling time only effected the browning but it did not significantly effect the visual appearance, skin colour, weight loss and soluble solids concentration. Treatment combinations of storage temperature and storage duration were found to have significant effects on the visual appearance, skin colour, weight loss and soluble solids concentration. However, the treatment did not significantly effect browning. Storage temperature of 10°C resulted slow loss of visual appearance, delayed changes on the skin colour, lowest weight loss, and the lowest changes in soluble solids concentration of fruit. Acceptable visual appearance of the fruit stored at 10°C was up to 3.6 weeks compared to only 1.6 and 1.3 weeks for the fruit stored at 5 and 15°C, respectively. In addition, the fruit stored at 10°C were found to have lowest incident of browning compared to those stored at 5°C, while the fruit stored at 15°C were ripened, developed senescence, shrivelled and freckled. Results of this research can be used by guava producers in deciding the time level for their precooling and temperature setting for their cold room.

Radulovic *et al* (2007) evaluated changes of quality parameters in watermelon during storage. The pH value changes slightly during storage indicating the microbiological degradation of carbohydrates is negligible, and we may assume that all biochemical changes are due to enzymatic activity. Positive correlation between the weight loss and the decrease of reducible sugars was found with a highly significant correlation coefficient ($r = 0.96$, $P = 0.01\%$). After 7 days of storage the content of reducible sugars decreased for 42.5%, and in two weeks of storage for another 3.76%, with no significant difference between the first and the second week of storage ($P = 0.01\%$). After the first week of storage no statistically significant difference was found for the amount of total and soluble solids, but after the second week for both parameters a decrease of about 15% was measured. The greatest changes that can be related with the loss of sweetness occurred after the first week of storage. In the second week of storage the predominant changes related to the physical properties of watermelon (flesh firmness, crystalline structure).

Méndez and Falqué (2007) studied the effect of storage time and container type on the quality of extra-virgin olive oil. Each olive oil was stored in five different containers at room temperature with the same surface area of exposition to air and light: clear PET bottle, PET bottle (covered with Al foil), glass bottle, tin, and Tetra-brik. The results showed a gradual loss of quality during storage,

especially in plastic or glass bottles. The best containers for commercial packing of extra-olive oil were tin and Tetra-brik.

Jangchud *et al* (2007) studied the quality changes of burnt aromatic coconut during 28-day storage in different packages. Regardless of the packaging treatments, weight loss of whole burnt coconut increased with storage time. Transmittance and lightness (L^*) values of coconut water decreased ($P < 0.05$) with longer storage time. The pH of coconut water and coconut meat from the vacuum-packed treatment decreased as storage time increased. Sensory analysis showed that, for all treatments, the yellowness intensity of coconut water increased whereas its transparency decreased with time. The sourness intensity of vacuum-packed coconut water increased on later days of storage. Only the film-wrapped coconut, having the shortest shelf-life, had mold on its shell and husk at the end of storage. This study showed that the unwrapped, film-wrapped and vacuum-packed burnt coconuts could be stored for up to 14, 18 and 28 days, respectively, under the conditions used in this study.

Patel *et al* (2008) studied the effect of storage conditions on the quality characteristics of onion. Average % weight losses were 23.7 and 10.2 under natural and forced ventilated storage, respectively. The total soluble solids (TSS) reduced from 13.6 to 9.9% and to 10.7% under natural and forced ventilated storage, respectively. Total sugars content reduced from 6.4 to 5.2 and to 5.3% under natural and forced ventilated storage, respectively. The pyruvic acid content reduced from 6.5 to 6.2 and 6.0 micromole/g under natural and forced ventilated storage, respectively. The onion stored was better in forced ventilated storage structure as compared to natural ventilated storage.

Sammi and Masud (2009) studied the effect of different packaging systems on the quality of tomato (*Lycopersicon esculentum* var. Rio Grande) fruits during storage. The results showed that within each ripening stage, the treated fruits remained better than that of control and all the ripening stages and treatments are significantly different ($P < 0.05$) from each other. It can also be deduced that treated fruits showed lower weight loss (%), total soluble solids (TSS) contents, acidity and spoilage incidence while ascorbic acid contents, sugar to acid ratio, flavour, texture, colour and overall acceptability were higher in treated fruits when compared with control at the red stage of ripening. Total sugars (%) were low in fruits treated with calcium chloride and boric acid with or without potassium permanganate.

Vargas-Vargas *et al* (2010) evaluated the quality changes and shelf life of fresh-cut Pitahaya (*Hylocereus undatus*) slice through packaging and low temperature storage. The results indicate the necessity of use of chlorine to diminish the microbial populations of slices, also, the storage temperature influences significantly in changes of weight loss and quality characteristics, acidity, pH and firmness of pulp. The pitahaya slices fresh-cut stored at 4°C were able to maintain the

shelf life until for 25 days, having a good sensorial acceptance and maintaining its microbiological stability during the whole study.

Sundararaj *et al* (2010) evaluated the encapsulation for in vitro short-term storage and exchange of ginger (*Zingiber officinale* Rosc.) germplasm. For short term storage of germplasm, sucrose-dehydrated synseeds were found better than air-dehydrated or fresh synseeds. Synseeds dehydrated in 0.25M sucrose liquid medium for 16 h and stored in cryovials (without medium) at 25 °C for 8 weeks and 12 weeks exhibited 53% and 13% conversion, respectively, on MS (3% sucrose) + 2.5 mg/l BA medium. Plantlets obtained from stored synseeds were hardened, established successfully ex vitro and were morphologically similar to each other as well as their mother plants. This synseed protocol could be useful for short-term storage and exchange of germplasm of ginger between national as well as international laboratories.

2.9 Weight change

Joiner and Mackey (1962) studied weight loss, specific gravity and mealiness during storage of russet burbank potatoes. Mealiness, evaluated by a taste panel, increased slightly up to 6 months of storage at 40 F and 85% rh. Specific gravity increased slightly in storage, the lower specific gravity classes, 1.085, 1.090 and 1.095 increased more than the higher classes. Over 50% of the total weight loss during storage occurred during the first 60 days. Loss after this period amounted to 1/2 to 1 gram per month depending on the size of the tuber. Tubers that increased in specific gravity when stored, lost significantly more weight than those that decreased, fluctuated, or remained unchanged in gravity during storage. Tubers that showed no change in specific gravity in storage had a significantly higher mealiness rating for the same gravity class than those that increased or those that decreased in gravity during storage.

Javanmardi and Kubota (2006) studied variation of lycopene, antioxidant activity, total soluble solids and weight loss of tomato during postharvest storage. Low temperature storage at 5°C in compare to 12°C inhibited weight loss and enhancement of lycopene and TSS but antioxidant activity was increased as much as 1.77 times. Room temperature stored tomatoes showed significant increase in lycopene content and weight loss, but no effect on TSS and antioxidant activity during 7 d storage. TSS was not affected either by room temperature or low temperature storage, but weight loss, lycopene content and antioxidant activity at room temperature in compare to low temperature stored tomatoes were significantly different. The results showed that postharvest environmental conditions need to be considered carefully for evaluation of particular bioactive compounds in fresh fruit and vegetables.

Sherafati *et al* (2010) determined variation of weight loss, phenolic compounds, Vitamin C of different bell pepper cultivars fruit during storage. Our results showed that fruits' water loss

increased during storage in all cultivars. However, the degree of water loss was significantly different in pepper cultivars. In fact, some cultivars were more susceptible to water loss than others. There was a significant difference in fruit quality characteristics such as total phenolic content, vitamin C, sugar and acidity content among cultivars at harvest and during storage periods. In some genotypes, phenolic compounds and vitamin C increased slightly at the end of storage but in others, it was unchanged. Overall, the results demonstrated that changes of fruits weight loss, and total phenolic content and vitamin C during storage is significantly dependent on fruit cultivars.

CHAPTER III

MATERIAL AND METHODS

The present study was under taken to study the change in the quality parameters of dried ginger under different packaging and storage conditions and to select the best packaging material and storage conditions for improving the shelf life of dried ginger. The storage condition includes the room temperature and refrigerated temperature. The different parameters studied during storage were colour, flavour, volatile oil, shrinkage/swelling, weight loss/gain and moisture content.

3.1 Procuring of ginger

3.2 Peeling and cutting of ginger

3.3 Drying of ginger

3.4 Formation of ginger powder

3.5 Procuring of packaging material

3.6 Storage

3.6.1 Room temperature

3.6.2 Refrigerated temperature

3.7 Nitrogen flushing and vacuum packaging

3.8 Quality parameters of dried rhizome, dried ginger flakes and ginger powder

3.8.1 Colour

3.8.2 Flavour

3.8.3 Volatile oil

3.8.4 Weight loss/gain

3.8.5 Moisture content

3.8.6 Shrinkage/Swelling

3.1 Procuring of ginger

The ginger was procured from a local market (Mandi) of Ludhiana during the month of November 2010-january 2011 in three shifts. In the first shift the ginger was processed for storage at room temperature, in the second shift the processed ginger was stored at refrigerated temperature after processing and in the third shift for nitrogen flushing and vacuum packaging. The ginger was carefully transported to the department to prevent any injuries to occur. The ginger was then manually graded and cleaned to sort out any damaged and diseased product.

3.2 Peeling and cutting of ginger

Peeling of ginger was done manually with the help of knives and peelers. The cutting of ginger was done with the help of cutter that was present in the food engineering laboratory. The required ginger flakes were obtained with the help of this equipment. The other two ginger products were whole rhizome and ginger powder.



Fig. 3.1 Cutter

3.3 Drying of ginger

The drying of ginger flakes and whole rhizome was carried out with the help of a tray drier. The product was dried at a temperature of 60°C. The sample was dried upto 12-14% (wb) moisture content. After drying, the sample was taken out, brought to room temperature, packed, sealed and stored.



Fig. 3.2 Tray dryer

3.4 Formation of ginger powder

The ginger powder was obtained by grinding the dried ginger flakes in a mixer and grinder and then passing the powder through a sieve. The sieve allows only the fine particles to pass through it. The ginger powder was then packaged and sealed in different packaging materials for storage.

3.5 Procuring of packaging material

The packaging material used in the experiment includes:

- a. HDPE (High Density Polyethylene)
- b. Laminated aluminium films
- c. PET containers
- d. Glass containers

HDPE and laminated aluminium films had a thickness of 200 and 150 gauge respectively and had a capacity of 30g each. The diameter and height of PET and glass container was 61.12mm;76mm and 61.6mm;87mm with a capacity of 50g each.

3.6 Storage

The packaging material was procured from the local market of Ludhiana. The three samples ie. Dried whole rhizome, dried ginger flakes and dried ginger powder were weighed 10 gram each and packed in the above packaging material, sealed with the help of a sealing machine and then stored at room temperature and refrigerated temperature.

3.6.1 Room temperature

The dried samples of ginger were stored at room temperature for four months from December 2010-march 2011 in the food engineering laboratory. The temperature and relative humidity varied according to the season.



Fig. 3.3 The four different packaging materials used in research.

3.6.2 Refrigerated temperature

The samples were stored in a refrigerator at a temperature of 3-5°C for duration of four months from januray-april 2011. The temperature was maintained throughout the storage.

3.7 Nitrogen flushing and vacuum packaging

The industry demands the use of preservation methods which increases the shelf life of manufactured foods ensuring food safety. In this sense, the food industry has developed different packaging technologies in order to extend the shelf life of products. Among these technologies, vacuum packaging and modified atmosphere packaging (MAP) prevent products from contamination and evaporative losses and also extend storage life (Stiles, 1990). In MAP, food products are packed in an atmosphere which has been modified so that its composition is something other than air (Hintlian & Hotchkiss, 1986). The optimisation of the gas mixture composition is critical to ensure both product quality and safety (Møller, Jensen, Olsen, Skibsted, & Bertelsen, 2000). The gases normally used for MAP include carbon dioxide, oxygen and nitrogen. The most important gas, from a microbiological standpoint is CO₂, which effectively inhibits the growth of many microorganisms, including spoilage bacteria (Hotchkiss, Werner, & Lee, 2006).

The nitrogen flushing was done using Indvac nitrogen flushing machine. As nitrogen flushing was possible only in flexible pouches, so it was done only in HDPE and laminated aluminium films. The nitrogen flushing was done for dried whole rhizome and dried ginger flakes only.



Fig. 3.4 Nitrogen flushing machine

The following figure clearly shows that nitrogen flushing was only successful for laminated aluminium films and it was not successful for HDPE films.



Fig. 3.5 Nitrogen flushing being done in laminated aluminium films and HDPE

Vacuum packaging was also possible only for flexible pouches. So it was also done for HDPE and laminated aluminium films. Vacuum packaging was unsuccessful for both the films. Only dried whole rhizome and dried ginger flakes were vacuum packed.

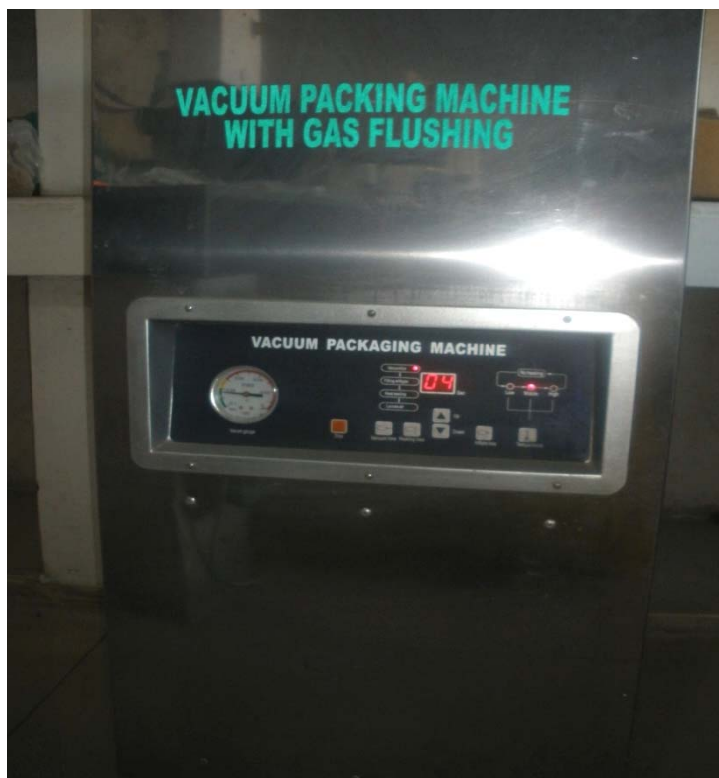


Fig. 3.6 Vacuum packaging machine

The samples were stored at room temperature and refrigerated temperature after nitrogen flushing.

3.8 Quality parameters of whole rhizome, ginger flakes and ginger powder

3.8.1 Colour

Colour is one of the important quality parameters, which indicates the stage of ripening. It also affects the commercial value of the product. The basic purpose of colour measurement was to get an idea of comparative change in colour at different temperature and with storage time. The colour of dried ginger was measured by using Miniscan XE plus Hunter Lab Colorimeter (Fig.3.7). The colour was described by a tristimulus value of 'L', 'a' and 'b' where L indicates intensity of colour i.e. lightness which varies from L=100 for perfect white to L=0 for black. 'a' and 'b' are chromaticity dimensions which give understandable designations of colour i.e. the value of 'a' measured redness when positive, grey when zero and greenness when negative and the value of 'b' measured yellowness when positive, grey when zero and blueness when negative. Before measuring the colour, the colorimeter was calibrated using white and black plates provided along with equipment, then the sample was placed in close contact with the colorimeter lens so that the light which falls on the samples should reflect back and no light is transmitted to the surroundings. Fig.3.8 shows the coordinate system of the 'L', 'a' and 'b' solid. Results can be expressed in the 'L', 'a' and 'b' coordinates directly.

In order to ascertain the practical significance of changes in objective measures of dried ginger colour during storage, chroma (C^*) and hue angle (h°) was calculated from L^* , a^* and b^* colour coordinates. Chroma represents colour saturation which varies from dull (low value) to vivid colour (high value) and hue angle is defined as a colour wheel with red-purple at an angle of 0° , yellow at 90° , bluish-green at 180° , and blue at 270° (McGuire, 1992). The values for the above were computed using the following equations (Anonymous, 1991; McGuire, 1992):

$$C^* = (a^{*2} + b^{*2})^{1/2}$$

$$h^\circ = \tan^{-1} b^*/a^*$$



Fig. 3.7: Colour measurement using Miniscan XE plus Hunter Lab Colorimeter

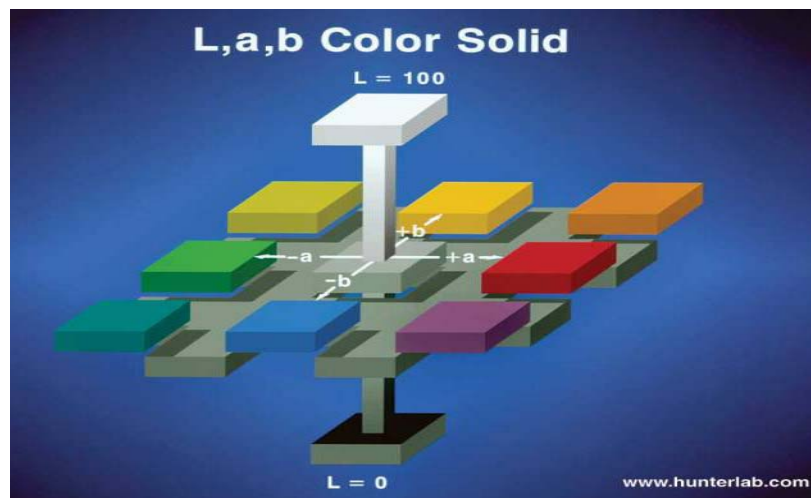


Fig. 3.8 The Judd-Hunter Lab solid

3.8.2 Flavour

The flavor of the sample is evaluated on the basis of hedonic scale. The scale is as follows:

- 1- Extremely bad
- 2- Bad
- 3- Fairly bad
- 4- Slightly bad
- 5- Neither good nor bad
- 6- Slightly good
- 7- Fairly good
- 8- Good
- 9- Extremely good

(Akbudak and Eris, 2004)

3.8.3 Volatile oil

The apparatus for volatile oil was boiling flask, shortneck, 1 or 2 L with T.S. 24/40 ground joint, suitable electric heating mantle or oil bath, variable voltage transformer to control heat, magnetic stirrer with Teflon-covered stirring bar, volatile oil traps, cleveger with T.S. 24/40 ground joints, west condenser, 400 mm. length with drip tip and T.S. 24/40 ground joints and the reagents used were xylene, ACS grade and antifoam agent.

Sufficient size sample was weighed accurately to yield 2 to 5 ml of oil and transfer quantitatively to flask -- using water if necessary. Add about 500 ml of water. If magnetic stirring was to be used, insert stirring bar. Assemble apparatus as shown in Fig.3.9, selecting the trap depending upon the density of the oil to be trapped. Heat the flask to boiling and maintain a reflux rate of 1 to 2 drops per second. Reflux until two consecutive readings taken at 1 hour intervals show no change of oil volume in the trap. Cool to 20°C either by allowing to stand in air or immersing trap in a suitable water bath.

(AOAC Official Methods of Analysis 962.17.)

$$\text{Volatile oil} = \frac{(\text{Vol. of oil} - \text{Vol. of xylene in blank})}{\text{Wt. of sample}} \times 100$$

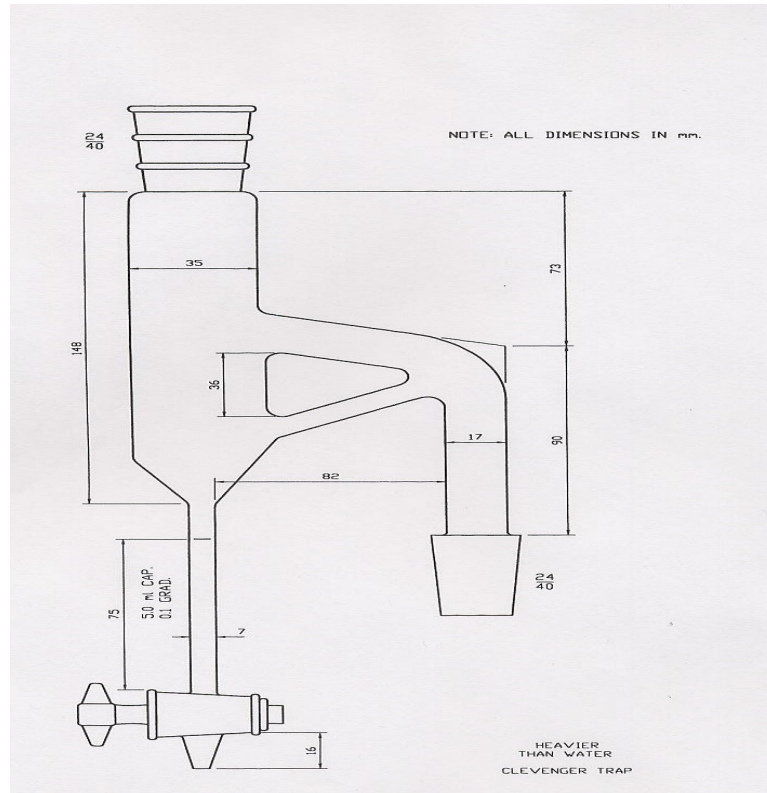


Fig. 3.9 Apparatus for measuring volatile oil

3.8.4 Weight loss/gain

Initial weight of the sample was noted at the time of keeping the sample for storage. The final weight of the sample to be used for analysis of flavour and color change was noted at the time of observation. The weighing was done with the digital balance having least count of 0.5 g. The samples were weighed after every month.

3.8.5 Moisture content

Moisture content of fresh and stored dried ginger samples was determined. Approx. gm sample was taken in petri dish and that petri dish placed in oven at 105 °C for 24 hours till constant weight as reported by (Chegini and Ghobadian, 2007). Following formula was used to calculate the percentage of moisture content.

$$\text{Moisture content (\%)} = \frac{\text{Weight of original sample (gm)} - \text{weight of dried sample (gm)}}{\text{Weight of original sample (gm)}}$$

3.8.6 Shrinkage/Swelling

Shrinkage of stored dried ginger samples was determined. A measured quantity of toluene was taken and poured in a measuring cylinder. Approx. gm sample was taken and was put in the cylinder. The rise in the level of toluene was noted. The shrinkage/swelling value was given in ml.

CHAPTER IV

RESULT AND DISCUSSION

The present research was conducted to study the effect of packaging material and storage conditions on shelf life and quality of dried ginger. The dried rhizome, dried ginger flakes and ginger powder were stored in 4 different packaging materials i.e. HDPE, laminated aluminium films, PET and glass containers and were stored in two different environments i.e. low temperature storage and room temperature storage. Various physiological and quality parameters observed during storage include colour, volatile oil, flavor, weight change, moisture content and shrinkage/swelling. All these parameters were recorded at a interval of one month at room temperature and refrigerated temperature. The dried ginger was stored for a duration of 4 months. The experimental results were statistically analysed by SPSS 11.5. The results of different experiments under different storage conditions have been discussed as under:

4.1 Effect of storage conditions on various quality parameters of dried ginger packed in different packaging materials

4.1.1 Effect of storage conditions on colour of dried ginger

4.1.1.1 Effect of storage conditions on lightness of dried ginger

4.1.1.1.1 Effect of storage conditions on lightness of dried ginger flakes

The lightness recorded for the 4 month storage of dried ginger flakes using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.1. It is clear from the Table 4.1.1.1 that among all the packaging materials, the refrigerated samples showed a higher value of lightness as compared to room temperature. In HDPE, lightness decreased from 50.92 to 33.75 at room temperature and from 50.92 to 36.91 at refrigerated temperature. In laminated aluminium films, maximum lightness (45.64) was maintained in nitrogen flushed refrigerated samples followed by nitrogen flushed room temperature samples (42.71) and samples stored at refrigeration without nitrogen flushing (35.34). In laminated aluminium films, the minimum lightness was recorded for room temperature samples (32.98). PET containers showed that refrigeration temperature (30.75) better maintained the lightness than the room temperature (28.83). In glass containers, during the 4 month storage at room and refrigerated conditions, lightness decreased as 50.92, 43.12, 33.05, 35.72, 31.46 and 50.92, 53.12, 45.97, 41.74 and 40.62.

Lozano-de-Gonzalez et al. (1993) reported that the lightness (L^* value) of ‘Red Delicious’ apple rings decreased sharply during 48 h at 1°C. Kim et al (1993b) reported a similar result with colour changes of 12 apple cultivars: all cultivars showed a rapid decrease in L^* values.

Table 4.1.1.1 Effect of storage conditions on lightness of dried ginger flakes.

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	50.92	43.36	40.51	39.93	33.75
Refg.	50.92	43.36	40.88	38.30	36.91
Lam Al.					
Room	50.92	43.13	34.70	35.36	32.98
Refg.	50.92	44.36	36.52	35.81	35.34
LA NF					
Room	50.92	49.96	45.81	45.83	42.71
Refg.	50.92	49.68	49.52	46.49	45.64
PET					
Room	50.92	48.43	35.53	35.84	28.83
Refg.	50.92	46.52	42.90	38.98	30.75
Glass					
Room	50.92	43.12	33.05	35.72	31.46
Refg.	50.92	53.12	45.97	41.74	40.62

4.1.1.1.2 Effect of storage conditions on lightness of dried rhizome

The lightness recorded for the 4 month storage of dried rhizome using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.2. It is clear from the Table 4.1.1.2 that a higher value of lightness was obtained at refrigerated temperature as compared to room temperature for all the packaging material. In HDPE, the lightness value decreased from 54.16 to 42.43 at room temperature and from 54.16 to 46.32 at refrigerated

temperature during a storage period of 4 months. In laminated aluminium films, with or without nitrogen flushing, refrigerated temperature recorded a higher value of lightness (53.69) and (51.23) than room temperature (44.87) and (46.73). Similar were the results for PET and glass containers, refrigerated values (52.98) and (53.86) were higher than room temperature (52.72) and (51.02).

Table 4.1.1.2 Effect of storage conditions on lightness of dried rhizome

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	54.16	54.39	53.63	53.46	42.43
Refg.	54.16	54.39	48.77	48.27	46.32
Lam Al.					
Room	54.16	54.60	54.55	50.12	46.73
Refg.	54.16	53.32	52.17	51.98	51.23
LA NF					
Room	54.16	51.21	51.84	52.14	44.87
Refg.	54.16	56.20	54.35	53.81	53.69
PET					
Room	54.16	53.25	54.77	55.44	52.72
Refg.	54.16	56.92	55.53	53.19	52.98
Glass					
Room	54.16	55.06	50.06	51.52	51.02
Refg.	54.16	55.06	54.79	54.53	53.86

4.1.1.1.3 Effect of storage conditions on lightness of ginger powder

The lightness recorded for the 4 month storage of ginger powder using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.3. The Table 4.1.1.3 states that there is a little variation of lightness stored at room temperature and refrigerated temperature. In HDPE, at room temperature lightness decreased from 58.74 to 54.12 and

at refrigerated temperature it decreased from 58.74 to 56.55. In laminated aluminium films, the trends observed at room and refrigerated temperature were 58.74, 57.89, 54.23, 53.51, 53.12 and 58.74, 57.89, 56.22, 56.55, 56.72. In PET and glass containers, the value of lightness observed during the fourth month at room and refrigerated temperature were 55.04 and 55.60; 54.39 and 55.49.

Table 4.1.1.3 Effect of storage conditions on lightness of ginger powder

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	58.74	57.84	56.23	55.64	54.12
Refg.	58.74	57.84	56.80	56.77	56.55
Lam Al.					
Room	58.74	57.89	54.23	53.51	53.12
Refg.	58.74	57.89	56.22	56.55	56.72
PET					
Room	58.74	57.93	56.53	55.51	55.04
Refg.	58.74	57.93	55.69	56.54	55.60
Glass					
Room	58.74	57.86	56.39	54.64	54.39
Refg.	58.74	57.86	57.16	56.16	55.49

The data of colour change in terms of L value was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A1 (Appendix A). It was seen that physical forms, packages and storage period were significant at 5% level where as replications were not significant at 5% level. Besides, the interaction between physical form & packages, physical form & storage period and packages & storage period were found to be significant at 5% level. The significance of mean differences for packaging materials were also tested and mostly these differences were not significant at 5% level (Appendix B).

4.1.1.2 Effect of storage conditions on chroma of dried ginger

4.1.1.2.1 Effect of storage conditions on chroma of dried ginger flakes

The chroma recorded for the 4 month storage of dried ginger flakes using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.4. It is clear from the Table 4.1.1.4 that in HDPE a higher value of chroma was obtained at room temperature (12.21) than at refrigerated temperature (12.14). In laminated aluminium films, highest chroma value was obtained in nitrogen flushed refrigerated samples (13.18) followed by nitrogen flushed room temperature. samples (13.16) and room temperature. samples without nitrogen flushing (12.23). The lowest value of chroma in laminated aluminium films was recorded for refrigerated samples without nitrogen flushing (10.90).

Table 4.1.1.4 Effect of storage conditions on chroma of dried ginger flakes

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	15.59	14.19	13.75	13.49	12.21
Refg.	15.59	13.77	13.37	12.54	12.14
Lam Al.					
Room	15.59	14.90	13.70	12.72	12.23
Refg.	15.59	12.74	12.66	12.58	10.90
LA NF					
Room	15.59	14.46	13.63	12.99	13.16
Refg.	15.59	14.72	14.53	13.67	13.18
PET					
Room	15.59	13.46	12.78	12.15	9.64
Refg.	15.59	14.29	13.99	13.89	10.53
Glass					
Room	15.59	15.27	12.97	12.83	10.87
Refg.	15.59	15.27	15.23	15.15	14.03

In PET containers, the trend obtained for refrigeration was 15.59, 14.29, 13.99, 13.89, 10.53 and for room temperature was 15.59, 13.46, 12.78, 12.15, 9.64. In glass containers, at room temperature the chroma value decreased from 15.59 to 10.87 and at refrigerated temperature the chroma value decreased from 15.59 to 14.03.

4.1.1.2.2 Effect of storage conditions on chroma of dried rhizome

The chroma recorded for the 4 month storage of dried rhizome using HDPE, laminated aluminium film, PET and glass containers at different temperature are shown in Table 4.1.1.5. The Table 4.1.1.5 states that in HDPE films, at room temperature, chroma value increased from 12.05 to 14.67 and at refrigerated temperature, it increased from 12.05 to 12.61.

Table 4.1.1.5 Effect of storage conditions on chroma of dried rhizome.

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	12.05	12.87	13.18	13.52	14.67
Refg.	12.05	12.87	11.72	12.27	12.61
Lam Al.					
Room	12.05	13.65	13.76	13.42	14.11
Refg.	12.05	11.10	11.10	13.09	12.30
LA NF					
Room	12.05	13.00	12.55	12.67	12.98
Refg.	12.05	14.69	13.05	13.35	13.27
PET					
Room	12.05	13.77	14.08	14.12	14.78
Refg.	12.05	13.57	13.01	12.53	11.53
Glass					
Room	12.05	12.34	12.46	13.67	13.80
Refg.	12.05	14.53	10.67	14.30	11.12

In laminated aluminium films, highest chroma value was recorded for room temperature (14.11) followed by nitrogen flushed refrigerated samples (13.27) and nitrogen flushed room temperature samples (12.98). The lowest chroma value for laminated aluminium films was recorded for refrigerated samples without nitrogen flushing (12.30). In case of PET and glass containers, room temperature conditions (14.78) and (13.80) recorded a higher value than refrigerated conditions (11.53) and (11.12).

4.1.1.2.3 Effect of storage conditions on chroma of ginger powder

The chroma recorded for the 4 month storage of ginger powder using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.6. The Table 4.1.1.6 shows that a higher chroma values are observed for refrigeration than for room temperature. The chroma values obtained at refrigeration and room temperature during the fourth month were 18.73, 18.82, 18.57, 18.52 and 16.05, 15.93, 16.05, 16.18 for HDPE, laminated aluminium films, PET containers and glass containers.

Table 4.1.1.6 Effect of storage conditions on chroma of ginger powder.

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	20.91	15.66	14.33	16.29	16.05
Refg.	20.91	19.66	18.93	18.69	18.73
Lam Al.					
Room	20.91	19.46	14.22	16.61	15.93
Refg.	20.91	19.98	18.93	18.88	18.82
PET					
Room	20.91	16.77	14.07	16.16	16.05
Refg.	20.91	19.20	19.06	18.68	18.57
Glass					
Room	20.91	18.37	17.99	16.59	16.18
Refg.	20.91	19.37	19.04	18.71	18.52

The data of colour change in terms of chroma value was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A2 (Appendix A). It was seen that physical forms and storage period were significant at 5% level where as packages and replications were not significant at 5% level. Besides, the interaction between physical form & packages, physical form & storage period and packages & storage period were found to be significant at 5% level. The significance of mean differences for packaging materials were also tested and mostly these differences were significant at 5% level (Appendix B).

4.1.1.3 Effect of storage conditions on hue angle of dried ginger

4.1.1.3.1 Effect of storage conditions on hue angle of dried ginger flakes

The hue angle recorded for the 4 month storage of dried ginger flakes using HDPE, laminated aluminium film, PET and glass containers at different temperature are shown in Table 4.1.1.7. It is clear from the Table 4.1.1.7 that hue angle recorded a higher value at refrigeration than at room temperature in all the packaging material. This means that the whiteness of the samples were more maintained at refrigerated temperature. At refrigerated temperature the highest hue angle was recorded as 75.13 degrees for glass containers and lowest was 70.88 for PET containers. At room temperature the maximum value of hue angle was obtained (71.11 degrees) for nitrogen flushed samples while the minimum (64.18 degrees) was for PET containers.

4.1.1.3.2 Effect of storage conditions on hue angle of dried rhizome

The hue angle recorded for the 4 month storage of dried rhizome using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.8. The Table 4.1.1.8 states that hue angle had a higher value at refrigerated temperature than at room temperature in all the packaging material except for glass containers. In HDPE and PET containers, refrigeration (79.48 to 71.03 degrees) and (79.48 to 73.42 degrees) maintained the hue angle in a better way as compared to the room temperature (79.48 to 69.06 degrees) and (79.48 to 73.42 degrees) during the 4 month storage duration. In laminated aluminium films, nitrogen flushed samples at refrigeration recorded the maximum hue angle (79.48 to 73.51 degrees) followed by laminated aluminium films without nitrogen flushing at refrigeration (79.48 to 72.83 degrees) and room temperature (79.48 to 72.30 degrees). In laminated aluminium films the minimum hue angle was recorded for nitrogen flushed samples stored at room temperature (79.48 to 59.54 degrees). In glass containers, a higher hue angle was observed for room temperature than for refrigerated temperature.

The values obtained for fourth month were (73.63 degrees) at room temperature and (69.64 degrees) at refrigerated temperature.

Table 4.1.1.7 Effect of storage conditions on hue angle (degrees) of dried ginger flakes.

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	77.89	71.98	69.17	67.37	65.79
Refg.	79.89	76.99	75.49	74.04	73.54
Lam Al.					
Room	77.89	77.99	68.96	67.87	66.67
Refg.	79.89	75.82	75.36	74.98	73.86
LA NF					
Room	77.89	77.46	75.85	75.23	71.11
Refg.	79.89	77.29	76.43	75.94	74.33
PET					
Room	77.89	74.70	68.33	66.79	64.18
Refg.	79.89	79.44	78.70	77.35	70.88
Glass					
Room	77.89	77.66	70.05	70.89	67.96
Refg.	79.89	79.66	78.57	74.69	75.13

Table 4.1.1.8 Effect of storage conditions on hue angle (degrees) of dried rhizome

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	79.48	75.48	74.92	73.67	69.06
Refg.	79.48	77.48	72.99	73.04	71.03
Lam Al.					
Room	79.48	76.10	75.27	73.86	72.30
Refg.	79.48	77.99	76.29	73.71	72.83
LA NF					
Room	79.48	75.07	73.87	73.77	59.54
Refg.	79.48	75.81	75.33	74.76	73.51
PET					
Room	79.48	75.19	75.23	75.48	73.25
Refg.	79.48	74.82	74.71	73.82	73.42
Glass					
Room	79.48	73.25	73.06	72.98	73.63
Refg.	79.48	72.25	71.92	71.54	69.64

4.1.1.3.3 Effect of storage conditions on hue angle of ginger powder

The hue angle recorded for the 4 month storage of ginger powder using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.1.9. The Table 4.1.1.9 shows that at refrigeration, a higher hue angle was obtained than at room temperature during the 4 month storage interval. HDPE and laminated aluminium films showed that hue angle decreased slowly at refrigerated temperature (81.81 to 79.67 degrees) and (81.81 to 79.61 degrees) than at room temperature (81.81 to 77.33 degrees) and (81.81 to 76.76 degrees). In PET and glass containers higher value of hue angle was observed during fourth month at refrigerated temperature (79.17 degrees) and (78.95 degrees) than at room temperature (76.56 degrees) and (75.90 degrees).

Table 4.1.1.9 Effect of storage conditions on hue angle (degrees) of ginger powder

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	81.81	77.46	77.61	77.56	77.33
Refg.	81.81	80.46	80.02	78.99	79.67
Lam Al.					
Room	81.81	79.31	77.96	76.32	76.76
Refg.	81.81	80.01	79.81	79.41	79.61
PET					
Room	81.81	79.03	78.41	77.78	76.56
Refg.	81.81	80.72	79.48	79.54	79.17
Glass					
Room	81.81	80.89	77.21	77.22	75.90
Refg.	81.81	80.89	79.71	79.43	78.95

The data of colour change in terms of hue angle was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A3 (Appendix A). It was seen that physical forms, storage period and replications were significant at 5% level where as packages were not significant at 5% level. Besides, the interaction between physical form & packages, physical form & storage period and packages & storage period were found to be significant at 5% level. The significance of mean differences for packaging materials was also tested and mostly these differences were not significant at 5% level (Appendix B).

4.1.2 Effect of storage conditions on volatile oil of dried ginger

4.1.2.1 Effect of storage conditions on volatile oil of dried ginger flakes

The trends of volatile oil of dried ginger flakes packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.2.1. In

HDPE, the volatile oil was well maintained at refrigerated temperature than at room temperature. At room temperature the value decreased from 1.34% to 0.92% during the 4 month storage period. At refrigerated temperature the values obtained during storage were 1.34, 1.25, 1.12, 1.06 and 0.94%. In laminated aluminium films, the minimum reduction in volatile oil was experienced in nitrogen flushed refrigerated samples. At 0 day the value of volatile oil was 1.34% and at fourth month its 0.98%. It was followed by samples stored at refrigeration in which the final volatile oil content remains as 0.96% during the fourth month. Storage at room temperature along with nitrogen flushing comes third in which the final volatile oil comes out to be 0.94%. Maximum volatile oil was lost during storage at room temperature. The values recorded were 1.34, 1.21, 1.08, 1.06 and 0.89% respectively. In PET and Glass containers, a higher volatile oil content value can be obtained with refrigeration. In PET containers it was 0.96% in fourth month of storage and 0.94% at room temperature and in glass containers it was 0.98% at refrigerated temperature and 0.96% at room temperature. These values were measured during the fourth month.

4.1.2.2 Effect of storage conditions on volatile oil of dried rhizome

The trends of volatile oil of dried rhizome packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.2.2. In HDPE, at room temperature the volatile oil content decreased from 1.37% to 0.83% and at refrigerated temperature the volatile oil content decreased from 1.37% to 0.81%. Both these samples were stored for 4 months. In laminated aluminium films, the nitrogen flushing volatile oil of ginger showed a higher value than the samples that are not nitrogen flushed. The volatile oil content of dried rhizome showed almost a similar trend under both the storage conditions i.e. room temperature and refrigerated temperature when they are nitrogen flushed. At room temperature the value decreased from 1.37% to 0.92% and at refrigerated temperature the volatile oil decreased as 1.37% to 0.91%. Without nitrogen flushing, volatile oil was not much affected by the storage conditions. At room temperature the trend recorded was 1.37, 1.2, 1.13, 0.94 and 0.83%. At refrigerated temperature the volatile oil recorded for 4 months was 1.37, 1.22, 1.1, 0.97 and 0.83% respectively. In PET and Glass containers, there was a little effect of storage conditions on volatile oil. While using PET containers, at room temperature the values obtained were 1.37, 1.21, 1.13, 0.94 and 0.84% and at refrigerated temperature the values recorded were 1.37, 1.24, 1.11, 0.98 and 0.83% during the 4 month storage interval. With glass containers, at room temperature the volatile oil decreased from 1.37 to 0.86% and at refrigerated temperature the volatile oil decreased from 1.37 to 0.85%.

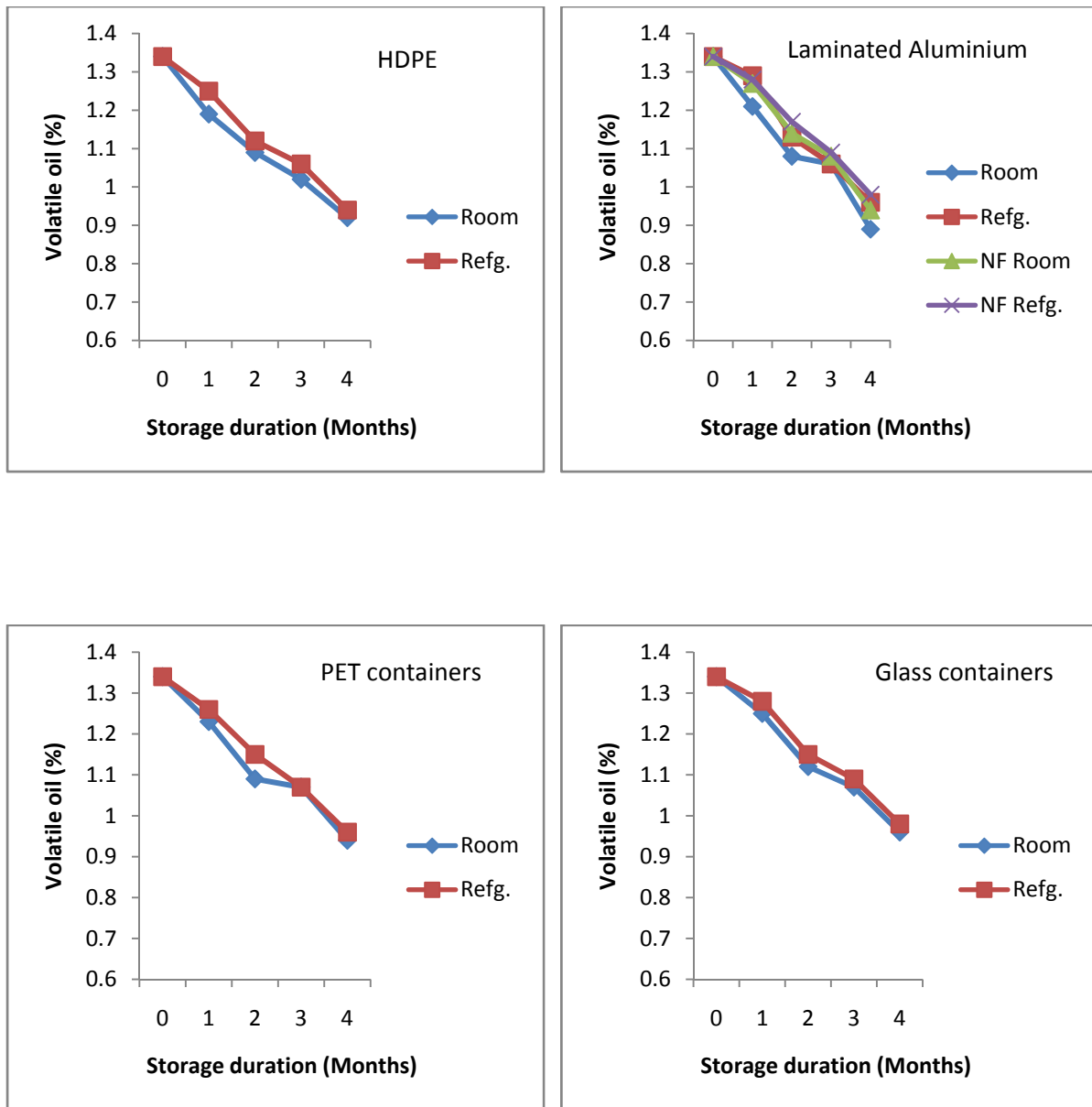


Fig. 4.1.2.1 Effect of storage conditions on volatile oil content of dried ginger flakes using different packaging material.

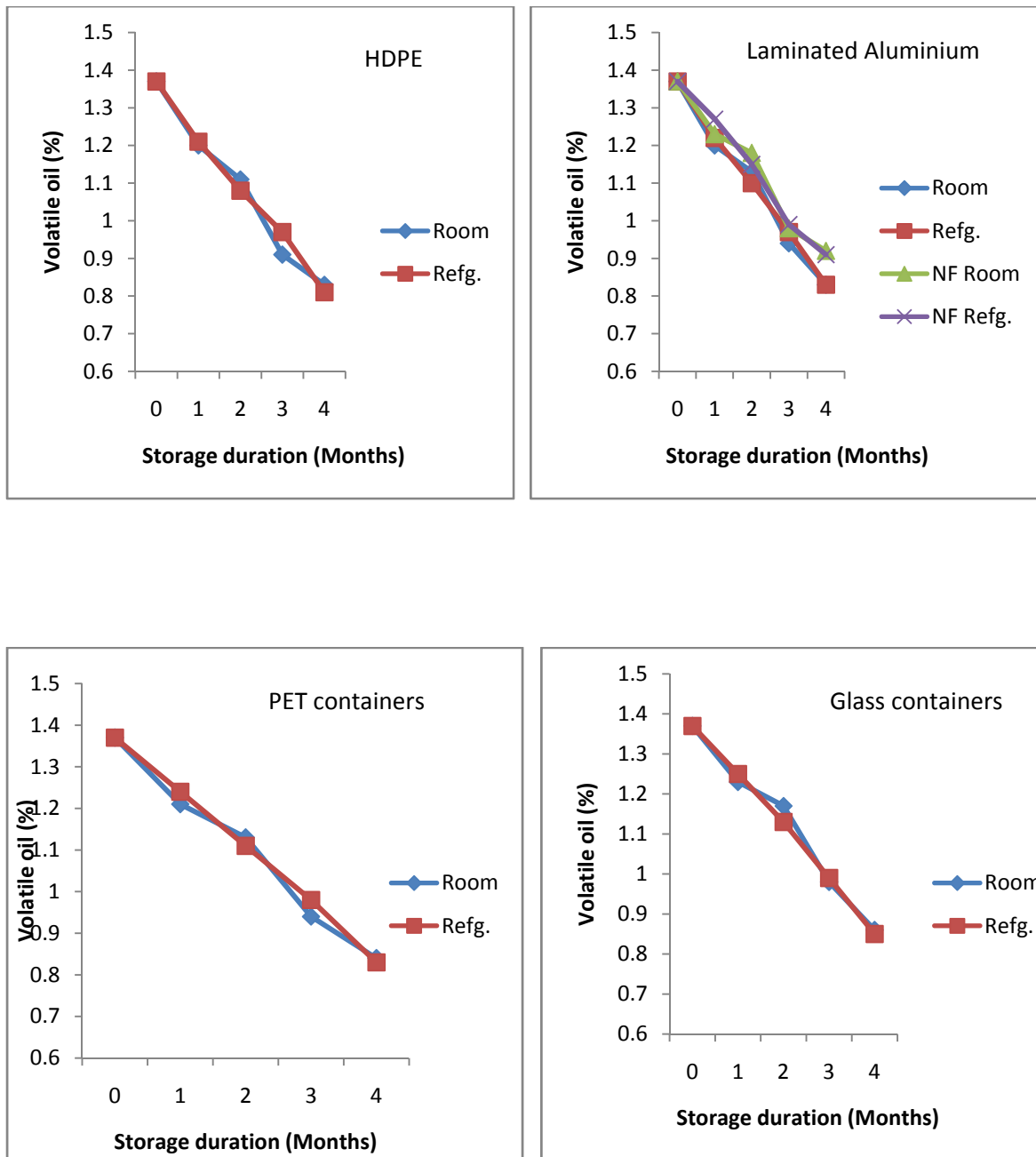


Fig. 4.1.2.2 Effect of storage conditions on volatile oil content of dried rhizome using different packaging material.

4.1.2.3 Effect of storage conditions on volatile oil of ginger powder

The trends of volatile oil of ginger powder packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.2.3. HDPE shows that volatile oil content of ginger powder was higher at refrigerated temperature than at room temperature. At refrigerated temperature volatile oil decreased from 1.42 to 1.02% and at room temperature, it decreased from 1.42 to 0.92% during the 4 month storage period. In laminated aluminium films, the refrigerated value of volatile oil of ginger powder was greater than room temperature volatile oil value. At room temperature the values measured were 1.42, 1.21, 1.07, 1.04 and 0.95% respectively and at refrigerated temperature the values obtained were 1.42, 1.22, 1.2, 1.08 and 1.05% during the storage period of 4 months. PET and Glass containers illustrates that at refrigerated temperature volatile oil content decreased at a slower rate than at room temperature. In PET containers, at room temperature the volatile oil content decreased from 1.42 to 0.95% and at refrigerated temperature the volatile oil content decreased from 1.42 to 1.05% while in case of glass containers, at room temperature the value of volatile oil varied from 1.42 to 0.97% and during refrigeration, the volatile oil ranged from 1.42 to 1.07% for a storage period of 4 months.

Ginger powders processed and stored at room temperature and refrigerated temperature generally contained the highest levels of volatile oil content. The volatile oil concentration was higher in the refrigerated samples. Similar results were reported by Zhang X (1994). However, a study on changes in oleoresin content of ginger during storage (Richardson 1967) showed that about 20% of ginger oleoresin in dried ground ginger was lost after 3 months storage at room temperature. It is evident from the above discussion that ginger powder stored at refrigeration was more stable. The reason could be that gingerols are more stable in dried forms. Baranowski (1985), Chen et al (1986), Connell (1969) and Shanthi Narasimhan and Govindarajan (1978) reported that higher gingerol levels indicate sample freshness.

The data of volatile oil was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A4 (Appendix A). It was seen that physical forms, storage period, packages and replications were significant at 5% level. Besides, the interaction between physical form & storage period was found to be significant at 5% level where as interaction between physical form & packages and packages & storage period were not significant at 5 % level. The significance of mean differences for packaging materials were also tested and mostly these differences were not significant at 5% level (Appendix B).

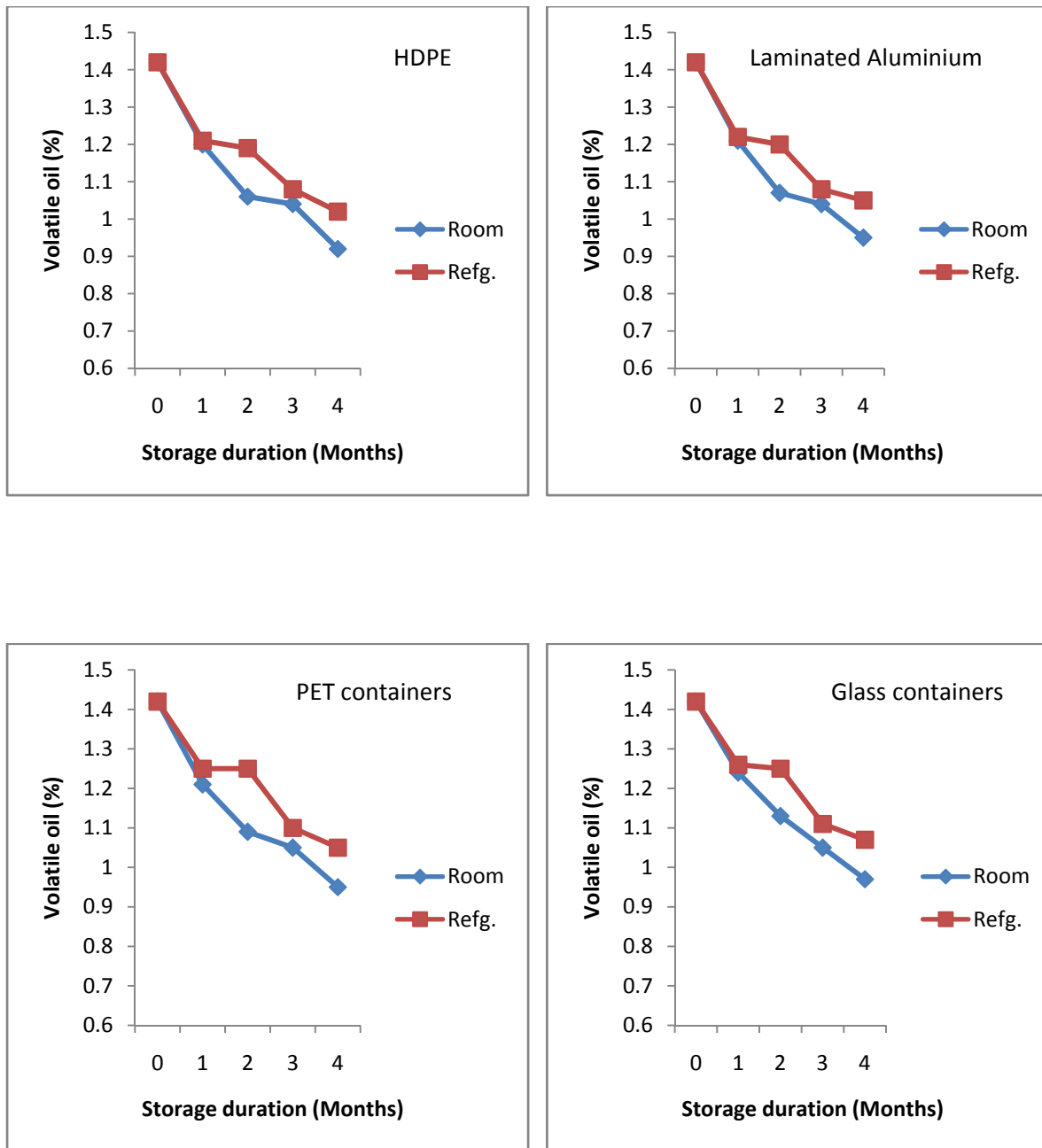


Fig. 4.1.2.3 Effect of storage conditions on volatile oil of ginger powder using different packaging material.

4.1.3 Effect of storage conditions on flavor of dried ginger

4.1.3.1 Effect of storage conditions on flavour of dried ginger flakes

The flavour recorded for the 4 month storage of dried ginger flakes using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.3.1. It is clear from the Table 4.1.3.1 that at both the storage conditions, using HDPE packaging material the flavour decreased at almost same rate. When the samples are nitrogen flushed, the flavour was maintained throughout the storage at both the temperature. The values were recorded on a hedonic scale. It was 9 at 0 day and it remains 8 after 4 months at both the storage conditions. Without nitrogen flushing a better flavour was observed in case of refrigerated temperature as compared to room temperature. At refrigeration, the hedonic scale value goes upto 6 after 4 months and at room temperature the value goes upto 5 after 4 months. In PET containers, the value of flavour decreased at a steady rate at both the storage conditions during the 4 month storage. The value decreased as 9, 8, 7, 6 and 5. In glass containers, the flavour value decreased at almost same rate i.e. from an initial value of 9 to a final value of 5 after 4 months of storage at both the storage conditions i.e. room temperature and refrigerated temperature.

4.1.3.2 Effect of storage conditions on flavour of dried rhizome

The flavour recorded for the 4 month storage of dried rhizome using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.3.2. It is evident from Table 4.1.3.2 that in HDPE flavour deteriorates at a faster rate at room temperature as the value decreased from 8 to 4 during the 4 month storage. At refrigerated temperature the value of flavour decreased from 9 to 5. Flavour was maximum maintained in refrigerated stored nitrogen flushed package. The value ranges from 8 to 6 during the 4 month storage. It was followed by nitrogen flushed package stored at room temperature and the value decreased from 8 to 5. At refrigerated temperature without nitrogen flushing, the value decreased from 9 to 5. The storage at room temperature comes last as the value of flavour decreased from 8 to 4. In PET containers, flavour decreased at almost same rate under both the storage conditions. At room temperature the value decreased from 8 to 5 and at refrigerated temperature the value decreased from 9 to 5. The glass containers follow the same trend as in PET containers. At both the storage conditions i.e. at room temperature and refrigerated temperature the flavour loss remains almost same. At room temperature the value decreased from 8 to 5 and at refrigerated temperature the value decreased from 9 to 5.

Table 4.1.3.1 Effect of storage conditions on flavor of dried ginger flakes using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	9	8	6	5	5
Refg.	9	6	6	5	5
Lam Al					
Room	9	8	7	5	5
Refg.	9	8	7	6	6
LA NF					
Room	9	8	8	8	8
Refg.	9	8	8	8	8
PET					
Room	9	8	7	6	5
Refg.	9	8	7	6	5
Glass					
Room	9	8	7	6	5
Refg.	9	8	7	5	5

Table 4.1.3.2 Effect of storage conditions on flavor of dried rhizome using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	8	6	5	5	4
Refg.	9	5	5	5	5
Lam Al					
Room	8	6	5	4	4
Refg.	9	5	5	5	5
LA NF					
Room	8	6	5	5	5
Refg.	8	7	7	6	6
PET					
Room	8	5	5	5	5
Refg.	9	5	5	5	5
Glass					
Room	8	5	5	5	5
Refg.	9	5	5	5	5

4.1.3.3 Effect of storage conditions on flavour of ginger powder

The flavour recorded for the 4 month storage of ginger powder using HDPE, laminated aluminium films, PET and glass containers at different temperature are shown in Table 4.1.3.3. Table 4.1.3.3 shows that flavour decreased at almost same rate under both the storage conditions. At room temperature as well as refrigerated temperature the value of flavour decreased from 9 to 6. In laminated aluminium films, the flavour was maintained at refrigerated temperature than at room temperature. At room temperature the flavour value decreased from 9 to 6 in a 4 month storage time and at refrigerated temperature the flavour value decreased from 9 to 7. It is quite evident from the table that in PET

containers, flavour was unaffected by the storage conditions. It decreased at the same rate from 9 to 6 in a 4 month storage time. In glass containers, flavour was maintained at refrigerated temperature as compared to room temperature. At refrigerated temperature the value decreased from 9 to 7 whereas at room temperature the flavour value decreased from 9 to 6 during the 4 month storage time.

Table 4.1.3.3 Effect of storage conditions on flavor of ginger powder using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	9	8	7	7	6
Refg.	9	7	7	7	6
Lam Al					
Room	9	8	7	7	6
Refg.	9	9	8	7	7
PET					
Room	9	8	8	6	6
Refg.	9	8	7	6	6
Glass					
Room	9	8	8	7	6
Refg.	9	9	8	7	7

The data of flavour was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A5 (Appendix A). It was seen that physical forms, storage period and packages were significant at 5% level, while replications were not significant at 5% level. Besides, the interaction between physical form & storage period and packages & storage period was found to be significant at 5% level where as interaction between physical form & packages were not significant at 5 % level. The significance of mean differences for packaging materials were also tested and mostly these differences were not significant at 5% level (Appendix B).

4.1.4 Effect of storage conditions on shrinkage/swelling of dried ginger

4.1.4.1 Effect of storage conditions on shrinkage/swelling of dried ginger flakes

The values of shrinkage/swelling of dried ginger flakes packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Table 4.1.4.1. It is evident from the Table 4.1.4.1 that in HDPE, the value of shrinkage/swelling was 1.5 for room temperature and 2 for refrigerated temperature throughout the storage period of 4 months. In laminated aluminium films, the value of shrinkage/swelling remains 2 for the storage period of 4 months in case of refrigerated temperature and nitrogen flushed samples when stored at room temperature and refrigerated temperature.

Table 4.1.4.1 Effect of storage conditions on shrinkage/swelling of dried ginger flakes using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	1.5	1.5	2	1.5	1.5
Refg.	2	2	2	2	2
Lam Al					
Room	1.5	2	2	2	2
Refg.	2	2	2	2	2
LA NF					
Room	2	2	2	2	2
Refg.	2	2	2	2	2
PET					
Room	1.5	2	2	1.5	2
Refg.	2	2	2	2	2
Glass					
Room	1.5	2	2	1.5	1.5
Refg.	2	2	2	2	2

When the samples were stored at room temperature the value at 0 day was 1.5 and then it rises to 2 for the rest of the storage duration. In PET containers, at room temperature the shrinkage/swelling value varies from 1.5 to 2 and at refrigerated temperature it remains same i.e. 2 for the storage duration of 4 months. In glass containers, at refrigerated temperature the shrinkage/swelling value remains 2 throughout the storage length and at room temperature it varies from 1.5 to 2 for a duration of 4 months.

4.1.4.2 Effect of storage conditions on shrinkage/swelling of dried rhizome

The shrinkage/swelling of dried rhizome packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Table 4.1.4.2.

Table 4.1.4.2 Effect of storage conditions on shrinkage/swelling of dried rhizome using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	1.5	2	1.5	2	1.5
Refr.	1.5	2	1.5	1.5	1.5
Lam Al					
Room	1.5	2	1.5	1.5	1.5
Refr.	1.5	2	1.5	1.5	1.5
LA NF					
Room	2	2	2	2	2
Refr.	2	2	2	2	2
PET					
Room	1.5	2	1.5	1.5	1.5
Refr.	1.5	2	1.5	1.5	1.5
Glass					
Room	1.5	2	1.5	1.5	1.5
Refr.	1.5	2	1.5	1.5	1.5

Table 4.1.4.2 illustrates that in HDPE, the shrinkage/swelling value lies between 1.5 to 2 under both the storage conditions for a duration of 4 months. In case of nitrogen flushed samples, the value of shrinkage/swelling remains 2 throughout the storage period under room and refrigerated temperature. In laminated aluminium films, without nitrogen flushing, the samples stored at room and refrigerated temperature, the value of shrinkage/swelling lies between 1.5 to 2. When packaging was done in PET and glass containers, the value of shrinkage/swelling varies from 1.5 to 2.

4.1.4.3 Effect of storage conditions on shrinkage/swelling of ginger powder

The value of shrinkage/swelling of ginger powder packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Table 4.1.4.3. At room temperature, the value of shrinkage/swelling is same in all the packaging material i.e. it lies between 2-2.5 and at refrigeration it remains 2 for HDPE, laminated aluminium films and PET containers throughout the storage period and for glass containers it varies from 1.5-2.

Table 4.1.4.3 Effect of storage conditions on shrinkage/swelling of ginger powder using different packaging material

Packaging material	Fresh	1 Month	2 Month	3 Month	4 Month
HDPE					
Room	2	2	2.5	2	2
Refg.	2	2	2	2	2
Lam Al					
Room	2	2	2.5	2	2
Refg.	2	2	2	2	2
PET					
Room	2	2	2.5	2	2
Refg.	2	2	2	2	2
Glass					
Room	2	2	2.5	2	2
Refg.	2	2	2	1.5	1.5

The data of shrinkage/swelling was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A6 (Appendix A). It was seen that physical forms, storage period and packages were significant at 5% level, while replications were not significant at 5% level. Besides, the interaction between physical form & storage period was found to be significant at 5% level where as interaction between physical form & packages and packages & storage period were not significant at 5 % level. The significance of mean differences for packaging materials were also tested and mostly these differences were not significant at 5% level (Appendix B).

4.1.5 Effect of storage conditions on weight change of dried ginger

4.1.5.1 Effect of storage conditions on weight change of dried ginger flakes

The trends of weight change of dried ginger flakes packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.5.1. During storage in HDPE, weight change was more in flakes at room temperature than at refrigerated temperature. In refrigeration the weight was quite stable after one month while at room temperature the weight was unstable. Laminated aluminium films showed that weight change was minimum in case of samples stored at room temperature along with nitrogen flushing and is maximum in storage at room temperature. The weight increases at a steady rate in case of storage at refrigerated temperature. In case of storage at refrigerated temperature along with nitrogen flushing the weight first decreased and then increased. PET containers showed that weight of flakes while stored at room temperature was decreasing at a steady rate while the weight change at refrigerated temperature was quite unsteady. The weight change was more at refrigerated temperature than at room temperature. Glass containers showed that weight was decreasing at a constant rate at room temperature while at refrigerated temperature the weight change was unstable. The weight change at refrigerated temperature was less than at room temperature.

4.1.5.2 Effect of storage conditions on weight change of dried rhizome

The trends of weight change of dried rhizome packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.5.2. In HDPE, the weight change was least at refrigerated temperature and at room temperature the weight was increasing steadily. Storage in laminated aluminium films showed that weight was least effected while storage at refrigerated temperature followed by nitrogen flushing done at room temperature. Nitrogen flushing at refrigerated temperature comes third and the weight change was

mostly effected while storage at room temperature. The storage in PET containers states that weight was almost constant at refrigerated temperature and its unsteady at room temperature. In Glass containers, the weight increased in case of room temperature and decreased in case of refrigerated temperature. The weight change was less at refrigerated temperature than at room temperature.

The results indicate that the storage temperature influences significantly in changes of weight loss and quality characteristics. This was also reported by Vargas-Vargas L (2010) while studying the Quality Changes and Shelf Life of Fresh-cut Pitahaya (*Hylocereus undatus*) Slice through Packaging and Low Temperature Storage.

4.1.5.3 Effect of storage conditions on weight change of ginger powder

The trends of weight change of dried ginger powder packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.5.3. In HDPE, weight change was less in case of storage at room temperature while the weight change trend at refrigerated temperature was quite uneven. In laminated aluminium films, the weight was increasing at a steady rate in case of storage at room temperature while at refrigerated temperature weight change was unsteady. PET containers showed that weight change was less in case of storage at room temperature than at refrigerated temperature. In Glass containers, the weight was almost constant at room temperature while at refrigerated temperature it was unsteady.

The data of weight change was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A7 (Appendix A). It was seen that physical forms and packages were significant at 5% level, while replications and storage period were not significant at 5% level. Besides, the interaction between physical form & storage period, physical form & packages and packages & storage period was found to be significant at 5% level. The significance of mean differences for packaging materials were also tested and mostly these differences were significant at 5% level (Appendix B).

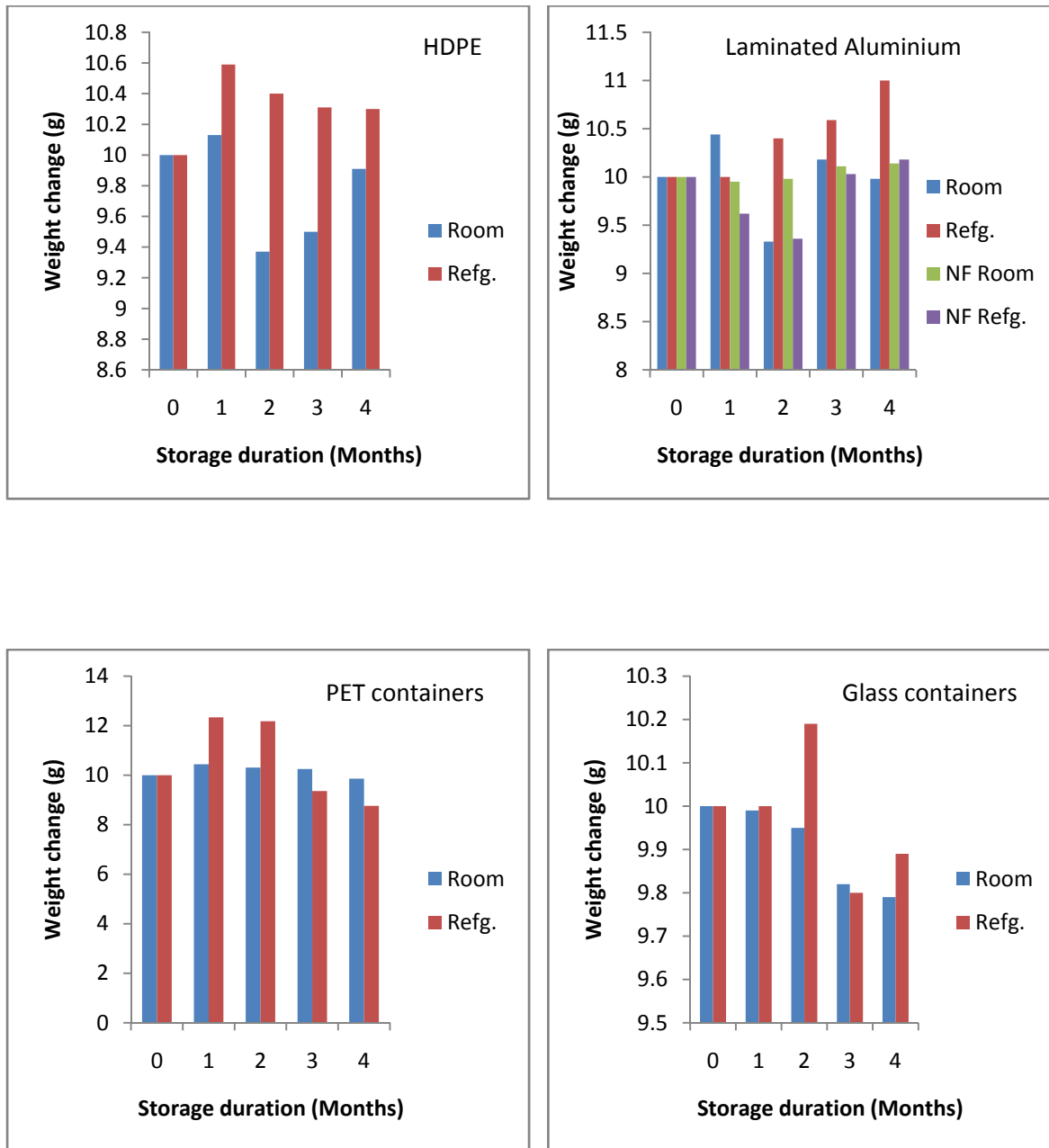


Fig. 4.1.5.1 Effect of storage conditions on weight change of dried ginger flakes using different packaging material.

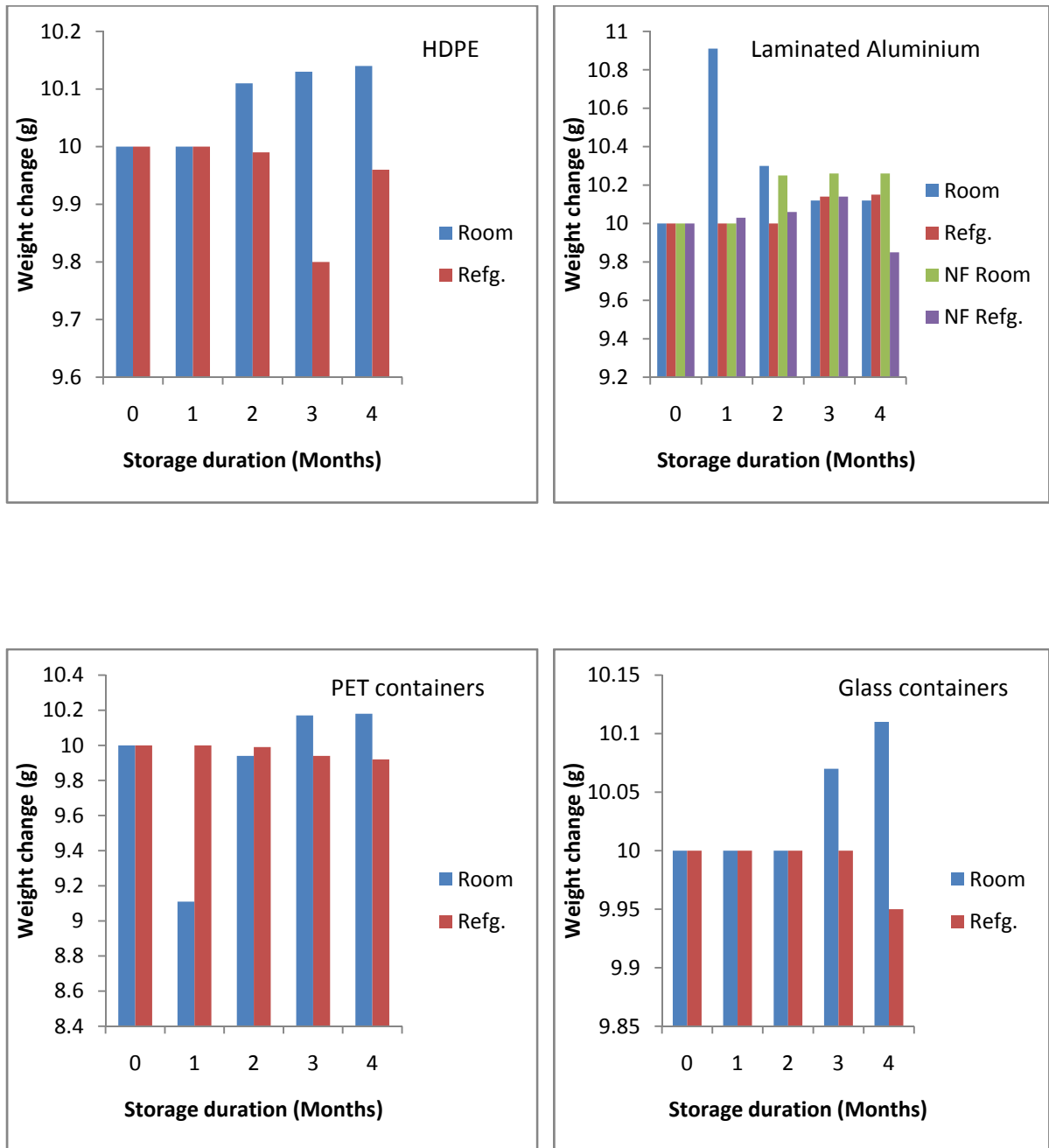


Fig. 4.1.5.2 Effect of storage conditions on weight change of dried rhizome using different packaging material.

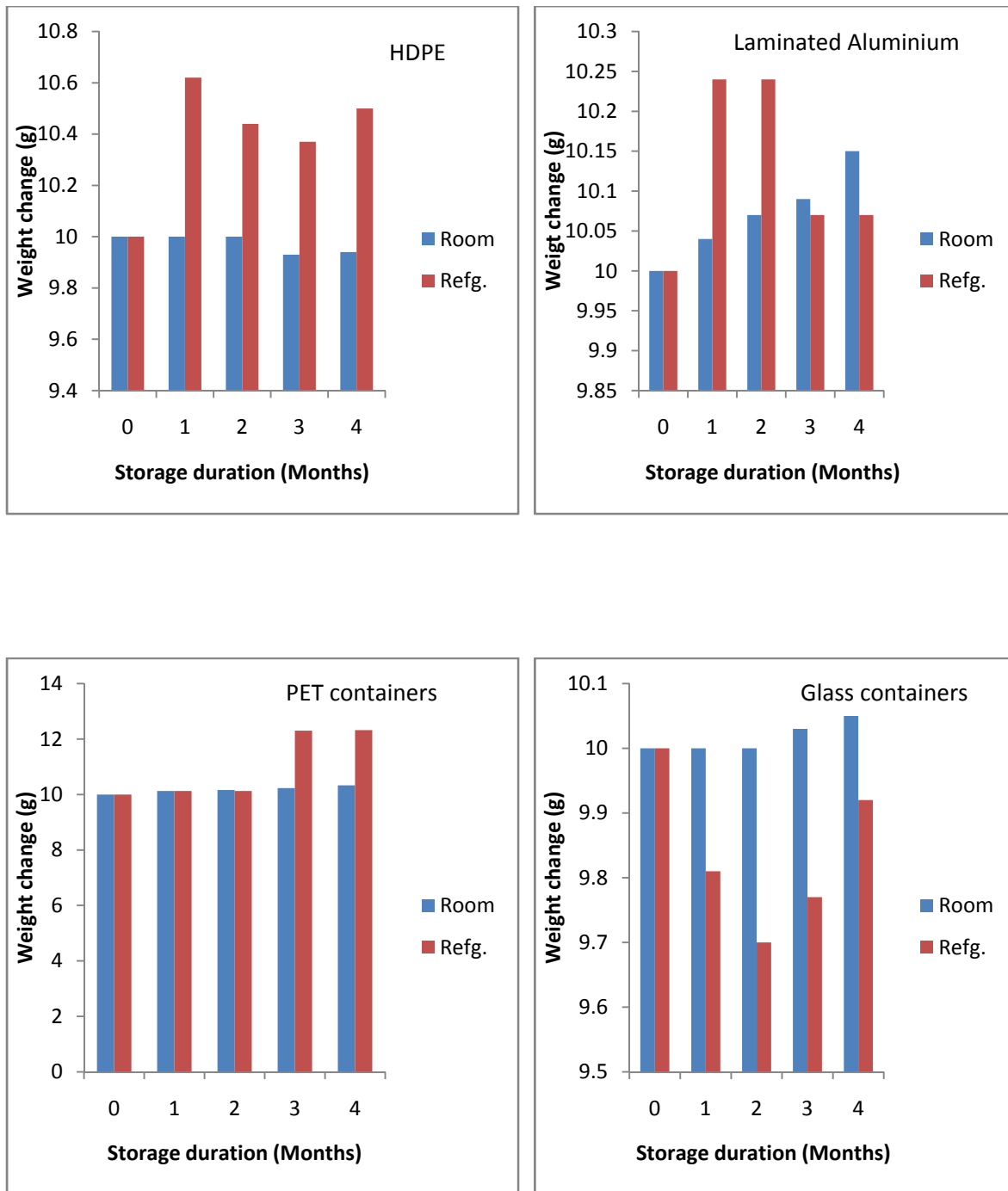


Fig. 4.1.5.3 Effect of storage conditions on weight change of ginger powder using different packaging material.

4.1.6 Effect of storage conditions on moisture content of dried ginger

4.1.6.1 Effect of storage conditions on moisture content of dried ginger flakes

The trends of moisture content of dried ginger flakes packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.6.1. In HDPE, the moisture content of flakes at room temperature increased from an initial value of 3.86% to a final value of 13.85% after storage of 4 months. The moisture content at refrigerated temperature varied from 3.86 to 7.28%. Moisture content increased at a higher rate in case of room temperature storage than at refrigerated temperature. During storage in laminated aluminium films, the moisture content was least effected in nitrogen flushed refrigerated stored samples. The moisture content was 3.86% at 0 day and was 3.33% after 4 months. It was followed by refrigerated stored samples whose final moisture content is 10.58%. The room temperature storage comes third with 11.26% moisture content during fourth month. The highest moisture content was observed in case of nitrogen flushed stored samples at room temperature with 12.72%. PET containers showed that moisture content reached a higher level while storage at room temperature than at refrigerated temperature. At room temperature the moisture content range lies between 3.86 to 12.7% and at refrigerated temperature the moisture content varied from 3.86 to 9.9% during the 4 month storage. In Glass containers, the moisture content at room temperature attained a higher value than refrigerated temperature. At room temperature the value of moisture content increased as 3.86, 8.43, 10.6, 12.87 to 13.69%. At refrigerated temperature the value of moisture content varied as 3.86, 4.12, 8, 8.72 to 8.84%.

4.1.6.2 Effect of storage conditions on moisture content of dried rhizome

The trends of moisture content of dried rhizome packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in Fig. 4.1.6.2. In HDPE, the moisture content reached a higher value during storage at room temperature than at refrigerated temperature. The moisture content increased from 10.55 to 12.55% at room temperature and decreased from 10.55 to 9.95% at refrigerated temperature. In laminated aluminium films, the moisture content reached the highest value in case of nitrogen flushed stored samples at room temperature with 12.47% followed by 11.80% moisture content at room temperature storage and 9.21% moisture content at nitrogen flushed refrigerated storage. The least moisture content change was observed in case of refrigerated storage with 8.58% as the final value. In all these cases the samples were stored for 4 months and the value of initial moisture content was 10.55%.

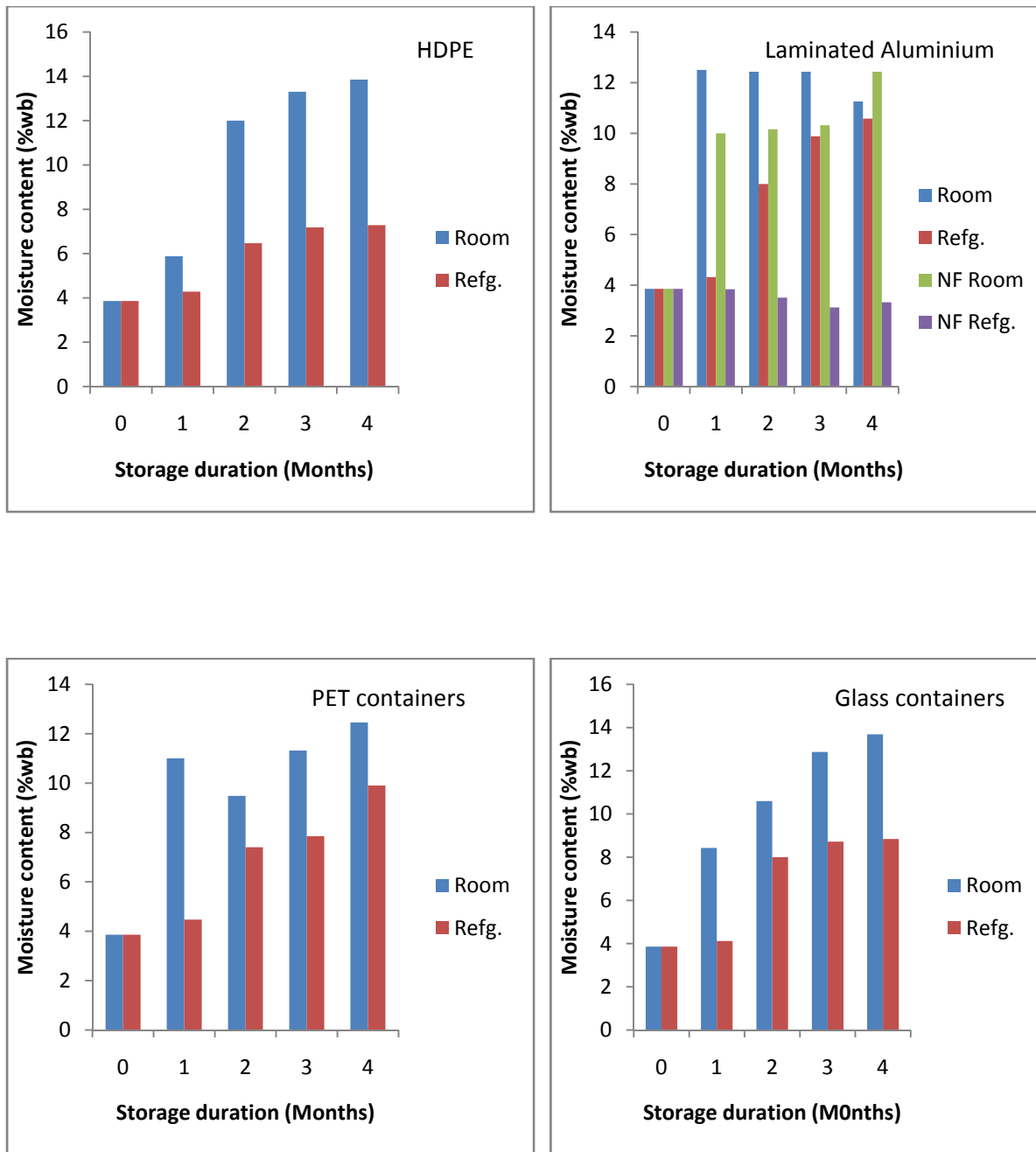


Fig. 4.1.6.1 Effect of storage conditions on moisture content of dried ginger flakes using different packaging material.

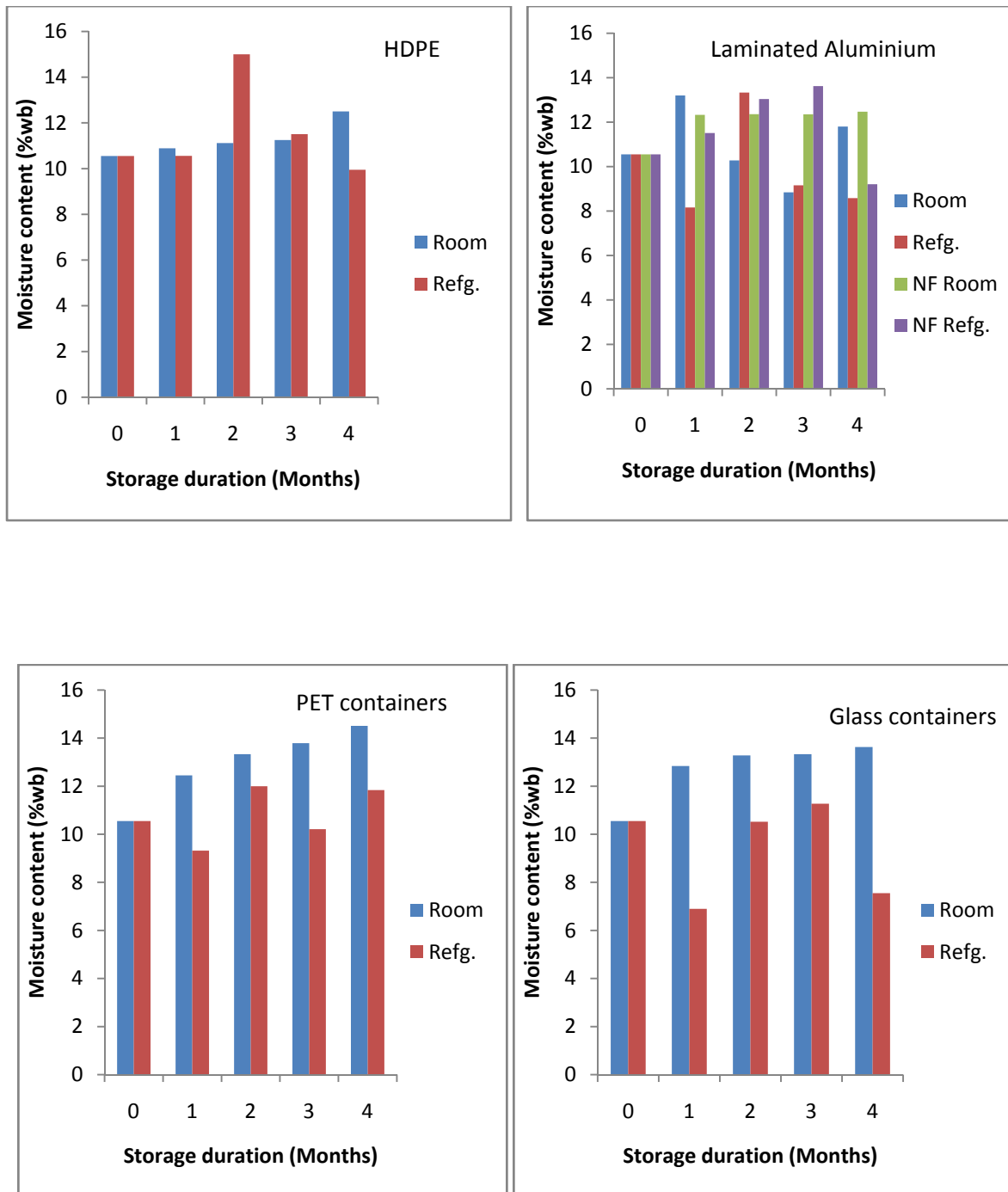


Fig. 4.1.6.2 Effect of storage conditions on moisture content of dried rhizome using different packaging material.

During storage in PET containers, moisture content increased at a steady rate during storage at room temperature. The values were 10.55, 12.84, 13.28, 13.33 and 13.63%. At refrigerated temperature the moisture content decreased from 10.55 to 7.55%. Glass containers stated that during 4 month storage the moisture content at room temperature attained a higher value than at refrigerated temperature. At room temperature the value of moisture content increased from 10.55 to 15.13% and at refrigerated temperature the value increased from 10.55 to 11.84%.

4.1.6.3 Effect of storage conditions on moisture content of ginger powder

The trends of moisture content of ginger powder packaged in HDPE, laminated aluminium films, PET and glass containers at different temperature during 4 month storage are shown in fig. 4.1.6.3. HDPE showed that moisture content at room temperature reached a higher value than refrigerated temperature. The values at room temperature were 6.1, 10.9, 11.5, 12.5 and 18.35% for a duration of 4 month storage. Each reading was taken after a month interval. At refrigerated temperature the value ranged from 6.1 to 8.16%. In laminated aluminium films, the moisture content at room temperature attained a higher value than at refrigeration. During the fourth month, the moisture content goes upto 15.5% at room temperature and 7.41% at refrigerated temperature. Initially at both the storage conditions the value of moisture content was 6.1%. PET containers recorded that the values of moisture content were unstable during the storage period of 4 months. The value of ginger powder at 0 day storage was 6.1% and 11.49% during the fourth month in case of room temperature. At refrigerated temperature the moisture content varied from 6.1% at 0 day to 7.98% at fourth month. Glass containers revealed that at room temperature, moisture content increased at a steady rate and goes upto 15.5% starting from an initial value of 6.1%. The values of moisture content obtained during the 4 month storage were 6.1, 8.1, 9.52, 12.86 and 15.5%. At refrigerated temperature the change in value of moisture content was observed as 6.1% at 0 day and 7.58% at 4 month. The value of moisture content increased at a rapid rate during storage at room temperature than at refrigerated temperature.

The data of moisture content was statistically analyzed to determine the significance of the effect of different parameters such as physical forms, packages, storage period and their interactions and the results are indicated in Table A8 (Appendix A). It was seen that physical forms, storage period and replications were significant at 5% level, while packages were not significant at 5% level. Besides, the interaction between physical form & storage period, physical form & packages and packages & storage period was found to be significant at 5% level. The significance of mean differences for packaging materials were also tested and mostly these differences were not significant at 5% level (Appendix B).

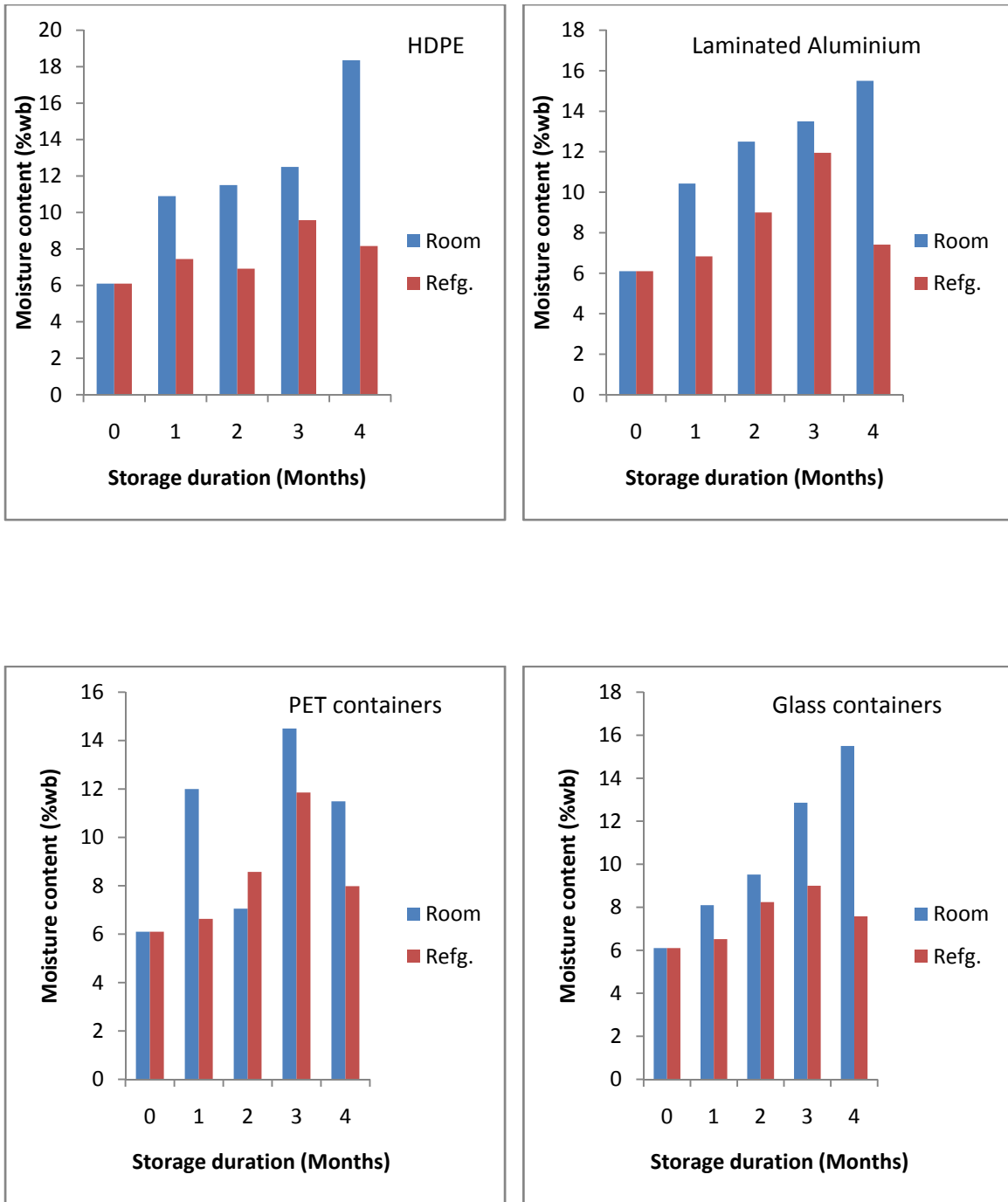


Fig. 4.1.6.3 Effect of storage conditions on moisture content of ginger powder using different packaging material.

4.2 Effect of packaging material on various quality parameters of dried ginger at various storage conditions

4.2.1 Effect of packaging material on colour of dried ginger

4.2.1.1 Effect of packaging material on colour of dried ginger flakes

4.2.1.1.1 Effect of packaging material on lightness of dried ginger flakes

Fig. 4.2.1.1 represents the effect of packaging material on lightness of dried ginger flakes at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that refrigerated temperature gave better results of lightness in all the packaging material. At both the storage conditions, the nitrogen flushed samples gave the best results. (50.92 to 42.71 at room temperature) and (50.92 to 45.64 at refrigerated temperature). PET containers showed the maximum decrease in lightness during the storage period at room temperature (50.92 to 28.83) and refrigerated temperature (50.92 to 30.75).

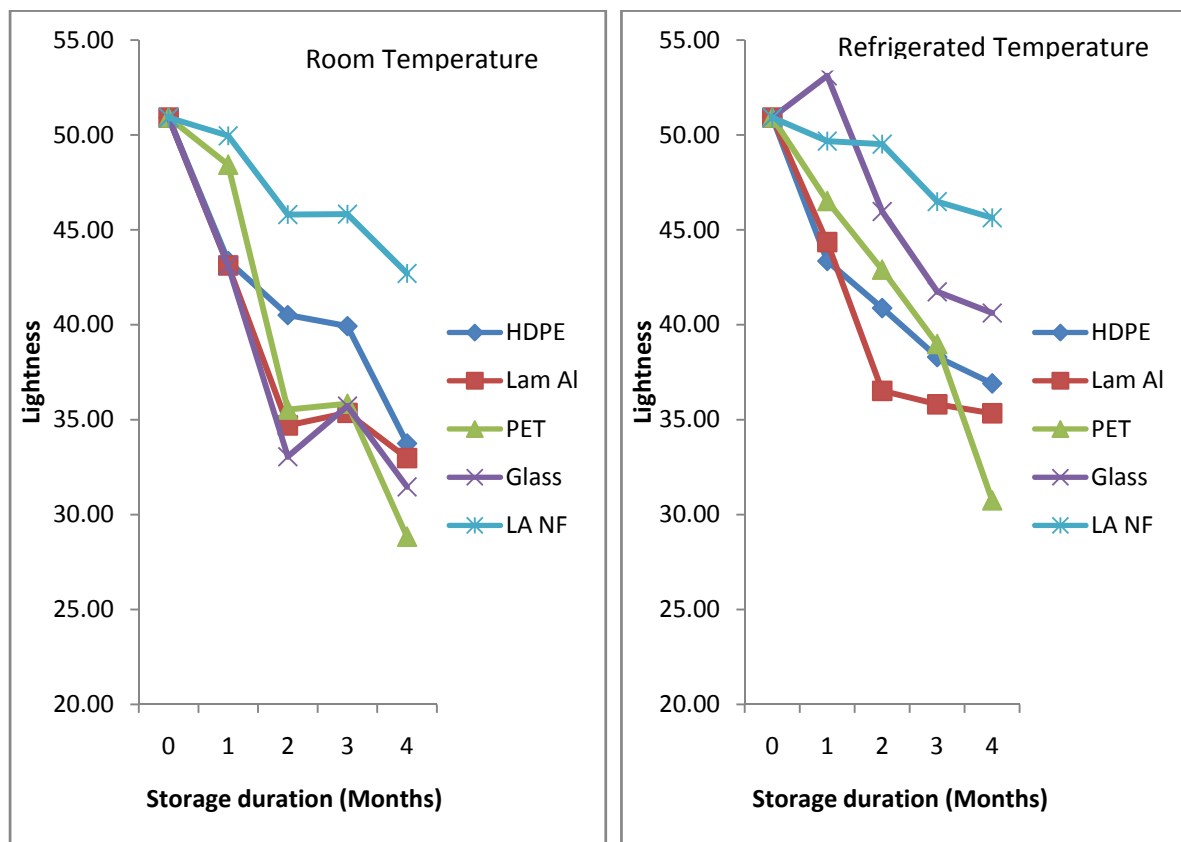


Fig. 4.2.1.1 Effect of packaging material on lightness of dried ginger flakes at storage conditions.

4.2.1.1.2 Effect of packaging material on chroma of dried ginger flakes

Fig. 4.2.1.2 represents the effect of packaging material on chroma of dried ginger flakes at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that HDPE and nitrogen flushed samples gave better results at room temperature and PET and glass containers gave better results at refrigerated temperature. Chroma gave the best results with glass containers at refrigerated temperature (15.59 to 14.03) and nitrogen flushed samples at room temperature (15.59 to 13.16). The minimum value of chroma was recorded for PET containers both at room temperature (15.59 to 9.64) and at refrigerated temperature (15.59 to 10.53) during a storage period of 4 months.

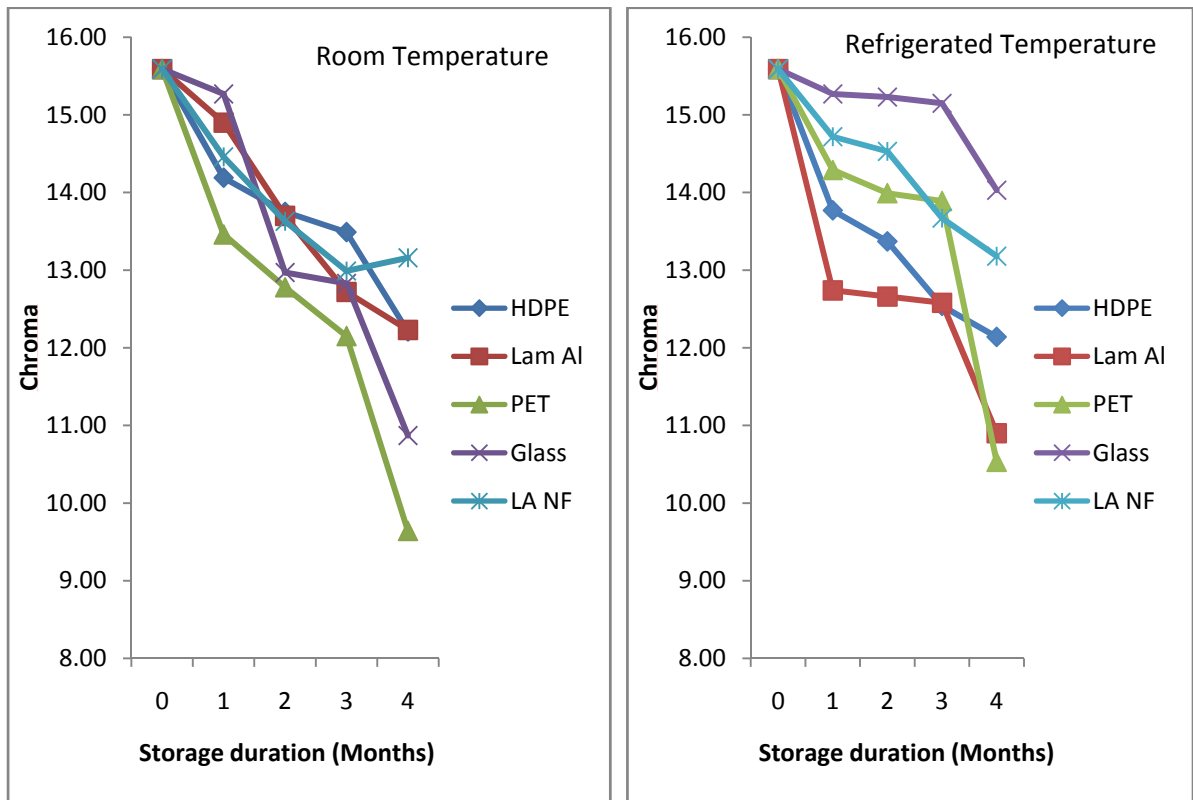


Fig. 4.2.1.2 Effect of packaging material on chroma of dried ginger flakes at storage conditions.

4.2.1.1.3 Effect of packaging material on hue angle of dried ginger flakes

Fig. 4.2.1.3 represents the effect of packaging material on hue angle of dried ginger flakes at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that refrigerated samples maintained the hue angle as compared to room temperature samples. At refrigerated temperature glass containers (79.89 to 75.13 degrees) gave the best results of hue angle

and at room temperature nitrogen flushed samples (77.89 to 71.11 degrees) gave the best results. The lowest values of hue angle were measured in PET containers both at room temperature (77.89 to 64.18 degrees) and refrigerated temperature (79.89 to 70.88 degrees) during the storage period.

Similar results were quoted by (Nasar-Abbas *et al*, 2008) which states that flushing with N₂ reduced colour darkening in faba beans. Nitrogen substantially reduced changes in L* C* and h° values.

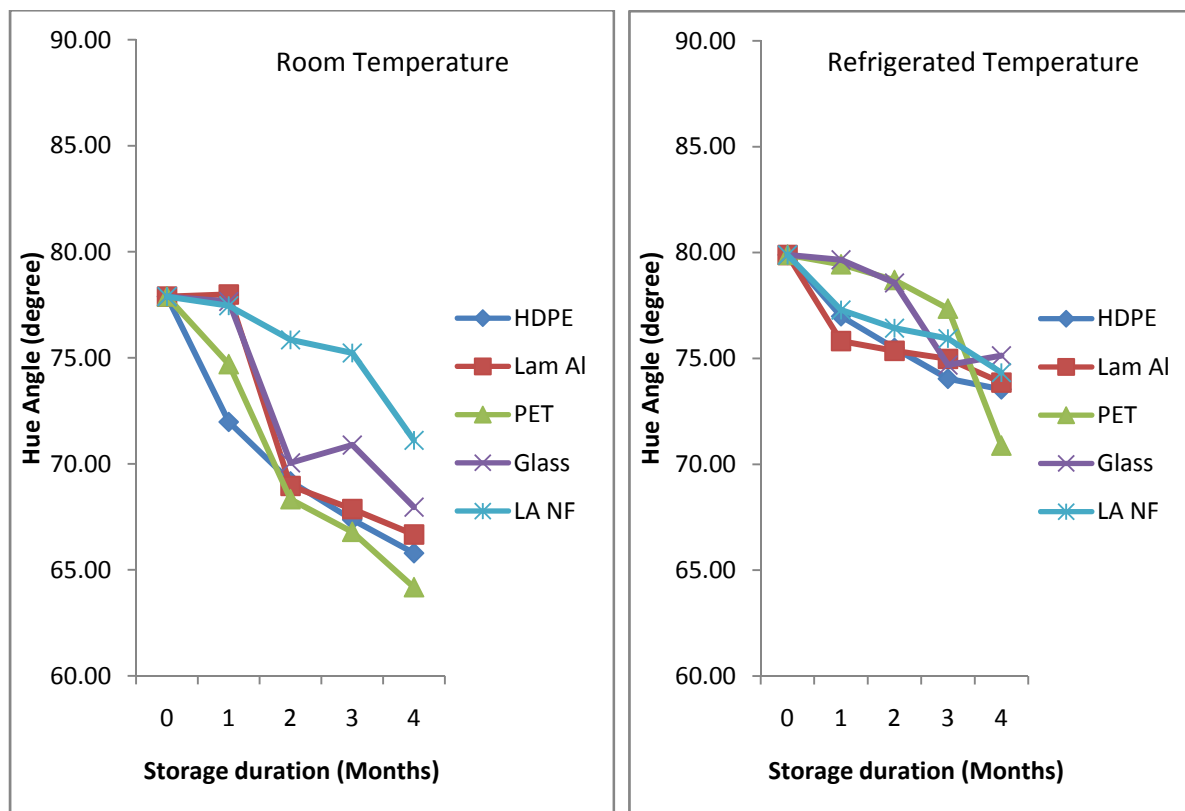


Fig. 4.2.1.3 Effect of storage conditions on hue angle (degrees) of dried ginger flakes at storage conditions.

4.2.1.2 Effect of packaging material on colour of dried rhizome

4.2.1.2.1 Effect of packaging material on lightness of dried rhizome

Fig. 4.2.1.4 represents the effect of packaging material on lightness of dried rhizome at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that at refrigerated temperature lightness was preserved more than the room temperature. At refrigerated temperature glass containers (54.16 to 53.86) showed the maximum value of lightness and at room temperature PET containers (54.16 to 52.72) showed the highest value of lightness. HDPE recorded

the lowest value of lightness both at room temperature (54.16 to 42.43) and refrigerated temperature (54.16 to 46.32) during the storage period of 4 months.

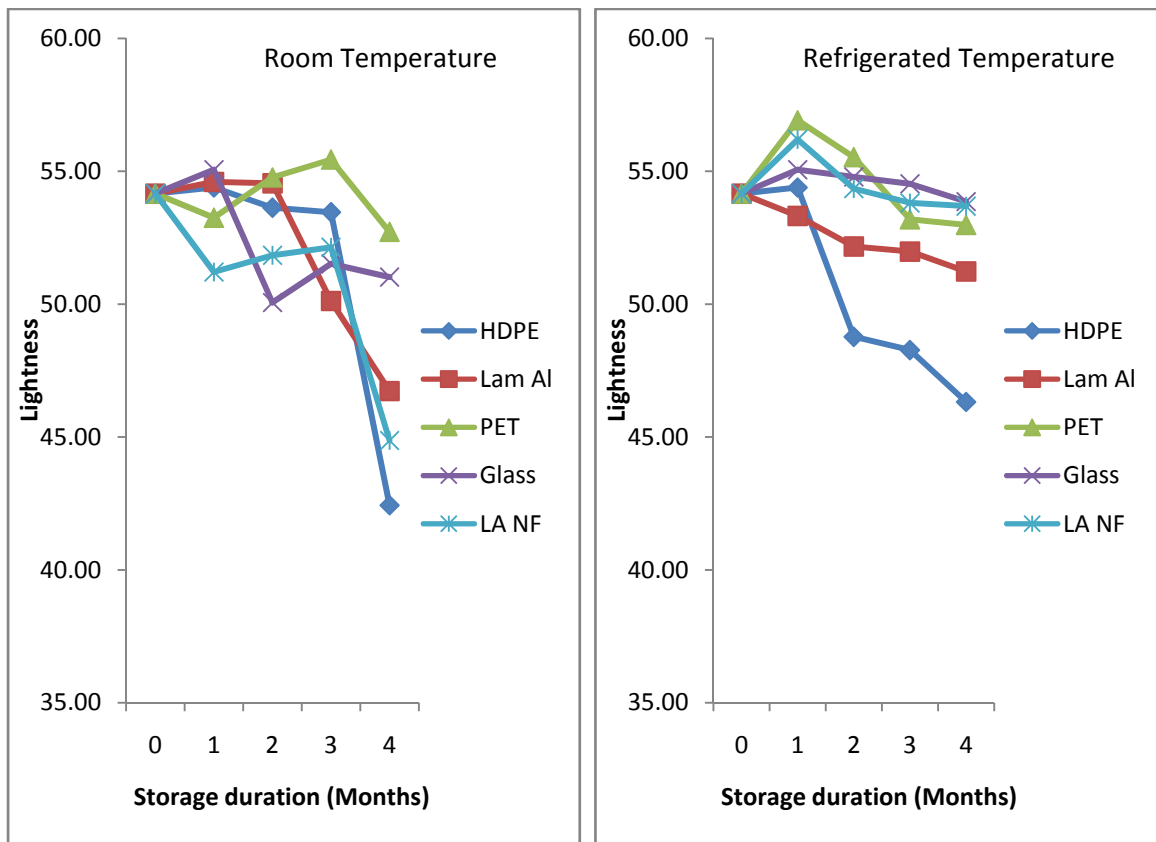


Fig. 4.2.1.4 Effect of packaging material on lightness of dried rhizome at storage conditions

4.2.1.2.2 Effect of packaging material on chroma of dried rhizome

Fig. 4.2.1.5 represents the effect of packaging material on chroma of dried rhizome at room temperature and refrigerated temperature during the storage period of 4 months. At refrigerated temperature chroma values showed greater variation while at room temperature, the chroma values were increasing in all the packaging material. At refrigerated temperature the chroma values were increasing in HDPE (12.05 to 12.61), laminated aluminium films (12.05 to 12.30) and nitrogen flushed laminated aluminium packaging (12.05 to 13.27) while it was decreasing in PET (12.05 to 11.53) and glass containers (12.05 to 11.12). At room temperature the chroma value showed a maximum increase in PET containers (12.05 to 14.78) from its initial value and a minimum increase in nitrogen flushed laminated aluminium packaging (12.05 to 12.98) from its initial value.

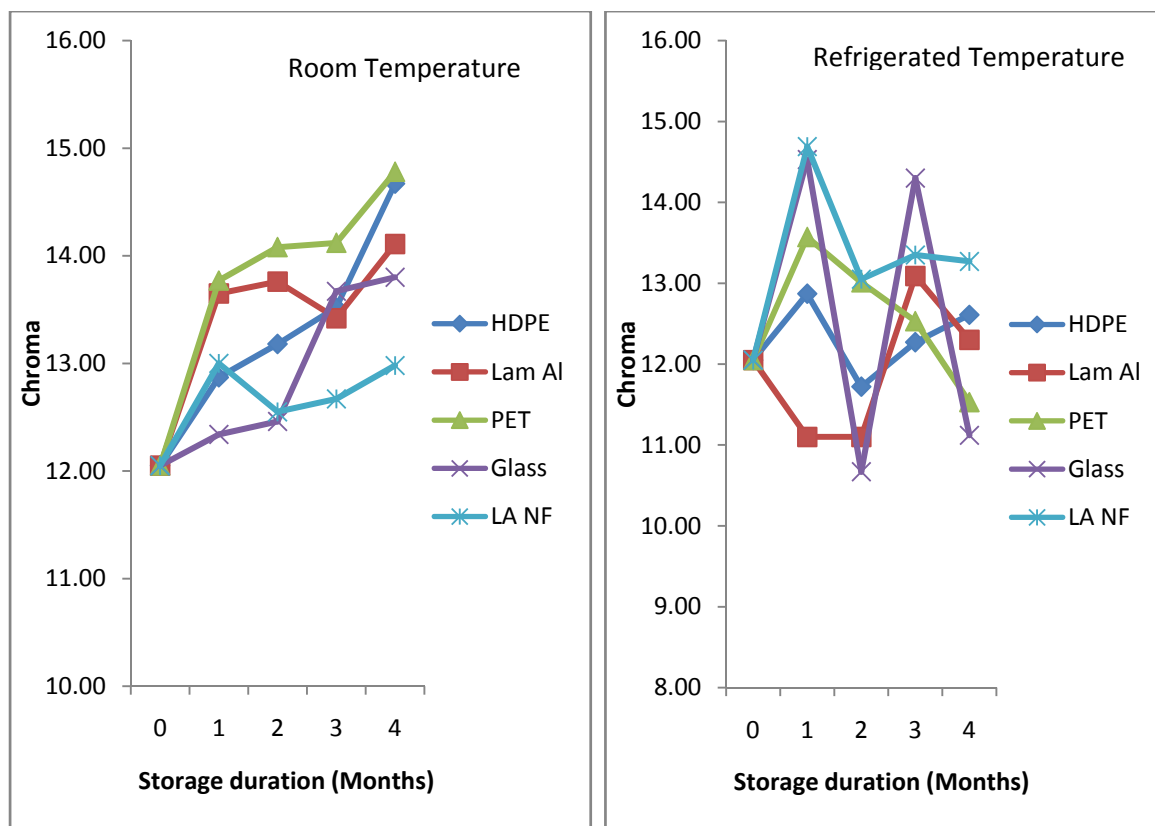


Fig. 4.2.1.5 Effect of packaging material on chroma of dried rhizome at storage conditions

4.2.1.2.3 Effect of packaging material on hue angle of dried rhizome

Fig. 4.2.1.6 represents the effect of packaging material on hue angle of dried rhizome at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that refrigeration showed better results as compared to room temperature in all the packaging material except glass containers. At refrigerated temperature nitrogen flushed samples (79.48 to 73.51) showed minimum variation in hue angle and at room temperature minimum variation was shown by glass containers (79.48 to 73.63) during the storage period of 4 months.

4.2.1.3 Effect of packaging material on colour of ginger powder

4.2.1.3.1 Effect of packaging material on lightness of ginger powder

Fig. 4.2.1.7 represents the effect of packaging material on lightness of ginger powder at room temperature and refrigerated temperature during the storage period of 4 months. It was observed that lightness was maintained at refrigerated temperature than at room temperature. At refrigerated temperature, laminated aluminium films (58.74 to 56.72) gave the minimum variation for lightness

during the storage period followed by HDPE (58.74 to 56.55), PET (58.74 to 55.60) and glass containers (58.74 to 55.49). At room temperature, PET containers (58.74 to 55.04) preserved the lightness of the ginger powder followed by glass containers (58.74 to 54.39), HDPE (58.74 to 54.12) and laminated aluminium films (58.74 to 53.12).

Samples under modified atmospheres kept L constant during the whole period of storage, showing values at the end of the storage period very similar to those at the packaging moment. (García-Esteban et al, 2004).

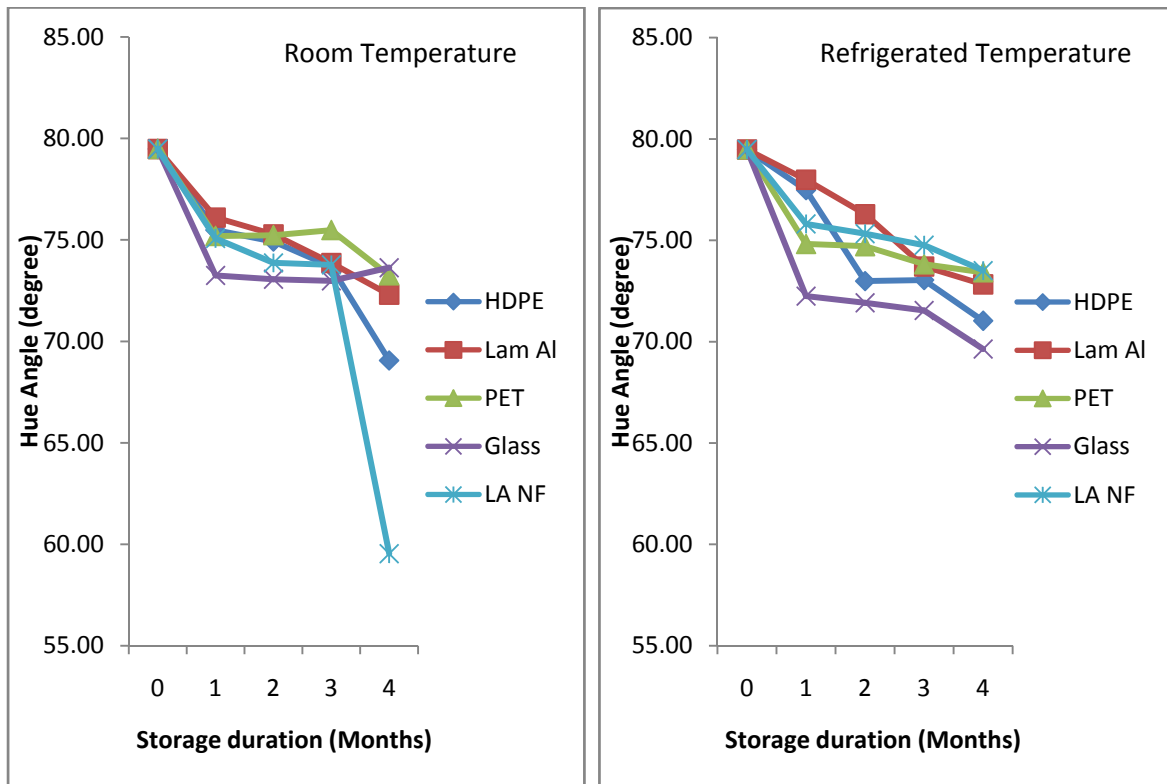


Fig. 4.2.1.6 Effect of packaging material on hue angle of dried rhizome at storage conditions

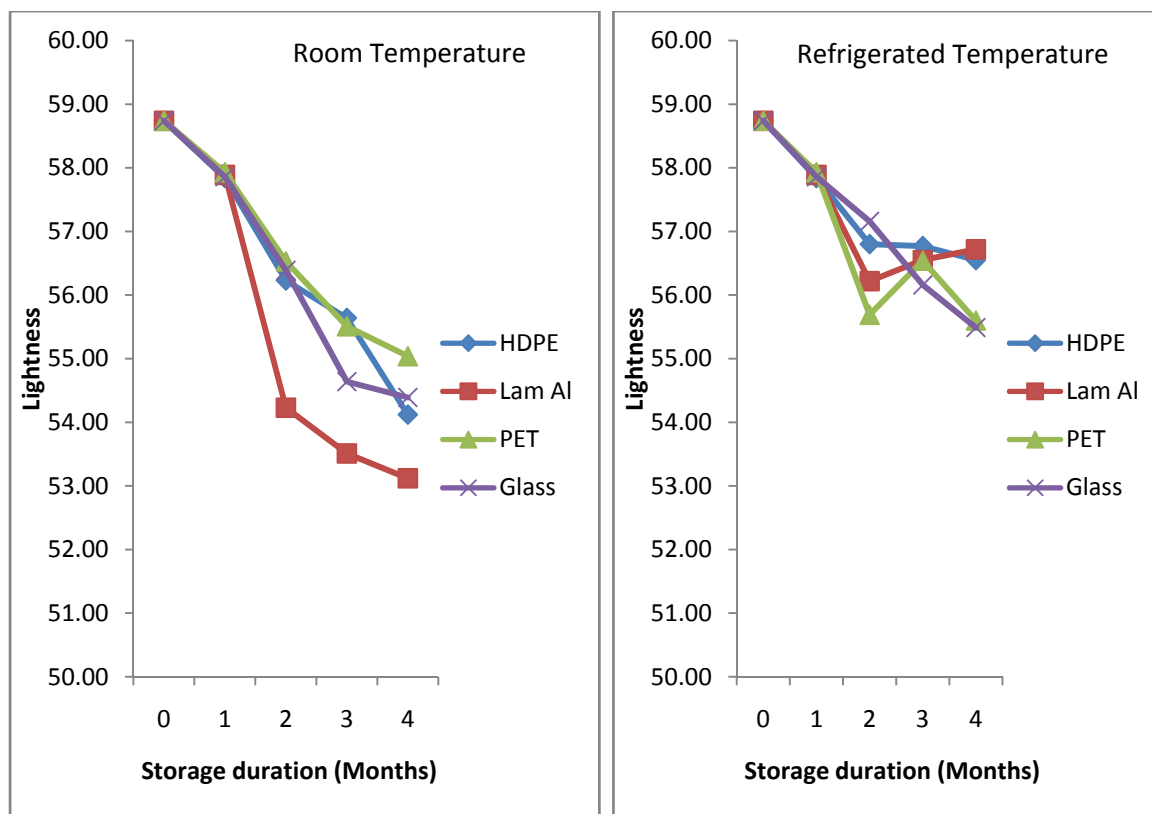


Fig. 4.2.1.7 Effect of packaging material on lightness of ginger powder at storage conditions

4.2.1.3.2 Effect of packaging material on chroma of ginger powder

Fig. 4.2.1.8 represents the effect of packaging material on chroma of ginger powder at room temperature and refrigerated temperature during the storage period of 4 months. Better chroma values were obtained at refrigerated temperature than at room temperature. At refrigerated temperature, chroma showed a minimum decrease during storage in laminated aluminium films (20.91 to 18.82) followed by HDPE (20.91 to 18.73), PET (20.91 to 18.57) and glass containers (20.91 to 18.52). At room temperature the lowest decrease in chroma value was observed for glass containers (20.91 to 16.18) followed by HDPE and PET containers (20.91 to 16.05) and laminated aluminium films (20.91 to 15.93).

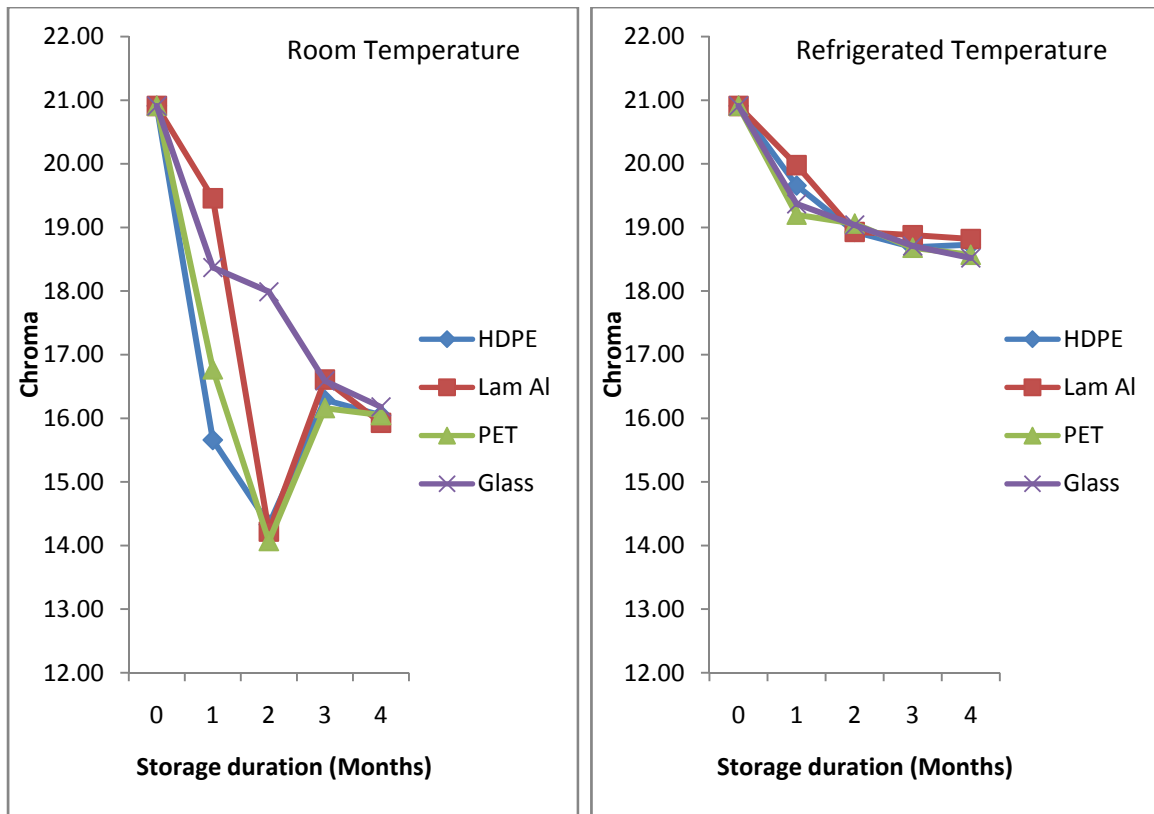


Fig. 4.2.1.8 Effect of packaging material on chroma of ginger powder at storage conditions

4.2.1.3.3 Effect of packaging material on hue angle of ginger powder

Fig. 4.2.1.9 represents the effect of packaging material on hue angle of ginger powder at room temperature and refrigerated temperature during the storage period of 4 months. The hue angle was maintained at refrigerated temperature in a better way as compared to room temperature. At refrigerated temperature and at room temperature maximum hue angle was maintained in HDPE (81.81 to 79.67; 81.81 to 77.33) followed by laminated aluminium films (81.81 to 79.61; 81.81 to 76.76), PET (81.81 to 79.17; 81.81 to 76.56) and glass containers (81.81 to 78.95; 81.81 to 75.90) during the storage period of 4 months.

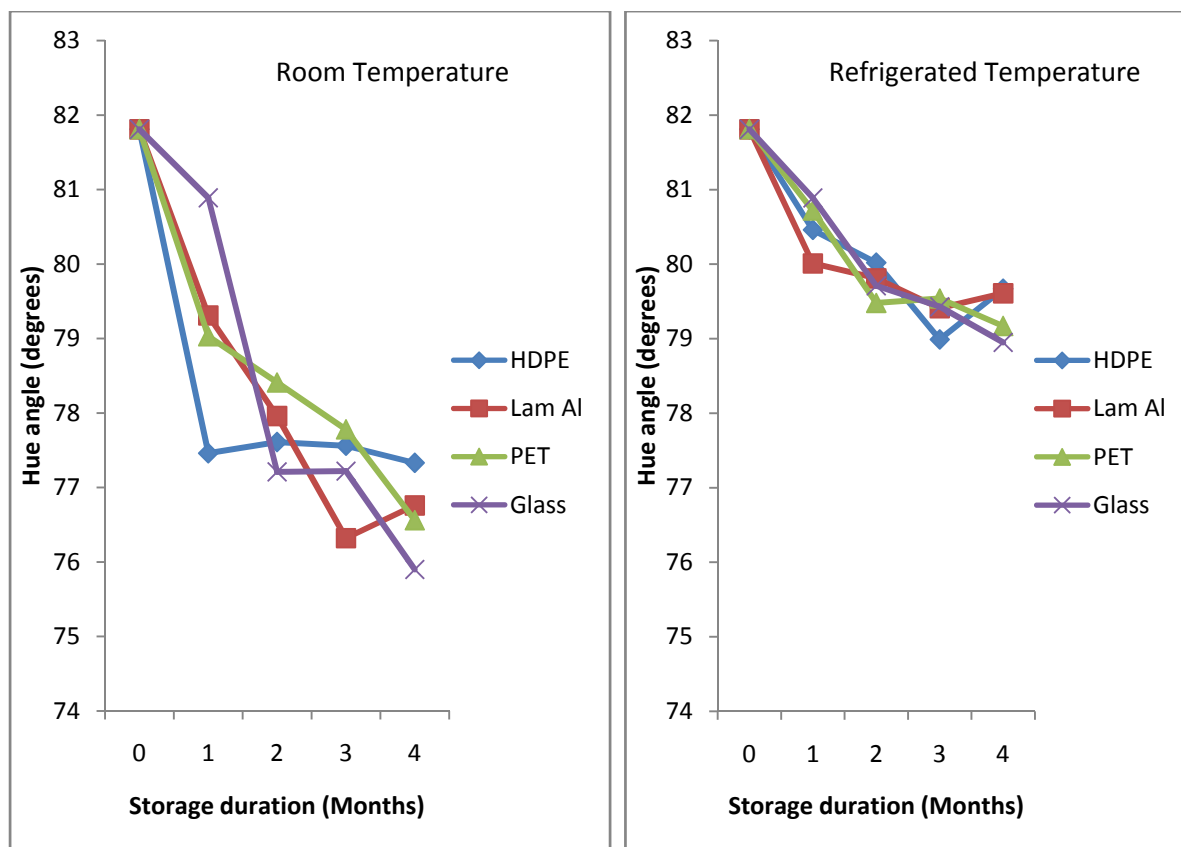


Fig. 4.2.1.9 Effect of packaging material on hue angle of ginger powder at storage conditions

4.2.2 Effect of packaging material on volatile oil of dried ginger

4.2.2.1 Effect of packaging material on volatile oil of dried ginger flakes

The trend of volatile oil of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in fig. 4.2.2.1. The fig. illustrates that in glass containers the volatile oil decreased at the slowest rate. The readings obtained were 1.34, 1.25, 1.12, 1.07 and 0.96%. The PET containers and nitrogen flushed samples showed almost a similar trend. In both the cases the volatile oil measured during fourth month comes out to be 0.94%. In HDPE packaging, the volatile oil decreased from an initial value of 1.34% to a final value of 0.92% during a 4 month storage time. The lowest volatile oil was observed in laminated aluminium films in which the final value during the fourth month comes out to be 0.89%. The values obtained were 1.34, 1.21, 1.08, 1.06 and 0.89%.

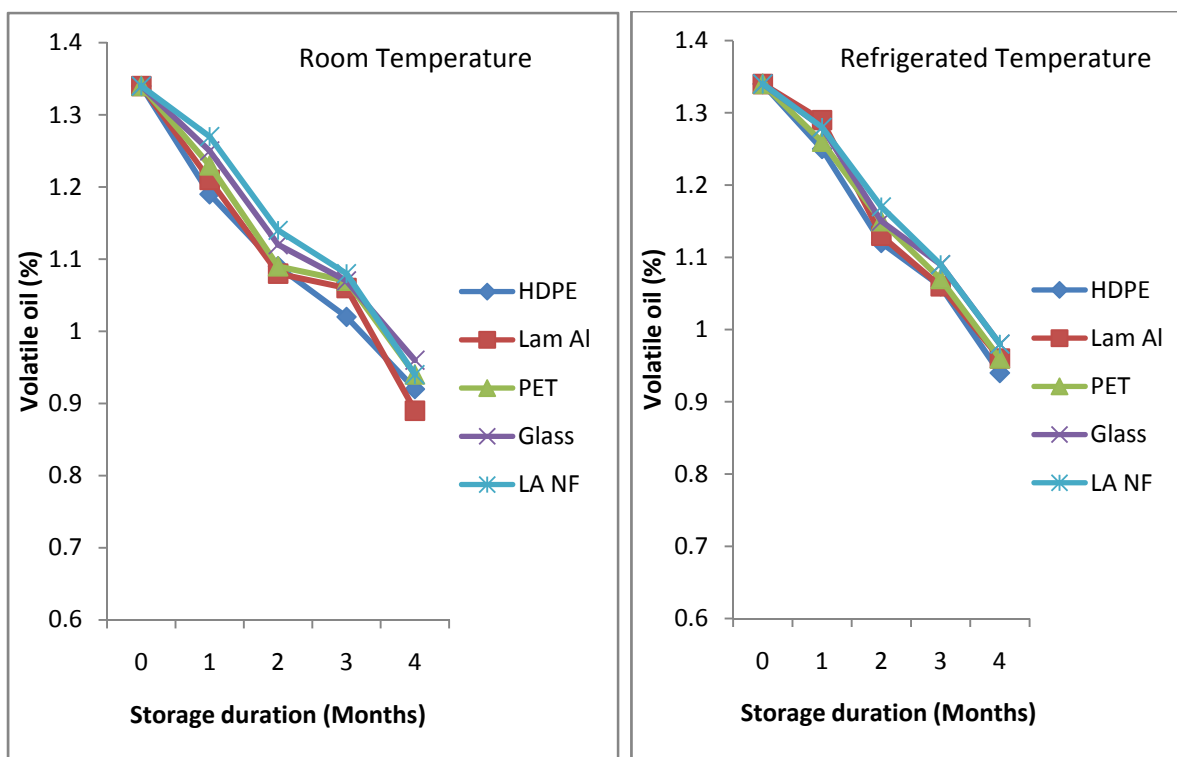


Fig. 4.2.2.1 Effect of packaging material on volatile oil of dried ginger flakes at storage conditions

The trend of volatile oil of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.2.1. The fig. shows that the highest value of volatile oil was measured for glass containers and nitrogen flushed samples. The value of volatile oil was 1.34% at 0 day and 0.98% at 4 month. For storage in laminated aluminium films and PET containers, the volatile oil content, during fourth month was 0.96%. The lowest volatile oil content was recorded for HDPE films, the values obtained were 1.34, 1.25, 1.12, 1.06 and 0.94%.

4.2.2.2 Effect of packaging material on volatile oil of dried rhizome

The trend of volatile oil of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.2.2. The fig. indicates that volatile oil was maximum maintained in nitrogen flushed samples stored in laminated aluminium films. The value decreased from 1.37% at 0 day to 0.92% at 4th month. The nitrogen flushed samples were followed by glass and PET containers in terms of maintaining the volatile oil of dried rhizome. The final volatile oil of glass and PET containers measured during the fourth month was 0.86% and 0.84%. Among all packaging material, HDPE and laminated aluminium films showed the minimum volatile oil content with 0.83%.

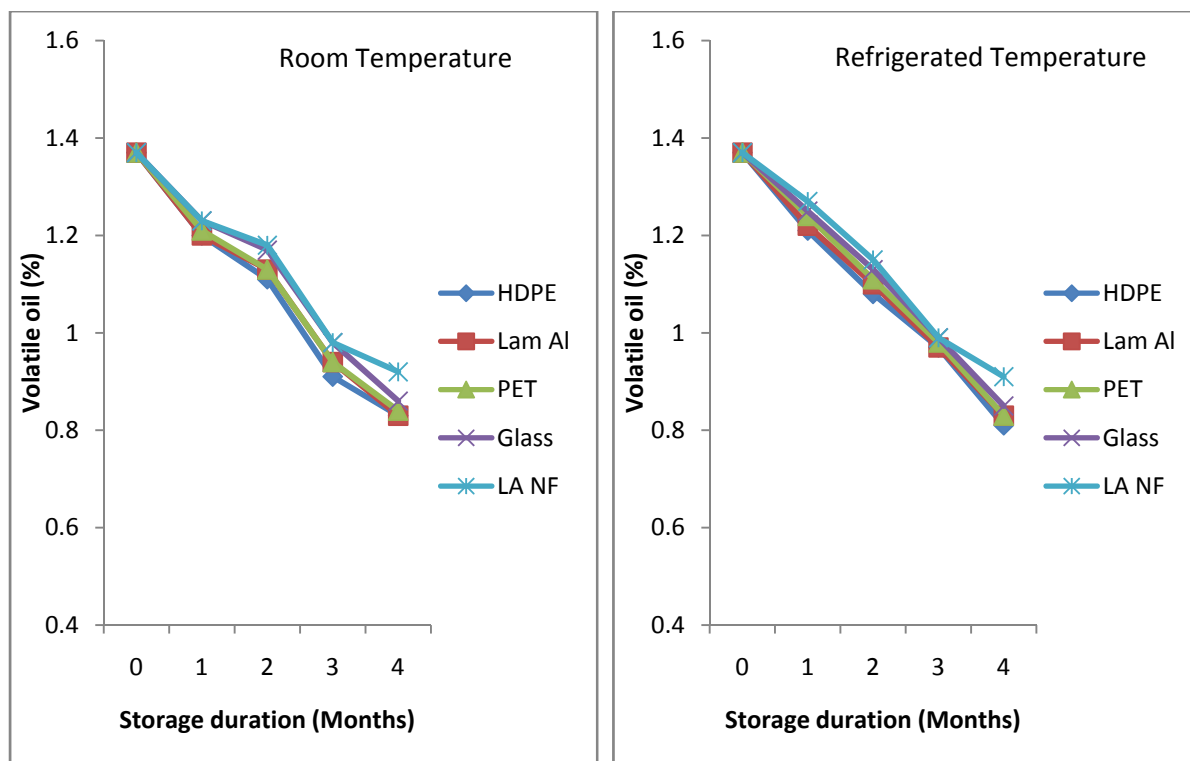


Fig. 4.2.2.2 Effect of packaging material on volatile oil of dried rhizome at storage conditions

The trend of volatile oil of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.2.2. The fig. illustrates that volatile oil showed highest value in nitrogen flushed stored samples in laminated aluminium films. The values obtained were 1.37, 1.27, 1.15, 0.99 and 0.91%. It was followed by glass containers in which the volatile oil was 0.85% during the fourth month. The volatile oil showed almost a similar trend for both PET containers and laminated aluminium films. In both the cases, volatile oil content at 0 day was 1.37% and at 4th month was 0.83%. Among all the packaging material, the volatile oil decreased at the fastest rate in HDPE films. The values recorded were 1.37, 1.21, 1.08, 0.97 and 0.81%.

4.2.2.3 Effect of packaging material on volatile oil of ginger powder

The trend of volatile oil of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.2.3. The Fig. shows that volatile oil showed the highest value during storage in glass containers. The readings observed were 1.42, 1.24, 1.13, 1.05 and 0.97% respectively. During storage in laminated aluminium films and PET containers, the volatile oil content showed almost a similar trend. In both the cases the initial value was 1.42% at 0 day and 0.95% at 4th month. HDPE packaging and

storage showed the lowest value of volatile oil content. The volatile oil decreased at a much faster rate as compared to storage in other packaging materials. The values recorded were 1.42, 1.2, 1.06, 1.04 and 0.92% respectively.

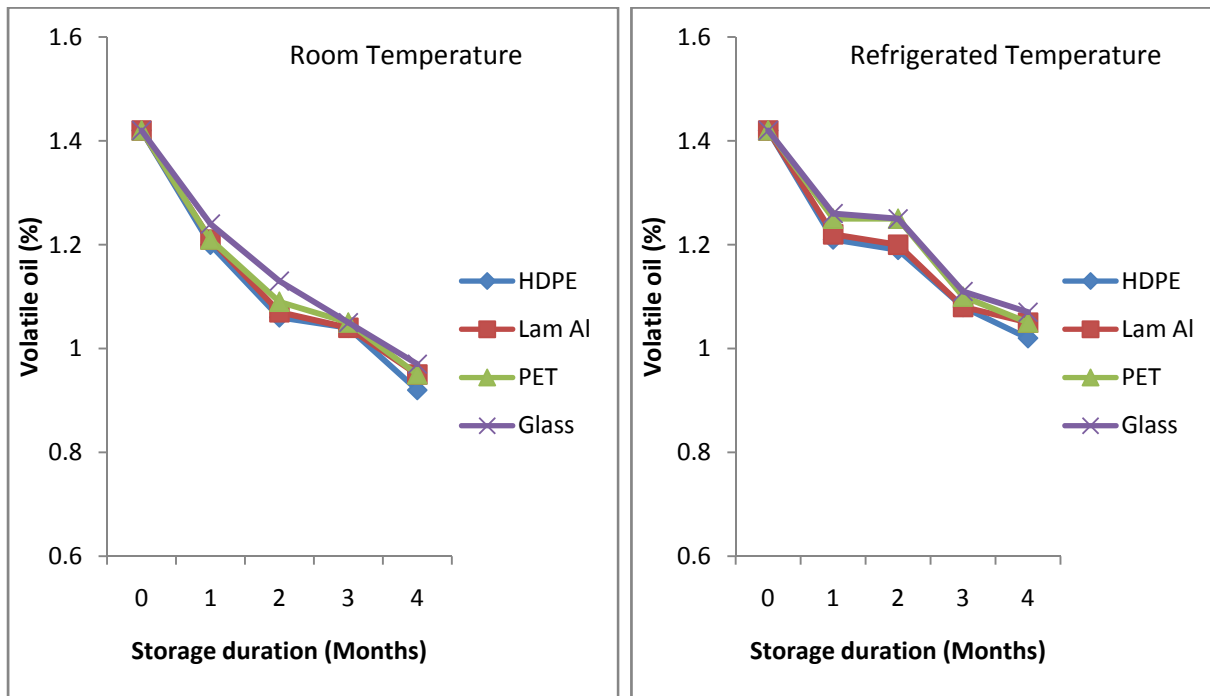


Fig. 4.2.2.3 Effect of packaging material on volatile oil of ginger powder at storage conditions

The trend of volatile oil of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.2.3. The fig. illustrates that maximum value of volatile oil was measured during storage in glass containers. The value at 0 day was 1.42% and at 4th month was 1.07%. Laminated aluminium films and PET containers recorded almost similar trend for volatile oil during the storage interval. The value recorded at 4th month was 1.05%. Lowest volatile oil was measured in HDPE films. The values obtained were 1.42, 1.21, 1.19, 1.08 and 1.02%.

4.2.3 Effect of packaging material on flavour of dried ginger

4.2.3.1 Effect of packaging material on flavour of dried ginger flakes

The trend of flavour of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.3.1. The Fig.4.2.3.1 suggests that flavour was well maintained in nitrogen flushed packaged samples. The nitrogen flushing was done in laminated aluminium films. PET and

glass containers showed a similar trend of flavor during storage of 4 months. The hedonic scale value decreased from 9 to 5 during storage in PET and glass containers. Lowest value of flavour was obtained in laminated aluminium films and HDPE films. The hedonic scale values observed for HDPE during the 4 months were 9, 8, 6, 5 and 5.

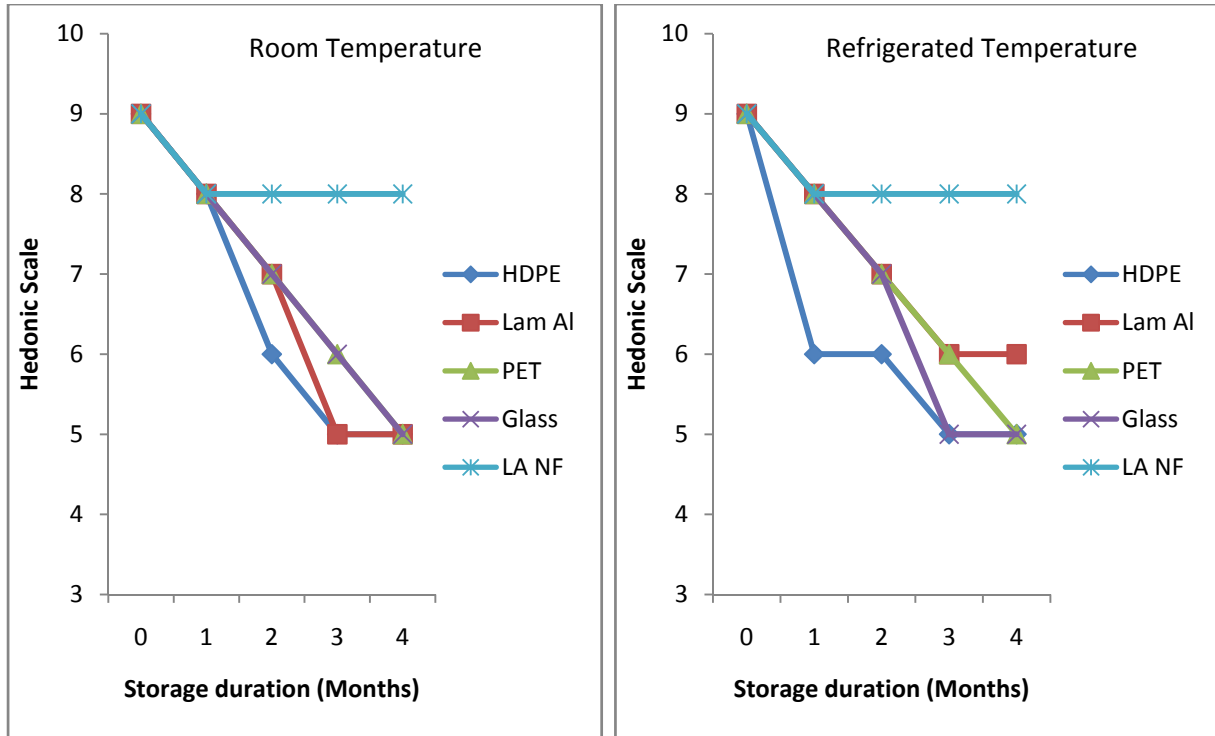


Fig. 4.2.3.1 Effect of packaging material on flavour of dried ginger flakes at storage conditions

The trend of flavour of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.3.1. The Fig.4.2.3.1 signifies that flavor was maximum maintained in nitrogen flushed samples. The hedonic scale value decreased from 9 to 8 during the 4 month storage. It was followed by laminated aluminium films packaging. Flavor in PET and glass containers showed almost a similar trend. Flavor was most effected during storage in HDPE films. The hedonic scale values recorded were 9, 6, 6, 5 and 5.

From the above discussion it is evident that the sensory attributes are affected by the packaging type. This was also stated by Hong and Kim (2004).

4.2.3.2 Effect of packaging material on flavour of dried rhizome

The trend of flavour of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.3.2. It is quite evident from the fig. that highest value of flavour was obtained in those samples where nitrogen flushing was done. These nitrogen flushed samples were stored in laminated aluminium films. The values obtained were 8, 6, 5, 5 and 5. Both the PET and glass containers showed a similar trend i.e. the value decreased from 8 to 5 during a storage period of 4 months. The flavour was least maintained in HDPE and laminated aluminium films as the hedonic scale value decreased from 8 to 4.

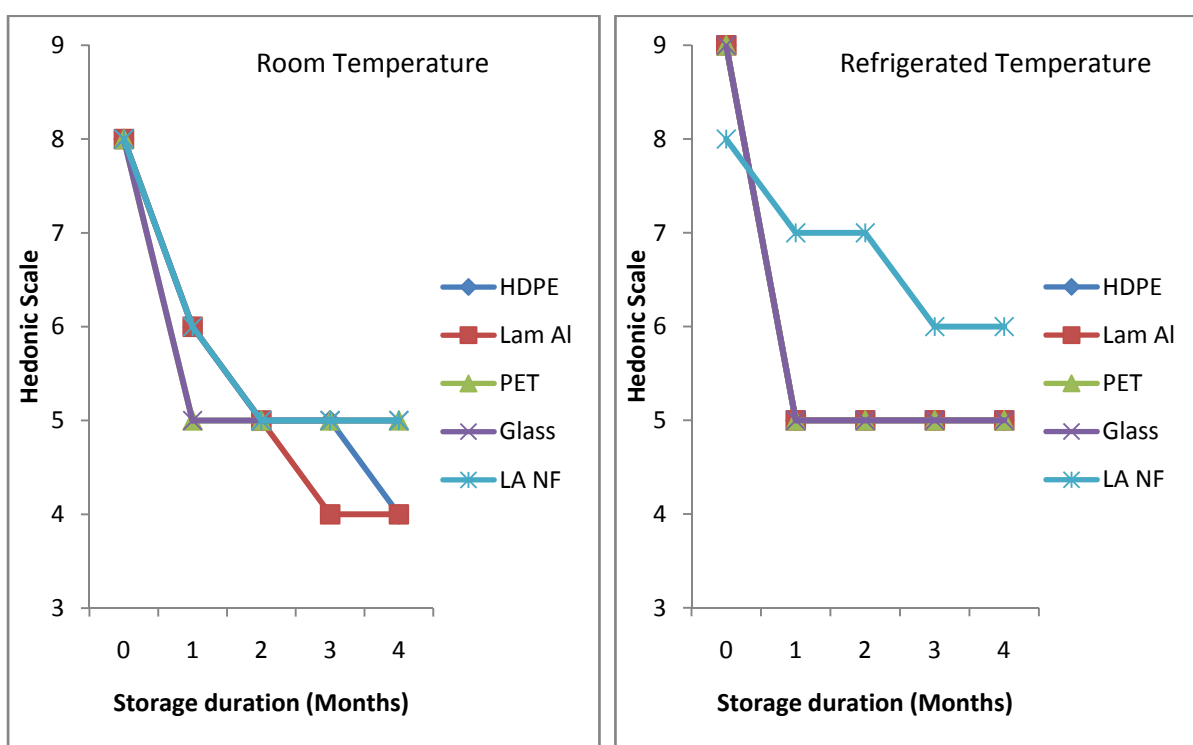


Fig. 4.2.3.2 Effect of packaging material on flavour of dried rhizome at storage conditions

The trend of flavour of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.3.2. The fig. illustrates that highest flavour was retained in nitrogen flushed samples packed in laminated aluminium films. The hedonic scale value decreased from 8 to 6 during the 4 month storage interval. The four packaging material i.e. HDPE films, laminated aluminium films, PET and glass containers showed the similar trend for flavour during storage. The readings obtained were 9, 5, 5, 5 and 5.

4.2.3.3 Effect of packaging material on flavour of ginger powder

The trend of flavour of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.3.3. The fig. shows that maximum flavour value was obtained in glass containers. The observations recorded were 9, 8, 8, 7 and 6. HDPE and laminated aluminium films showed a similar trend for flavour i.e. 9, 8, 7, 7 and 6 during the 4 month storage period. The minimum flavour value was obtained in PET containers.

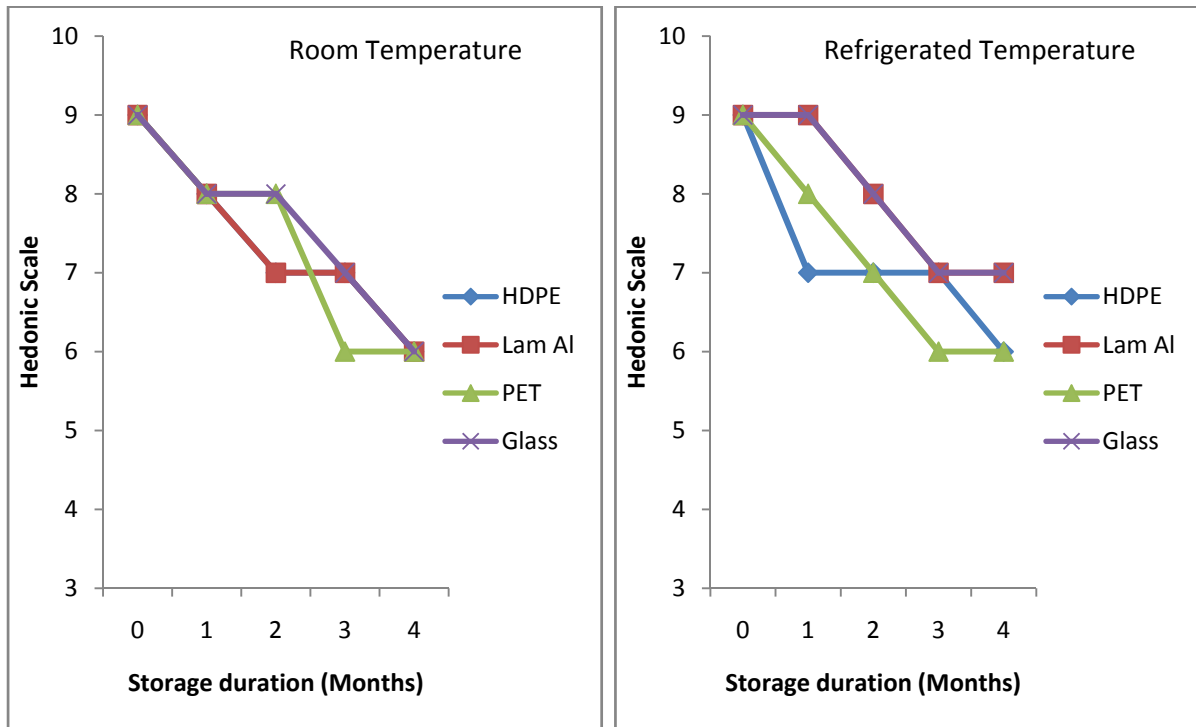


Fig. 4.2.3.3 Effect of packaging material on flavour of ginger powder at storage conditions

The trend of flavour of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.3.3. The fig. shows that glass containers and laminated aluminium films recorded the highest hedonic scale value. The readings obtained were 9, 9, 8, 7 and 7. It was followed by PET containers. Among all the packaging material flavour was least retained in HDPE films. The hedonic scale value decreased from 9 to 6 during the 4 month storage interval.

4.2.4 Effect of packaging material on shrinkage/swelling of dried ginger

4.2.4.1 Effect of packaging material on shrinkage/swelling of dried ginger flakes

The trend of shrinkage/swelling of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.4.1. The fig. conveys that highest value of shrinkage/swelling was obtained in nitrogen flushed packed samples in laminated aluminium films. The value remained same throughout the storage period of 4 months i.e. 2. The remaining packaging material i.e. HDPE films, laminated aluminium films, PET and glass containers, they all show a range of 1.5-2 during the storage period of 4 months.

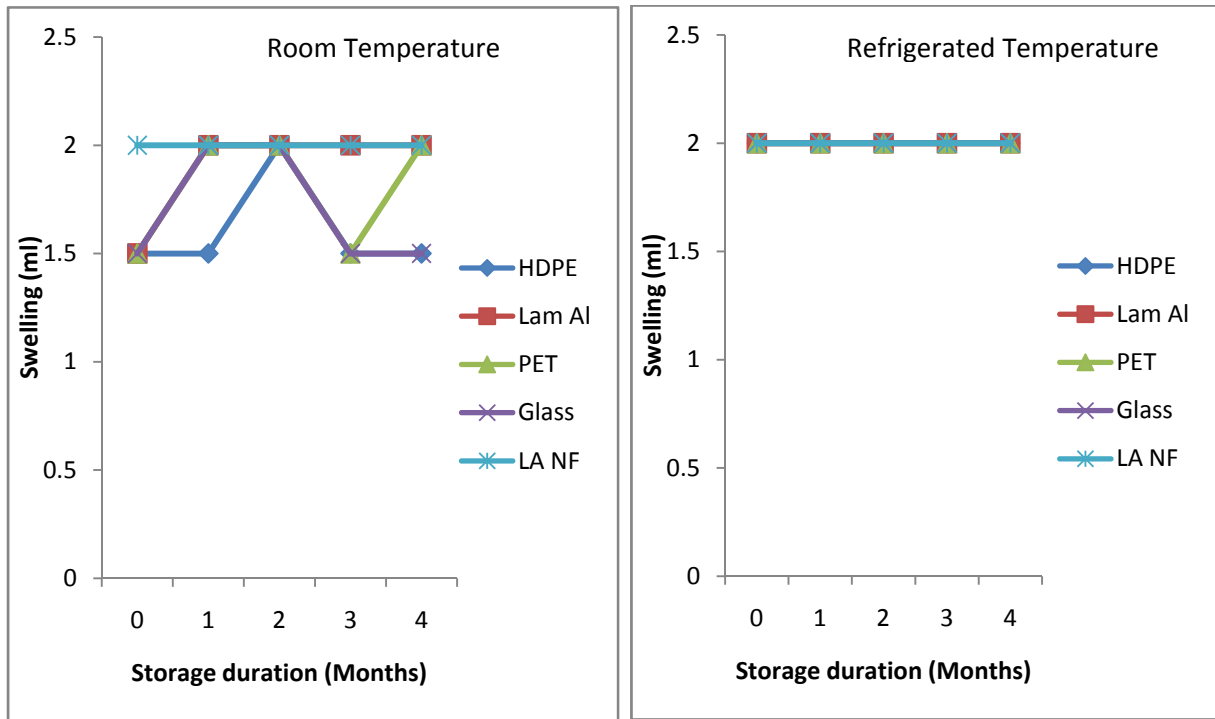


Fig. 4.2.4.1 Effect of packaging material on shrinkage/swelling of dried ginger flakes at storage conditions

The trend of shrinkage/swelling of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.4.1. The fig. clears that the shrinkage/swelling value for all packaging material remains same i.e. 2.

4.2.4.2 Effect of packaging material on shrinkage/swelling of dried rhizome

The trend of shrinkage/swelling of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.4.2. The fig. indicates that maximum shrinkage/swelling i.e. 2 was obtained in nitrogen flushed packaged laminated aluminium films. The shrinkage/swelling value for HDPE, laminated aluminium films, PET and glass containers lies between 1.5-2 during the 4 month storage period.

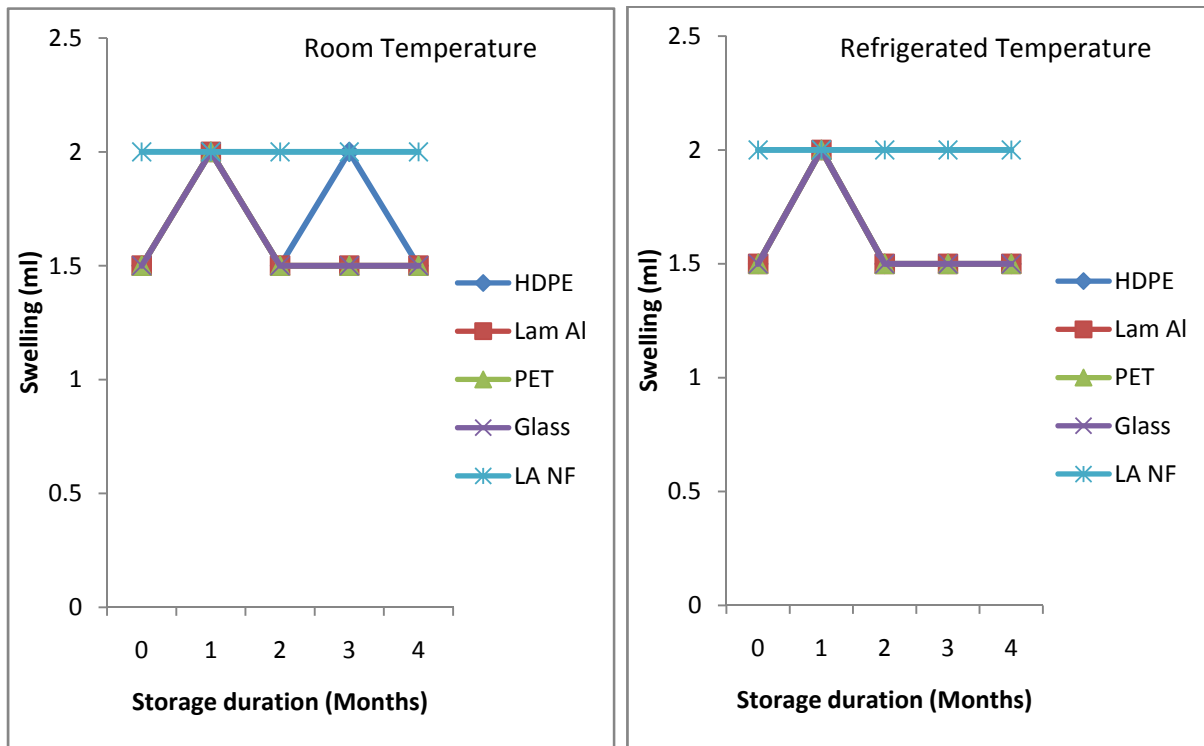


Fig. 4.2.4.2 Effect of packaging material on shrinkage/swelling of dried rhizome at storage conditions

The trend of shrinkage/swelling of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.4.2. The fig. signifies that for nitrogen flushed samples, the shrinkage/swelling value obtained was 2. HDPE films, laminated aluminium films, PET and glass containers, they all show that shrinkage/swelling value lied in the range of 1.5-2 during the 4 month storage period.

4.2.4.3 Effect of packaging material on shrinkage/swelling of ginger powder

The trend of shrinkage/swelling of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.4.3. The Fig. illustrates that in all the 4 packaging materials: HDPE, laminated aluminium films, PET and glass containers, the value of shrinkage/swelling lies between 2-2.5.

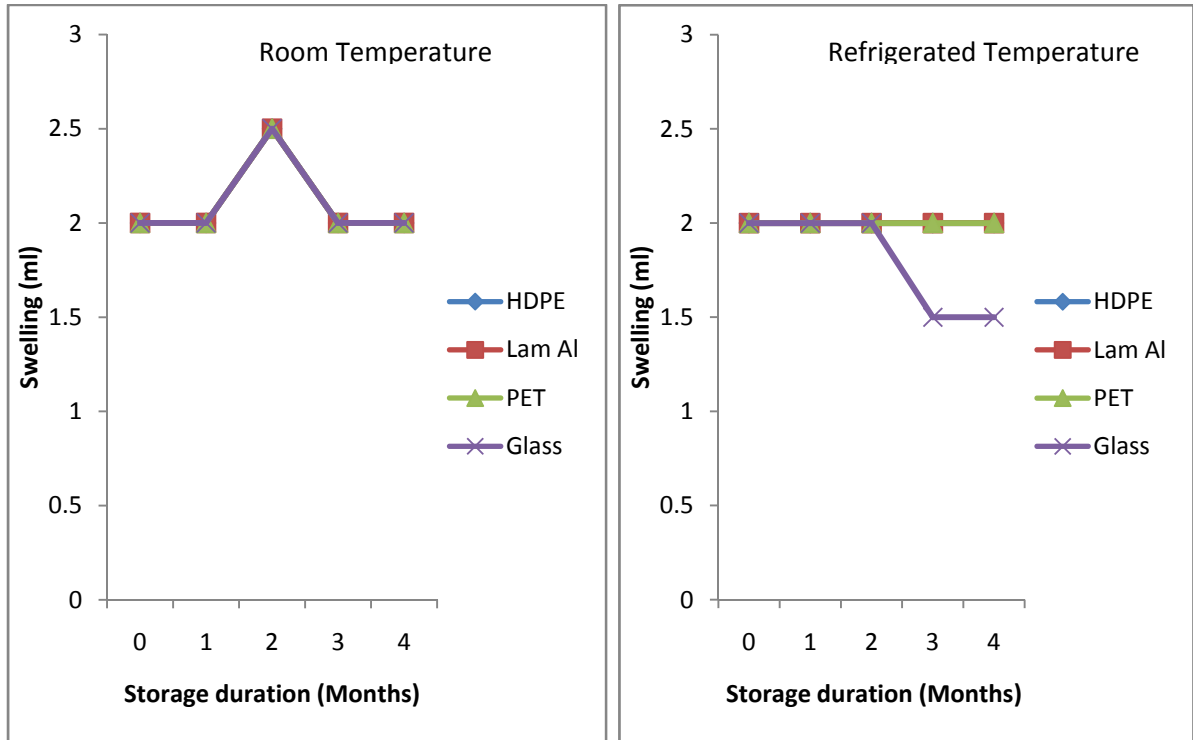


Fig. 4.2.4.3 Effect of packaging material on shrinkage/swelling of ginger powder at storage conditions

The trend of shrinkage/swelling of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.4.3. The Fig. illustrates that for HDPE films, laminated aluminium films and PET containers, the shrinkage/swelling value remains 2 during the 4 month storage. For glass containers, shrinkage/swelling value ranged from 1.5-2.

4.2.5 Effect of packaging material on weight change of dried ginger

4.2.5.1 Effect of packaging material on weight change of dried ginger flakes

The trend of weight change of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.5.1. Maximum weight change was experienced in HDPE followed by laminated aluminium films. The PET containers come third in weight change. In glass containers the weight change decreased at a steady rate. The values obtained for glass for the 4 month storage were 10, 9.99, 9.95, 9.82 and 9.79g. The minimum weight change was recorded for nitrogen flushed packed samples in laminated aluminium films. The readings recorded were 10, 9.95, 9.98, 10.11 and 10.14g.

Lowest weight change was measured in MAP samples. The lower weight losses in MAP compared with other packaging material originated from low rates of water loss in MAP due to the limitation of atmosphere by packaging with plastic package materials having different permeabilities. Similarly, Kader (1985), Anthony *et al* (1990), Agar *et al* (1994) and Kim *et al*. (1998) determined in their study on the storage of peaches and nectarines that the most important problem during storage and shelf life was weight loss.

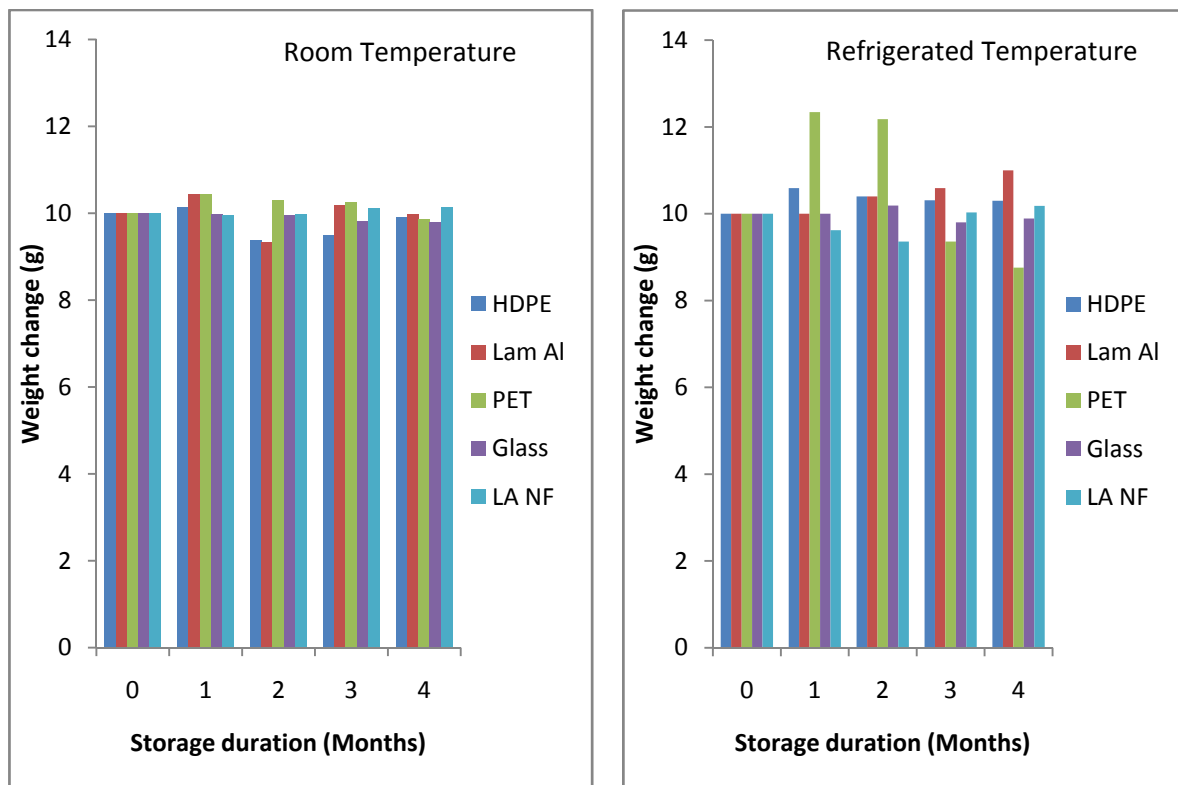


Fig. 4.2.5.1 Effect of packaging material on weight change of dried ginger flakes at storage conditions

The trend of weight change of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.5.1. The fig. shows that maximum weight change was experienced in PET containers. Laminated aluminium films showed the highest weight gain i.e. 11g starting with an initial weight of 10g. In HDPE films, the initial weight was 10g and after 4 months it comes out to be 10.3g. In nitrogen flushed samples, the readings observed were 10, 9.62, 9.36, 10.03 and 10.18g. The minimum weight change was recorded for glass containers.

4.2.5.2 Effect of packaging material on weight change of dried rhizome

The trend of weight change of dried ginger rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.5.2. The highest value of weight change was recorded in laminated aluminium films followed by PET containers. The nitrogen flushed samples stored in laminated aluminium films comes third after PET containers. The weight had shown a slight increase from its initial value. The figure signifies that the lowest weight change was experienced in HDPE and glass containers. The readings measured for glass containers were 10, 10, 10, 10.07 and 10.11g.

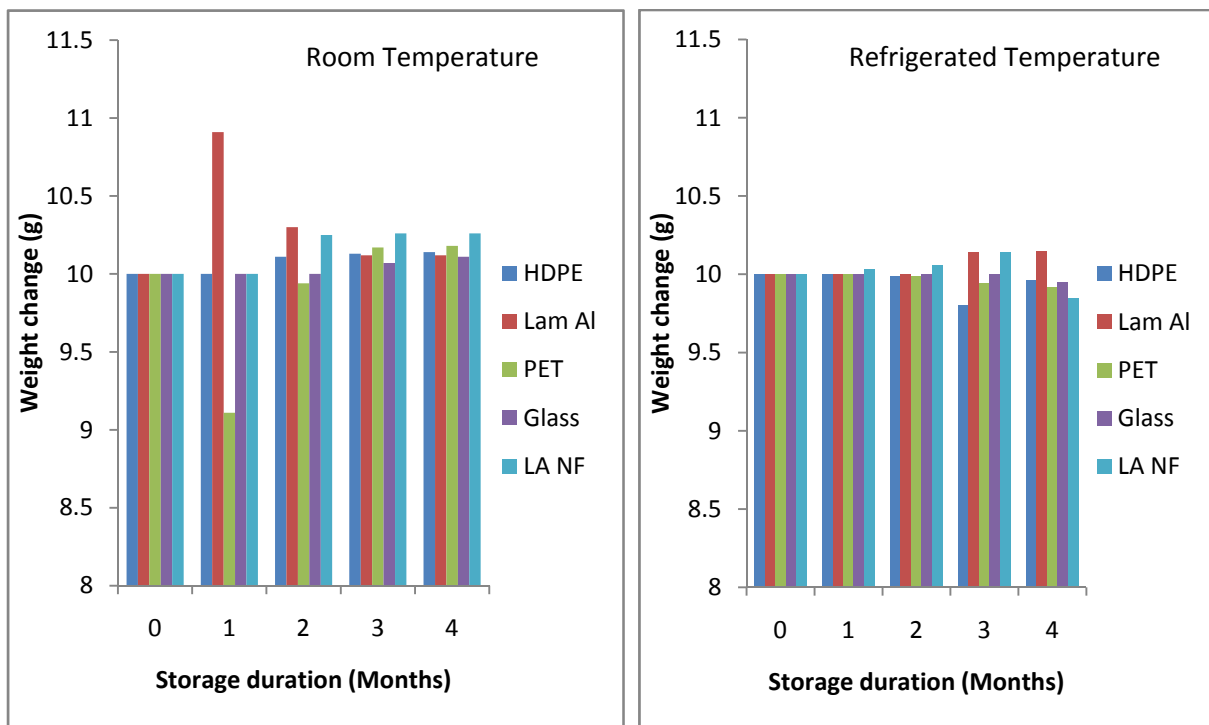


Fig. 4.2.5.2 Effect of packaging material on weight change of dried rhizome at storage conditions

The trend of weight change of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.5.2. The Fig. shows that highest variation in weight change was observed in nitrogen flushed samples followed by laminated aluminium films packaging and then PET containers. The minimum weight change was observed in HDPE and glass containers.

4.2.5.3 Effect of packaging material on weight change of ginger powder

The trend of weight change of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.5.3. The Fig. clearly shows that there was a steady increase in weight of ginger powder during storage in PET containers. The weights recorded at 0 day, 1 month, 2 month, 3 month, 4 month were 10, 10.13, 10.16, 10.23 and 10.33g respectively. The PET containers were followed by laminated aluminium films and HDPE. The packaging material that showed the minimum change in weight was glass containers. The readings recorded were 10, 10, 10, 10.03 and 10.05g during the four month storage.

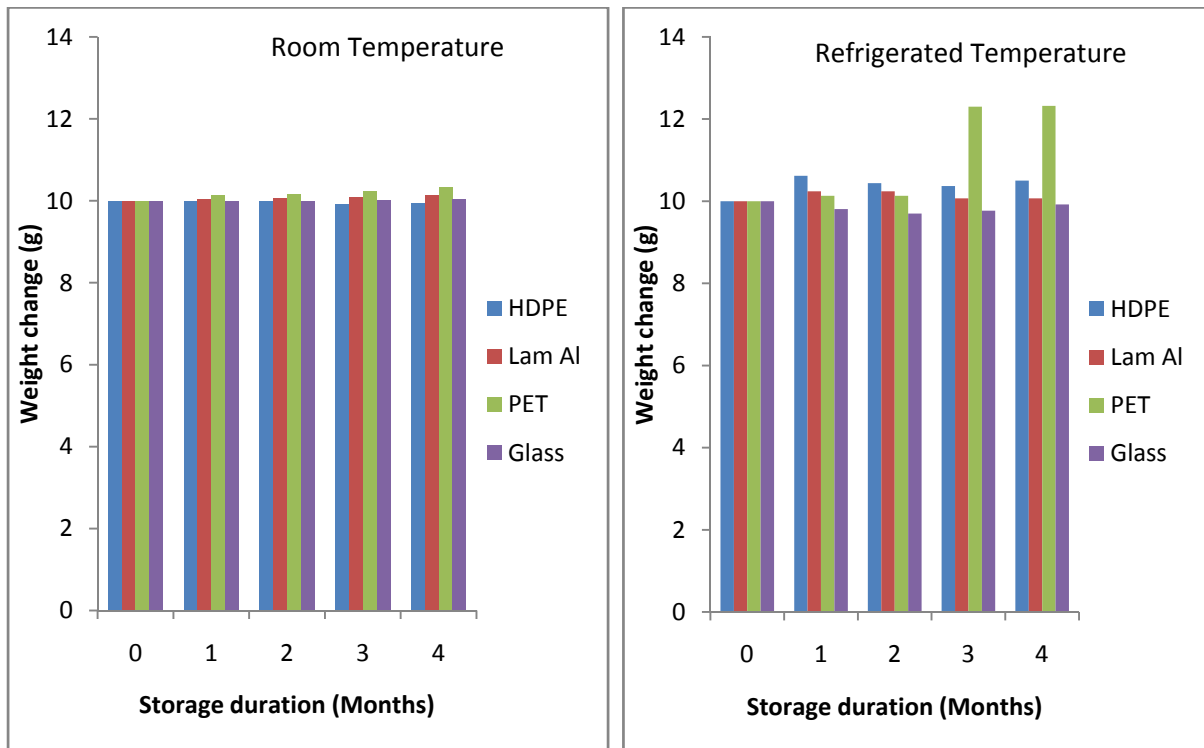


Fig. 4.2.5.3 Effect of packaging material on weight change of ginger powder at storage conditions

The trend of weight change of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.5.3. The weight increased at the highest rate in PET containers. The readings observed were 10, 10.13, 10.13, 12.3 and 12.32g. HDPE films showed quite variation in the weight of ginger powder. Weight change was most stable in laminated aluminium films. The observed readings were 10, 10.24, 10.24, 10.07 and 10.07g. In glass containers, weight observed at 0 day was 10g and during 4 month it was recorded as 9.92g.

4.2.6 Effect of packaging material on moisture content of dried ginger

4.2.6.1 Effect of packaging material on moisture content of dried ginger flakes

The trend of moisture content of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.6.1. The graph signifies that the packaging material that was most resistant to moisture was laminated aluminium films. The initial moisture content was 3.86% at 0 day and 11.26% at 4th month. Next to laminated aluminium films was PET containers and nitrogen flushed stored samples in laminated aluminium films. HDPE films came fourth with moisture content rising each month. The highest moisture was gained by glass containers and the values obtained during the four month storage were 3.86, 8.43, 10.6, 12.87 and 13.69%.

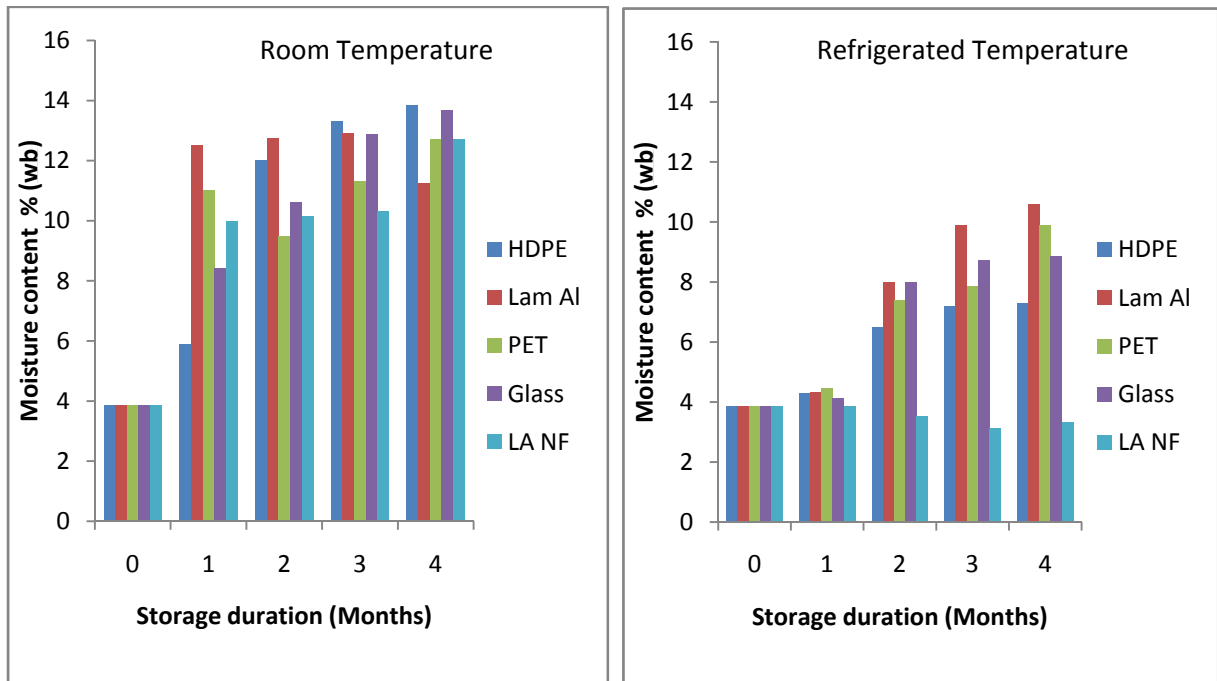


Fig. 4.2.6.1 Effect of packaging material on moisture content of dried ginger flakes at storage conditions

The trend of moisture content of dried ginger flakes stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.6.1. Fig. signifies that the highest moisture content was observed during storage in laminated aluminium films. The moisture content observed was 3.86% at 0 day and 10.58% at 4 month. Laminated aluminium films were followed by PET and glass containers. For PET containers, moisture content was 9.9% during fourth month and for glass containers, it was 8.84% for the 4 month. For HDPE films, the values obtained were 3.86, 4.28, 6.47, 7.18 and 7.28%. Nitrogen flushed samples showed the minimum increase in the moisture content during the 4 month storage. During the fourth month, moisture content was 3.33%.

4.2.6.2 Effect of packaging material on moisture content of dried rhizome

The trend of moisture content of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in fig. 4.2.6.2. The Fig. illustrates that lowest moisture content was gained by laminated aluminium films followed by nitrogen flushed samples packed in laminated aluminium films. The final moisture content recorded for laminated aluminium films was 11.8% and for nitrogen flushed samples was 12.47%. HDPE showed a constant rise in moisture content throughout the storage period. The readings obtained were 10.55, 10.89, 11.12, 11.25 and 12.5%. The packaging materials that recorded a maximum gain of moisture were PET and glass containers. The highest moisture content was obtained in glass containers storage i.e. 15.13%.

The PET containers show a marginal change in moisture content during storage. Similar results were quoted by Sulochanamma *et al* (2008) during the study of storage characteristics of large cardamom and seeds in different packages.

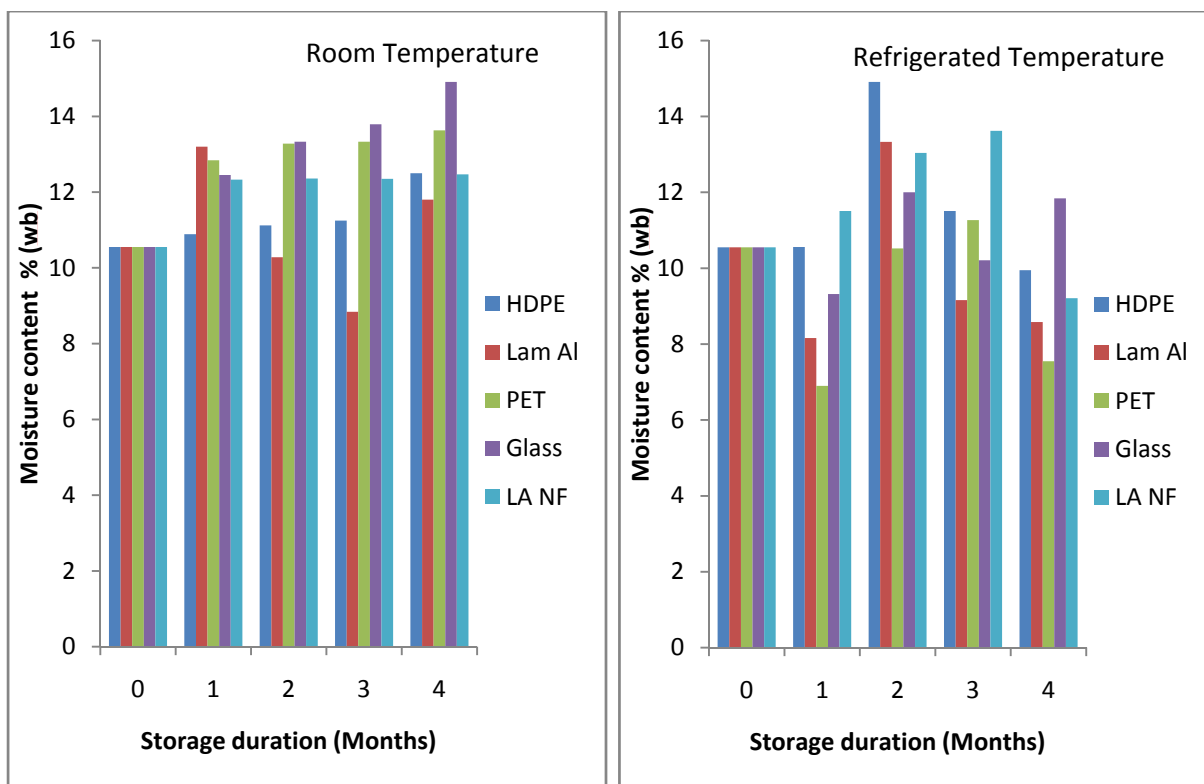


Fig. 4.2.6.2 Effect of packaging material on moisture content of dried rhizome at storage conditions

The trend of moisture content of dried rhizome stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.6.2. Fig. clears that maximum variation in moisture content was observed in HDPE films. The readings observed for 4 months were 10.55, 10.56, 15, 11.51 and 9.95%. HDPE films were followed by laminated aluminium films and nitrogen flushed samples packed in laminated aluminium films where the moisture content reaches 13%. In glass containers, the moisture content at 0 day was 10.55% and at 4th month was 11.84%. The minimum variation in moisture content was observed with PET containers where the moisture content reached a highest value of 11.27%.

4.2.6.3 Effect of packaging material on moisture content of ginger powder

The trend of moisture content of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at room temperature for a duration of 4 month is shown in Fig. 4.2.6.3. The Fig. conveys that maximum moisture was gained in HDPE films during storage. The observations recorded were 6.1, 10.9, 11.5, 12.5 and 18.35%. In laminated aluminium films and glass containers, moisture content increased from an initial value of 6.1% at 0 day

to 15.5% at 4th month. The minimum moisture content was gained by PET containers as the value of moisture content at 4th month was 11.49%.

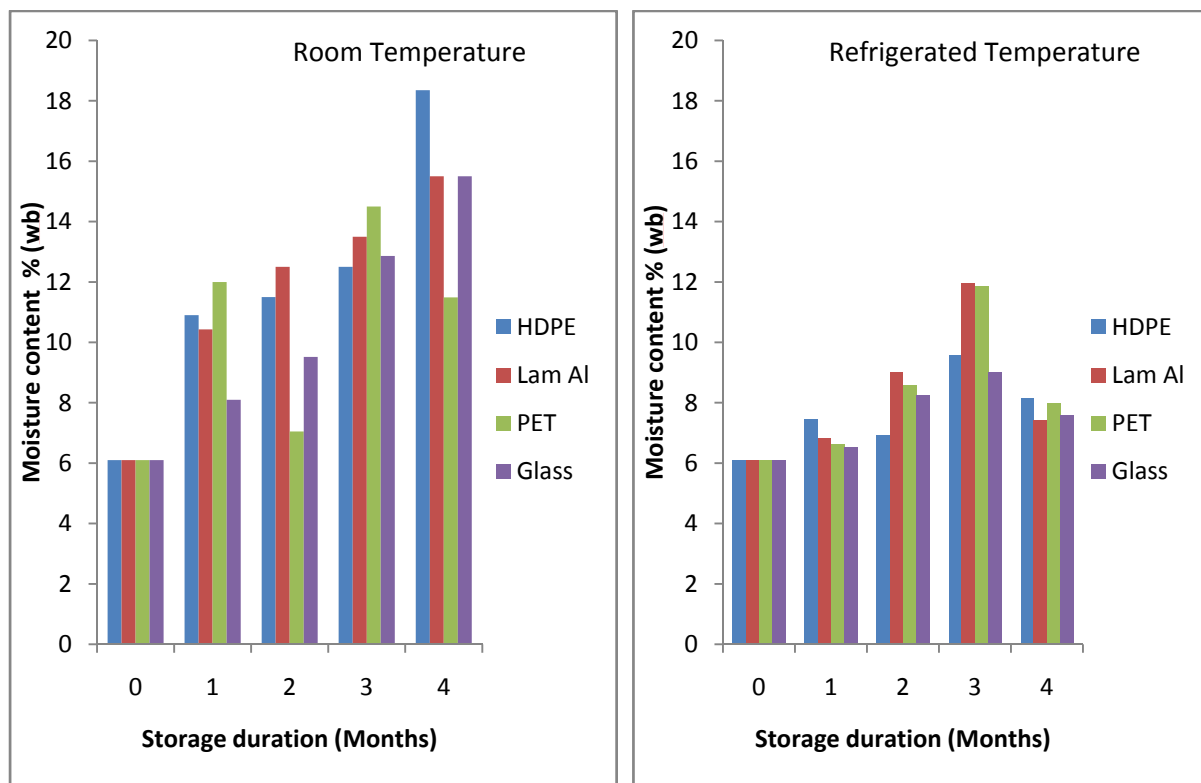


Fig. 4.2.6.3 Effect of packaging material on moisture content of ginger powder at storage conditions

The trend of moisture content of ginger powder stored in four different packaging material i.e. HDPE, laminated aluminium film, PET and glass containers at refrigerated temperature for a duration of 4 month is shown in Fig. 4.2.6.3. The fig. clears that highest values of moisture content was observed during storage in laminated aluminium films (11.95%) and PET containers (11.85%). The values recorded for HDPE films were 6.1, 7.45, 6.92, 9.58 and 8.16% during the 4 month storage. Minimum deviation was noted for glass containers where a maximum of 9% of moisture content was measured.

CHAPTER V

SUMMARY

The present study was done to study the effect of packaging material and storage conditions on shelf life and quality of dried ginger. Experiments to prepare three physical forms of dried ginger i.e. dried ginger flakes, dried rhizome and ginger powder were conducted using tray drier at the department of processing and food engineering. These three physical forms of dried ginger were then stored in four different packaging material i.e. HDPE films, laminated aluminium films, PET containers and glass containers. After packaging these samples were then stored at room temperature and refrigerated temperature for a duration of 4 months. The quality was evaluated after every month to identify the most suitable packaging film for extending the shelf-life of dried ginger. Various observations recorded were: colour, volatile oil, moisture content, weight loss, flavor and shrinkage/swelling.

The following conclusions were drawn from the study:

- Refrigerated conditions was observed as better than room conditions in almost all the quality parameters measured.
- Powder was observed as the best physical form followed by flakes and rhizome.
- The packaging material that showed the best results was glass containers and nitrogen flushed laminated aluminium films followed by laminated aluminium films, HDPE and PET containers.
- The colour was explained in terms of hue angle, chroma and lightness. The best colour of dried ginger in the form of flakes and dried rhizome during the storage period was observed in glass containers and nitrogen flushing at refrigerated conditions.
- The colour of ginger powder showed almost similar results at room and refrigerated temperature. The best packaging material observed was laminated aluminium films and glass containers.
- The volatile oil showed the best results with storage in glass containers (1.42-0.97%) or nitrogen flushing(1.34-0.98%) in flakes and rhizome at refrigerated temp. In powder form, glass containers came out as the best packaging material at refrigerated temperature.
- Nitrogen flushed samples (Flakes and Rhizome) showed the best results during the storage period and in powder form, glass containers maintained the flavour.
- For weight change, the variation was minimum observed in glass containers [Room Temperature: Powder(10-10.05g) ;Refrigerated temperature: Rhizome(10-9.95g)] during the

storage period followed by laminated aluminium films at both room and refrigerated temperature.

- Nitrogen flushed samples of flakes showed minimum variation in moisture content at both the storage conditions [Room Temperature :(3.86-12.72%), Refrigerated Temperature (3.86-3.33%)]. The moisture content of powder was most preserved in glass containers at room temperature (6.1-15.5%) and refrigerated temperature (6.1-7.58%).
- For shrinkage/swelling, almost similar reading was given at both the storage conditions and in all the packaging material by the three physical forms of ginger [Flakes(1.5-2), Rhizome(1.5-2), Powder(2-2.5)]
- In ginger powder, better results were even observed during storage at room temperature as compared to other physical forms.

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APPENDIX A

Table A1: Univariate Analysis of Variance: L value

Tests of Between-Subjects Effects

Dependent Variable: LVALUE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8703.907(a)	42	207.236	58.523	.000
Intercept	338771.333	1	338771.333	95668.671	.000
PHYFORM	5916.332	2	2958.166	835.383	.000
PACKAGE	147.248	4	36.812	10.396	.000
STORAGE	1325.461	4	331.365	93.577	.000
REPLICAT	3.925	1	3.925	1.108	.295
PHYFORM * PACKAGE	359.222	7	51.317	14.492	.000
PHYFORM * STORAGE	694.862	8	86.858	24.529	.000
PACKAGE * STORAGE	131.797	16	8.237	2.326	.006
Error	343.486	97	3.541		
Total	349775.624	140			
Corrected Total	9047.393	139			

a R Squared = .962 (Adjusted R Squared = .946)

Table A2: Univariate Analysis of Variance: Chroma value

Tests of Between-Subjects Effects

Dependent Variable: CHROMA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	757.792(a)	42	18.043	29.574	.000
Intercept	29527.691	1	29527.691	48399.082	.000
PHYFORM	433.588	2	216.794	355.349	.000
PACKAGE	3.584	4	.896	1.469	.218
STORAGE	78.067	4	19.517	31.990	.000
REPLICAT	.830	1	.830	1.361	.246
PHYFORM * PACKAGE	20.429	7	2.918	4.784	.000
PHYFORM * STORAGE	176.931	8	22.116	36.251	.000
PACKAGE * STORAGE	19.869	16	1.242	2.035	.018
Error	59.179	97	.610		
Total	30470.454	140			
Corrected Total	816.970	139			

a R Squared = .928 (Adjusted R Squared = .896)

Table A3: Univariate Analysis of Variance: Hue Angle**Tests of Between-Subjects Effects**

Dependent Variable: HUEANGLE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2652.880(a)	42	63.164	27.399	.000
Intercept	762754.463	1	762754.463	330863.167	.000
PHYFORM	831.102	2	415.551	180.255	.000
PACKAGE	18.141	4	4.535	1.967	.106
STORAGE	1196.032	4	299.008	129.702	.000
REPLICAT	14.509	1	14.509	6.294	.014
PHYFORM * PACKAGE	216.376	7	30.911	13.408	.000
PHYFORM * STORAGE	137.901	8	17.238	7.477	.000
PACKAGE * STORAGE	119.636	16	7.477	3.243	.000
Error	223.619	97	2.305		
Total	780166.310	140			
Corrected Total	2876.499	139			

a R Squared = .922 (Adjusted R Squared = .889)

Table A4: Univariate Analysis of Variance: Volatile Oil**Tests of Between-Subjects Effects**

Dependent Variable: VOLOIL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.406(a)	42	.105	53.720	.000
Intercept	157.817	1	157.817	80823.365	.000
PHYFORM	.054	2	.027	13.725	.000
PACKAGE	.034	4	.008	4.300	.003
STORAGE	3.535	4	.884	452.554	.000
REPLICAT	.405	1	.405	207.417	.000
PHYFORM * PACKAGE	.022	7	.003	1.585	.149
PHYFORM * STORAGE	.106	8	.013	6.799	.000
PACKAGE * STORAGE	.033	16	.002	1.053	.410
Error	.189	97	.002		
Total	165.545	140			
Corrected Total	4.595	139			

a R Squared = .959 (Adjusted R Squared = .941)

Table A5: Univariate Analysis of Variance: Flavour**Tests of Between-Subjects Effects**

Dependent Variable: FLAVOUR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	331.127(a)	42	7.884	20.506	.000
Intercept	6022.716	1	6022.716	15664.591	.000
PHYFORM	108.348	2	54.174	140.901	.000
PACKAGE	8.414	4	2.104	5.471	.001
STORAGE	171.957	4	42.989	111.811	.000
REPLICAT	1.207	1	1.207	3.140	.080
PHYFORM * PACKAGE	5.386	7	.769	2.001	.063
PHYFORM * STORAGE	11.098	8	1.387	3.608	.001
PACKAGE * STORAGE	10.998	16	.687	1.788	.044
Error	37.295	97	.384		
Total	6401.000	140			
Corrected Total	368.421	139			

a R Squared = .899 (Adjusted R Squared = .855)

Table A6: Univariate Analysis of Variance: Shrinkage/Swelling**Tests of Between-Subjects Effects**

Dependent Variable: SHRINKAG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.366(a)	42	.199	5.435	.000
Intercept	486.502	1	486.502	13273.794	.000
PHYFORM	4.491	2	2.246	61.267	.000
PACKAGE	.987	4	.247	6.732	.000
STORAGE	.932	4	.233	6.356	.000
REPLICAT	.029	1	.029	.780	.379
PHYFORM * PACKAGE	.288	7	.041	1.123	.355
PHYFORM * STORAGE	1.366	8	.171	4.660	.000
PACKAGE * STORAGE	.854	16	.053	1.456	.133
Error	3.555	97	.037		
Total	498.500	140			
Corrected Total	11.921	139			

a R Squared = .702 (Adjusted R Squared = .573)

Table A7: Univariate Analysis of Variance: Weight Change

Tests of Between-Subjects Effects

Dependent Variable: WEIGHT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.226(a)	42	.124	4.203	.000
Intercept	13790.013	1	13790.013	465746.056	.000
PHYFORM	.397	2	.198	6.701	.002
PACKAGE	.678	4	.170	5.727	.000
STORAGE	.200	4	.050	1.688	.159
REPLICAT	.002	1	.002	.068	.795
PHYFORM * PACKAGE	1.350	7	.193	6.513	.000
PHYFORM * STORAGE	.983	8	.123	4.150	.000
PACKAGE * STORAGE	1.711	16	.107	3.612	.000
Error	2.872	97	.030		
Total	14129.360	140			
Corrected Total	8.098	139			

a R Squared = .645 (Adjusted R Squared = .492)

Table A8: Univariate Analysis of Variance: Moisture Content

Tests of Between-Subjects Effects

Dependent Variable: MC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1195.718(a)	42	28.469	25.728	.000
Intercept	17316.322	1	17316.322	15648.893	.000
PHYFORM	95.328	2	47.664	43.074	.000
PACKAGE	2.638	4	.659	.596	.666
STORAGE	690.848	4	172.712	156.081	.000
REPLICAT	12.726	1	12.726	11.501	.001
PHYFORM * PACKAGE	59.868	7	8.553	7.729	.000
PHYFORM * STORAGE	214.934	8	26.867	24.280	.000
PACKAGE * STORAGE	92.825	16	5.802	5.243	.000
Error	107.336	97	1.107		
Total	19073.817	140			
Corrected Total	1303.054	139			

a R Squared = .918 (Adjusted R Squared = .882)

APPENDIX B

ESTIMATED MARGINAL MEANS

PACKAGES

1. UNIVARIATE ANALYSIS OF VARIANCE: L value

Multiple Comparisons

Dependent Variable: LVALUE
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.7560	.48587	.123	-.2083	1.7203
	3.00	-.4877	.48587	.318	-1.4520	.4767
	4.00	.5503	.48587	.260	-.4140	1.5147
	5.00	.7440	.54322	.174	-.3341	1.8221
2.00	1.00	-.7560	.48587	.123	-1.7203	.2083
	3.00	-1.2437(*)	.48587	.012	-2.2080	-.2793
	4.00	-.2057	.48587	.673	-1.1700	.7587
	5.00	-.0120	.54322	.982	-1.0901	1.0661
3.00	1.00	.4877	.48587	.318	-.4767	1.4520
	2.00	1.2437(*)	.48587	.012	.2793	2.2080
	4.00	1.0380(*)	.48587	.035	.0737	2.0023
	5.00	1.2317(*)	.54322	.026	.1535	2.3098
4.00	1.00	-.5503	.48587	.260	-1.5147	.4140
	2.00	.2057	.48587	.673	-.7587	1.1700
	3.00	-1.0380(*)	.48587	.035	-2.0023	-.0737
	5.00	.1937	.54322	.722	-.8845	1.2718
5.00	1.00	-.7440	.54322	.174	-1.8221	.3341
	2.00	.0120	.54322	.982	-1.0661	1.0901
	3.00	-1.2317(*)	.54322	.026	-2.3098	-.1535
	4.00	-.1937	.54322	.722	-1.2718	.8845

Based on observed means.

* The mean difference is significant at the .05 level.

2. UNIVARIATE ANALYSIS OF VARIANCE: Chroma

Multiple Comparisons

Dependent Variable: CHROMA
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.4110(*)	.20167	.044	-.8113	-.0107
	3.00	.0190	.20167	.925	-.3813	.4193
	4.00	-.1733	.20167	.392	-.5736	.2269
	5.00	1.2093(*)	.22548	.000	.7618	1.6568
2.00	1.00	.4110(*)	.20167	.044	.0107	.8113
	3.00	.4300(*)	.20167	.036	.0297	.8303
	4.00	.2377	.20167	.241	-.1626	.6379
	5.00	1.6203(*)	.22548	.000	1.1728	2.0678
3.00	1.00	-.0190	.20167	.925	-.4193	.3813
	2.00	-.4300(*)	.20167	.036	-.8303	-.0297
	4.00	-.1923	.20167	.343	-.5926	.2079
	5.00	1.1903(*)	.22548	.000	.7428	1.6378
4.00	1.00	.1733	.20167	.392	-.2269	.5736
	2.00	-.2377	.20167	.241	-.6379	.1626
	3.00	.1923	.20167	.343	-.2079	.5926
	5.00	1.3827(*)	.22548	.000	.9352	1.8302
5.00	1.00	-1.2093(*)	.22548	.000	-1.6568	-.7618
	2.00	-1.6203(*)	.22548	.000	-2.0678	-1.1728
	3.00	-1.1903(*)	.22548	.000	-1.6378	-.7428
	4.00	-1.3827(*)	.22548	.000	-1.8302	-.9352

Based on observed means.

* The mean difference is significant at the .05 level.

3. UNIVARIATE ANALYSIS OF VARIANCE: Hue Angle
Multiple Comparisons

Dependent Variable: HUEANGLE
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.7523	.39203	.058	-1.5304	.0257
	3.00	-.5853	.39203	.139	-1.3634	.1927
	4.00	-.7503	.39203	.059	-1.5284	.0277
	5.00	.5452	.43831	.217	-.3247	1.4151
2.00	1.00	.7523	.39203	.058	-.0257	1.5304
	3.00	.1670	.39203	.671	-.6111	.9451
	4.00	.0020	.39203	.996	-.7761	.7801
	5.00	1.2975(*)	.43831	.004	.4276	2.1674
3.00	1.00	.5853	.39203	.139	-.1927	1.3634
	2.00	-.1670	.39203	.671	-.9451	.6111
	4.00	-.1650	.39203	.675	-.9431	.6131
	5.00	1.1305(*)	.43831	.011	.2606	2.0004
4.00	1.00	.7503	.39203	.059	-.0277	1.5284
	2.00	-.0020	.39203	.996	-.7801	.7761
	3.00	.1650	.39203	.675	-.6131	.9431
	5.00	1.2955(*)	.43831	.004	.4256	2.1654
5.00	1.00	-.5452	.43831	.217	-1.4151	.3247
	2.00	-1.2975(*)	.43831	.004	-2.1674	-.4276
	3.00	-1.1305(*)	.43831	.011	-2.0004	-.2606
	4.00	-1.2955(*)	.43831	.004	-2.1654	-.4256

Based on observed means.

* The mean difference is significant at the .05 level.

4. UNIVARIATE ANALYSIS OF VARIANCE: Volatile oil

Multiple Comparisons

Dependent Variable: VOLOIL
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0217	.01141	.061	-.0443	.0010
	3.00	-.0227(*)	.01141	.050	-.0453	.0000
	4.00	-.0357(*)	.01141	.002	-.0583	-.0130
	5.00	-.0355(*)	.01276	.006	-.0608	-.0102
2.00	1.00	.0217	.01141	.061	-.0010	.0443
	3.00	-.0010	.01141	.930	-.0236	.0216
	4.00	-.0140	.01141	.223	-.0366	.0086
	5.00	-.0138	.01276	.281	-.0392	.0115
3.00	1.00	.0227(*)	.01141	.050	.0000	.0453
	2.00	.0010	.01141	.930	-.0216	.0236
	4.00	-.0130	.01141	.257	-.0356	.0096
	5.00	-.0128	.01276	.317	-.0382	.0125
4.00	1.00	.0357(*)	.01141	.002	.0130	.0583
	2.00	.0140	.01141	.223	-.0086	.0366
	3.00	.0130	.01141	.257	-.0096	.0356
	5.00	.0002	.01276	.990	-.0252	.0255
5.00	1.00	.0355(*)	.01276	.006	.0102	.0608
	2.00	.0138	.01276	.281	-.0115	.0392
	3.00	.0128	.01276	.317	-.0125	.0382
	4.00	-.0002	.01276	.990	-.0255	.0252

Based on observed means.

* The mean difference is significant at the .05 level.

5. UNIVARIATE ANALYSIS OF VARIANCE: Flavour

Multiple Comparisons

Dependent Variable: FLAVOUR
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.0333	.16010	.836	-.2844	.3511
	3.00	-.1000	.16010	.534	-.4178	.2178
	4.00	-.0333	.16010	.836	-.3511	.2844
	5.00	-.3000	.17900	.097	-.6553	.0553
2.00	1.00	-.0333	.16010	.836	-.3511	.2844
	3.00	-.1333	.16010	.407	-.4511	.1844
	4.00	-.0667	.16010	.678	-.3844	.2511
	5.00	-.3333	.17900	.066	-.6886	.0219
3.00	1.00	.1000	.16010	.534	-.2178	.4178
	2.00	.1333	.16010	.407	-.1844	.4511
	4.00	.0667	.16010	.678	-.2511	.3844
	5.00	-.2000	.17900	.267	-.5553	.1553
4.00	1.00	.0333	.16010	.836	-.2844	.3511
	2.00	.0667	.16010	.678	-.2511	.3844
	3.00	-.0667	.16010	.678	-.3844	.2511
	5.00	-.2667	.17900	.140	-.6219	.0886
5.00	1.00	.3000	.17900	.097	-.0553	.6553
	2.00	.3333	.17900	.066	-.0219	.6886
	3.00	.2000	.17900	.267	-.1553	.5553
	4.00	.2667	.17900	.140	-.0886	.6219

Based on observed means.

6. UNIVARIATE ANALYSIS OF VARIANCE: Shrinkage/Swelling

Multiple Comparisons

Dependent Variable: SHRINKAG
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.1000(*)	.04943	.046	-.1981	-.0019
	3.00	-.1333(*)	.04943	.008	-.2314	-.0352
	4.00	-.0500	.04943	.314	-.1481	.0481
	5.00	-.1417(*)	.05527	.012	-.2514	-.0320
2.00	1.00	.1000(*)	.04943	.046	.0019	.1981
	3.00	-.0333	.04943	.502	-.1314	.0648
	4.00	.0500	.04943	.314	-.0481	.1481
	5.00	-.0417	.05527	.453	-.1514	.0680
3.00	1.00	.1333(*)	.04943	.008	.0352	.2314
	2.00	.0333	.04943	.502	-.0648	.1314
	4.00	.0833	.04943	.095	-.0148	.1814
	5.00	-.0083	.05527	.880	-.1180	.1014
4.00	1.00	.0500	.04943	.314	-.0481	.1481
	2.00	-.0500	.04943	.314	-.1481	.0481
	3.00	-.0833	.04943	.095	-.1814	.0148
	5.00	-.0917	.05527	.100	-.2014	.0180
5.00	1.00	.1417(*)	.05527	.012	.0320	.2514
	2.00	.0417	.05527	.453	-.0680	.1514
	3.00	.0083	.05527	.880	-.1014	.1180
	4.00	.0917	.05527	.100	-.0180	.2014

Based on observed means.

* The mean difference is significant at the .05 level.

7. UNIVARIATE ANALYSIS OF VARIANCE: Weight change

Multiple Comparisons

Dependent Variable: WEIGHT
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.1660(*)	.04443	.000	-.2542	-.0778
	3.00	-.1373(*)	.04443	.003	-.2255	-.0492
	4.00	-.0327	.04443	.464	-.1208	.0555
	5.00	-.1485(*)	.04967	.004	-.2471	-.0499
2.00	1.00	.1660(*)	.04443	.000	.0778	.2542
	3.00	.0287	.04443	.520	-.0595	.1168
	4.00	.1333(*)	.04443	.003	.0452	.2215
	5.00	.0175	.04967	.725	-.0811	.1161
3.00	1.00	.1373(*)	.04443	.003	.0492	.2255
	2.00	-.0287	.04443	.520	-.1168	.0595
	4.00	.1047(*)	.04443	.020	.0165	.1928
	5.00	-.0112	.04967	.823	-.1098	.0874
4.00	1.00	.0327	.04443	.464	-.0555	.1208
	2.00	-.1333(*)	.04443	.003	-.2215	-.0452
	3.00	-.1047(*)	.04443	.020	-.1928	-.0165
	5.00	-.1158(*)	.04967	.022	-.2144	-.0172
5.00	1.00	.1485(*)	.04967	.004	.0499	.2471
	2.00	-.0175	.04967	.725	-.1161	.0811
	3.00	.0112	.04967	.823	-.0874	.1098
	4.00	.1158(*)	.04967	.022	.0172	.2144

Based on observed means.

* The mean difference is significant at the .05 level.

8. UNIVARIATE ANALYSIS OF VARIANCE: Moisture content

Multiple Comparisons

Dependent Variable: MC
LSD

(I) PACKAGE	(J) PACKAGE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.1657	.27161	.543	-.7047	.3734
	3.00	.0540	.27161	.843	-.4851	.5931
	4.00	-.2360	.27161	.387	-.7751	.3031
	5.00	.1797	.30367	.555	-.4230	.7824
2.00	1.00	.1657	.27161	.543	-.3734	.7047
	3.00	.2197	.27161	.421	-.3194	.7587
	4.00	-.0703	.27161	.796	-.6094	.4687
	5.00	.3453	.30367	.258	-.2574	.9480
3.00	1.00	-.0540	.27161	.843	-.5931	.4851
	2.00	-.2197	.27161	.421	-.7587	.3194
	4.00	-.2900	.27161	.288	-.8291	.2491
	5.00	.1257	.30367	.680	-.4770	.7284
4.00	1.00	.2360	.27161	.387	-.3031	.7751
	2.00	.0703	.27161	.796	-.4687	.6094
	3.00	.2900	.27161	.288	-.2491	.8291
	5.00	.4157	.30367	.174	-.1870	1.0184
5.00	1.00	-.1797	.30367	.555	-.7824	.4230
	2.00	-.3453	.30367	.258	-.9480	.2574
	3.00	-.1257	.30367	.680	-.7284	.4770
	4.00	-.4157	.30367	.174	-1.0184	.1870

Based on observed means.

B) Parameters of dried ginger measured at refrigerated temperature

Physical Form	Packaging material	Weight Change (g)					Moisture Content (%wb)					Volatile Oil (%)				
		Fresh	1 Month	2 Month	3 Month	4 Month	Fresh	1 Month	2 Month	3 Month	4 Month	Fresh	1 Month	2 Month	3 Month	4 Month
Flakes	HDPE	10	10.59	10.4	10.31	10.3	3.86	4.28	6.47	7.18	7.28	1.34	1.25	1.12	1.06	0.94
	Lam Al	10	10	10.4	10.59	11	3.86	4.32	8	9.88	10.58	1.34	1.29	1.13	1.06	0.96
	PET	10	12.34	12.18	9.36	8.76	3.86	4.47	7.4	7.85	9.9	1.34	1.26	1.15	1.07	0.96
	Glass	10	10	10.19	9.8	9.89	3.86	4.12	8	8.72	8.84	1.34	1.28	1.15	1.09	0.98
	LA NF	10	9.62	9.36	10.03	10.18	3.86	3.84	3.51	3.125	3.33	1.34	1.28	1.17	1.09	0.98
Rhizome	HDPE	10	10	9.99	9.8	9.96	10.55	10.56	15	11.51	9.95	1.37	1.21	1.08	0.97	0.81
	Lam Al	10	10	10	10.14	10.15	10.55	8.16	13.33	9.16	8.58	1.37	1.22	1.1	0.97	0.83
	PET	10	10	9.99	9.94	9.92	10.55	6.9	10.52	11.27	7.55	1.37	1.24	1.11	0.98	0.83
	Glass	10	10	10	10	9.95	10.55	9.32	12	10.21	11.84	1.37	1.25	1.13	0.99	0.85
	LA NF	10	10.03	10.06	10.14	9.85	10.55	11.51	13.04	13.62	9.21	1.37	1.27	1.15	0.99	0.91
Powder	HDPE	10	10.62	10.44	10.37	10.5	6.1	7.45	6.92	9.58	8.16	1.42	1.21	1.19	1.08	1.02
	Lam Al	10	10.24	10.24	10.07	10.07	6.1	6.83	9	11.95	7.41	1.42	1.22	1.2	1.08	1.05
	PET	10	10.13	10.13	12.3	12.32	6.1	6.63	8.57	11.85	7.98	1.42	1.25	1.25	1.1	1.05
	Glass	10	9.81	9.7	9.77	9.92	6.1	6.52	8.24	9	7.58	1.42	1.26	1.25	1.11	1.07

APPENDIX C
A) Parameters of dried ginger measured at room temperature

Physical Form	Packaging material	Weight Change (g)					Moisture Content (%wb)					Volatile Oil (%)				
		Fresh	1 Month	2 Month	3 Month	4 Month	Fresh	1 Month	2 Month	3 Month	4 Month	Fresh	1 Month	2 Month	3 Month	4 Month
Flakes	HDPE	10	10.13	9.37	9.5	9.91	3.86	5.88	12	13.3	13.85	1.34	1.19	1.09	1.02	0.92
	Lam Al	10	10.44	9.33	10.18	9.98	3.86	12.5	12.75	12.9	11.26	1.34	1.21	1.08	1.06	0.89
	PET	10	10.44	10.31	10.25	9.86	3.86	11	9.48	11.32	12.7	1.34	1.23	1.09	1.07	0.94
	Glass	10	9.99	9.95	9.82	9.79	3.86	8.43	10.6	12.87	13.69	1.34	1.25	1.12	1.07	0.96
	LA NF	10	9.95	9.98	10.11	10.14	3.86	10	10.16	10.32	12.72	1.34	1.27	1.14	1.08	0.94
Rhizome	HDPE	10	10	10.11	10.13	10.14	10.55	10.89	11.12	11.25	12.5	1.37	1.2	1.11	0.91	0.83
	Lam Al	10	10.91	10.3	10.12	10.12	10.55	13.2	10.28	8.84	11.8	1.37	1.2	1.13	0.94	0.83
	PET	10	9.11	9.94	10.17	10.18	10.55	12.84	13.28	13.33	13.63	1.37	1.21	1.13	0.94	0.84
	Glass	10	10	10	10.07	10.11	10.55	12.45	13.33	13.79	15.13	1.37	1.23	1.17	0.98	0.86
	LA NF	10	10	10.25	10.26	10.26	10.55	12.33	12.36	12.35	12.47	1.37	1.23	1.18	0.98	0.92
Powder	HDPE	10	10	10	9.93	9.94	6.1	10.9	11.5	12.5	18.35	1.42	1.2	1.06	1.04	0.92
	Lam Al	10	10.04	10.07	10.09	10.15	6.1	10.43	12.5	13.5	15.5	1.42	1.21	1.07	1.04	0.95
	PET	10	10.13	10.16	10.23	10.33	6.1	12	7.05	14.5	11.49	1.42	1.21	1.09	1.05	0.95
	Glass	10	10	10	10.03	10.05	6.1	8.1	9.52	12.86	15.5	1.42	1.24	1.13	1.05	0.97

VITA

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