QUALITY PARAMETERS OF GINGER PASTE DURING STORAGE AND ITS RHEOLOGICAL BEHAVIOUR

By

THINGUJAM BIDYALAKSHMI DEVI

DEPARTMENT OF AGRICULTURAL PROCESSING AND FOOD ENGINEERING
COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
ORISSA UNIVERSITYOF AGRICULTURE AND TECHNOLOGY
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Department of Agricultural Processing and Food Engineering
College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology
Bhubaneswar - 751 003, Odisha.

Dr. Sanjaya Kumar Dash
Professor & Head

CERTIFICATE-I

This is to certify that the thesis entitled **"Quality parameters of ginger paste during storage and its rheological behaviour"** submitted in partial fulfillment of degree of **Master of Technology (Agricultural Engineering)** in **Processing and Food Engineering** of Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fid*e research work carried out by **Thingujam Bidyalakshmi Devi** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information availed during the investigation have been duly acknowledged by her.

Bhubaneswar
Date: 5th June, 2013

(Dr. Sanjaya Kumar Dash)
Professor & Head

CERTIFICATE-II

This is to certify that the thesis entitled **"Quality parameters of ginger paste during storage and its rheological behaviour"** submitted in partial fulfillment of degree of **Master of Technology (Agricultural Engineering)** in **Processing and Food Engineering** of Orissa University of Agriculture and Technology, Bhubaneswar by **Thingujam Bidyalakshmi Devi** has been approved by the student's advisory committee after an oral examination on the same in collaboration with the external examiner.

Approved by Advisory Committee

Chairman: **(Dr. Sanjaya K Dash)**

Members: **(Dr. Kalpana Rayaguru)**

(Dr. M. K. Panda)

(Dr. A. K. Parida)

External Examiner

Dedicated to,

My beloved parents

Mr. Thingujam Gokulchand Singh

and

Mrs. Thingujam Memcha Devi

and

My Family…

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Place : Bhubaneswar

Date : (Thingujam Bidyalakshmi Devi)

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Chapter 1

INTRODUCTION

Ginger *(Zingiber officinale)* is one of the earliest known oriental spices and is being cultivated in India for use both as fresh vegetable and as a dried spice, since time immemorial. It is one of more than 1,400 species belonging to the *Zingiberaceae* family; turmeric and cardamom are the two other important members of the same family. The crop occupies fourth position among spices produced in India. With regard to export, ginger occupies fifth position in terms of quantity and sixth position in export earning among spices. The spice is extensively grown in the tropics, with the main exporting countries being India, Nigeria, Australia, China and Jamaica. The estimated production of ginger in India is 2,81,160 MT from an area of 83,220 ha, with a productivity of 3,379 kg/ha (2003-04).

Importance of ginger is well known and its medicinal, nutritional and commercial values have been reported by many researchers. One hundred grams of edible ginger contain approximately 9 g protein, 6 g fiber, 116 g calcium, 71 g carbohydrate, and 147 IU of Vitamin A (Farrell, 1999). Ginger is known to contain many powerful antioxidants. It is good for the gastric system and increases digestive enzyme activity; it is known to cure motion sickness, upset stomachs, headaches, congestion, and lowering fevers when added to the bath water. Other benefits include cleansing of the colon, reducing spasm and cramps, stimulating circulation, and aiding the metabolism, stress relief, and the increased circulatory response, which raises oxygen levels. It also helps in minimizing joint pain from arthritis and other inflammatory disorders.

Fresh spices are perishable in nature and the major causes of spoilage are improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes, chemical reactions and structural changes during storage. The postharvest losses of ginger are high but could be considerably reduced if it is properly stored and processed immediately after the harvest. Ginger can be used to produce processed and semi-processed products such as powder, flakes, candy, ready to serve beverages, paste, etc. Drying of ginger has the limitation in that the volatile oils and chemical compounds responsible for pungent flavours, especially gingerols and pigments, are highly heat sensitive (Baranowski, 1985; Pezzutti & Crapiste, 1997). The loss of volatile oils from dehydrated ginger can be substantial and it has been reported that ground ginger can lose up to 50% of its volatile oils during 6 months storage, depending upon the packaging material used (Govindarajan, 1982). Therefore, there is an urgent need to explore alternate processes for the preservation of ginger and to develop products based on these. Ginger paste is one such alternate product and can be stored for long periods without much alteration of the freshness of the material and can also be considered as a minimally processed food (Baranowski, 1985; Ahmed & Shivhare, 2001; Ahmed et al., 2002).

Recently the market for spice pastes has increased significantly mainly because of the success of fast food industries. However, the technology of proper storage and preservation of ginger paste is often not available to the small scale processors, for which the ginger produced in the small scale industries often cannot compete with the major brands available in the market. Further, the type of packaging and storage conditions often do not match the requirements of the paste, and hence, the quality of the paste deteriorates during storage. There are also degradation of colour, flavor and other parameters limiting the shelf life and use. Therefore, study of changes in physico-chemical properties such as pH, total soluble solid (TSS), total solid (TS), acidity, water activity, etc. as affected by the different storage conditions are important for deciding the effective shelf life of the paste and thus recommending a suitable packaging method to the entrepreneurs.

Colour is an important sensory attribute because it is usually the first property the consumer observes and minimizing the colour/ pigment losses during processing and storage is of primary concern to the processor. Loss of colour and increased browning during processing and storage of processed foods are influenced by many factors like pH, acidity, storage temperature and duration etc. (Garcia et al., 1999). The pH of the processed product influences the length of storage time of these products. It has also been established that an acidified food (pH < 4.6) requires only pasteurization (Garcia et al., 1999) to retain its fresh spice odour (Baranowski, 1985). pH measurement is important as changes in pH have so many effects on the rate of chemical reactions, enzyme activity as well as microbial load. It is also a factor of inhibiting the microorganism growth. Water activity is the amount of water in a food that is available for use by microorganisms. While temperature, pH and several other factors influence whether an organism will grow in a product and the rate at which it grows, water activity is often the most important factor. The lowest water activity at which the vast majority of spoilage bacteria will grow is about 0.90. The water activity for mould and yeast growth is about 0.61 with the lower limit for growth of mycotoxigenic moulds at 0.78 (www.aqualab.com). It not only influences microbial spoilage but also chemical and enzymatic reactivity. Therefore, samples should be tested for the important factors that indicate and/or influence the shelf life.

In addition, the knowledge of the rheological characteristics and viscosity of fluids is also important in the design of flow processes, in quality control, in storage and processing stability. Furthermore, viscoelastic behaviour of materials are also dependent on time as well as temperature and moisture content (Rao and Steffe, 1992). Thus, it is important to have a good understanding of the flow behaviour characteristics to improve the processing performance of food emulsions. The rheological properties particularly the viscosity of food products are strongly influenced by temperature, concentration and physical state of dispersion. The preparation method of ginger paste involves unit operations such as mixing, pasteurization etc. for which different type of equipment may be used and the power required by such equipment is dependent on the food texture and rheological properties. Therefore, it is considered important to study the rheological properties of ginger paste as function of temperature.

Keeping above facts in view, the project was undertaken to study the change in physiochemical characteristics of ginger paste during storage and to estimate the shelf life in different environment and packaging conditions. In addition, the rheological properties of the ginger paste were studied as a function of temperature.

Objectives of the study

1. To study the change in quality parameters of ginger paste during storage.
2. To study the rheological behavior of ginger paste and its temperature dependence.

Chapter 2

REVIEW OF LITERATURE

This chapter deals with the previously published work on ginger paste and related studies. Besides, available information related to the determination of quality parameters of ginger paste during storage and rheological behavior as evidenced from published literature is also included.

2.1 Ginger and its importance

India is rightly called as “spice bowl of the world” for its production of variety and superior quality of spices. Ginger was given its official botanical name *Zingiber Officinale*, by the famous eighteenth-century Swedish botanist, Linnaeus. Linnaeus derived the genus title *Zingiber* from its Indian Sanskrit name *singabera* which means shaped like a horn. Originating in southern China, cultivation of ginger has spread to India, Southeast Asia, West Africa, and the Caribbean. Ginger is one of more than 1,400 species belonging to the *Zingiberaceae* family; the other members of the *Zingiberaceae* family are turmeric (a principal component of curry) and cardamom. **(**Anast, http://nogreaterjoy.org)

Ginger occupies fourth position among spices produced in India. With regard to export, ginger occupies fifth position in terms of quality and sixth position in export earning among spices. The production of ginger in India during 2010-11 was 702.0 thousand MT from an area of 149.1 thousand ha with a productivity of 4.7 MT/ha (nhb.gov.in). Though ginger is an annual crop, its production depends on weather parameters. Area, production and productivity have consistently shown an increasing trend during the last three decades. Owing to versatility in adoption for climate and soil, ginger is grown in almost all the states in India. However, Kerala, Meghalaya, Arunachal Pradesh and Odisha together contribute over 60% of the total production. Kerala has highest area of 14,570 ha with production of 49,950 tonnes. It accounts for about 19% both in area and production followed by Meghalaya (18.60%) and Arunachal Pradesh (11.80%). Odisha ranks fourth with a share of 10.20% in production. India has an excellent research and developmental support in spices production. The Indian council of Agricultural Research with All India Co-ordinated Research Project on spices, has the responsibility of providing research support. Besides research on post-harvest management and value addition is also have been done in the laboratories of CSIR (Thanuja, 2006*)*.

2.1.1 Health benefits of ginger

Importance of ginger is well known and is also reported by many researchers in medicinal values, nutritional values as well as in commercial values. Ginger is known to help motion sickness (some even say it rivals the drug Dramamine), upset stomachs, headaches, congestion, and lowering fevers when added to the bath water. Other benefits include cleansing of the colon, reducing spasm and cramps, stimulating circulation, and aiding the metabolism. Ginger is also used by many as a mood enhancer, or aphrodesiac, possibly because of the cineole content, which contributes to stress relief, and the increased circulatory response, which raises oxygen levels. Ginger is known to contain many powerful antioxidants (Valenzuela, www.agroforestry.net).

It is good for the gastric system because it increases the pH of stomach acid, reducing its acidity, which in turn lowers the rate of gastric secretions, and increases digestive enzyme activity. Although very effective against all forms of nausea, PDR health officials do not recommend taking ginger root for morning sickness associated with pregnancy, although millions of Chinese women traditionally eat ginger root during pregnancy to combat morning sickness. Ginger can also be used to prevent scurvy. Ginger helps to regulate the natural inflammatory response of the body. There are several studies that demonstrate very positive results on minimizing joint pain from arthritis and other inflammatory disorders (Valenzuela, www.agroforestry.net).

Ginger is used throughout the world as a spice or fresh herb in cooking and a variety of other value-added products including flavoring in candies, beverages, liqueurs, ice cream, baked goods, curry powder blends, sauces, and various condiments. Ginger is also used in traditional medicine to treat several ailments including nausea, motion sickness, migraine, dyspepsia, and to reduce flatulence and colic. Young rhizomes that are harvested early are also used in pickles and confectionery. One hundred grams of edible ginger contain approximately 9 g protein, 6 g fibre, 116 g calcium, 71 g carbohydrate, and 147 IU of Vitamin A (Farrell, 1999).

Table No. 2.1 Nutritional Facts of ginger

Component	per 100 g of product	Component	per 100 g of product
Crude Fibre (g)	2.86	Carbohydrates (g)	40.52
Protein (g)	2.75	Fat (g)	3.94
Calcium (mg)	23.99	Phosphorus (mg)	71.85
Energy (kCal)	80.26	Iron (mg)	4.22
Minerals (mg)	1.43		

(www.farmerbrands.in)

2.1.2 Variety, maturity level and storage condition

There are so many varieties of ginger, an estimated 50 in India alone. Each variety has its own unique taste and aroma, depending upon its soil and how it is grown. Pungent varieties are often found in Africa, and milder varieties grown in China (Conley, http://accessnewage.com).

The early harvest, from 5 to 6 months after planting, yields tender rhizomes with less fibre for use as candies. The second harvest about 2 months later when plants are about 85% of their maximum size, yields rhizomes with the highest content of essential oils and oleoresins, used for the preparation of dehydrated products. The fully mature rhizomes obtained at the last harvest are used for drying and for grinding to produce powdered ginger (Valenzuela, www.agroforestry.net).

Production for syrup and for the confectionery market requires early harvested ginger with lower fibre content. Ginger that is not processed immediately is often preserved in brine. After it is drained from brine, the ginger may be cut, graded by hand, peeled, boiled, and impregnated with sugar syrups to produce ginger syrup. Ginger that is harvested fully mature may also be peeled and dehydrated for further processing into ground ginger, or sold as sliced or whole dried ginger.

Recommended storage conditions of ginger include temperatures of 12–13°C and relative humidity (RH) of 85–90%. Storage at 65% RH leads to dehydration and wilting. Storage temperatures below 12°C will cause chilling injury resulting in tissue softening and breakdown, decay, and skin discoloration (Valenzuela, www.agroforestry.net).

The time of harvest after planting depends on the end-use. For fresh products and preserves, one should harvest rhizomes while they are still tender, low in pungency and fibre content, therefore before they are fully mature. Harvest for dried spices and oil is best at full maturity, when the leaves turn yellow; leaving the rhizomes in the ground past that stage may reduce pungency and oil content, and increase the fibre content (Plotto, 2002).

2.1.3 Preparation of paste

Topno *et al.* (2011) conducted a study on ginger-garlic paste in which ginger paste was made after breaking the rhizomes into pieces to expose the crevices and then washed in running water to remove the adhering mud. Again the cleaned rhizomes were scraped with a knife to remove dirt as well as spoiled portion. Ginger rhizomes were soaked in potassium metabisulphite solution (1 g/L) for 12 h and washed thoroughly; rhizomes were peeled using a vegetable peeler. The peeled rhizomes were passed through a hammer mill fitted with 30 mesh (500 mm) to get a fine paste.

Ahmed (2004) prepared ginger paste by adding common salt at 8% (w/w) to ginger puree to increase its total soluble solids (TSS). Fresh ginger puree had a pH of 6.38 and was adjusted to 4.05 by adding 30% citric acid solution (w/v). It has been established that an acidified food ($pH < 4.6$) requires only pasteurization (Garcia *et al.*, 1999) to retain its fresh spice odour (Baranowski, 1985). The paste was therefore, thermally processed at 80^0C for 15 min and packaged immediately in selected containers.

Baranowski (1985) also prepared ginger paste using fresh, mature ginger rhizomes. It is then washed and stored at 25°C until processing. Citric acid was added to reduce the pH (to 4.15) so that simple pasteurization would suffice as a heat process. Roughly 12 kg paste was prepared by blending 8 batches of 1.5 kg each. Each batch consisted of 750g each of freshly sliced ginger root and water, 15g xanthan gum stabilizer (“Keltrol”, Kelco, San Diego, CA) and 7.5 mL 30% w/v citric acid solution, which were comminuted for 2 min in a food processor. The paste was heated in a steam kettle to 80°C, packed into 202x314 cans, seamed, inverted for 3 min, cooled in running water for 15 min and air dried. The process time from application of heat to finish seaming was roughly 12 min.

Paste is characterized as the product obtained after addition of common salt and organic acid to the puree (Ahmed & Shivhare, 2001). Thus, Ahmed *et al.* (2004) converted coriander puree to paste by addition of 2% sodium chloride (w/w) and the required volume of 30% (w/v) citric acid to adjust the pH to approximately 4.2. Salt level was selected by a preliminary sensory test. Salt increased total soluble solids of puree. After pasteurization at 80^0C for 15 min the paste was hot-filled into pre-sterilized glass bottles. The bottles were cooled by spraying chilled water and stored at selected temperatures (5, 25 and 37±1 ^{0}C) for 6 months.

2.2.1 Storage condition

Temperature of storage is important as it can slow down the growth of the microorganisms that are important to food safety and quality. All microorganisms respond to temperature in their rate of growth. The lower the storage temperature, the slower is the rate of growth. The lowest temperature which inhibits growth classifies the microorganisms into the psychrophiles (cold loving), mesophiles (grow at room temperature), and thermophiles (grow at high temperatures). Mesophiles are spoilage organisms in dry shelf stored products. Psychrophiles are spoilage microorganisms in refrigerated products (Romeo and Brody, 2000).

Baranowski (1985) studied odor change and changes in color and flavor components of ginger paste. To evaluate odor changes, cans that are filled with ginger paste were stored at either -10^0 or 25°C. The pastes were sampled at 0, 4, 8, 16 and 24 week of storage. The 0 week stored samples were evaluated immediately after their preparation. Odour was evaluated by a 10 member trained panel. In the second study, to evaluate changes in color and flavor components, samples were stored at -10^0, 10^0, $25^0$and 37°C. Colour was monitored by Hunter color difference meter values. Samples were taken at the same time interval as in the first study.

Ahmed (2004) processed ginger paste at 80^0C for 15 min and packed immediately in containers viz. glass, polyethylene terephthalate (PET) or a high-density-poly-ethylene (HDPE) pouch. Paste was stored at 5 ± 1° and 25 ± 1 ^{0}C for 120 days. The samples were analysed periodically for colour, total soluble solids, pH and titrable acidity.

Ahmed and Shivare (2001) studied rheology and storage characteristics of garlic paste. Thermally processed garlic paste at 80^0C for 15 min was packed immediately in containers viz. glass, polyethylene terephthalate (PET) or high-density-poly-ethylene (HDPE) pouches. Storage studies were carried out at 25 ±1 ^{0}C and 5 ±1 ^{0}C for 124 d. The samples were analyzed periodically for color, total soluble solids (TSS), pH, and titrable acidity.

An acidified food (pH<4.5) requires only pasteurization for shelf-stability and therefore the coriander paste was heat-treated at 80^{0}C for 15 min and immediately hot-filled into pre-sterilized glass bottles. The bottles were cooled by spraying chilled water and stored at selected temperatures (5, 25 and 37±1^{o}C) for 6 months. The samples were analyzed at intervals of 1 month for colour, TSS, pH and salt content. (Ahmed *et al.* 2004).

2.3. Physiochemical studies of ginger paste

2.3.1 Water activity

All microorganisms require water to grow, and an index used to determine the availability of water to support microbial growth is the water activity. Molds require the least water activity to support growth, generally a water activity of 0.7. Yeasts are generally inhibited from growing at a water activity of 0.85. Bacteria on the other hand, are generally inhibited from growing at a water activity as high as 0.90. Bacterial spores generally do not germinate at water activity below 0.94. (Romeo and Brody, 2000).

Water activity is a critical factor that determines shelf life. Below 0.60, no microbiological growth is possible. However, there remain a number of food spoilage microbes that can grow within the range 0.8 - 0.6. The risk of food poisoning must be considered in low acid foods (pH > 4.5) with a water activity greater than a_w 0.86. By measuring water activity, it is possible to predict which microorganisms will and will not be potential sources of spoilage. In addition to influencing microbial spoilage, water activity can play a significant role in determining the activity of enzymes and vitamins in foods and can have a major impact their color, taste, and aroma. It can also significantly impact the potency and consistency of pharmaceuticals (http://class.fst.ohio-state.edu).

Ahmed *et al.* (2007) studied the water activity of tamarind juice concentrate using water activity meter at 20^{0}C. The water activity of the paste was found out to be

0.66. Ahmed and Shivare (2001) stated that the water activity of garlic paste was observed to be 0.86 by following the method of Proctor (1951).

Igual *et al.* (2010) studied the water activity of grapefruit (“Star Ruby”) using a dew point hygrometer (FA-st Lab, GBX, France). The mean values (and standard deviation) of a_w grapefruit (“Star Ruby”) was observed to be 0.988 (0.003).

2.3.2 Total soluble solids and total solids

According to Ahmed and Shivare (2001), total soluble solids (^{0}Brix) of garlic puree/paste was determined using a refractometer (Atago, Japan) at 20^{0}C. To determine total solids, paste was dried under vacuum at 70^{0}C to constant weight (16 to 18 h). Each experiment was replicated twice, and the average values were used in the analysis. TSS and total solids values were 33°Brix and 27%. TSS and total solids of garlic paste did not change ($P \leq 0.05$) during storage.

Total soluble solids (TSS) (^{0}Brix) of coriander leaf paste were measured with a refractrometer (Atago, Japan). It was observed that there was no significant change in TSS during storage (Ahmed *et al.*, 2004).

Ahmed (2004) determined total soluble solids (^{0}Brix) of ginger paste using a refractrometer (Atago, Tokyo, Japan). To determine total solids, paste was dried under vacuum at 70 ^{0}C to constant weight (16–18 h). Total soluble solids (TSS) and total solids were 11.6 ^{0}Brix and 15.72%, respectively. TSS of ginger paste did not change significantly ($P > 0.05$) during storage.

Topno *et al.* (2010) determined total soluble solids (°Brix) with a digital bench top Abbe Refractometer at 20^{0}C (Atago Co.Ltd., Tokyo, Japan). To determine the total soluble solids, the paste was dried under vacuum at 70^{0}C to constant weight. The dried samples were allowed to cool in desiccators for 30 min and then weighed (AOAC, 1995). There was no significant change ($p>0.05$) of TSS during storage. Total solid (%) is given by the following formula.

Total solids, % = (mass of dried sample /mass of fresh sample) x100

Ahmed *et al.* (2007) studied total soluble solid (TSS) of tamarind Juice concentrate using a hand refractometer and expressed in ^{0}Brix. The TSS of the paste was found out to be 71^{0}Brix.

2.3.3 pH

pH is defined as the logarithm of the reciprocal of hydrogen ion concentration in g/l. It is of importance as a measure of the active acidity which influence the flavor or palatability of a product and effects the processing requirements (Rangana, 2002).

The pH of food is also a factor inhibiting microbiological growth. Yeasts and molds are not inhibited at the pH levels of most foods. Spores of bacteria which are resistant to inactivation by heat or chemical disinfectants, generally do not germinate at a pH of 4.6 and below (Romeo and Brody, 2000).

According to Topno *et al.* (2010), for measuring pH, the ginger-garlic paste sample (5 g) was diluted with 45 mL distilled water, and pH was measured with glass electrode (EUTECH Instruments, Selangor, Malaysia). Sodium chloride was determined by titration with silver nitrate. The initial pH of the paste was around 5.4 at which level microbial spoilage will be rapid. Therefore, lowering of the pH to 4 to 4.5 by addition of an acidulant such as citric acid (25% solution) helps in reducing the spoilage which imparts slight acidic or sour taste to the products, but would not affect to any describe level the eating quality of the food product. It was observed that pH was slightly increased with increasing processing time.

Ahmed and Shivare (2001) determined pH of garlic paste by using pH meter with glass electrode at 20^0C (Systronics, India). The pH of the paste was 4.1% and it does not change ($p \leq 0.05$) during storage. Similarly, pH of ginger paste was measured using pH-meter with glass electrode (Systronics, Ahmedabad, India) at 20^0C. The pH of ginger paste was 4.05 and there was no change during storage (Ahmed, 2004).

Ahmed et al. (2004) measured pH of coriander puree/paste using a pH meter (Systronics, India) with glass electrode at 25^0C. It was observed that there was no significant change ($p > 0.05$) of pH of the paste during storage. Ahmed *et al.* (2007) studied pH of tamarind Juice concentrate using a pH meter. The pH of the paste was found out to be 2.1.

2.3.4 Acidity

Topno *et al.* (2010) studied physico-chemical properties of ginger-garlic paste. Titrable acidity in the processed paste was measured in terms of citric acid following the method described by Wang *et al.* (1995). For measuring titrable acidity, 5 g paste were diluted with 95 mL distilled water making the volume to 100 mL, then filtered through Whatman no. 41 filter paper and titrated against 0.1 N NaOH to pH 8 using phenolphthalein indicator. Acidity was expressed as percent citric acid by weight. Sodium chloride was determined by titration with silver nitrate (Ranganna, 1986). The titrable acidity varied depending on pH conditions with different processing durations.

According to Ahmed and Shivare (2001), titrable acidity of garlic paste was measured in terms of citric acid following the method described by Wang *et al.* (1995). Five g paste diluted with 95 mL distilled water making the volume to 100 mL, filtered through Whatman 41 filter paper and titrated against 0.1 N NaOH, using phenolphthalein as an indicator. Sodium chloride was determined by titration with silver nitrate. The acidity of garlic paste was 0.35%. The titrable acidity of garlic paste did not change ($P \leq 0.05$) during storage. Similarly, Ahmed (2004) concluded that the acidity of ginger paste was found out to be 0.32% (in terms of anhydrous citric acid) and there is no significant change ($p>0.05$) during storage.

2.3.5 Colour

According to Topno *et al.* (2011), color measurement of ginger-garlic paste was done by the method of Hunt (1991). It was measured and compared using a Hunter colorimeter model “Lab scan XE” (Hunter Associates Laboratory, Reston, VA) using universal software, based on three color coordinates namely L, a, and b. The instrument is calibrated using a standard white (L = 90.70, a = -1.08. b = 0.65) and blank reference tile under illuminated conditions such as “C” illumination and via angle 2°. The Hunter color (L, a, b) values of fresh ginger–garlic paste were 53.8, 3.0 and 21.7, respectively. The color values a and b (green and yellow) decreased, whereas the L (lightness) values increased with decrease in pH. Slight decrease in green color was observed during addition of salt whereas the addition of citric acid alone substantially increased the greening of ginger–garlic paste. The Hunter color value of the paste containing both sodium chloride and citric acid was -1.3. Hence, the acidic condition of paste considerably favored the formation of green pigment.

Ahmed (2004) also measured colour of ginger paste using a Hunter colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) based on three colour coordinates, namely L, a and b. The instrument ($45^0/0^0$ geometry, D25 optical sensor, 10^0 observer) was calibrated against a standard white reference tile (L = 90.55, a = -0.71, b = 0.39). A glass cell containing the heat-treated puree was placed above the light source and post processing L, a, b values were recorded. The Hunter colour L, a and b values of prepared ginger paste were 59.93, 2.01 and 22.95, respectively.

Ahmed (2004) stated that the colour of ginger paste is a complex one, varying from light brown to yellowish, and it changed during storage. Storing paste both at 5 and 25 ^{0}C resulted in the gradual increase in the Hunter a-value, while L- and b-values decreased. In practice, any change in a- and b-values are associated with simultaneous change in the L-value. The Hunter colour combination (Lb/a) was considered as a quality index parameter for ginger paste and was correlated with storage period using the following equation.

$$Lb/a = k_1 \exp(k_2 D) \tag{2.1}$$

where, k_1 (dimensionless) and k_2 (day)$^{-1}$ are constants, and D is duration of storage (days). Storage temperature significantly ($P < 0.05$) affected Lb/a while packaging materials did not ($P > 0.05$). The rate of colour degradation was faster at 25 ^{0}C than at 5^{0}C. The faster colour degradation was due to heat induced browning. The decrease in colour values during storage was also probably because of the oxidation of pigments. The rate constants of colour degradation of paste packed in PET containers and glass bottles were almost the same, but lower than in HDPE packages. It can, therefore, be recommended that the paste be stored at 5 ^{0}C in PET or glass containers.

Ahmed and Shivare (2001) conducted the color measurement of garlic puree/paste was carried out using a Hunter colorimeter model D25 optical sensor (Hunter Assoc. Laboratory Inc., Reston, Va., U.S.A.) on the basis of 3 color values, namely *L, a,* and *b.* Both temperature and storage period had an effect ($P \leq 0.05$) on the total color of garlic paste. Storing paste at 25^{0}C resulted in gradual degreening where as greenness increased with time at 5^{0}C . Complete degreening of garlic paste occurred at about 48 to 52 days of storage at 25°C. Similar observations on degreening of garlic products and bananas with storage period at and above 23^{0}C have been reported by Lukes (1986), Rejano and others (1997), and Kajuna and others (1998). Total color as represented by L x a x b was used to describe the variation in color of paste. An equation similar to that proposed by Kajuna and others (1998) was used to relate the variation of Hunter L x a x b values with temperature and period of storage.

$$L \text{ x } a \text{ x } b = k_1 + k_2 \text{ x } T \text{ x } D \tag{2.2}$$

It was reported that packaging materials did not affect total color ($P > 0.05$) at 25^0C but the effect was significant ($P \leq 0.05$) at 5^0C. Samples packed in glass containers showed minimum greening while maximum greening was noticed in PET containers at 5^0C. Glass containers may, therefore, be recommended for storage of garlic paste at 25^0C. Results of this study indicated that garlic paste should be stored at 25^0C and be held for at least 48 to 52 d before reaching the consumer.

Ahmed *et al.* (2004) measured the visual colour of coriander leaf puree and found that the degradation of colour of coriander leaf puree, during thermal processing and storage of paste at selected temperatures followed first-order reaction kinetics.

Igual *et al.* (2010) also compared the colour of different grapefruit jams obtained by conventional, osmotic dehydration (OD) without thermal treatment and microwave (MW) techniques by measuring the reflection spectrum (Minolta, CM 3600D, Tokyo, Japan).

2.3.6 Microbiological study

Microbiological spoilage is the most significant type of spoilage in terms of economic loss to the industry and consumer dissatisfaction with the processed food. Microorganisms which cause spoilage are grouped into the yeasts, molds, and bacteria. Reproduction of these microorganisms to generate numbers that cause spoilage requires conditions favorable for their growth. (Romeo and Brody, 2000).

The growth of some bacteria, yeasts and moulds in food may lead to either food spoilage or food poisoning. The time taken for microorganisms to affect foods will depend on their levels in the food when it is produced, as well as any further contamination the food may suffer during packing, storage and other handling. Definition of the end of shelf life is usually based on numbers of microorganisms present or on recommended guidance. (www.foodsafety.gov.nz)

According to Topno *et al.* (2011), enumeration of coliforms, mesophilic aerobes and yeasts and molds of ginger-garlic paste were done by pour plate and spread plate method following the procedure of the International Commission on Microbiological Specifications (ICMSF, 1992). Violet red bile agar for coliform bacteria, plate count agar (PCA) for mesophilic aerobes and potato dextrose agar (PDA) for yeast and molds procured from Himedia, India were used. Ten grams of ginger garlic paste sample were weighed in duplicates into 90 mL of 0.1% peptone water aseptically, homogenized and serial dilution was carried out. One milliliter of the appropriate dilution of the sample was taken in sterile petri plates and 15 mL of respective agar maintained at 45°C were poured into plates and allowed to solidify. Set plates were incubated at 37C for 48 h and colony count was taken after 24–48 h of incubation for bacteria. The potato dextrose plates for yeasts and molds were incubated at 27^0C for 3–4 days and colony count was recorded.

It was observed that all samples were sanitarily appropriate for human consumption, as the level of microorganisms present in ginger–garlic processed paste was below the recommended level (APHA, 2001). Initially, total plate count (TPC) in fresh ginger–garlic paste was $2x10^2$ colony-forming unit (cfu)/g, whereas the coliform and yeast and mold counts were below 10 and 100 cfu/g, respectively. Thermal processing of paste at 85°C for 2 and 5 min reduced TPC to 65 while coliforms, yeast and mold were found to be nil. Addition of sodium benzoate (200 ppm) helped in controlling microbial load completely. In control sample (pH 5.4) the TPC increased from 65 to 200 cfu/g, coliform was nil and yeast and mold counts increased from 0 to 25 cfu/g during 6 months storage at 25±5°C .The presence of bacteria of public health significance was typically low in the product and was considerably lower than the prescribed count (Pimm, 1994). It can therefore be inferred that prepared ginger–garlic paste in retort pouches stored more than 6 months was microbiologically safe. The product was packed in retort pouches made by 12 mm PET, 12 mm Al, 15 mm nylon, and 75 mm CPP is the most commonly used in retort pouches and is the only one used indigenously at present (Vijayalakshmi *et al.* 2003). Baranowski (1985) and Giridhar *et al.* (1996) recommended a process temperature of 80°C for ginger–garlic paste with a pH of approximately 4.0. The combination of antioxidant stabilizer and preservative was very important for the preparation of a high-quality ginger–garlic paste.

Ahmed *et al.* (2004) concluded that the total plate counts (TPC) and lactobacillus counts of the coriander paste before thermal treatment were $3x10^4$ and $3.7x10^3$/g, respectively, while the coliform and yeast and mold counts were below 10 and 100, respectively. Thermal processing of paste reduced TPC to 100 while lactobacillus, coliforms and yeast and molds were found to be negative. The TPC values increased from 100 to 950 cfu/g, while coliforms were absent and lactobacillus and yeast and mold counts increased from nil to less than 100 during 6 months of storage. The presence of bacteria of public health significance was below the prescribed limit (Pimm, 1994). It can therefore be concluded that prepared paste stored up to 6 months was microbiologically safe.

Osuntogun *et al.* (2004) studied the microbial quality of commercially produced non-alcoholic beverages like ginger beer, soya milk, soborodo drink and kunun-zaki. An aliquot of 1ml of the freshly prepared samples or from serially diluted samples was placed and on nutrient agar, MRS agar and Potato Destrose Agar using the spread plate method for bacterial and fungal isolation respectively. The nutrient agar plates were incubated at 37^0C for 24 hrs for bacterial isolation. MRS agar plate were incubated anaerobically for Lactobacillus. Fungi were isolated at 28-30^0C for 3-5 days on PDA. Pure cultures of each of the isolates were prepared and identified using morphological and biochemical characteristics. The sorghum gruel (kunu-zaki) was characterized by the presence of lactic acid bacteria, that is Lactobacillus and streptococcus while penicillium and aspergillus were the fungal isolates. Ginger beer had some lactic bacteria i. e. Lactobacillus and Leuconostoc along with Bacillus, Staphylicoccus Candida and Saccharomyces. The soyamilk had only Pseudomonas species while the Roselle drink (Soborodo) had no bacterial isolate but contained Aspergillus species and Trichodema species.

2.4 Study of rheological properties

Rheology is the science of deformation and flow behaviour of matter. The consistency of a Newtonian fluid like water, milk or clear fruit juice can be characterized by the term viscosity. Viscosity of non-Newtonian fluid however changes with changing rate of shear and hence should be characterized by more than one parameter. Viscosity of some non-Newtonian fluids as do not change with the duration of shear rate (such fluids are called time-independent non-Newtonian fluids) (Rizvi & Mittal, 1997). Rheology concerns with the flow and deformation of a substance under applied forces; and attempts to define a relationship between the stress acting on a given material and the resulting deformation and/or flow that takes place. These rheological properties have several applications in the field of food acceptability, food processing and food handling (Barosa-Canovas *et al.* 1996;

Molwane & Gunjal, 1985). Rheological data are also needed for computation in any unit operation involving flow (e.g., pump sizing, filtration and extrusion etc.); and serve significant role in the analysis of flow conditions in many food processing operations such as pasteurization, concentration and dehydration. Rheological properties are determined by measuring force and deformation as a function of time. (Dak *et al.,* 2006).

Knowledge of rheological properties of food puree/paste is essential for the product development and design and evaluation of the process equipment (Ahmed and Shivare, 2001). Knowledge of rheological properties is important for food scientists for various reasons. Rheology provides guidelines in defining a set of parameters, which can be used to correlate with quality attributes of food products. Information about the rheological characteristics of food products is used by food engineers to design processing parameters and flow characteristics of the fluid foods. Rheological characteristics of the paste depends on various factors like temperature, composition, total soluble solids, and particle size and may also depend on the rate of share or share stress, the duration of shear as well as previous shear history. Correct flow characterization of ginger paste would help processors to develop new products and formulations (Ahmed, 2004).

Ahmed (2004) stated that rheological studies provide information on how best to control the flow properties so that the desired end product can be prepared. In food products, rheology provides guidelines for defining a set of parameters, which can be correlated with other quality attributes.

Ahmed *et al.* (2007) stated that rheological measurements have been considered as an analytical tool to provide fundamental insights on the structural organization of food and play an important role in heat transfer to fluid foods.

The design of food processing operations such as mixing, pumping, heating and cooling require the knowledge of rheological behaviour and flow properties (Ahmed *et al.*, 2005). It is also known that visco-elastic properties play important roles in the handling and product quality of both minimally processed foods such as fruits and vegetables and industrial processed foods such as culinary sauces (Omoregbe *et al.* 2008).

Ahmed *et al.* (2004) stated that knowledge of the rheological properties of food products is essential for product development, design and evaluation of process equipment such as pumps, piping, heat exchangers, evaporators, sterilizers and mixers. Rheological measurements have also been considered as an analytical tool to provide fundamental insight of the structural organization of food. Various factors affecting the rheological behaviour of fruit puree and concentrates include temperature.

According to Sanchez *et al.* (2003), viscosity has been traditionally one of the main quality attributes considered to determine the overall quality and acceptability of tomato products. They mentioned that tomato paste with higher consistency can lead to a significant cost saving in the production of tomato-based finished products.

Rheological properties may give a quantitative contribution to texture characterization when using different formulations. Emulsions (mayonnaise) shows a yield stress, a pseudoplastic behaviour and time dependent characteristics (Peressini, *et al.* 1998; Batista *et al.* 2006). Power Law, Herschel–Bulkley and Casson models have been widely used to describe mayonnaise and salad dressing flow properties (Izidoro *et al.* 2009).

Dak *et al.* (2007) reported that knowledge of rheological properties of fluid foods are important for quality, understanding the texture, process engineering application, correlation with sensory evaluation, designing of transport system, equipment design (heat exchanger and evaporator), deciding pump capacity and power requirement for mixing etc.

2.4.1 Viscometric behaviour with respect to speed

Conceicao *et al.* (2012) conducted rheological measurements of frozen and thawed pineapple pulp with a concentric cylinder Brookfield rheometer (DV-III ULTRA; Brookfield Engineering Laboratories, Massachusetts - USA) using a small sample adapter (13R/RP; 19.05 mm in diameter and 64.77 mm in depth) and spindle (SC4-18; 17.48 mm in diameter and 31.72 mm in length) (Brookfield Engineering Laboratories, MA - USA). A Brookfield EX-200 thermostatic bath (Brookfield Engineering Laboratories, MA-USA) was used to adjust the temperature of the sample to 25^0C. For each test, the filled sample cup (6.7 mL) and spindle were temperature equilibrated for approximately 15 min (Pereira *et al.*, 2011).

Ahmed (2004) reported that after equilibrating the ginger paste filled sample cup (12 mL) and spindle for about 15 min , the samples were subjected to three cycle shear changes from 0 to 200 s^{-1} in 3 min, steady shear at 200 s^{-1} for 3 min, followed by a return to 0 s^{-1} in 3 min. The rheograms were evaluated by software (Haake RV20 version 2.3). For steady flow measurement of tamarind juice concentrates, the rheometer was programmed for the set temperature and equilibrated for 10 min following which a two-cycle programmed shear changing from 0.1 to 100 s^{-1} in 5 min and back to 0 s^{-1} in next 5 min. Rheological parameters (shear stress, apparent viscosity and shear rate) were obtained from the software. (Ahmed *et al.* 2007)

The rheological measurements (shear stress – shear rate and viscosity) as well as viscoelastic properties of the three culinary sauces (mustard sauce, Veri-peri Sauces, garlic chilli sauce) were made using an Anton Paar MC51 rheometer (Anton Paar GmbH, Ostfilden, Germany). The measurement system used for this work consists of a measuring cup of radius 21 mm and bob of radius 19.5 mm. The gap length was 60 mm and cone angle of the measuring bob was 120^0C (Omoregbe & Bushi, 2008).

Keshani *et al.* (2012) conducted rheological measurements of pomelo juice concentrates in a controlled-stress rheometer (RheoStress 600, Haake, Karlsruhe, Germany). Shear stress/shear rate rotation ramp tests (mechanical spectra) were performed using a cone sensor (C35/2° Ti; 222–1632; 35 mm diameter, 2° angle), with 0.105 mm gap and a measuring plate cover (MPC 35; 222–1549). The sample compartment was controlled at a temperature of 25°C using a water bath/circulator Haake DC-30 and a Haake universal temperature controler system (UTC) (Haake, Karlsruhe, Germany). Ascending and descending flow curves of shear stress versus shear rate were carried out in the range of 0-1000 s^{-1} during 15 s.

Ahmed (2004) studied rheological characteristics (shear stress, shear rate, apparent viscosity) of ginger paste with a Brookfield RVDV-III rheometer (Brookfield Eng,Lab, Stoughton, MA, USA) in the temperature range of 25 to 65^0C by placing a sample volume of approximately 10mL sample compartment using SCR-21/13R spindle. Shear stress, shear rate and apparent viscosity of paste were recorded between 50 and 150 s^{-1}. Thermostatic water bath (TC 500) provided with the instrument was used to regulate the sample temperature.

Sanchez *et al.* (2003) conducted a test on dynamic viscoelasticity measurements and viscous flow of tomato paste with a controlled-stress rheometer (Bohlin CS-50, Gloucestershire, U.K.). Oscillatory tests were performed inside the linear viscoelastic region using a serrated plate-plate geometry (25 mm, 3-mm gap) in a frequency range between 0.01 to 100 rad/s. Viscous flow curves were obtained using a serrated plate-plate geometry (25 mm, 3-mm gap) to prevent wall-slip phenomena. Since a slight increase in shear stress, after the onset of the shear-thinning region, produces a dramatic increase in shear rate, a controlled-shear-rate rheometer (Haake RV20, Karlsruhe, Germany) with a serrated plate-plate geometry (20 mm, 3-mm gap) was also used to cover the shear rate range between 10^{-1}/s and 10^{2}/s. Maceiras *et al.* (2006) studied rheological properties of fruit puree (raspberry, strawberry, peach and prune). The filled sample cup and spindle was equilibrated at the interest temperature for about 20 minutes and sheared a programmed continuous sequence in which the shear rate was increased linearly from 17.8 to 445 s^{-1} in the next 10 min collecting shear stress-shear rate data continuously at 30 s intervals. The temperature of the samples was controlled with a precision of ±0.1^{o}C.

Ahmed and Shivare (2001) measured apparent viscosity of the garlic paste using a rheometer model RVDV-III (Brookfield Engg. Lab. Inc., Stoughton, Mass., U.S.A.) in the temperature range of 50 to 90 ^{0}C. The paste was placed in a 500-mL graduated glass beaker with flat bottom. The S-4 spindle was selected for the sample measurement and was used without spindle guard of the viscometer. The viscosity measurements were carried out between 30 and 150 rpm. Thermostatic water bath (TC 500) provided with the instrument regulated the sample temperature (±1^{0}C). Ahmed *et al.* (2004) measured rheology of coriander puree by using a rotational viscometer (Haake Model RV20; Haake Mess-Technik, Karlsrulhe, Germany), equipped with an M-05 OSC measuring head and MV1 rotor (o.d. 20.04 mm and height 60 mm) in a concentric cylindrical cup (i.d. 21 mm) assembly, interfaced to a microcomputer for control and data acquisition. The sample compartment was maintained at a constant temperature using a water bath/ circulator (Haake, Model FK-2). For each test, the filled sample cup and spindle were temperature-equilibrated for about 15 min and the samples were subjected to three-cycle shear changes from 0 to 300 s^{-1} over 5 min, steady shear at 300 s^{-1} over 5 min followed by back to 0 s^{-1} in the next 5 min. In order to perform a quantitative comparison of coriander puree sample various rheological models, based on shear stress-shear rate, were tested (Newtonian, Power law, Casson, Bingham and Herschel Bulkley model) using software (Haake RV20 version 2.3) and the best fit model was selected on the basis of standard error.

2.4.2 Effect of concentration and temperature on rheology

Omoregbe and Bushi (2008) performed a test on rheological characteristics of South African commercial sauces in which the temperature was varied from 10^0C to 60^0C and shear rate was varied from 0.1 to 800 s^{-1}. The result show that the apparent viscosity values obtained for mustard sauce varied from 4.06 Pa.s at 10^0C and low shear rate of 15 s^{-1} to 0.118 Pa s at 50 ^{0}C and at a shear rate of 800 s^{-1}. Similar values for the garlic sauce varied from 1.96 Pa.s at a shear rate of 15 s^{-1} to 0.051 Pa.s at 50^0C and a shear rate of 800 s^{-1}. The values obtained for veri-peri ranged from 0.024 Pa.s at 50^0C and 800 s^{-1} to 0.652 Pa.s at 10^0C and shear rate of 15 s^{-1}.

Ahmed *et al.* (2007) studied the steady-shear and small-amplitude oscillatory rheological properties of tamarind (Tamarindus indica L.) juice concentrate (TJC) in the temperature range of 10–90 ^{0}C using a controlled-stress rheometer. Under steady-shear deformation tests, shear stress–shear rate data were adequately fitted to the Herschel-Bulkley and Casson model at lower (10–30^0C) and higher (50-90^0C) temperature range, respectively. The rheological characteristics of the ginger paste were studied by using a computer controlled rotational viscometer over the temperature range of 20–80 ^{0}C. The yield stress decreased exponentially with process temperature and ranged between 3.86 and 27.82 Pa. The flow behaviour index (n) varied between 0.66 and 0.82 over the temperature range. Both consistency index and apparent viscosity decreased with increase in temperature and the process activation energies were found to be in the range of 16.7 to 21.9 kJ mol^{-1} (Ahmed, 2004).

Keshani *et al.* (2012) studied the rheological behavior of the pomelo juices at different concentrates (20, 30.4, 40.4, 53.4 and 60.4°Brix) and temperatures within the range 23 to 60°C. The apparent viscosity of pomelo juice at different concentration was reduced with increasing temperature and shear rate. At all temperatures, the consistency index of pomelo juice increased with increasing concentrations. The effect of concentration, C of pomelo juice on either apparent viscosity, η or the consistency index, K of the power law model can be described by either exponential or power law relationship It was observed that the concentration increases, the flow behavior show the Non- Newtonian while at lower concentration pomelo juice tends to Newtonian behavior. Herschel-Bulkley model exists at higher concentration of pomelo juice as there is no yield stress observation in low temperature for almost range concentrations. Power Law model indicates that pomelo juice presents pseudoplastic behavior for all concentration and temperature studied, as the flow behavior index obtained is less than 1. The analysis of apparent viscosity curve for pomelo juice shows typical shear thinning behavior.

Ahmed (2004) concluded that apparent viscosity (η) and consistency coefficient (K) decreased significantly ($P<0.05$) with increase in the temperature of ginger paste. It is seen that for ginger paste K decreased from the value of 269.9 to 29.3 Pa.s^n while the corresponding value of η ranged between 791.2 and 145.8 Pa.s. The Arrheniius model described well the dependence of apparent viscosity at a shear rate of 0.37 s^{-1} and the consistency index of the Herschel-Bulkley model on temperature.

The rheological behaviour of different fruits (raspberry, strawberry, peach and prune), fresh or cooked, was determined using a rotational viscometer at different temperatures ranging from ranging from 20 to 40^{0}C. The shear rate values ranged from 17.8 to 445 s^{-1}. A marked change in the rheological behaviour of all purees, fresh or cooked, with increasing the temperature was observed. The apparent viscosity decreases with the temperature in all cases. In industrial operations a product is submitted to a range of shear rates and it is important to know how the viscosity will change with temperature at these shear rates to adequately design the equipments for these operations (Maceiras *et al.,* 2006).

Ahmed and Shivare (2001) measured apparent viscosity of the garlic paste using a rheometer model RVDV-III (Brookfield Engg. Lab. Inc., Stoughton, Mass., USA) in the temperature range of 50 to 90 ^{0}C. The paste was placed in a 500-mL graduated glass beaker with flat bottom. The S-4 spindle was selected for the sample measurement and was used without spindle guard of the viscometer between 30 and 150 rpm. Garlic paste behaved as a non-Newtonian material. Apparent viscosity of garlic paste decreased with increase in rpm of spindle (shear rate is directly proportional to rotational speed of spindle) and temperature. Variation of apparent viscosity with temperature followed the Arrhenius equation.

Ahmed *et al.* (2004) studied the rheological characteristics of the coriander leaf puree. It was evaluated using a computer-controlled Haake rotational viscometer at 50, 60, 70 and 80 ^{0}C and it was found that the Herschel–Bulkley model adequately represented shear stress-shear rate data. Temperature dependency of the consistency index and apparent viscosity at a shear rate of 100 s^{-1} followed the Arrhenius relationship and the flow activation energy ranged between 17.2 and 17.9 kJ/mol. The consistency index decreased with increase of temperature and it has been commonly reported by researchers (Hernandez *et al.*, 1995; Rao, 1977; Vitali and Rao, 1984). Dependencies of consistency index and apparent viscosity on process temperatures were adequately described by the Arrhenius equation.

Izidoro *et al.* (2009) conducted test on rheological properties of emulsions stabilized by green banana with a rotational Haake Rheostress 600 rheometer and a cone and plate geometry sensor (60-mm diameter, 2^o cone angle), using a gap distance of 1mm. The rheological responses were influenced by the difference in green banana pulp proportions and also by the temperatures (10 and 25^{o}C), the mixtures presented shear-thinning (pseudoplastic) behaviour and the rheological parameters were well represented by the Power Law model. With an increase in temperature, a decrease in flow behaviour index (n) and consistency coefficient (K) were observed. Good fit models were developed for flow behaviour index and consistency coefficient. Flow characteristics of juice of ‘‘Kesar’’ mango have been investigated and rheological parameters were evaluated using rotational viscometer at temperature 20, 30, 40, 50, 60 and 70^{0}C at concentration of 7.6%, 11.69%, 16.37% and 26% total solid. The experimental results followed the power law model for the best fit and the values of flow behaviour index (n) was less than unity (0.20–0.33) at all temperature and concentration revealing the shear-thinning (pseudoplasticity) nature of juice (Dak *et al.* 2007).

Thus, from the above discussions it is concluded that most of the methods for preparation of ginger paste and the quality analysis of the ginger pastes have been standardized. However, there was a need to recommend suitable storage conditions for the ginger paste developed under the National Agricultural Innovation project (NAIP) along with the study of its characteristics. Thus the study was planned to study the storability of ginger paste in different types of packages and storage conditions.

Chapter 3

MATERIALS AND METHODS

This chapter deals with the experimental setup and procedures followed for the study. Further, the methods used for determination of various physico-chemical and microbial quality parameters during storage of ginger paste have also been explained. As the objective of the work suggested, we prepared the ginger paste and then stored it in three types of packaging materials at two storage temperatures to observe the effect of storage parameters on the change in quality parameters of the paste.

3.1 Preparation of ginger paste

The ginger paste was prepared as per the standard laid down by the National Agricultural Innovation project on “A value chain on ginger and ginger products” operating at OUAT, Bhubaneswar. Initially the raw ginger (Cv. Suprabha) (Plate 3.1) was obtained from the farmers directly in the month of November, which corresponded to 5 months after planting. At that time, there is less fibre development, and hence, quality of the paste will be better than late harvested crops. The ginger was washed in tap water to remove the adhering soil materials. Peeling and trimming was done after soaking it in luke warm water for few minutes. The peeled ginger were then sliced and blanched at 90^0C for 15 minutes. Blanched slices were then ground finely into puree using a commercial wet grinder. Paste is characterized as the product obtained after adding common salt and organic acid to the puree (Ahmed, 2004). The paste was prepared by adding 15% salt (w/w), 0.01% citric acid (w/w), 0.002 % KMS (w/w) and 0.1% vinegar (w/w). The flow chart for the preparation of ginger paste is given in Fig. 3.1.

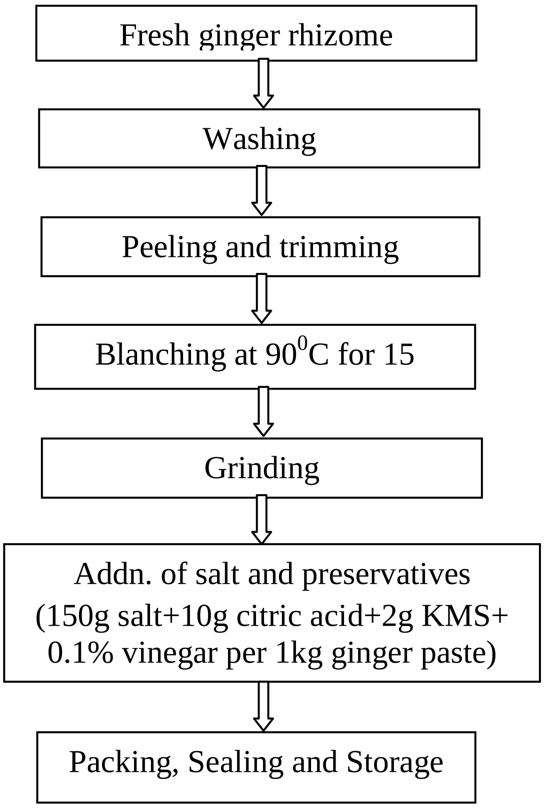


Fig. 3.1 Process flowchart for preparation of ginger paste

3.2. Independent parameters of the study

To study the effect of packaging materials on shelf life of ginger paste, the paste was stored at room temperature (20-25°C) and in cold room maintained at 5^0C. Temperature of storage is important as it can slow down the growth of the microorganisms that are important for food safety and quality. Previous studies for paste such as ginger paste, garlic paste etc. conducted by different researchers have used packaging materials like glass, polyethylene terephthalate and high-density-polyethylene and storage temperature of 5 ± 1^0C and 25 ± 1^0C (Ahmed, 2004 and Ahmed *et al.* 2001). We also used three types of packaging materials, viz. PET jar, HDPE flexible film and MPP pouches for the study so as to recommend the most cost effective packages to the small entrepreneurs. The storage was continued for 120 days and the samples were analysed for different quality parameters at 15 days interval. The experiments were done in three replications.

One sided open pouches of MPP and HDPE were brought from market and they were shaped into the effective package dimension of 15 cm x 21 cm. A hand operated sealing machine (DMT, Impulse sealer, Divya machine tools, India) was used to seal the pouches for MPP and HDPE after filling of the paste. The size of the PET bottle was kept as 275 g, which was the standard size available in the market. Plate.3.3 shows the freshly prepared ginger paste which was filled (200g) in each selected packaging materials.

A walk-in-type of cold room, which maintained the temperature at ±1^{0}C was used for the study.

Thus, the independent parameters used in this study are as follows.

3.1 Independent parameters

Ginger raw material	Variety: Suprava harvested 5 months after planting
Ginger paste sample size	200 g
Type of package and size	MPP (15 cm x 21 cm) HDPE (15 cm x 21 cm) PET jar (275g)
Storage temperature	Room temperature (RT) (20°-25°C) Cold room (5±1°C)
Storage period	120 days (Quality analysis carried out at 15 days intervals)

3.3 Quality analysis of samples

To study the change in different quality parameters of the ginger paste, the samples were drawn from the storage chambers at 15 days interval up to 120 days. The experiment was designed in such a way that three packages (three replications) of each packaging material were drawn from each storage condition on each day of analysis.

The quality parameters studied for the analysis are as follows.

1. Physicochemical properties
    a. Water activity
    b. Total Soluble Solids (TSS)
    c. Total Solid (TS)
    d. pH
    e. Acidity

f. Colour
g. Microbial count (bacterial load, total mould load)

3.3.1 Water activity

Water activity of the paste was measured using water activity meter (Make: Labswift-a_w Model: Novasina AG, Plate.3.4) at room temperature (25 ± 1^0C). At first, the water activity meter was warmed up for 15 mins. The cup was filled with the sample up to the brim and kept inside the water activity chamber as per the manufacturer's instructions. The observations were taken after the steady water activity value was indicated.

3.3.2 Total soluble solids (TSS)

The TSS (^{0}Brix) of the paste was measured using digital refractometer (Pocket Refractometer, Atago) (Plate 3.5). Firstly, the refractometer was calibrated using distilled water. The paste was squeezed by using muslin cloth and the drops obtained were used for the measurement of TSS.

3.3.3 Total solid

Preliminary experiments were conducted to standardize the temperature-time combination of gravimetric drying method. 5-6 g of the samples was kept in hot air oven for 42 hours. The total solid content of the sample was found as follows.

$$\mathrm{TS} = \mathrm{Amt.\ of\ sample} - \mathrm{Moisture\ evaporated} \qquad (3.1)$$

3.3.4 pH

The pH of the paste was measured using digital pH meter (EUTECH Instruments, Malayasia) with glass electrode at 25^0C. The sample was diluted in the ratio of 1:2, i.e. 5 g of sample was diluted with 10 ml of distilled water. Plate 3.6 shows the pH meter which was used for the experiment.

3.3.5 Acidity

The titrable acidity of the processed paste was measured in terms of anhydrous citric acid (%). For measuring titrable acidity, 5 g of sample was diluted with distilled water and make up the volume in a volumetric flask up to 50ml. It was then filtered through whatman no. 41 filter paper. 5ml of aliquot was pipette out into 250 ml conical flask and added with 50 ml distilled water. The prepared sample was titrated

Plate.3.1. Fresh Ginger (Cv. Suprava)

Plate.3.2. Hand operated sealing machine(DMT, Impulse sealer, Divya machine tools)

Plate.3.3. Freshly prepared ginger paste in different packaging material

Plate.3.4. Water Activity Meter(Make: Labswift-a_w Model: Novasina AG)

Plate.3.5. Brix Meter (Pocket Refractometer, Atago)

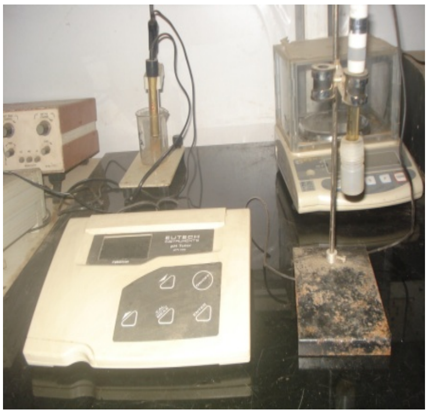


Plate.3.6. Digital pH meter (EUTECH Instruments)

Plate.3.7. Acidity measurement (Titration method)

Plate.3.8. Hunter Lab colorimeter (Model: ColorFlex, Hunter Lab, USA)

Plate.3.9. Laminar flow chamber for microbial analysis

Plate.3.10. Incubator

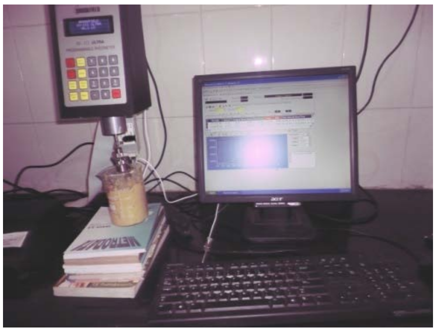


Plate.3.11. Rheometer (Make: Brookfield Model: LVDV-III Ultra)

against 0.1 N NaOH using phenolphthalein indicator as light pink as the end point (Plate.3.7). Acidity was expressed as percent citric acid by weight (Rangana, 2002) as follows.

$$\text{Acidity, \%} = \frac{\text{E.W. of acid x } V_1 \text{ x N } \mathbf{x} \text{ } V_3}{10 \text{ x W x } V_2} \qquad (3.2)$$

Where,

E.W. of acid = Equivalent weight of anhydrous citric acid, 64
V_1 = Make up volume
N= Normality of NaOH = 0.1
V_3 = Volume of NaOH used
V_2 = Volume of aliquot taken for titration
W = Weight of the sample.

3.3.6 Colour

Hunter Lab colorimeter (Model: ColorFlex, Hunter Lab, USA) (Fig 3.11) (Plate.3.8) was used for measuring the surface colour in terms of lightness (L*-value), redness (a*-value) and yellowness (b*-value) of stored ginger paste. L* is a measure of the brightness from black (0) to white (100). Parameter a* describes red-green colour with positive a* values indicating redness and negative a* values indicating greenness. Parameter b* describes yellow-blue colour with positive b*values indicating yellowness and negative b*-values indicating blueness. Prior to colour measurement, the colorimeter was calibrated to a standard black glass and standard white tile (X-79.11, Y-84.00, Z-88.18; L-93.45, a-1.11, b-1.40). The paste from each package was placed in measuring bowl of colorimeter for each measurement and the means of 3 measurements were taken. The total colour difference of the paste with respect to the fresh sample was measured which is given by ΔE.

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \qquad (3.3)$$

3.3.7 Microbial analysis

Microbiological analysis was carried out immediately after processing and at days of sample analysis throughout the storage period. All samples were analyzed for the populations of mesophilic aerobic bacteria and total mould load. Results were expressed as colony forming units per gram (cfu/g).

$$\text{Colony/ml} = (\text{No. of colonies/plate}) \text{ x Reciprocal of dilution factor} \tag{3.4}$$

All the glasswares were sterilized before conducting the experiment using retort. Also, the laminar flow chamber (Plate.3.9) was sterilized before operation by keeping ON the UV light. 1g of paste was measured using digital electronic balance. Samples were serially diluted (1:9) and total aerobic bacteria were enumerated using the spread plate on to appropriate media. Nutrient agar (NA) was used for total aerobic bacteria; it was incubated at 37 °C for 2 days. Similarly, total mould load/ fungi were enumerated by using Potato Dextrose Agar (PDA) as the growing media and incubated at 37 °C for 2 days at incubator (Plate.3.10). Duplicate samples were examined on each day of analysis.

3.4 Rheological properties

The rheological property of ginger paste was measured using programmable rheometer (Make: Brookfield Model: LVDV-III Ultra) with the program Rheocalc 32 (Plate 3.11). The spindle LV-4 with guard-leg was chosen for the measurement of rheological behavior of the ginger paste. A sample of 500 ml of paste was used in a glass beaker of 600 ml size for all experiments. Similar equipment was used in the rheological study of Totapuri Mango (Dak et al, 2006) and Kesar mango juice (Dak et al, 2007). The program used for the study is as follows:

SSP :LV-4
SSN :00
LSC :21
SSI :5
WTI :00:00:05
DSP
LEC

The observations were taken in such a way that the torque value remained within 10 to 100%. The shear rate was taken from 5 to 105 s^{-1}. The data obtained from the software was exported to excel sheet and the curve was fitted using curve fitting expert software. The rheological behavior of non-newtonian fluid can be expressed by different flow models viz. Herschel-Bulkley model, power law, Bingham plastic and Casson model. Out of these models, Herschel-Bulkley is appropriate for many fluid foods and it is convenient because Newtonian, Power law or Bingham plastic behavior may be considered as special cases. (Steffe, 1992). Herschel-Bulkley model is given by

$$\tau - \tau_0 = K(\gamma)^n \qquad (3.5)$$

where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), γ is the shear rate $(s)^{-1}$, K is the consistency coefficient (Pa.s^n), and n is the flow behavior index (dimensionless).

To study the effect of temperature on viscosity, the paste was initially heated in a water bath placed on an induction heater and after the paste was heated to the desired temperature, we shifted them to a constant temperature water batch. The temperature was continuously monitored using a digital probe thermometer. The viscosity was measured at three different temperatures (30, 45, 60 ^{0}C). The temperature during operation was continuously taken by the temperature probe which is attached with the rheometer itself.

3.5 Analysis of data

The experiments were planned using factorial completely randomized design (CRD) with three replications. The data obtained were submitted to analysis of variance and the least significant differences were used to compare the different treatments individually. The analysis was carried out using SAS version 9.3.

Chapter 4

RESULTS AND DISCUSSION

As per the objective of the study, the effect of storage conditions on physic-chemical properties of ginger paste was studied. Also, a study was conducted to know the rheological behavior of ginger paste with respect to the temperature. This chapter deals with the results of the experiments carried out related to the study. As mention in previous chapter the study was conducted in 15 days interval and quality analysis of the product was done at 60^{th}, 90^{th} and 120^{th} days of storage.

4.1 Physicochemical properties during storage

Fig. 4.1- 4.8 shows the change in different parameters of ginger paste during storage.

The changed in water activity (a_w) with respect to time is shown in Fig. 4.1. It was observed that the water activity almost remained constant during the first 6 weeks of storage after which it started reducing. The initial water activity of the samples were found to be 0.873±0.001, which reduced to between 0.881±0.014 to 0.854±0.013 after 45 days of storage and to between 0.744±0.008 to 0.734±0.009 after 120 days of storage. The reduced water activity in general indicates higher stability of the commodity against microbial destructions. Most of the bacterial growth happens at around a_w 0.9. Below a_w 0.9, most of the bacteria do not survive except the halophilic and osmophillic bacteria. In ginger paste salt concentration is about 15% (total weight basis), which might have lead to growth of halophilic bacteria. When the halophilic bacteria grow in a salt medium, they have the tendency to remove salt from their cytoplasm to the surrounding through the cell wall and take water from the surrounding to the cytoplasm for their survival. As the storage period is increased, number of microorganism also increased. Thus the bacteria might have taken water from the surrounding through their cell wall inside the cell resulting in reduction in water activity in the surroundings.

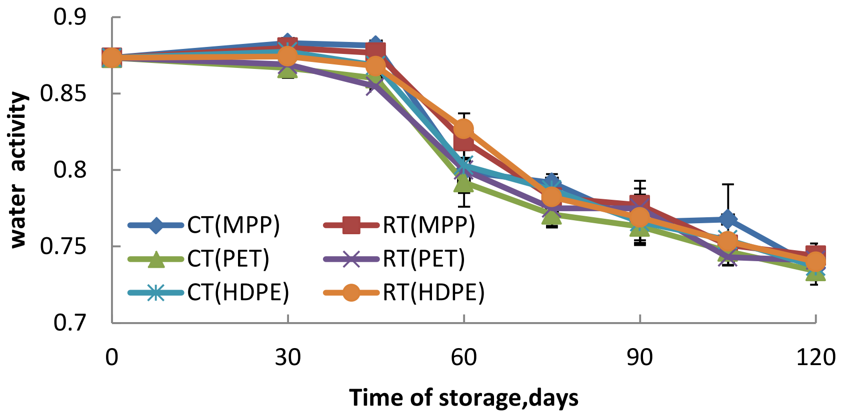


Fig.4.1. Changes of water activity during storage

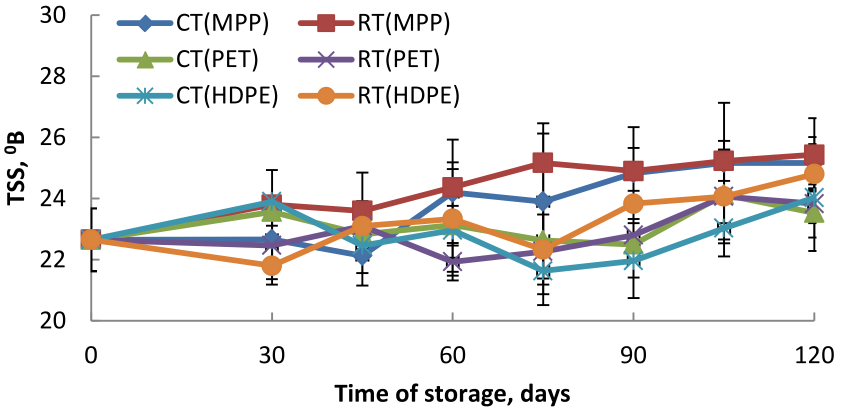


Fig.4.2. Changes of TSS during storage

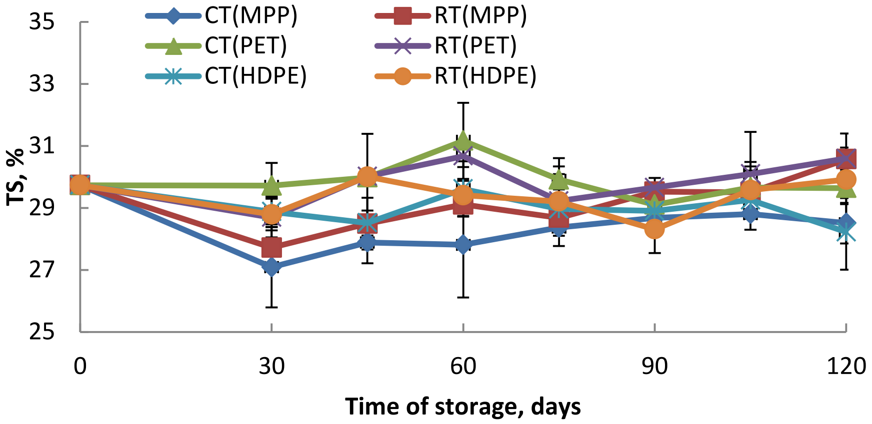


Fig.4.3. Changes of TS during storage

As observed from Fig. 4.2, there was no systematic change in the TSS value of the ginger paste, though in general there was a slight increase in the TSS value during storage. The TSS of ginger paste changed from the initial value of 22.65±1.03^{0}B to a minimum of 21.63±0.757^{0}B and a maximum of 25.433±1.201^{0}B in different packaging conditions after 120 days of storage. Previous studies on coriander leaf puree, ginger paste and ginger garlic paste also indicated that the change in TSS were not significant when the commodities were stored in different packaging materials (Ahmed and Shivhare, 2001; Ahmed et al., 2004; Ahmed, 2004; Topno et al., 2010).

Fig. 4.3 shows the change in total solids (TS) with respect to storage time. It was observed that the total solids almost remained constant during the storage period, which ranged from 28.221±1.217% to 30.590±0.356% for all the packaging material after 120 days of storage. It indicated that all the packaging materials selected effectively prevented moisture loss from the samples. Ahmed (2004) and Topno et al. (2010) also observed that there was no change in TS for different packaging materials for ginger and ginger-garlic paste for PET, HDPE and glass container.

Fig. 4.4 shows the changes of pH of the ginger paste during the period of storage. It was observed that the pH of the paste changed from the initial value of 3.11±0.01 to between 3.187±0.015 to 3.217±0.006 during the period of storage in different package conditions. Thus the pH did not vary much with the period of storage. Similar observations were also made by Ahmed and Shivare (2001) and Ahmed (2004) for ginger paste when the paste was stored in HDPE, PET and glass jars. Lower the pH, the commodity will be more stable against the microbial spoilage. As such the ginger paste was found to be stable against bacterial spoilage for 120days of storage.

The behavior of acidity of ginger paste stored at different packaging materials and at different storage conditions is shown in Fig. 4.5. The initial value of the acidity was observed to be 1.126±0.057% which changed up to a minimum of 0.981±0.133% and maximum of 1.557±0.196% during the storage period. Therefore, it was observed that there is no much variation in the acidity of the paste during the period of storage. Similar observations were also found by Ahmed and Shivare (2001).

In general, when pH value increases, acidity decreases, and vice versa. However in our observations there were variations in the rate of changes of pH and acidity. It might be because pH is a measure of H^+ concentration which gives a quantitative measure of acidity. But the acidity that we measured is citric acid equivalent only.

There was noticeable change in colour of all the samples kept in different conditions. As observed from Fig. 4.6, the maximum change in colour took place during the first 6 weeks of storage. Subsequently, the rate of change as indicated by the ΔE values reduced. It was observed that in general the change in colour was higher for the room temperature stored samples than the cold store samples.

Fig. 4.7 shows the changes of total bacterial count (TBC) of the ginger paste during the period of storage. It was observed that TBC of the paste changed from the initial value of $1.333\pm0.254\times10^5$ cfu/g to $7\pm1\times10^5$cfu/g in different packaging conditions. According to general microbiological safety criteria for foods (Food Administration, Manual version 2, Oct, 1995), the acceptable limit of the total plate count is 5×10^5 cfu/g for herbs and spices and for the foods that needs further cooking before consumption. It was observed that all the samples in cold room were within acceptable limit except sample in HDPE on 120th day. Similarly, the samples in different packaging materials at room temperature were not acceptable at the end of storage.

Similarly, Fig.4.8 shows the changes of total mould count (TMC) of the ginger paste during the period of storage. The TMC of the paste changed from the initial value of $0.333 \pm0.033\times10^5$ cfu/g to $1.33 \pm0.153\times10^5$ cfu/g in different packaging conditions. Considering 1×10^5 (Plotto, 2002) as the acceptable limit of molds, it was observed that the sample in HDPE and PET stored at room temperature are not acceptable from 105th days of storage till the end of storage. Mold can favorably grow in the paste which may be due to the water activity of the samples which lies between 0.881 ± 0.014 to 0.734 ± 0.009. Low moisture, or temperature and high salt or sugar are unfavorable for the growth of bacteria, rather it provides a favorable environment for the growth of yeast and molds. Moreover, yeasts and molds are acid tolerant and can grow at $pH<0.4$.

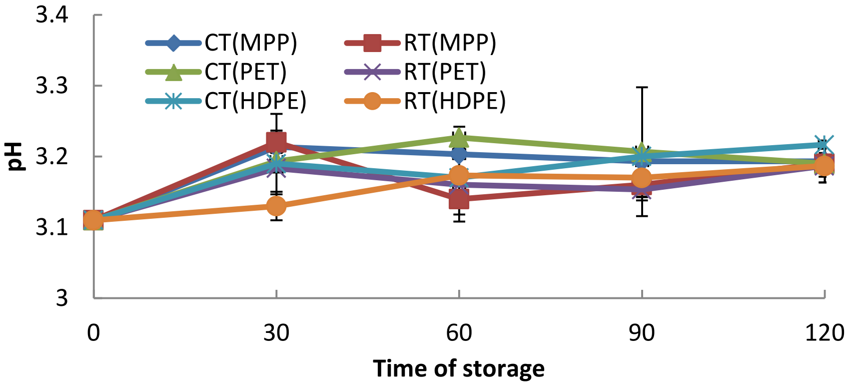


Fig.4.4. Changes of pH during storage

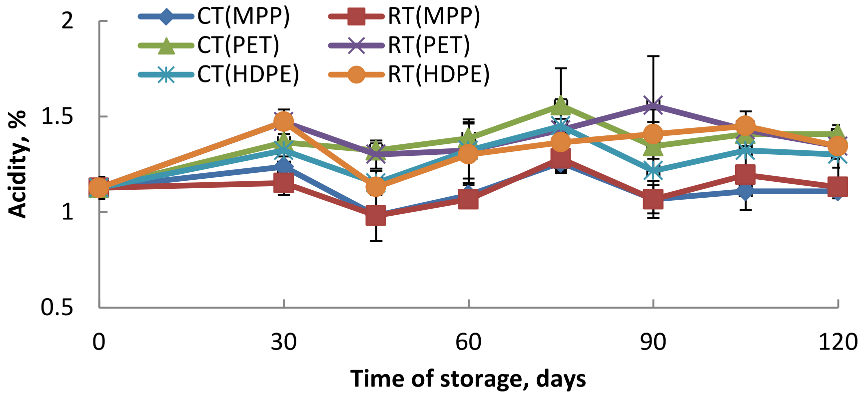


Fig.4.5. Changes of acidity during storage

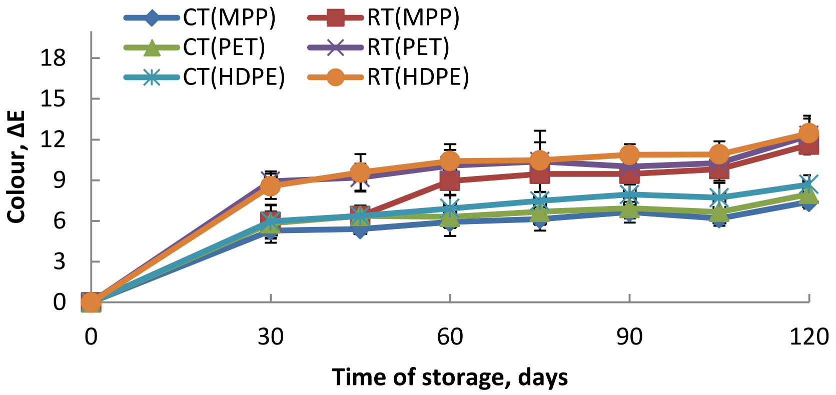


Fig.4.6. Changes of colour during storage

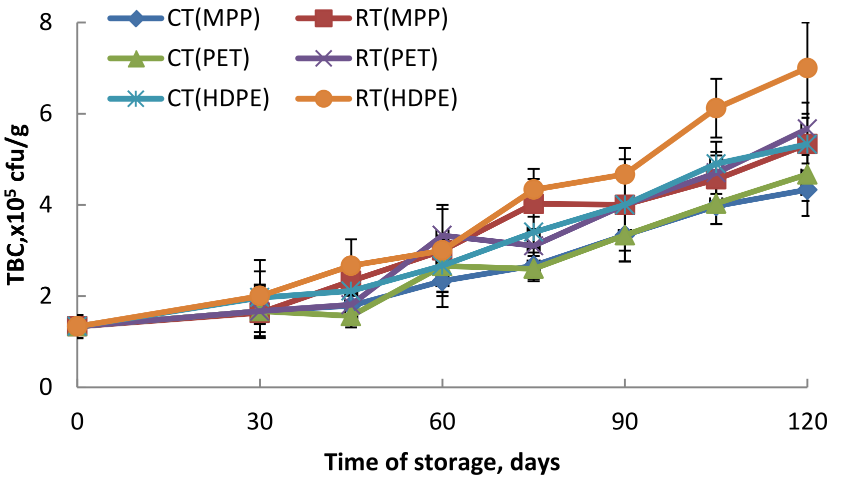


Fig.4.7. Changes of TBC during storage

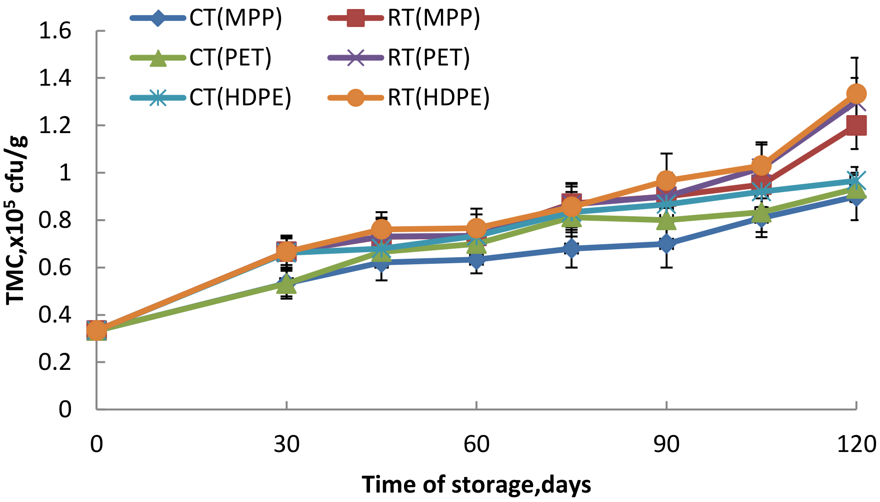


Fig.4.8. Changes of TBC during storage

In general it was observed that both total mold count (TMC) and total bacterial count (TBC) increased with the storage period. For 90 days storage period all the samples in different packaging materials and storage temperatures were acceptable from the bacterial count point of view, however, as regards to mold count, only the samples stored in 5°C temperature were acceptable. The samples stored in different packages at 25°C were beyond the acceptable limit of mold count which is $1x10^5$. For 120 days of storage only the samples stored in MPP and PET at 5°C storage temperature were acceptable in view of safe bacterial load, but the mold count within all the packaging materials kept at 5°C were within acceptable limit.

4.1.1 Effect of storage conditions on quality on 60th day

The change in different quality parameters of the ginger paste as affected by the different packaging materials and temperature of storage are given in Fig. 4.9 to 4.11 for 60 days of storage. Plate 4.18 and Plate 4.19 shows the samples in different packaging material and storage temperature on 60th day of storage.

Fig. 4.9 (A) shows the water activity values as observed for different types of packages and storage conditions. The statistical analysis of the observations (Annexure I) indicates that the type of package has significant influence on the change in water activity values. The mean value of water activity of the paste stored in HDPE was found to be 0.815 whereas it was 0.809 and 0.796 for MPP and PET, respectively. Similarly, the storage temperature also influenced the water activity of the paste. In general the cold room stored ginger paste had a mean water activity value of 0.798 as compared to 0.815 for the room temperature stored paste. The change in effect due to package type and temperature interaction is given in Table 4.1. The least water activity was observed for PET stored sample in cold temperature (0.792±0.016). However there was no significant difference in the water activity of ginger paste kept in PET at room temperature and that between the samples stored in PET at cold room and MPP at cold room conditions.

Fig. 4.9 B shows the differences of TSS on 60th day of storage. The type of packaging material had significant influence on the change in TSS values as observed from statistical analysis (Annexure I). In general the MPP packages showed higher TSS values than the others though there was no significant difference between HDPE and MPP packages. However, the storage temperature did not significantly influence the TSS value as observed from the individual effects. The change in effect due to package type and temperature interaction is given in Table 4.1. The maximum TSS was observed for MPP stored sample in room temperature (24.37±0.600). However, there was no significant difference in TSS values for paste stored in MPP in cold temperature and room temperature as well as HDPE at room temperature.

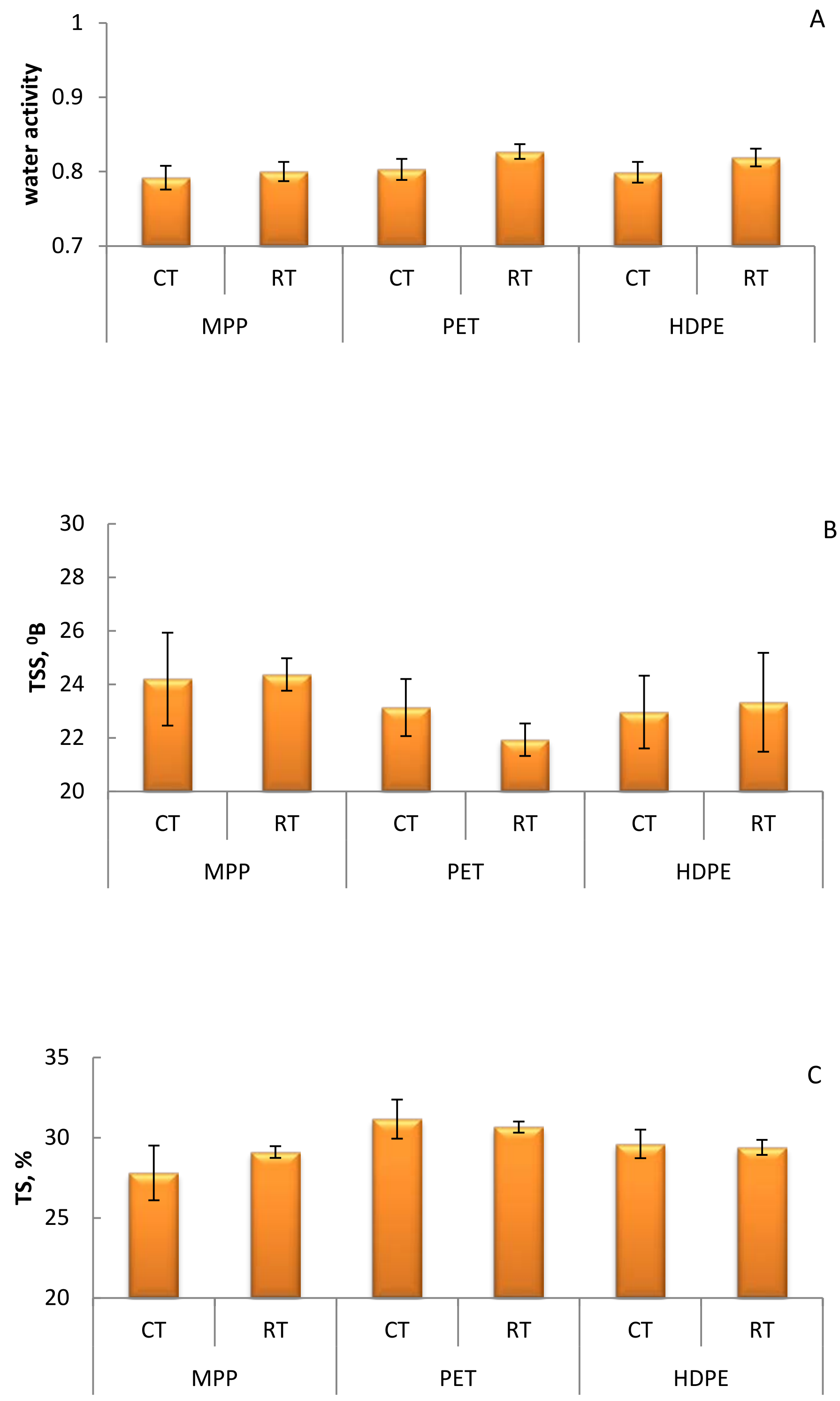


Fig. 4.9 Different physico-chemical parameters of ginger paste on 60th day of storage. (A) Water activity; (B) Total soluble solids; (C) Total solids

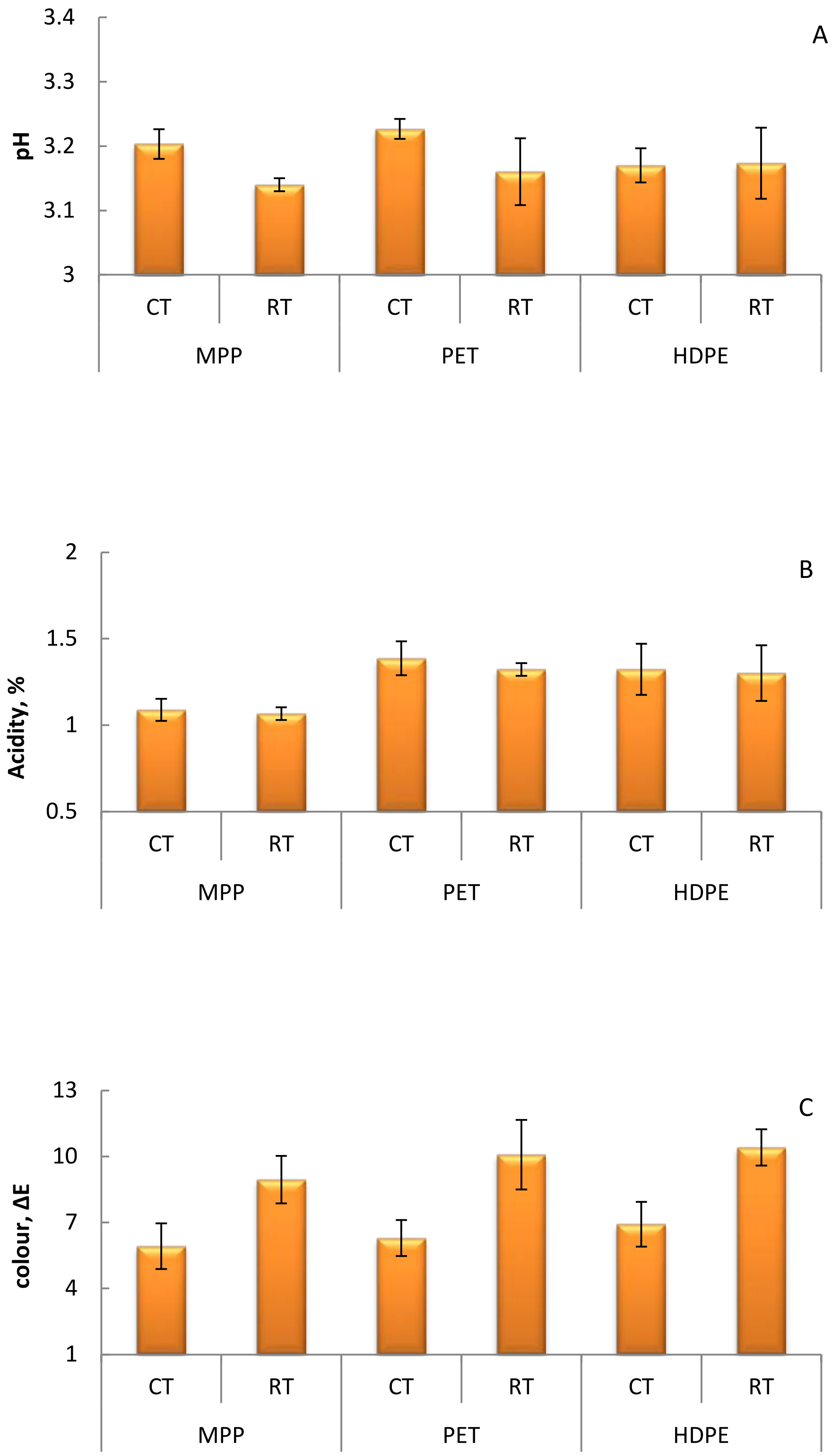
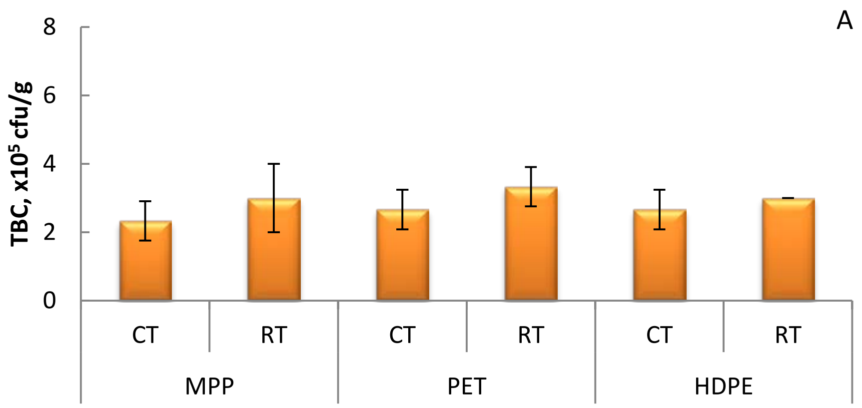


Fig. 4.10 Different physico-chemical parameters of ginger paste on 60th day of storage. (A) pH; (B) Acidity; (C) Change in colour



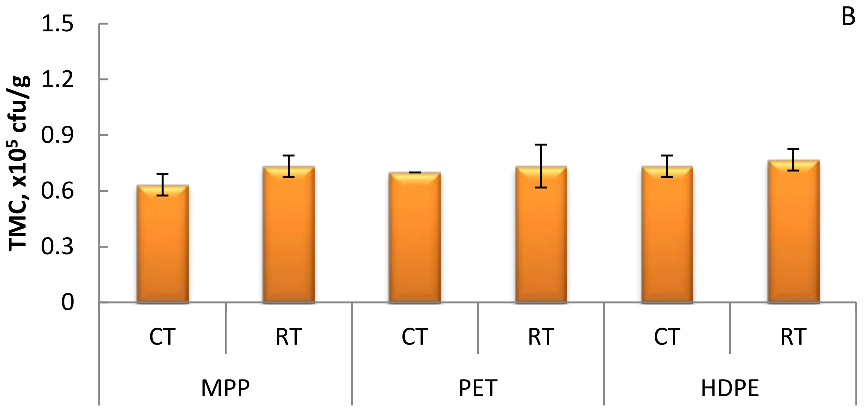


Fig. 4.11 Different physico-chemical parameters of ginger paste on 60th day of storage. (A) TBC (B) TMC

Table 4.1 a_w, TSS and TS values of ginger paste on 60th day of storage

Type of package	**Storage temp**	**Water activity**	**TSS, °Brix**	**TS, %**
HDPE	CT	0.803 ± 0.014^{b}	22.967 ± 1.358^{a}	29.610 ± 0.894^{a}
HDPE	RT	0.827 ± 0.010^{a}	$23.333 \pm 1.850^{a,c}$	29.404 ± 0.472^{a}
MPP	CT	$0.799 \pm 0.014^{b,c}$	24.200 ± 1.735^{c}	27.808±1.701
MPP	RT	0.819 ± 0.012^{a}	24.370 ± 0.600^{c}	29.109 ± 0.367^{a}
PET	CT	0.792 ± 0.016^{c}	23.133 ± 1.069^{a}	31.163 ± 1.228^{b}
PET	RT	$0.800 \pm 0.013^{b,c}$	21.933±0.611	30.669 ± 0.351^{b}

(The mean values with same superscripts are statistically not significantly different)

Table 4.2 pH, acidity and ΔE values of ginger paste on 60th day of storage

Type of package	Storage temp	pH	Acidity, %	ΔE
HDPE	CT	3.170±0.026^{a}	1.323±0.148^{a}	6.920±1.017^{a}
HDPE	RT	3.173±0.055^{a}	1.301±0.161^{a}	10.414±0.825^{b}
MPP	CT	3.203±0.023^{b}	1.088±0.064^{b}	5.920±1.040^{c}
MPP	RT	3.140±0.010^{c}	1.067±0.037^{b}	8.947±1.074
PET	CT	3.227±0.015^{b}	1.387±0.0978^{a}	6.294±0.818^{a,c}
PET	RT	3.160±0.052^{a,c}	1.322±0.037^{a}	10.081±1.582^{b}

(The mean values with same superscripts are statistically not significantly different)

Table 4.3 TBC and TMC values of ginger paste on 60th day of storage

Type of package	Storage Temp	TBC,x10^{5} cfu/g	TMC,x10^{5} cfu/g
HDPE	CT	2.667±0.577^{a}	0.733±0.058^{a}
HDPE	RT	3.000±0.000^{a,b}	0.767±0.058^{a}
MPP	CT	2.333±0.577^{a}	0.633±0.058
MPP	RT	3.000±1.000^{a,c}	0.733±0.058^{a}
PET	CT	2.667±0.577^{a}	0.700±0.000^{a}
PET	RT	3.333±0.577^{b,c}	0.733±0.12^{a}

(The mean values with same superscripts are statistically not significantly different)

Similarly, the PET samples in cold room showed higher total solids than any other type of package and temperature conditions (Fig. 4.9 C). The details of the statistical analysis (Annexure I) indicate that PET maintained higher total solids than the other packages though the temperature effect was insignificant. The change in effect due to package type and temperature interaction is given in Table 4.1. The maximum TS was observed for PET stored sample in cold room (31.163±1.228%). However there was no significant difference between the samples stored in PET jars in cold room and that in room temperature.

The pH values were not significantly affected by the type of package, but were affected by the temperature (Annexure I). The change in effect due to package type and temperature interaction is given in Table 4.2. The minimum pH value (3.140±0.01) was observed for MPP stored sample in room temperature. However, it was not significantly different from the samples stored in PET at room temperature.

The acidity values showed a different trend. The mean value of acidity of the paste stored in MPP was found out to be 1.077% which was 1.312% and 1.355% for HDPE and PET respectively (Fig. 4.10 (B); Annexure I). Also, the storage temperature has no significant influenced on acidity of the paste. The cold room stored ginger paste had a mean acidity value of 1.266% as compared to 1.230% for the room temperature stored paste. The highest acidity was observed for PET samples stored in cold room and it was not significantly different from the PET stored in room temperature and the HDPE samples in both room temperature and cold room conditions (Table 4.2).

The change in colour values for the type of package and storage conditions are given in Fig.10(C). As observed from the statistical analysis (Annexure I), it was observed that the type of packaging materials had no significant influence in change in colour, ΔE value. The mean value of ΔE of the paste stored in MPP was found out to be 7.433 which was 8.187 and 8.667 for PET and HDPE respectively. However, there was significant influence on the ΔE value by the temperature of storage. The mean ΔE value of the paste stored in cold temperature was 6.378 while for room temperature, it was 9.814. The change in effect of colour value due to package type and temperature interaction is given in Table 4.2. The minimum change in colour was observed in sample stored at MPP at cold room which had no significant difference from PET stored at cold room.

The total bacterial count (TBC) was not significantly affected by the type of package as well as storage on 60th day of storage (Annexure I). Fig. 4.11 (A) shows the TBC of the paste in different storage conditions on 60th day of storage. The change in effect due to package type and temperature interaction is given in Table 4.3. The minimum TBC value ($2.333 \pm 0.577 \times 10^5$ cfu/g) was observed for sample stored at MPP cold room temperature. However, it was not significantly different from all type of packaging material except PET at room temperature.

The total mould count (TMC) was not significantly affected by the type of package as well as storage temperature (Annexure I). The change in effect due to package type and temperature interaction is given in Table 4.3. The minimum TMC value ($0.633 \pm 0.058 \times 10^5$ cfu/g) was observed for MPP stored sample in cold room temperature (Table 4.3 and Fig. 4.11 (B)). TMC of the sample in MPP at cold room is different from other types of packaging material though all the samples are at acceptable limit.

4.1.2 Effect of storage conditions on quality on 90th day

The change in different quality parameters of the ginger paste as affected by the different packaging materials and temperature of storage are given in Fig. 4.12 and 4.14 after 90 days of storage. Plate.4.20 and Plate.4.21 show the samples in different packaging materials on 90th day of storage.

The statistical analysis of the observations (Annexure II) on water activity indicates that the type of package has no significant influence on water activity values. Fig. 4.12 (A) shows the TSS values of different packages at different storage condition on 90th day of storage. The mean values of water activity of the paste stored in MPP, PET and HDPE were found to be 0.767, 0.769 and 0.772 respectively. Also, the individual effects of the storage temperature were not significantly different. In general the cold room stored ginger paste had a mean water activity value of 0.774 as compared to 0.765 for the room temperature stored paste. The change in effect due to package type and temperature interaction is given in Table 4.4. The least water activity was observed for PET stored sample in cold temperature having a_w value as 0.763±0.012. However there was no significant difference between all the samples stored at different packages and at different storage conditions.

The type of packaging material influenced the TSS values as observed from statistical analysis (Annexure I). Fig.12 (B) shows the TSS on 90th day of storage for the different storage conditions. Though, there was no significant difference between the effect of HDPE and PET, paste stored in MPP was different. The mean value of TSS of the paste stored in MPP was found out to be 24.867^{0}B whereas that was 22.900 ^{0}B and 22.65 ^{0}B for HDPE and PET, respectively. However, the storage temperature did not significantly influence the TSS of the paste. The cold room stored ginger paste had a mean TSS value of 23.100^{0}B as compared to 23.84 ^{0}B for the room temperature stored paste. The change in effect due to package type and temperature interaction is given in Table 4.4. The maximum TSS was observed for MPP stored sample in room temperature (24.900±0.200^{0}B). However, there was no significant difference between MPP stored sample at room temperature and MPP sample stored in cold temperature.

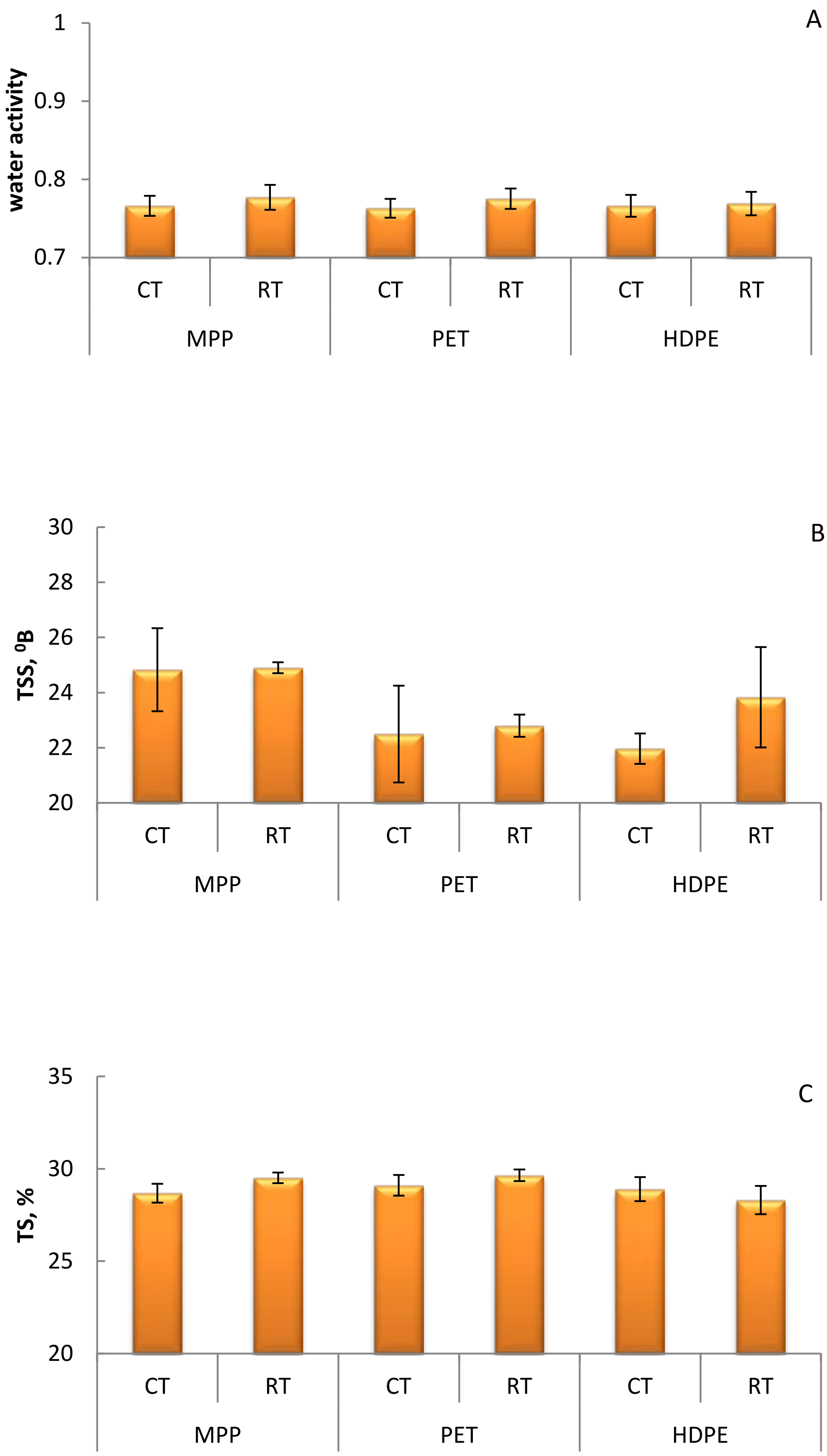


Fig. 4.12 Different physico-chemical parameters of ginger paste on 90th day of storage. (A) water activity; (B) Total soluble solids; (C) Total solids

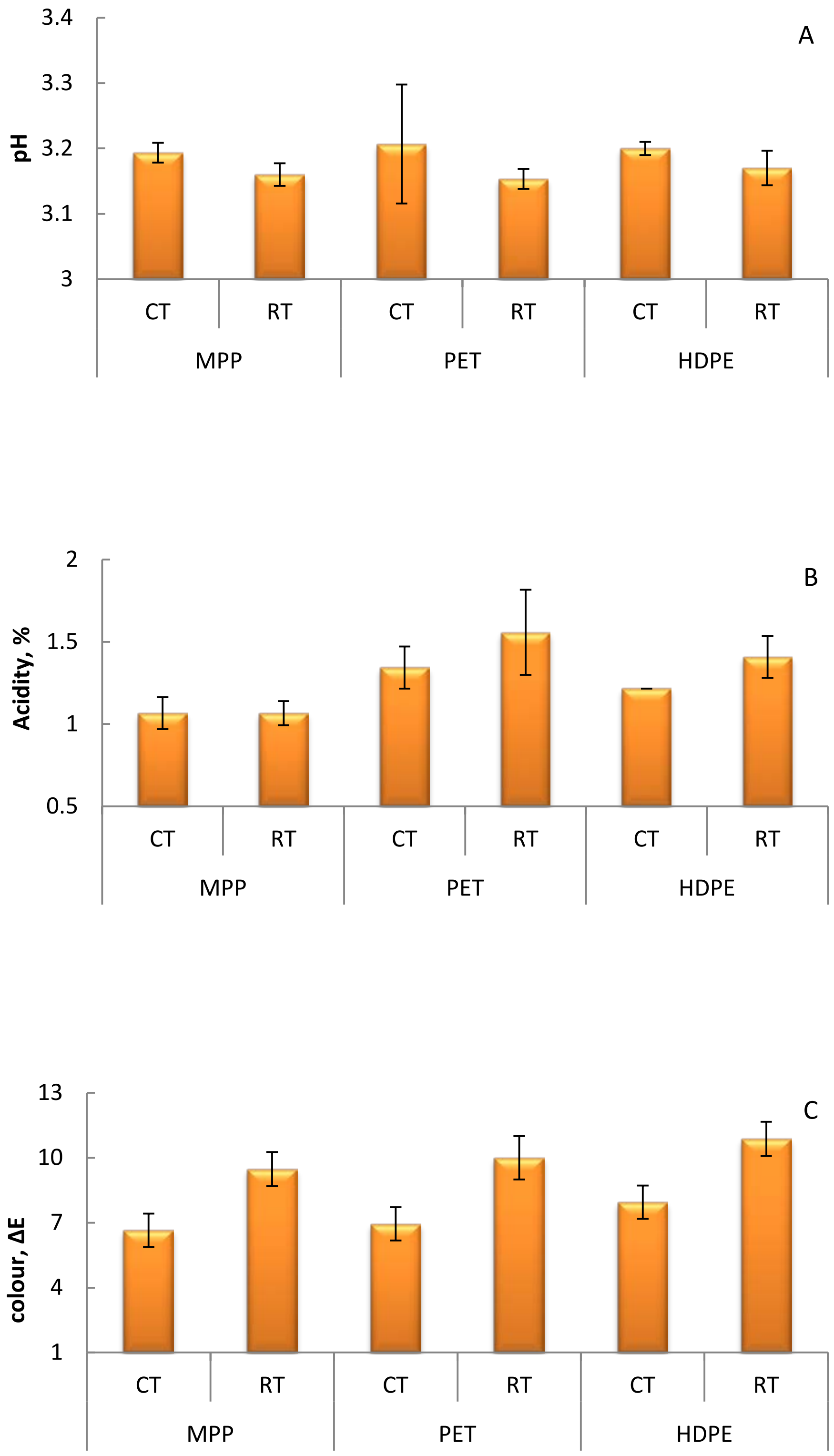


Fig. 4.13 Different physico-chemical parameters of ginger paste on 90th day of storage. (A) pH; (B) Acidity; (C) Change in colour

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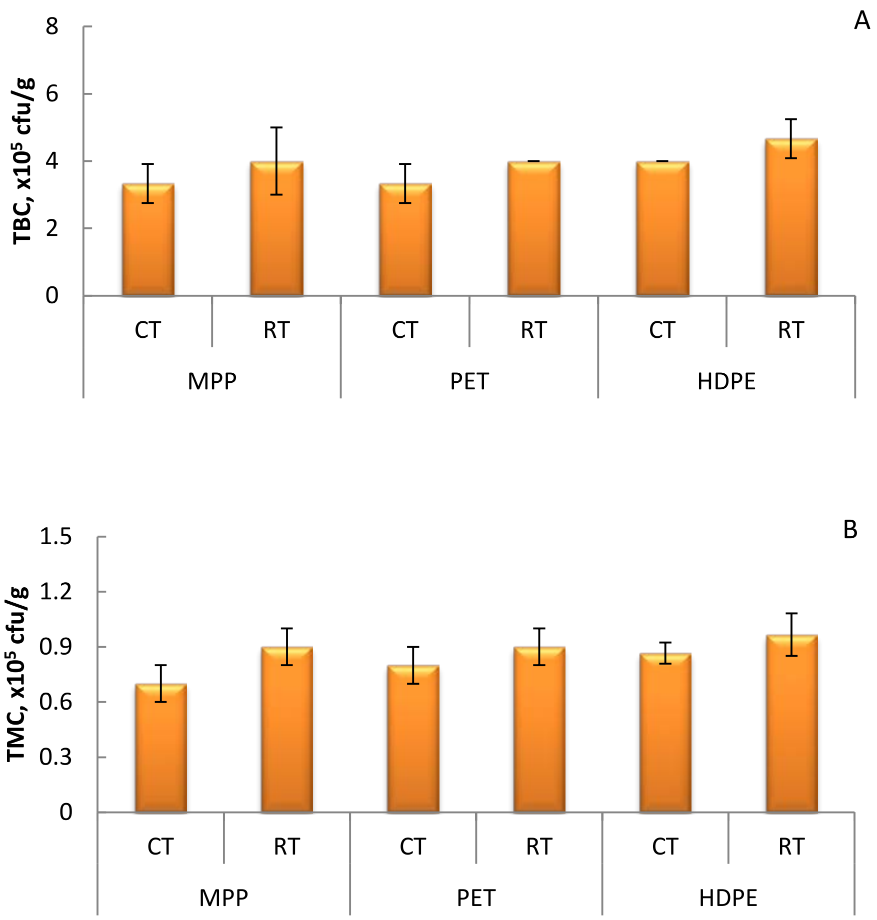

Fig. 4.14 Different physico-chemical parameters of ginger paste on 90th day of storage. (A) TBC (B) TMC

Table 4.4 a_w, TSS and TS values of ginger paste on 90th day of storage

Type of package	Storage Temp	Water activity	TSS, ^{0}Brix	TS, %
HDPE	CT	0.766 ± 0.014^{a}	21.967 ± 0.551^{a}	28.901 ± 0.648^{a}
HDPE	RT	0.769 ± 0.015^{a}	23.833 ± 1.823	28.308 ± 0.762^{b}
MPP	CT	0.766 ± 0.0136^{a}	24.833 ± 1.504^{b}	$28.675\pm0.513^{a,b}$
MPP	RT	0.777 ± 0.016^{a}	24.900 ± 0.200^{b}	29.521 ± 0.287^{c}
PET	CT	0.763 ± 0.012^{a}	22.500 ± 1.752^{a}	29.103 ± 0.559^{a}
PET	RT	0.775 ± 0.013^{a}	22.800 ± 0.400^{a}	29.655 ± 0.308^{c}

(The mean values with same superscripts are statistically not significantly different)

The paste in PET jars had maximum mean value of TS having 29.379%. As observed from the statistical analysis (Annexure II), there was no significant difference in the mean value of the paste between MPP and PET and between MPP and HDPE though there was significant difference between HDPE and PET. The mean value of TS of the paste was found out to be 28.605%, 29.098% and 29.379% for HDPE, MPP, PET respectively. But the storage temperature did not significantly influence the TS of the paste. The change in effect due to package type and temperature interaction is given in Table 4.4. The maximum TS was observed for PET stored sample in room temperature having 29.655±0.308 (Fig.4.12 C). However, there was no significant difference between the samples stored in PET jars at room temperature and sample stored at MPP at room temperature.

Table 4.5 pH, acidity and ∆E values of ginger paste on 120th day of storage

Type of package	Storage Temp	pH	Acidity, %	∆E
HDPE	CT	3.200±0.010^{a}	1.216±0.000	7.945±0.766
HDPE	RT	3.170±0.0265^{b}	1.408±0.128^{a}	10.876±0.790
MPP	CT	3.193±0.0153^{a,b}	1.067±0.097^{b}	6.649±0.766^{a}
MPP	RT	3.160±0.017^{b}	1.067±0.0739^{b}	9.476±0.791^{b}
PET	CT	3.207±0.091^{a}	1.344±0.128^{a}	6.949±0.766^{a}
PET	RT	3.153±0.015^{b}	1.557±0.259	10.000±1.000^{b}

(The mean values with same superscripts are statistically not significantly different)

Table 4.6 TBC and TMC values of ginger paste on 90th day of storage

Type of package	Storage Temp	TBC,x10^{5} cfu/g	TMC,x10^{5} cfu/g
HDPE	CT	4.000±0.000^{a}	0.867±0.058^{a}
HDPE	RT	4.667±0.577	0.967±0.115^{b}
MPP	CT	3.333±0.577^{b}	0.700±0.100
MPP	RT	4.000±1.000^{a}	0.900±0.100^{a,b}
PET	CT	3.333±0.577^{b}	0.800±0.100^{a}
PET	RT	4.000±0.000^{a}	0.900±0.100^{a,b}

(The mean values with same superscripts are statistically not significantly different)

The statistical analysis of the observations on pH (Annexure II & Table 4.5) indicated that the type of package did not have any significant influence on the change in pH value. Similarly, the effect of storage temperature was insignificant. In general the cold room stored ginger paste had a mean pH value of 3.2 as compared to 3.161

for the room temperature stored paste. As observed from Table 4.5**,** the minimum pH was observed for PET stored sample in room temperature (3.153±0.015), though there was no significant difference between the samples stored in MPP and HDPE in room condition and MPP stored sample in cold room.

Similarly, the maximum acidity was observed for PET stored sample in room temperature (1.557±0.259) (Table 4.5) and it was not significantly different from the HDPE samples stored at room temperature.

The difference in the colour of the samples was prominently observed. As observed from Fig. 13 (C) and the statistical analysis placed in Annexure II, in general the individual effect of the MPP was minimum though the PET was not significantly different from that. But the effect of storage temperature was considerable. Table 4.5 indicates that the minimum change in colour was for the MPP packages stored in cold room and though it was not significantly different from the PET in cold room condition.

On 90th day, the TBC was not significantly affected by the type of package, but was affected by the storage temperature (Annexure II). The change in effect due to package type and temperature interaction is given in Table 4.6. The minimum TBC value (3.333±0.577x10^5 cfu/g) was observed for MPP stored sample in cold room temperature. However, it was not significantly different from the samples stored in PET stored at cold temperature.

Similarly, the total mould count (TMC) was not significantly affected by the type of package, but was affected by the temperature (Annexure II). The change in effect due to package type and temperature interaction is given in Table 4.6. The minimum TMC value (0.700±0.100x10^5 cfu/g) was observed for MPP stored sample in cold room temperature. Fig.4.14 (A) and Fig. 4.14 (B) show the TBC and TMC of different packaging materials at different storage conditions.

4.1.3 Effect of storage conditions on quality on 120th day

The change in different quality parameters of the ginger paste as affected by the different packaging materials and temperature of storage are given in Fig. 4.15 and 4.17 after 120 days of storage. Plate 4.22 and Plate 4.23 show the samples at different packaging material on 120th day of storage.

The statistical analyses of the observations (Annexure III) indicate that the effect of type of package on water activity was not significantly different from each other. The mean values of water activity of the pastes stored in HDPE, MPP and PET was found out to be 0.738, 0.737, 0.740 respectively (Fig. 4.15 (A)). Also, the individual effects of storage temperature were insignificant. The cold room stored ginger paste had a mean water activity value of 0.736 as compared to 0.742 for the room temperature stored paste. It was observed that there was lower value of water activity for the sample stored in cold room than the sample at room temperature at the end of storage. As such the lower temperature reduces water activity. The change in effect due to package type and temperature interaction is given in Table 4.7. The least water activity was observed for PET stored sample in cold room having value 0.734±0.009. However, there was no significant difference between the samples stored in PET in cold room condition and all the other types of packages stored in different conditions except MPP stored in room temperature. In fact the MPP packages also showed lower water activity value than desired indicating that the sample could be stored safely in that condition.

The TSS of the samples were significantly affected by the type of packaging materials (Annexure III) at the end of the storage. Fig. 4.15 (B) shows the TSS values of paste taken from different packages at the end of storage. The statistical analysis indicated that the mean value of TSS of the paste stored in MPP was 25.300^{0}B whereas it was 24.417 ^{0}B and 23.683 ^{0}B for HDPE and PET, respectively; and the difference between MPP and HDPE as far as individual effects are concerned was insignificant. However, the variation in TSS due to individual effect of storage temperature was not significant. The interaction effects are shown in Table 4.7, where it is observed that the maximum TSS was observed for MPP stored sample in room temperature (25.433±1.201) which has no significant difference with sample stored at HDPE at room temperature (24.800±0.520) and MPP in cold room (25.167±0.850).

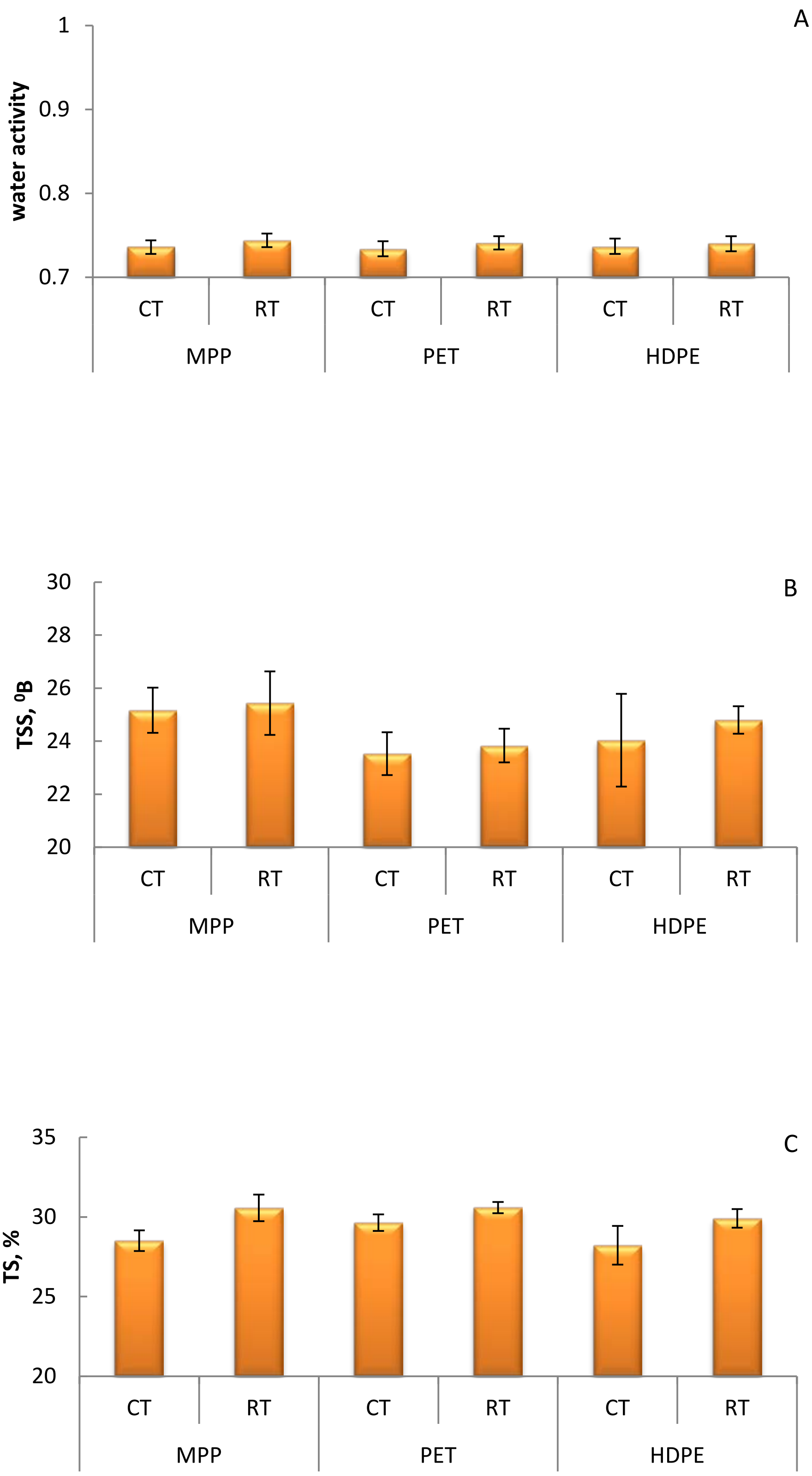

Fig. 4.15 Different physico-chemical parameters of ginger paste on 120th day of storage. (A) Water activity; (B) Total soluble solids; (C) Total solids

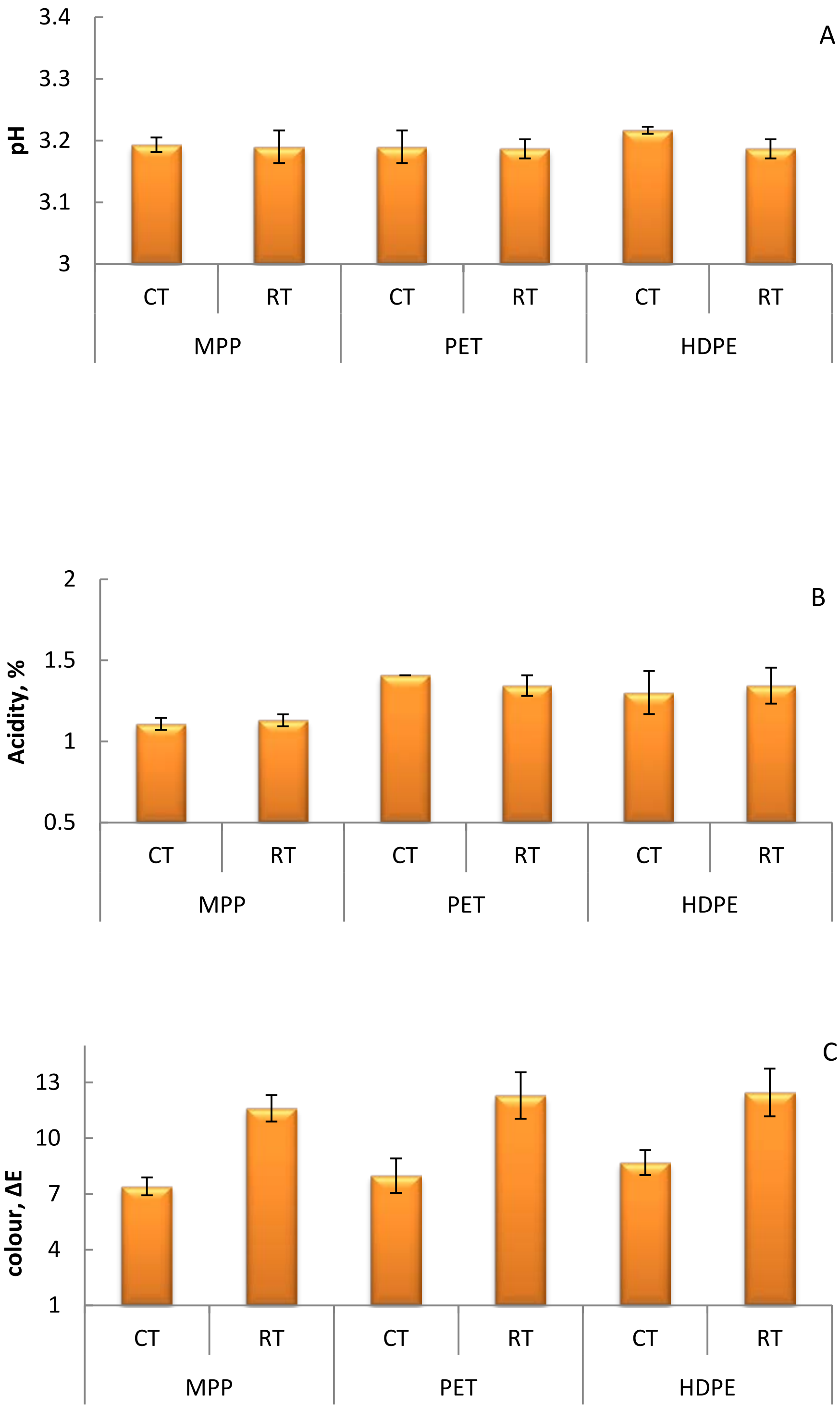

Fig. 4.16 Different physico-chemical parameters of ginger paste on 120th day of storage. (A) pH; (B) Acidity; (C) Change in colour

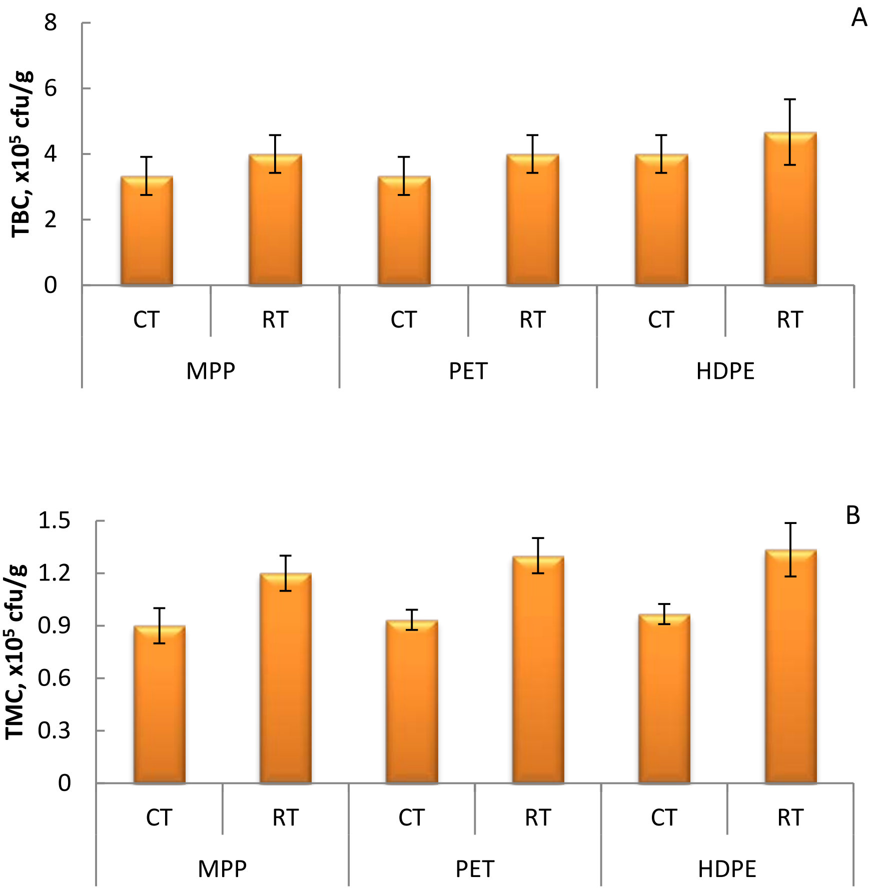

Fig. 4.17 Different physico-chemical parameters of ginger paste on 120th day of storage. (A) TBC (B) TMC

Similarly, the observation on total solids indicated that the paste in PET jars had maximum mean value of TS of 30.115%**.** However, this was not significantly different from the mean value of the paste stored in MPP. Similarly, the storage temperature also influenced on TS of the paste. The mean value of the paste stored in cold room was 28.79% whereas it was 30.355% for the sample stored at room temperature. The change in effect due to package type and temperature interaction is given in Table 4.7. The maximum TS was observed for PET stored sample in room temperature having mean value of 30.590±0.356%. This value was not significantly different from that of the samples stored in MPP at room temperature.

Neither the package type nor the storage temperature individually affected the pH values of the paste for 120 days of storage (Annexure III). The interaction affect also indicated that the HDPE samples in cold room condition had the maximum pH of 3.217±0.006, and the pastes in all other storage conditions were lower and not significantly different. The minimum pH was observed for PET and HDPE stored sample in room conditions (3.187±0.015) (Table 4.8). But the individual effect of the packaging material was significant on the acidity value (Annexure III), though the effect of temperature was not considerable. The change in effect due to package type and temperature interaction (Table 4.8) indicates that the maximum acidity was in PET stored sample in cold room (1.408±0.000).

Table 4.7 a_w, TSS and TS values of ginger paste on 120th day of storage

Type of package	Storage Temp	Water activity	TSS, ^{0}B	TS, %
HDPE	CT	0.737 ± 0.009^{a}	24.033 ± 1.747^{a}	28.221 ± 1.217^{a}
HDPE	RT	$0.740\pm0.009^{a,b}$	24.800 ± 0.520^{b}	29.912 ± 0.593^{b}
MPP	CT	0.736 ± 0.008^{a}	25.167 ± 0.850^{b}	28.508 ± 0.651^{a}
MPP	RT	0.744 ± 0.008^{b}	25.433 ± 1.201^{b}	30.565 ± 0.832^{c}
PET	CT	0.734 ± 0.009^{a}	23.533 ± 0.808^{a}	29.640 ± 0.517^{b}
PET	RT	$0.741\pm0.008^{a,b}$	23.833 ± 0.635^{a}	30.590 ± 0.356^{c}

(The mean values with same superscripts are statistically not significantly different)

Table 4.8 pH, acidity and ∆E values of ginger paste on 120th day of storage

Type of package	Storage Temp	pH	Acidity, %	∆E
HDPE	CT	3.217 ± 0.006	1.301 ± 0.133^{a}	8.698 ± 0.670
HDPE	RT	3.187 ± 0.015^{a}	1.344 ± 0.111^{a}	12.468 ± 1.288^{a}
MPP	CT	3.193 ± 0.011^{a}	1.109 ± 0.037^{b}	7.406 ± 0.484^{b}
MPP	RT	3.190 ± 0.026^{a}	1.131 ± 0.037^{b}	11.616 ± 0.709
PET	CT	3.190 ± 0.026^{a}	1.408 ± 0.000	7.984 ± 0.924^{b}
PET	RT	3.187 ± 0.015^{a}	1.344 ± 0.064^{a}	12.302 ± 1.243^{a}

(The mean values with same superscripts are statistically not significantly different)

Table 4.9 TBC and TMC values of ginger paste on 120th day of storage

Type of package	Storage Temp	TBC,x10^{5} cfu/g	TMC,x10^{5} cfu/g
HDPE	CT	5.333 ± 0.578^{a}	0.967 ± 0.058^{a}
HDPE	RT	7.000 ± 1.000	1.333 ± 0.153^{b}
MPP	CT	4.333 ± 0.578^{b}	0.900 ± 0.100^{a}
MPP	RT	5.333 ± 0.578^{a}	1.200 ± 0.100

PET	CT	4.667 ± 0.578^{b}	0.933 ± 0.058^{a}
PET	RT	5.667 ± 0.578^{a}	1.300 ± 0.100^{b}

(The mean values with same superscripts are statistically not significantly different)

The colour of the samples was not significantly affected by the change in packaging materials (Annexure III). The mean of ΔE of the paste stored in MPP was found out to be 9.510 whereas the values were 10.140 and 10.583 for PET and HDPE, respectively. However, there was significant influence on the ΔE value by the temperature of storage. The mean ΔE of the paste stored in cold room was 8.029 while for room temperature was 12.129. The change in effect of colour value ΔE due to package type and temperature interaction is given in Table 4.8. The minimum ΔE was observed in sample stored in MPP at cold room which was not significantly different than that stored in PET in cold room.

The total bacterial count (TBC) was significantly affected by the type of package as well as by the storage temperature (Annexure III) on 120 days of storage. The change in effect due to package type and temperature interaction is given in Table 4.9. The minimum TBC value ($4.333\pm0.578\times10^{5}$ cfu/g) was observed for MPP stored sample in cold room temperature. However, it was not significantly different from the samples stored in PET stored at cold temperature.

The total mould count (TMC) was not significantly affected by the type of package, but was affected by the temperature (Annexure III) on 120th day of storage. Table 4.9 indicates that the minimum TMC value ($0.900\pm0.100\times10^{5}$ cfu/g) was observed for MPP stored sample in cold room temperature. However, it was not significantly different from the samples stored in HDPE and PET stored at cold temperature.

Thus, we observed from the above analysis that the ginger paste can be stored for 4 months without challenge to the safety of the food. The physico-chemical parameters were not significantly affected by the storage conditions. But the colour, which is the most important parameter as regards to the acceptability of the paste, was significantly affected by the condition and duration of storage. It was observed that the colour degraded more for the samples stored at room temperature than the samples stored in cold room. It was observed that both TMC and TBC increased with the storage period. All the packaging materials and both storage temperatures could safely

Plate.4.18. 60th day storage of (A) PET (B) HDPE (C)MPP at room temperature

Plate.4.19. 60th day storage of (A) PET (B) HDPE (C)MPP at cold room.

Plate.4.20. 90th day storage of (A) PET (B) HDPE (C)MPP at room temperature

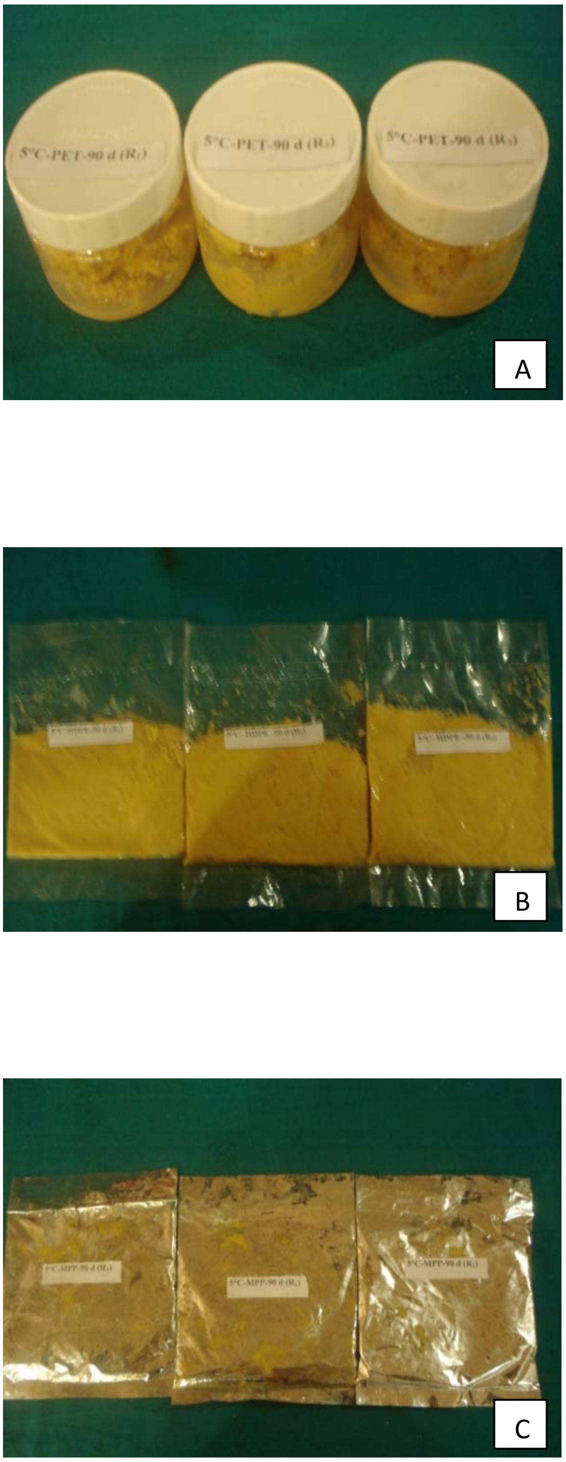

Plate.4.21. 90th day storage of (A) PET (B) HDPE (C)MPP at cold room.

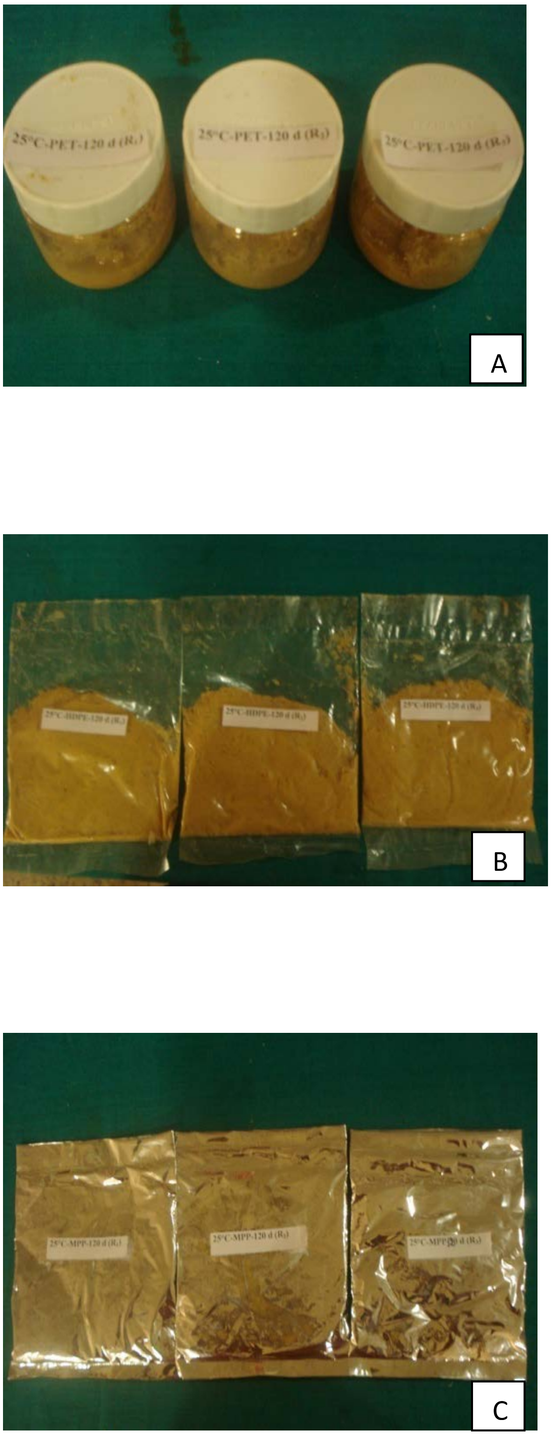

Plate.4.22. 120th day storage of (A) PET (B) HDPE (C)MPP at room temperature

Plate.4.23. 120th day storage of (A) PET (B) HDPE (C)MPP at cold room.

store the paste for 90 days from the bacterial count point of view, though as regards to mold count, only the samples stored in 5°C temperature were acceptable. The samples stored in different packages at 25°C were beyond the acceptable limit of mold count which is $1x10^5$. Similarly For the samples stored in MPP and PET at 5°C storage temperature were in acceptable condition up to 120 days of storage in view of safe bacterial load limit, but the mold count within all the packaging materials kept at 5°C were within acceptable limit.

Therefore, it is suggested that for storage of ginger paste, MPP or PET packages at cold room should be used. Previous studies have indicated higher shelf life of ginger paste in cold room conditions. But in those studies the paste was pasteurised at 80°C for 15 minutes. However, ginger is primarily valued for its flavour and pungency and Indian consumers normally would prefer ginger with pungency. Thus, in the present method, ginger was not pasterurised and it was observed that the unpasteurized paste prepared with added acidity could be stored up to 120 days without safety concerns.

4.2 Rheological behavior of ginger paste

As mentioned earlier, the rheological characteristics of the ginger paste were studied at 3 temperatures, viz. 30°, 45° and 60°C. The prepared ginger paste had the following characteristics: TSS-22.65±1.03^{0}B, TS-29.73±0.17%, pH-3.11±0.01.

Fig.4.2.1 shows the changes of shear stress with respect to shear rate. It indicates that some initial (yield) stress was required before the actual shear stress-shear rate behaviour was obtained. No significant changes were observed between the up (shear rate of 0–105 s^{-1}) and down curve (shear rate of 105-0 s^{-1}) and hence average values of the rheological parameters were considered. We also observed some abnormalities in shear stress data, which might have been due to the concentration of mass of ginger in a particular location in the beaker or the resistance by the fibres, which might have been present in the paste. Such abnormal data were sorted out from the observations while plotting the curves.

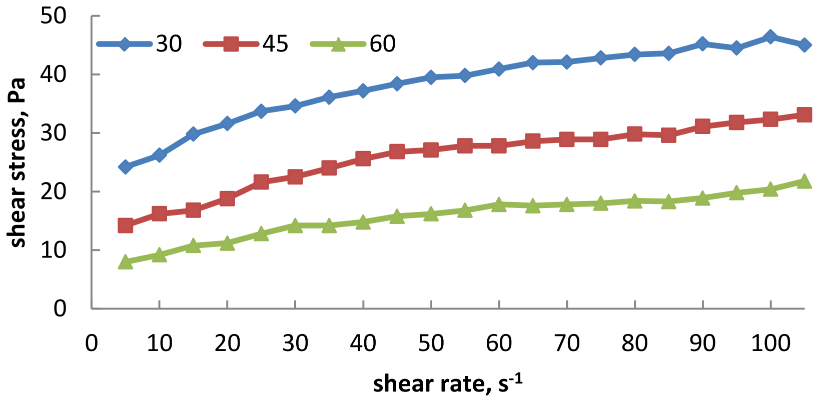

Fig.4.18 Rheogram of ginger paste at different temperatures

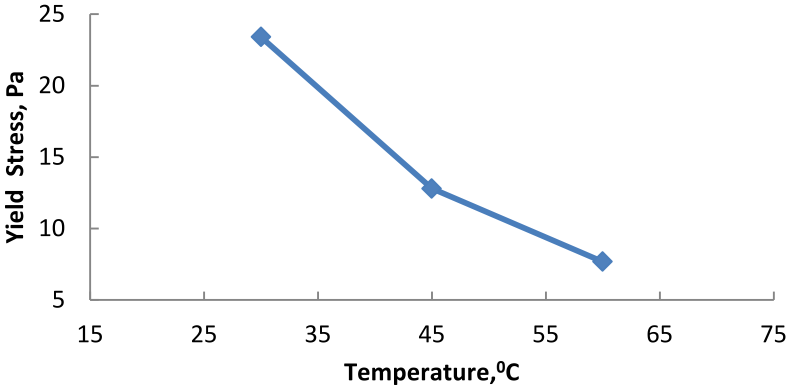

Fig.4.19 Effect of temperature on yield stress of ginger paste

The yield stress values as obtained from the Rheocalc 32 varied between 23.4 to 7.68 Pa within the temperature range of 30 to 60^{0}C. Yields stress data were also obtained from curve expert software by linear regression and were found to be almost at par with the observed values.

The yield values decreased with process temperature (Fig. 4.2.2). It is quite expected as at higher temperatures the food structure becomes weak and the yield stress would this decrease. It appears that the decrease is exponential in nature. We could not take more observations on the variation on the yield stress with respect to temperature, which would have helped to get a more definitive relationship between the yield stress and temperature. Yield stress is an important quality control parameter to process industries, particularly for comparing the overall characteristics of products made on different production lines. Moreover, a true value of the yield stress could be beneficial for the optimal design of food-processing systems such as those required during thermal processing (Steffe, 1992).

It was observed that shear stress-shear rate data fitted the Herschel Bulkley model adequately over the entire temperature range. The model is as follows.

$$\tau - \tau_0 = K(\gamma)^n \qquad (4.2.1)$$

where, τ is the shear stress, τ_0 is the yield stress and γ is the shear rate. K is the consistency coefficient and n the flow behavior index.

The different parameters as observed for the Herschel Bulkley model for the three temperature conditions is given in Table 4.2.

Table 4.10 Parameters for Herschel-Bulkley model

Temperature	Yield stress (Pa)	Consistency index, K ($Pa.s^n$)	Flow behavior index , n	R^2	SE
30^0C	23.4	1.321	0.619	0.9828	1.205
45^0C	12.8	1.131	0.623	0.984	1.09
60^0C	7.86	0.537	0.691	0.983	0.698

In all cases, R^2 values were more than 0.98 indicating that the shear stress and shear rate relationship could be explained by this model. The flow behaviour index of paste, n, increased with increase in temperature, and the paste behaved as a pseudoplastic fluid. Similar observations for various purees/pastes have been reported by various researchers (Ibarz et al., 1995; Ahmed et al., 1999; Ahmed 2004). At a particular shear rate (100 s^{-1}), we also changed the time of shear and observed that shear stress and apparent viscosity, at a constant shear rate were not sensitive to the time of shear and were almost constant. This implies that ginger paste exhibited time independent flow. Ahmed (2004) also found similar behaviour in the ginger paste.

Chapter 5

SUMMARY AND CONCLUSIONS

Major causes of spoilage of ginger are improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes, chemical reactions and structural changes during storage. The losses due to spoilage could be considerably reduced if it is properly stored and processed immediately after the harvest. Ginger paste is one of the products of ginger that can be stored for long periods without much alteration of the freshness of the material and can also be considered as a minimally processed food.

Generally, the quality of the paste deteriorates during storage as the type of packages and storage condition do not match. There are also degradation of colour, flavor and other parameters limiting the shelf life and use. Therefore, study of changes in physico-chemical properties such as pH, total soluble solid (TSS), total solid (%), acidity, water activity, colour, microbial load etc. as affected by the different storage conditions are important for deciding the effective shelf life of the paste and thus recommending a suitable packaging method to the entrepreneurs. Therefore, samples should be tested for the important factors that indicate and/or influence the shelf life.

In addition, the knowledge of the rheological characteristics and viscosity of fluids is also important in the design of flow processes, in quality control, in storage and processing stability.

Keeping above facts in view, the project was undertaken to study the change in physiochemical characteristics of ginger paste during storage and to estimate the shelf life in different environment and packaging conditions. The specific objectives were to study the change in quality parameters of ginger paste during storage and to study the rheological behaviour and its temperature dependence.

The ginger paste was prepared which using raw ginger (Cv. Suprabha), which corresponded to 5 months after planting. After washing in tap water, peeling and trimming was done after soaking it in luke warm water for few minutes. It was then sliced and blanched at 90^0C for 15 minutes. Blanched slices were then ground finely into puree using a commercial wet grinder. Paste is characterized as the product obtained after adding common salt and organic acid to the puree (Ahmed, 2004). The paste was prepared by adding 15% salt (w/w), 0.01% citric acid (w/w), 0.002% KMS (w/w) and 0.1% vinegar (w/w).

The parameters which were studied for quality analysis were pH, total soluble solid (TSS), total solid (%), acidity, water activity, colour, microbial load etc. In addition, rheological studies were carried out at different temperatures (30, 45, 60^0C). The observations were taken at 15 days interval and the whole study was carried out for 120 days. Quality analysis was done at 60^{th}, 90^{th} and 120^{th} day of storage.

The salient finding from the study are as below:

1. The initial water activity of the samples were found to be 0.873±0.001, which reduced to between 0.881±0.014 to 0.854±0.013 after 45 days of storage and to between 0.744±0.008 to 0.734±0.009 after 120 days of storage.
2. The TSS of ginger paste changed from the initial value of 22.65 ± 1.03^0B to a minimum of 21.63 ± 0.757^0B and a maximum of 25.433 ± 1.201^0B in different packaging conditions after 120 days of storage.
3. It was observed that the total solids almost remained constant during the storage period, which ranged from 28.221±1.217% to 30.590±0.356% for all the packaging material after 120 days of storage.
4. It was observed that the pH of the paste changed from the initial value of 3.11±0.01 to between 3.187±0.015 to 3.217±0.006 during the period of storage in different package conditions.
5. The initial value of the acidity was observed to be 1.126±0.057% which changed up to a minimum of 0.981±0.133% and maximum of 1.557±0.196% during the storage period.
6. It was observed that total bacterial load of the paste changed from the initial value of $1.333\pm0.25 \times10^5$ cfu/g to $7.0 \pm1.0 \times10^5$cfu/g in different packaging conditions. The TMC of the paste changed from the initial value of $0.33\pm0.0332 \times10^5$ cfu/g to $1.33\pm0.153 \times10^5$ cfu/g in different packaging conditions.

7. All the packaging materials and both storage temperatures could safely store the paste for 90 days from the bacterial count point of view, though as regards to mold count, only the samples stored in 5°C temperature were acceptable. The samples stored in different packages at 25°C were beyond the acceptable limit of mold count which is $1x10^5$. Similarly For the samples stored in MPP and PET at 5°C storage temperature were in acceptable condition up to 120 days of storage in view of safe bacterial load limit, but the mold count within all the packaging materials kept at 5°C were within acceptable limit.
8. The mean values of water activity of the pastes stored in HDPE, MPP and PET after 120 days of storage was found out to be 0.738, 0.737, 0.740 respectively. The least water activity was observed for PET stored sample in cold room having value 0.734±0.009. However, there was no significant difference between the samples stored in PET in cold room condition and all the other types of packages stored in different conditions except MPP stored in room temperature.
9. After 120 days of storage, the maximum TSS was observed for MPP stored sample at room temperature (25.433±1.201) which has no significant difference with sample stored in HDPE at room temperature (24.800±0.520) and MPP in cold room (25.167±0.850).
10. The maximum TS was observed for PET stored sample in room temperature having mean value of 30.590±0.356%. This value was not significantly different from that of the samples stored in MPP at room temperature.
11. The minimum pH was observed for PET and HDPE stored sample in room conditions (3.187±0.015). But the individual effect of the packaging material was significant on the acidity value, though the effect of temperature was not considerable. The change in effect due to package type and temperature interaction indicates that the maximum acidity was in PET stored sample in cold room (1.408).
12. The mean of ΔE of the paste stored in MPP was found out to be 9.510 whereas the values were 10.140 and 10.583 for PET and HDPE, respectively. However, there was significant influence on the ΔE value by the temperature of storage. The mean ΔE of the paste stored in cold room was 8.029 while for

room temperature was 12.129. The minimum ΔE was observed in sample stored in MPP at cold room which was not significantly different than that stored in PET in cold room.

13. The total bacterial count (TBC) was significantly affected by the type of package as well as by the storage temperature. The minimum TBC value ($4.333 \pm 0.578 \times 10^5$ cfu/g) was observed for MPP stored sample in cold room temperature. However, it was not significantly different from the samples stored in PET stored at cold temperature.
14. The minimum TMC value ($0.900 \pm 0.100 \times 10^5$ cfu/g) was observed for MPP stored sample in cold room temperature. However, it was not significantly different from the samples stored in HDPE and PET stored at cold temperature.
15. Thus the ginger paste can be stored for 4 months without challenge to its safety for consumption. The physico-chemical parameters were not significantly affected by the storage conditions. But the colour, which is the most important parameter as regards to the acceptability of the paste, was significantly affected by the condition and duration of storage. It was observed that the colour degraded more for the samples stored at room temperature than the samples stored in cold room. All the packaging materials and both storage temperatures could safely store the paste for 90 days from the bacterial count point of view, though as regards to mold count, only the samples stored in cold room temperature were acceptable. The samples stored in different packages in room temperature were beyond the acceptable limit of mold count which is 1×10^5. Similarly For the samples stored in MPP and PET at room temperature were in acceptable condition up to 120 days of storage in view of safe bacterial load limit, but the mold count within all the packaging materials kept in cold room were within acceptable limit.
16. The rheological characteristics of the ginger paste were studied at 3 temperatures, viz. 30°, 45° and 60°C.
17. An initial (yield) stress was required before the actual shear stress-shear rate behaviour for the ginger paste was obtained. No significant changes were observed between the up (shear rate of 0–105 s^{-1}) and down curve (shear rate

of 105-0 s^{-1}) and hence average values of the rheological parameters were considered.

18. The yield stress values as obtained from the Rheocalc 32 varied between 23.4 to 7.68 Pa within the temperature range of 30 to 60^0C.
19. The yield values decreased with process temperature. The decrease was exponential in nature.
20. The shear stress-shear rate data fitted the Herschel Bulkley model adequately over the entire temperature range. In all cases, R^2 values were more than 0.98 indicating that the shear stress and shear rate relationship could be explained by this model. The flow behaviour index of paste, n, increased with increase in temperature, and the paste behaved as a pseudoplastic fluid.

Chapter 6

SUGGESTIONS FOR FUTURE WORK

The present study provided an insight into the storage characteristics of the ginger paste and the suitability of the different types of packaging materials for storage of ginger paste. In view of the experience in the study, the following are suggested for future research work.

1) As the ginger paste is valued more for its flavour, further analysis on the retention of the gingerol and shagaol contant of the ginger paste during storage may be investigated.
2) More types of packaging materials including laminations may be tested for the storage of ginger paste.
3) The rheological behaviour of the paste may be studied at different paste concentrations and temperatures so as to get a definitive relationship between the paste behaviour with the change in concentration and the processing temperature.
4) Further analysis of the type of organisms in the paste may be conducted.

BIBLIOGRAPHY

Ahmed J (2004) Effects of temperature on rheological characteristics of ginger paste. Emir. J. Agric. Sc. 16(1): 43-49

Ahmed J (2004) Rheological behaviour and colour changes of ginger paste during storage. International Journal of Food Science and Technology 39: 325–330

Ahmed J and Shivhare US (2001) Thermal Kinetics of Color Change, Rheology, and Storage Characteristics of Garlic Puree/Paste. Journal of Food Science 66(5): 754-757

Ahmed J, Ramaswamy HS and Sashidhar KC (2007) Rheological characteristics of tamarind (Tamarindus indica L.) juice concentrates. LWT (40) : 225–231

Ahmed J, Shivhare US and Singh P (2004) Colour kinetics and rheology of coriander leaf puree and storage characteristics of the paste. Food Chemistry 84 : 605–611

Anonymous (1995) Microbiological reference criteria for food, Food Administration Manual S. 11: Microbiological Criteria Version 2.0 October 1995

Baranowski JD (1985). Storage Stability of a Processed Ginger Paste. Journal of Food Science 50: 932-933

Barosa-Canovas GV, Kokini JL, Ma L, & Ibarz A. (1996). The rheology of semi-liquid foods. Advances in Food and Nutrition Research 39: 1–69.

Batista AP, Raymundo A, Sousa I, and Empis J. (2006). Rheological characterization of coloured oilin-water food emulsions with lutein and phycocyanin added to the oil and aqueous phases. Food Hydrocolloids 20**:** 44–52.

Conceição MC, Fernandes TN, Prado MET and Resende JV (2012) Effect of sucrose and pectin addition on physical, chemical, thermal and rheological properties of frozen/thawed pineapple pulps. Korea-Australia Rheology Journal 24(3): 229-239

Dak M, Verma RC and Jaaffrey SNA (2007) Effect of temperature and concentration on Rheological properties of ‘‘Kesar’’ mango juice. Journal of Food Engineering 80 :1011–1015

Dak M, Verma RC and Sharma GP (2006) Flow characteristics of juice of ‘‘Totapuri’’ mangoes. Journal of Food Engineering 76 : 557–561

Farrell, K.T. (1999). Spices, Condiments, and Seasonings. 2nd Ed. Springer. New York.

Garcia P, Brenes M, Romero C & Garrido A. (1999). Color and texture of acidified ripe olives in pouches. Journal of Food Science 64: 218–251

Gilbert RJ, Louvois J de, Donovan T, Little C, Nye K, Ribeiro CD, Richards J, Roberts D and Bolton FJ (2000) Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. Communicable Disease and Public Health 3 (3):163-167

Giridhar N, Satyanarayana A. and Joshi GJ. (1996). Studies on preparation and Storage of ginger- garlic paste. Indian Food Packer 3:13–21.

Govindarajan VS. (1982) Ginger-chemistry, technology and quality evaluation: Part 2. CRC Critical Reviews in Food Science and Nutrition 17:189–258.

Igual M , Contreras C and Martinez-Navarrete N (2010). Non-conventional techniques to obtain grapefruit jam. Innovative Food Science and Emerging Technologies 11: 335–341

Ikhu-Omoregbe D and Bushi GM (2008) Rheological characteristics of South African commercial sauces. International Journal of Food Science and Technology 43: 2230–2236

Izidoro DR , Scheer AdeP and Sierakowski MR (2009). Rheological Properties of Emulsions Stabilized by Green Banana (Musa cavendishii) Pulp Fitted by Power Law Model. Brazilian Archives of Biology and Technology 52 (6): 1541-1553

Kajuna STAR, Bilanski WK, Mittal GS. (1998). Color changes in bananas and plantains during storage. J. Food Proc. Preserv 22:27-40.

Keshani S. Chuah AL and Russly AR (2012). Effect of temperature and concentration on rheological properties pomelo juice concentrates. International Food Research Journal 19 (2): 553-562

Lukes TM. 1986. Factors governing the greening of garlic paste. J. Food Sci. 51:1577-1582.

Maceiras R, Alvarez E and Cancela MA (2006) Rheological properties of fruit purees: Effect of cooking. Chemical Engineering Department, ETSEI, University of Vigo, 36200 Vigo, Spain

Molwane SD and Gunjal BB (1985) Viscometric characteristics of cold-break and hot-break extracted tomato juice concentrates. Journal of Food Science and Technology 22:353–357.

Molwane SD, & Gunjal BB (1985). Viscometric characteristics of cold-break and hot-break extracted tomato juice concentrates. Journal of Food Science and Technology 22: 353–357.

Osuntogun B and Aboaba OO (2004) Pakistan Journal of Nutrition. Microbiological and Physico-chemical evaluation of some non-alcoholic beverages 3 (3): 188-192

Peressini D, Sensidoni A, Ciondio B. (1998). Rheological characterization of traditional and light mayonnaises. Journal of Food Engineering 35**:** 409-417.

Pezzutti A & Crapiste GH. (1997). Sorptional equilibrium and drying characteristics of garlic. Journal of Food Engineering 31: 113–123.

Pimm A (1994) Ingredient hygiene and safety: Quality management systems. In Handbook of Industrial Seasoning, (E.W. Underriner and I.R. Hume eds.) pp. 119–150, Blackie Academic & Professional, Glasgow,U.K.

Plotto A. (2002) Ginger: Post-Production Management for Improved Market Access (http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Ginger.pdf)

Ranganna (2002) Handbook of analysis and quality control for fruits and vegetable products. Wiley Easter

Rao MA.and Steffe JF. (1992). Viscoelastic properties of foods. NY, USA: Elsevier Applied Science.

Rejano LAH, Sanchez A de Castro, Montano A (1997). Chemical characteristics and storage stability of pickled garlic prepared using different processes. J. Food. Sci. 62:1120-1123.

Rizvi SSH and Mittal GS (1997). Experimental methods in food engineering. New Delhi: CBS Publisher and Distributors, pp. 35– 51.

Rizvi SSH. and Mittal GS (1997). Experimental methods in food engineering. New Delhi: CBS Publisher and Distributors, pp. 35– 51.

Sanchez MC, Valencia C, Ciruelos A, Latorre A and Gallegos C (2003) Rheological Properties of Tomato Paste: Influence of the Addition of Tomato Slurry. Food Engineering and Physical Properties.

Steffe, J. (2012) Rheological method in food process engineering,second edition, Michigan state University

Thanuja WJ (2006). Export Performance and Competitiveness Of Ginger From India. MBA thesis submitted to Dept. of Agricultural marketing, Co-operation and Agribusiness Management College of Agriculture, University of Agricultural Sciences, Dharwad.

Toledo, RT and Brody A L (2000). Food Science, Technology, and Engineering, Overview for Food Product Development

Topno PN, Vinothini, Jayaprakash SH, Varadaiah V, Sheshagiri SH, Srinivas PM and Naidu MM (2001). Ginger–garlic paste in retort pouches and its quality. Journal of Food Process Engineering 66 (5): 1-8

Valenzuela H. Farm and Forestry Production and Marketing Profile of Ginger (gingiber offficinale) (http://www.agroforestry.net/scps/Ginger_specialty_crop.pdf)

Vijayalakshmi NS, Sathish HS and Ranagarao GCP (2003). Physico-Chemical studies on indigenous aluminium foil based retort pouches vis-à-vis their suitability for thermal processing. Pop. Plast. Pack. 7: 71–74.

Wang WM., Siddiq M., Sinha NK. and Cash JN (1995). Effect of processing conditions on the physicochemical and sensory characteristics of Stanley plum paste. J. Food Proc. Preser 19: 65–81.

www. accessnewage.com/articles/health/ginger1.html

www. pathogencombat.wur.nl/FSCS/Intervention Processes Design/ Intervention Equipment/ General/ ScientificLiterature/ Shared%20 Documents/preservation. pdf Chapter 3, Microbial Aspects of preservation

www.aqualab.com/education/measurement-of-water-activity-for- product-quality

www.class.fst.ohio-state.edu/fst605/Laboratories/Lab%201_Water%20Activity.pdf

www.farmerbrands.in/pdf/Ginger%20Paste.pdf

www.foodsafety.govt.nz/elibrary/industry/guide_calculatingcontains_background.pdf

www.nhb.gov.in

www.nogreaterjoy.org/wordpress/f/Ginger.pdf

Annexure-I

Statistical analysis of the data with SAS 9.3 for 60 days

Observed Data

Obs	Rep	Pack	Temp	a_w	TSS	TS	pH	Acidity	Colour	TBC	TMC
1	1	MPP	CT	0.830	23.30	25.8665	3.23	1.024	4.8795	2	0.6
2	1	MPP	RT	0.810	24.97	29.4179	3.14	1.088	9.0280	3	0.7
3	1	PET	CT	0.811	21.90	32.5769	3.24	1.408	6.3743	2	0.7
4	1	PET	RT	0.807	21.40	30.2646	3.19	1.344	8.4991	3	0.6
5	1	HDPE	CT	0.839	22.80	30.6373	3.20	1.152	5.9032	2	0.7
6	1	HDPE	RT	0.818	24.30	29.1268	3.11	1.472	9.5890	3	0.7
7	2	MPP	CT	0.822	23.10	28.5221	3.19	1.152	5.9198	2	0.6
8	2	MPP	RT	0.803	24.37	28.7035	3.15	1.024	9.9780	4	0.8
9	2	PET	CT	0.803	23.80	30.5384	3.23	1.472	7.0685	3	0.7
10	2	PET	RT	0.794	22.60	30.8987	3.10	1.344	10.0808	3	0.8
11	2	HDPE	CT	0.821	24.40	29.1839	3.15	1.408	6.9197	3	0.7
12	2	HDPE	RT	0.800	24.50	29.9495	3.20	1.152	10.4144	3	0.8
13	3	MPP	CT	0.806	26.20	29.0355	3.19	1.088	6.9601	3	0.7
14	3	MPP	RT	0.783	23.77	29.2044	3.13	1.088	7.8347	2	0.7
15	3	PET	CT	0.785	23.70	30.3728	3.21	1.280	5.4387	3	0.7
16	3	PET	RT	0.775	21.80	30.8429	3.19	1.280	11.6626	4	0.8
17	3	HDPE	CT	0.822	21.70	29.0085	3.16	1.408	7.9362	3	0.8
18	3	HDPE	RT	0.791	21.20	29.1359	3.21	1.280	11.2397	3	0.8

Water activity on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00278733	0.00055747	3.12	0.0495
Error	12	0.00214667	0.00017889		
Corrected Total	17	0.00493400			

R-Square	Coeff Var	Root MSE	Value Mean
0.564924	1.658050	0.013375	0.806667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.00117033	0.00058517	3.27	0.0735
Temp	1	0.00138689	0.00138689	7.75	0.0165
Pack*Temp	2	0.00023011	0.00011506	0.64	0.5428

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000179
Critical Value of t	2.17881
Least Significant Difference	0.0168

Means with the same letter are not significantly different.

t Grouping		Mean	N	Pack
	A	0.815167	6	HDPE
	A			
B	A	0.809000	6	MPP
B				
B		0.795833	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000179
Critical Value of t	2.17881
Least Significant Difference	0.0137

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	0.815444	9	CT
B	0.797889	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	0.82733333	0.01011599

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**RT**	**3**	0.80300000	0.01374773
MPP	**CT**	**3**	0.81933333	0.01222020
MPP	**RT**	**3**	0.79866667	0.01401190
PET	**CT**	**3**	0.79966667	0.01331666
PET	**RT**	**3**	0.79200000	0.01609348

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.82733333	1
HDPE	**RT**	0.80300000	2
MPP	**CT**	0.81933333	3
MPP	**RT**	0.79866667	4
PET	**CT**	0.79966667	5
PET	**RT**	0.79200000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.2933	0.9738	0.1642	0.1888	0.0614
2	0.2933		0.6732	0.9984	0.9995	0.9068
3	0.9738	0.6732		0.4503	0.4996	0.1976
4	0.1642	0.9984	0.4503		1.0000	0.9881
5	0.1888	0.9995	0.4996	1.0000		0.9781
6	0.0614	0.9068	0.1976	0.9881	0.9781	

TSS on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11.87869444	2.37573889	1.40	0.2908
Error	12	20.30666667	1.69222222		
Corrected Total	17	32.18536111			

R-Square	Coeff Var	Root MSE	Value Mean
0.369071	5.577614	1.300854	23.32278

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	9.47367778	4.73683889	2.80	0.1005
Temp	1	0.22000556	0.22000556	0.13	0.7247
Pack*Temp	2	2.18501111	1.09250556	0.65	0.5416

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.692222
Critical Value of t	2.17881
Least Significant Difference	1.6364

Means with the same letter are not significantly different.

t Grouping		Mean	N	Pack
	A	24.2850	6	MPP
	A			
B	A	23.1500	6	HDPE
B				
B		22.5333	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.692222
Critical Value of t	2.17881
Least Significant Difference	1.3361

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	23.4333	9	CT
A			
A	23.2122	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	22.9666667	1.35769412
HDPE	**RT**	**3**	23.3333333	1.85022521
MPP	**CT**	**3**	24.2000000	1.73493516
MPP	**RT**	**3**	24.3700000	0.60000000
PET	**CT**	**3**	23.1333333	1.06926766
PET	**RT**	**3**	21.9333333	0.61101009

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	22.9666667	1
HDPE	**RT**	23.3333333	2
MPP	**CT**	24.2000000	3
MPP	**RT**	24.3700000	4
PET	**CT**	23.1333333	5
PET	**RT**	21.9333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9992	0.8464	0.7689	1.0000	0.9181
2	0.9992		0.9589	0.9171	1.0000	0.7706
3	0.8464	0.9589		1.0000	0.9078	0.3330
4	0.7689	0.9171	1.0000		0.8450	0.2676
5	1.0000	1.0000	0.9078	0.8450		0.8600
6	0.9181	0.7706	0.3330	0.2676	0.8600	

Total solids on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	21.21265523	4.24253105	4.48	0.0155
Error	12	11.36042637	0.94670220		
Corrected Total	17	32.57308160			

R-Square	Coeff Var	Root MSE	Value Mean
0.651233	3.284120	0.972986	29.62700

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	18.24589344	9.12294672	9.64	0.0032
Temp	1	0.18046168	0.18046168	0.19	0.6702
Pack*Temp	2	2.78630011	1.39315006	1.47	0.2682

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.946702
Critical Value of t	2.17881
Least Significant Difference	1.224

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	30.9157	6	PET
B	29.5070	6	HDPE
B			
B	28.4583	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.946702
Critical Value of t	2.17881
Least Significant Difference	0.9994

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	29.7271	9	RT
A			
A	29.5269	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	29.6098972	0.89410272
HDPE	**RT**	**3**	29.4040616	0.47240576
MPP	**CT**	**3**	27.8080365	1.70089137
MPP	**RT**	**3**	29.1086034	0.36668651
PET	**CT**	**3**	31.1626875	1.22754374
PET	**RT**	**3**	30.6687253	0.35110141

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	29.6098972	1
HDPE	**RT**	29.4040616	2
MPP	**CT**	27.8080365	3
MPP	**RT**	29.1086034	4
PET	**CT**	31.1626875	5
PET	**RT**	30.6687253	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9998	0.2775	0.9863	0.4182	0.7629
2	0.9998		0.3911	0.9988	0.2992	0.6181
3	0.2775	0.3911		0.5921	0.0117	0.0333
4	0.9863	0.9988	0.5921		0.1744	0.4135
5	0.4182	0.2992	0.0117	0.1744		0.9871
6	0.7629	0.6181	0.0333	0.4135	0.9871	

pH on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.01457778	0.00291556	2.40	0.0155
Error	12	0.01460000	0.00121667		
Corrected Total	17	0.02917778			

R-Square	**Coeff Var**	**Root MSE**	**Value Mean**
0.499619	1.097262	0.034881	3.178889

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Pack	2	0.00187778	0.00093889	0.77	0.4839
Temp	1	0.00802222	0.00802222	6.59	0.0246
Pack*Temp	2	0.00467778	0.00233889	1.92	0.1887

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.001217
Critical Value of t	2.17881
Least Significant Difference	0.0439

Means with the same letter
are not significantly different.

t Grouping	**Mean**	**N**	**Pack**
A	3.19333	6	PET
A			
A	3.17167	6	MPP
A			
A	3.17167	6	HDPE

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.001217
Critical Value of t	2.17881
Least Significant Difference	0.0358

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	3.20000	9	CT
B	3.15778	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	CT	3	3.17000000	0.02645751
HDPE	RT	3	3.17333333	0.05507571
MPP	CT	3	3.20333333	0.02309401
MPP	RT	3	3.14000000	0.01000000
PET	CT	3	3.22666667	0.01527525
PET	RT	3	3.16000000	0.05196152

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	3.17000000	1
HDPE	RT	3.17333333	2
MPP	CT	3.20333333	3
MPP	RT	3.14000000	4
PET	CT	3.22666667	5
PET	RT	3.16000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		1.0000	0.8423	0.8904	0.4006	0.9991
2	1.0000		0.8904	0.8423	0.4607	0.9965
3	0.8423	0.8904		0.2951	0.9582	0.6585
4	0.8904	0.8423	0.2951		0.0844	0.9781
5	0.4006	0.4607	0.9582	0.0844		0.2505
6	0.9991	0.9965	0.6585	0.9781	0.2505	

Acidity on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.27511467	0.05502293	5.14	0.0094
Error	12	0.12834133	0.01069511		
Corrected Total	17	0.40345600			

R-Square	Coeff Var	Root MSE	Value Mean
0.681895	8.286632	0.103417	1.248000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.26760533	0.13380267	12.51	0.0012
Temp	1	0.00568889	0.00568889	0.53	0.4798
Pack*Temp	2	0.00182044	0.00091022	0.09	0.9190

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.010695
Critical Value of t	2.17881
Least Significant Difference	0.1301

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	1.35467	6	PET
A			
A	1.31200	6	HDPE
B	1.07733	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12

Error Mean Square	0.010695
Critical Value of t	2.17881
Least Significant Difference	0.1062

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	1.26578	9	CT
A			
A	1.23022	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	CT	3	1.32266667	0.14780167
HDPE	RT	3	1.30133333	0.16106313
MPP	CT	3	1.08800000	0.06400000
MPP	RT	3	1.06666667	0.03695042
PET	CT	3	1.38666667	0.09776161
PET	RT	3	1.32266667	0.03695042

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	1.32266667	1
HDPE	RT	1.30133333	2
MPP	CT	1.08800000	3
MPP	RT	1.06666667	4
PET	CT	1.38666667	5
PET	RT	1.32266667	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9998	0.1291	0.0860	0.9697	1.0000
2	0.9998		0.1908	0.1291	0.9057	0.9998
3	0.1291	0.1908		0.9998	0.0371	0.1291
4	0.0860	0.1291	0.9998		0.0242	0.0860
5	0.9697	0.9057	0.0371	0.0242		0.9697

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
6	1.0000	0.9998	0.1291	0.0860	0.9697	

Colour on 60th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	58.21715048	11.64343010	9.81	0.0006
Error	12	14.24209593	1.18684133		
Corrected Total	17	72.45924641			

R-Square	Coeff Var	Root MSE	Value Mean
0.803447	13.45644	1.089422	8.095917

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	4.64113846	2.32056923	1.96	0.1841
Temp	1	53.13530093	53.13530093	44.77	<.0001
Pack*Temp	2	0.44071108	0.22035554	0.19	0.8329

The GLM Procedure
t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.186841
Critical Value of t	2.17881
Least Significant Difference	1.3704

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	8.6670	6	HDPE
A			
A	8.1873	6	PET
A			
A	7.4334	6	MPP

The GLM Procedure

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.186841
Critical Value of t	2.17881
Least Significant Difference	1.1189

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	9.8140	9	RT
B	6.3778	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	6.9197206	1.01652032
HDPE	**RT**	**3**	10.4143609	0.82534496
MPP	**CT**	**3**	5.9197950	1.04030356
MPP	**RT**	**3**	8.9469263	1.07394795
PET	**CT**	**3**	6.2938533	0.81790366
PET	**RT**	**3**	10.0808451	1.58176421

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	6.9197206	1
HDPE	**RT**	10.4143609	2
MPP	**CT**	5.9197950	3
MPP	**RT**	8.9469263	4
PET	**CT**	6.2938533	5
PET	**RT**	10.0808451	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.0191	0.8624	0.2733	0.9779	0.0360
2	0.0191		0.0030	0.5849	0.0059	0.9988
3	0.8624	0.0030		0.0464	0.9979	0.0055
4	0.2733	0.5849	0.0464		0.0932	0.7927
5	0.9779	0.0059	0.9979	0.0932		0.0110
6	0.0360	0.9988	0.0055	0.7927	0.0110	

Total bacteria count on 60th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.83333333	0.36666667	0.94	0.4882
Error	12	4.66666667	0.38888889		
Corrected Total	17	6.50000000			

R-Square	Coeff Var	Root MSE	Value Mean
0.282051	22.00975	0.623610	2.833333

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.33333333	0.16666667	0.43	0.6610
Temp	1	1.38888889	1.38888889	3.57	0.0832
Pack*Temp	2	0.11111111	0.05555556	0.14	0.8683

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.388889
Critical Value of t	2.17881
Least Significant Difference	0.7845

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Pack**
A	3.0000	6	PET
A			
A	2.8333	6	HDPE
A			
A	2.6667	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.388889
Critical Value of t	2.17881
Least Significant Difference	0.6405

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Temp**
A	3.1111	9	RT
A			
A	2.5556	9	CT

Level of Pack	**Level of Temp**	**N**	**Value**	
			Mean	**Std Dev**
HDPE	**CT**	**3**	2.66666667	0.57735027
HDPE	**RT**	**3**	3.00000000	0.00000000
MPP	**CT**	**3**	2.33333333	0.57735027
MPP	**RT**	**3**	3.00000000	1.00000000
PET	**CT**	**3**	2.66666667	0.57735027
PET	**RT**	**3**	3.33333333	0.57735027

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	**Temp**	**Value LSMEAN**	**LSMEAN Number**
HDPE	**CT**	2.66666667	1
HDPE	**RT**	3.00000000	2
MPP	**CT**	2.33333333	3

Pack	Temp	Value LSMEAN	LSMEAN Number
MPP	**RT**	3.00000000	4
PET	**CT**	2.66666667	5
PET	**RT**	3.33333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9838	0.9838	0.9838	1.0000	0.7751
2	0.9838		0.7751	1.0000	0.9838	0.9838
3	0.9838	0.7751		0.7751	0.9838	0.4134
4	0.9838	1.0000	0.7751		0.9838	0.9838
5	1.0000	0.9838	0.9838	0.9838		0.7751
6	0.7751	0.9838	0.4134	0.9838	0.7751	

Total mold count on 60th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.03166667	0.00633333	1.43	0.2840
Error	12	0.05333333	0.00444444		
Corrected Total	17	0.08500000			

R-Square	Coeff Var	Root MSE	Value Mean
0.372549	9.302326	0.066667	0.716667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.01333333	0.00666667	1.50	0.2621
Temp	1	0.01388889	0.01388889	3.13	0.1025
Pack*Temp	2	0.00444444	0.00222222	0.50	0.6186

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.004444
Critical Value of t	2.17881
Least Significant Difference	0.0839

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	0.75000	6	HDPE
A			
A	0.71667	6	PET
A			
A	0.68333	6	MPP

The GLM Procedure

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.004444
Critical Value of t	2.17881
Least Significant Difference	0.0685

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	0.74444	9	RT
A			
A	0.68889	9	CT

The GLM Procedure

Level of Pack	Level of Temp	N	Value	
			Mean	**Std Dev**
HDPE	**CT**	**3**	0.73333333	0.05773503
HDPE	**RT**	**3**	0.76666667	0.05773503
MPP	**CT**	**3**	0.63333333	0.05773503
MPP	**RT**	**3**	0.73333333	0.05773503
PET	**CT**	**3**	0.70000000	0.00000000
PET	**RT**	**3**	0.73333333	0.11547005

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.73333333	1
HDPE	**RT**	0.76666667	2
MPP	**CT**	0.63333333	3
MPP	**RT**	0.73333333	4
PET	**CT**	0.70000000	5
PET	**RT**	0.73333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9880	0.4798	1.0000	0.9880	1.0000
2	0.9880		0.2139	0.9880	0.8172	0.9880
3	0.4798	0.2139		0.4798	0.8172	0.4798
4	1.0000	0.9880	0.4798		0.9880	1.0000
5	0.9880	0.8172	0.8172	0.9880		0.9880
6	1.0000	0.9880	0.4798	1.0000	0.9880	

Annexure-II

Statistical analysis of the data with SAS 9.3 for 90 days

Observed Data

Obs	Rep	Pack	Temp	a_w	TSS	TS	pH	Acidity	colour	TBC	TMC
1	1	MPP	CT	0.770	23.1	28.0895	3.21	0.960	5.8823	3	0.6
2	1	MPP	RT	0.768	24.7	29.1893	3.17	1.024	8.6849	3	0.8
3	1	PET	CT	0.765	24.2	29.5145	3.17	1.216	6.1823	3	0.7
4	1	PET	RT	0.776	23.2	29.3528	3.17	1.408	9.0000	4	0.8
5	1	HDPE	CT	0.775	21.6	29.4167	3.20	1.216	7.1823	4	0.8
6	1	HDPE	RT	0.780	25.8	27.6885	3.14	1.536	10.0849	4	0.9
7	2	MPP	CT	0.795	25.6	28.8981	3.18	1.088	6.6485	3	0.7
8	2	MPP	RT	0.752	25.1	29.6758	3.14	1.152	9.4756	4	0.9
9	2	PET	CT	0.771	22.6	29.3293	3.14	1.344	6.9485	3	0.8
10	2	PET	RT	0.762	22.4	29.9682	3.15	1.408	10.0000	4	0.9
11	2	HDPE	CT	0.780	22.6	29.1135	3.21	1.216	7.9485	4	0.9
12	2	HDPE	RT	0.765	23.5	29.1596	3.18	1.408	10.8756	5	0.9
13	3	MPP	CT	0.766	25.8	29.0401	3.19	1.152	7.4146	4	0.8
14	3	MPP	RT	0.779	24.9	29.6978	3.17	1.024	10.2663	5	1.0
15	3	PET	CT	0.790	20.7	28.4664	3.31	1.472	7.7146	4	0.9
16	3	PET	RT	0.752	22.8	29.6443	3.14	1.856	11.0000	4	1.0
17	3	HDPE	CT	0.752	21.7	28.1734	3.19	1.216	8.7146	4	0.9
18	3	HDPE	RT	0.752	22.2	28.0772	3.19	1.280	11.6663	5	1.1

Water activity on 90th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00045978	0.00009196	0.47	0.7895
Error	12	0.00233267	0.00019439		
Corrected Total	17	0.00279244			

R-Square	Coeff Var	Root MSE	Value Mean
0.164651	1.812001	0.013942	0.769444

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.00005644	0.00002822	0.15	0.8664
Temp	1	0.00033800	0.00033800	1.74	0.2119
Pack*Temp	2	0.00006533	0.00003267	0.17	0.8473

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000194
Critical Value of t	2.17881
Least Significant Difference	0.0175

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	0.771667	6	MPP
A			
A	0.769333	6	PET
A			
A	0.767333	6	HDPE

The GLM Procedure
t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000194
Critical Value of t	2.17881
Least Significant Difference	0.0143

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	0.773778	9	CT
A			
A	0.765111	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	0.76900000	0.01493318
HDPE	**RT**	**3**	0.76566667	0.01401190
MPP	**CT**	**3**	0.77700000	0.01571623
MPP	**RT**	**3**	0.76633333	0.01357694
PET	**CT**	**3**	0.77533333	0.01305118
PET	**RT**	**3**	0.76333333	0.01205543

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.76900000	1
HDPE	**RT**	0.76566667	2
MPP	**CT**	0.77700000	3
MPP	**RT**	0.76633333	4
PET	**CT**	0.77533333	5
PET	**RT**	0.76333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9996	0.9780	0.9999	0.9922	0.9953
2	0.9996		0.9107	1.0000	0.9517	0.9999
3	0.9780	0.9107		0.9290	1.0000	0.8286
4	0.9999	1.0000	0.9290		0.9639	0.9998
5	0.9922	0.9517	1.0000	0.9639		0.8901
6	0.9953	0.9999	0.8286	0.9998	0.8901	

TSS on 90th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	23.05611111	4.61122222	3.02	0.0542
Error	12	18.32000000	1.52666667		
Corrected Total	17	41.37611111			

R-Square	Coeff Var	Root MSE	Value Mean

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.526667
Critical Value of t	2.17881

R-Square	Coeff Var	Root MSE	Value Mean
0.557232	5.264025	1.235584	23.47222

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	17.68777778	8.84388889	5.79	0.0173
Temp	1	2.49388889	2.49388889	1.63	0.2254
Pack*Temp	2	2.87444444	1.43722222	0.94	0.4171

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.526667
Critical Value of t	2.17881
Least Significant Difference	1.5543

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	24.8667	6	MPP
B	22.9000	6	HDPE
B			
B	22.6500	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Least Significant Difference	1.2691

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	23.8444	9	RT
A			
A	23.1000	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	21.9666667	0.55075705
HDPE	**RT**	**3**	23.8333333	1.82300119
MPP	**CT**	**3**	24.8333333	1.50443788
MPP	**RT**	**3**	24.9000000	0.20000000
PET	**CT**	**3**	22.5000000	1.75214155
PET	**RT**	**3**	22.8000000	0.40000000

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	21.9666667	1
HDPE	**RT**	23.8333333	2
MPP	**CT**	24.8333333	3
MPP	**RT**	24.9000000	4
PET	**CT**	22.5000000	5
PET	**RT**	22.8000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.4727	0.1169	0.1052	0.9938	0.9568

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
2	0.4727		0.9122	0.8889	0.7687	0.9009
3	0.1169	0.9122		1.0000	0.2606	0.3879
4	0.1052	0.8889	1.0000		0.2371	0.3566
5	0.9938	0.7687	0.2606	0.2371		0.9996
6	0.9568	0.9009	0.3879	0.3566	0.9996	

Total solids on 90th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	3.89935685	0.77987137	2.67	0.0761
Error	12	3.50937190	0.29244766		
Corrected Total	17	7.40872874			

R-Square	Coeff Var	Root MSE	Value Mean
0.526319	1.863007	0.540784	29.02749

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	1.84451054	0.92225527	3.15	0.0793
Temp	1	0.32325680	0.32325680	1.11	0.3138
Pack*Temp	2	1.73158950	0.86579475	2.96	0.0901

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.292448
Critical Value of t	2.17881
Least Significant Difference	0.6803

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	29.3793	6	PET
A			

Means with the same letter are not significantly different.

t Grouping		Mean	N	Pack
B	A	29.0984	6	MPP
B				
B		28.6048	6	HDPE

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.292448
Critical Value of t	2.17881
Least Significant Difference	0.5554

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	29.1615	9	RT
A			
A	28.8935	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	28.9011889	0.64827377
HDPE	**RT**	**3**	28.3084486	0.76235454
MPP	**CT**	**3**	28.6758723	0.51279090
MPP	**RT**	**3**	29.5209528	0.28742900
PET	**CT**	**3**	29.1033931	0.55940222
PET	**RT**	**3**	29.6551136	0.30780162

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	28.9011889	1
HDPE	**RT**	28.3084486	2

Pack	**Temp**	**Value LSMEAN**	**LSMEAN Number**
MPP	**CT**	28.6758723	3
MPP	**RT**	29.5209528	4
PET	**CT**	29.1033931	5
PET	**RT**	29.6551136	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	**1**	**2**	**3**	**4**	**5**	**6**
1		0.7578	0.9947	0.7247	0.9968	0.5519
2	0.7578		0.9555	0.1360	0.4999	0.0835
3	0.9947	0.9555		0.4390	0.9196	0.2975
4	0.7247	0.1360	0.4390		0.9264	0.9996
5	0.9968	0.4999	0.9196	0.9264		0.8052
6	0.5519	0.0835	0.2975	0.9996	0.8052	

pH on 90th day

The GLM Procedure
Dependent Variable: Value

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	0.00749444	0.00149889	0.92	0.5020
Error	12	0.01960000	0.00163333		
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**

R-Square	**Coeff Var**	**Root MSE**	**Value Mean**
0.276604	1.270675	0.040415	3.180556

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Pack	2	0.00021111	0.00010556	0.06	0.9377
Temp	1	0.00680556	0.00680556	4.17	0.0639
Pack*Temp	2	0.00047778	0.00023889	0.15	0.8655

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.001633

Critical Value of t	2.17881
Least Significant Difference	0.0508

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**Pack**
	3.18500	6	HDPE
A			
A			
A	3.18000	6	PET
A			
A	3.17667	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.001633
Critical Value of t	2.17881
Least Significant Difference	0.0415

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**Temp**
A	3.20000	9	CT
A			
A	3.16111	9	RT

Level of Pack	**Level of Temp**	**N**	**Value**	
			Mean	**Std Dev**
HDPE	CT	3	3.20000000	0.01000000
HDPE	RT	3	3.17000000	0.02645751
MPP	CT	3	3.19333333	0.01527525
MPP	RT	3	3.16000000	0.01732051
PET	CT	3	3.20666667	0.09073772
PET	RT	3	3.15333333	0.01527525

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	3.20000000	1
HDPE	RT	3.17000000	2
MPP	CT	3.19333333	3
MPP	RT	3.16000000	4
PET	CT	3.20666667	5
PET	RT	3.15333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9368	0.9999	0.8232	0.9999	0.7189
2	0.9368		0.9774	0.9996	0.8677	0.9950
3	0.9999	0.9774		0.9058	0.9982	0.8232
4	0.8232	0.9996	0.9058		0.7189	0.9999
5	0.9999	0.8677	0.9982	0.7189		0.6041
6	0.7189	0.9950	0.8232	0.9999	0.6041	

Acidity on 90th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.57730844	0.11546169	6.04	0.0051
Error	12	0.22937600	0.01911467		
Corrected Total	17	0.80668444			

R-Square	Coeff Var	Root MSE	Value Mean
0.715656	10.83132	0.138256	1.276444

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.45374578	0.22687289	11.87	0.0014
Temp	1	0.08214756	0.08214756	4.30	0.0604
Pack*Temp	2	0.04141511	0.02070756	1.08	0.3694

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.019115
Critical Value of t	2.17881
Least Significant Difference	0.1739

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	1.45067	6	PET
A			
A	1.31200	6	HDPE
B	1.06667	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.019115
Critical Value of t	2.17881
Least Significant Difference	0.142

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	1.34400	9	RT
A			

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Temp**
A	1.20889	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	**Std Dev**
HDPE	CT	3	1.21600000	0.00000000
HDPE	RT	3	1.40800000	0.12800000
MPP	CT	3	1.06666667	0.09776161
MPP	RT	3	1.06666667	0.07390083
PET	CT	3	1.34400000	0.12800000
PET	RT	3	1.55733333	0.25865292

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	1.21600000	1
HDPE	RT	1.40800000	2
MPP	CT	1.06666667	3
MPP	RT	1.06666667	4
PET	CT	1.34400000	5
PET	RT	1.55733333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.5557	0.7681	0.7681	0.8583	0.0871
2	0.5557		0.0871	0.0871	0.9915	0.7681
3	0.7681	0.0871		1.0000	0.2116	0.0095
4	0.7681	0.0871	1.0000		0.2116	0.0095
5	0.8583	0.9915	0.2116	0.2116		0.4516
6	0.0871	0.7681	0.0095	0.0095	0.4516	

Colour on 90th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	44.55324390	8.91064878	13.33	0.0002
Error	12	8.02293797	0.66857816		
Corrected Total	17	52.57618187			

R-Square	Coeff Var	Root MSE	Value Mean
0.847404	9.453406	0.817666	8.649436

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	5.74377476	2.87188738	4.30	0.0392
Temp	1	38.77156021	38.77156021	57.99	<.0001
Pack*Temp	2	0.03790892	0.01895446	0.03	0.9721

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.668578
Critical Value of t	2.17881
Least Significant Difference	1.0286

Means with the same letter are not significantly different.

t Grouping		Mean	N	Pack
	A	9.4120	6	HDPE
	A			
B	A	8.4742	6	PET
B				
B		8.0620	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.668578
Critical Value of t	2.17881
Least Significant Difference	0.8398

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	10.1171	9	RT
B	7.1818	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	7.9484599	0.76615780
HDPE	**RT**	**3**	10.8756185	0.79071982
MPP	**CT**	**3**	6.6484599	0.76615780
MPP	**RT**	**3**	9.4756185	0.79071982
PET	**CT**	**3**	6.9484599	0.76615780
PET	**RT**	**3**	10.0000000	1.00000000

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	7.9484599	1
HDPE	**RT**	10.8756185	2
MPP	**CT**	6.6484599	3
MPP	**RT**	9.4756185	4
PET	**CT**	6.9484599	5
PET	**RT**	10.0000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.0089	0.4219	0.2701	0.6720	0.0804
2	0.0089		0.0004	0.3496	0.0008	0.7740
3	0.4219	0.0004		0.0114	0.9971	0.0031
4	0.2701	0.3496	0.0114		0.0244	0.9649
5	0.6720	0.0008	0.9971	0.0244		0.0065
6	0.0804	0.7740	0.0031	0.9649	0.0065	

Total bacteria count on 90th day

The GLM Procedure
Dependent Variable: Value

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	3.77777778	0.75555556	2.27	0.1140
Error	12	4.00000000	0.33333333		
Corrected Total	17	7.77777778			

R-Square	**Coeff Var**	**Root MSE**	**Value Mean**
0.485714	14.84615	0.577350	3.888889

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Pack	2	1.77777778	0.88888889	2.67	0.1101
Temp	1	2.00000000	2.00000000	6.00	0.0306
Pack*Temp	2	0.00000000	0.00000000	0.00	1.0000

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.333333
Critical Value of t	2.17881
Least Significant Difference	0.7263

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**Pack**
A	4.3333	6	HDPE
A			
A	3.6667	6	MPP
A			
A	3.6667	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.333333
Critical Value of t	2.17881
Least Significant Difference	0.593

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Temp**
A	4.2222	9	RT
B	3.5556	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	**Std Dev**
HDPE	**CT**	**3**	4.00000000	0.00000000
HDPE	**RT**	**3**	4.66666667	0.57735027
MPP	**CT**	**3**	3.33333333	0.57735027
MPP	**RT**	**3**	4.00000000	1.00000000
PET	**CT**	**3**	3.33333333	0.57735027
PET	**RT**	**3**	4.00000000	0.00000000

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	4.00000000	1
HDPE	**RT**	4.66666667	2
MPP	**CT**	3.33333333	3
MPP	**RT**	4.00000000	4
PET	**CT**	3.33333333	5
PET	**RT**	4.00000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.7189	0.7189	1.0000	0.7189	1.0000
2	0.7189		0.1194	0.7189	0.1194	0.7189
3	0.7189	0.1194		0.7189	1.0000	0.7189
4	1.0000	0.7189	0.7189		0.7189	1.0000
5	0.7189	0.1194	1.0000	0.7189		0.7189
6	1.0000	0.7189	0.7189	1.0000	0.7189	

Total mold count on 90th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.13111111	0.02622222	2.78	0.0684
Error	12	0.11333333	0.00944444		
Corrected Total	17	0.24444444			

R-Square	Coeff Var	Root MSE	Value Mean
0.536364	11.35900	0.097183	0.855556

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.04111111	0.02055556	2.18	0.1561
Temp	1	0.08000000	0.08000000	8.47	0.0131
Pack*Temp	2	0.01000000	0.00500000	0.53	0.6021

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.009444
Critical Value of t	2.17881
Least Significant Difference	0.1222

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	0.91667	6	HDPE
A			
A	0.85000	6	PET
A			
A	0.80000	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.009444
Critical Value of t	2.17881
Least Significant Difference	0.0998

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	0.92222	9	RT
B	0.78889	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	0.86666667	0.05773503
HDPE	**RT**	**3**	0.96666667	0.11547005
MPP	**CT**	**3**	0.70000000	0.10000000
MPP	**RT**	**3**	0.90000000	0.10000000
PET	**CT**	**3**	0.80000000	0.10000000
PET	**RT**	**3**	0.90000000	0.10000000

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.86666667	1
HDPE	**RT**	0.96666667	2
MPP	**CT**	0.70000000	3
MPP	**RT**	0.90000000	4
PET	**CT**	0.80000000	5
PET	**RT**	0.90000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.7999	0.3480	0.9979	0.9537	0.9979
2	0.7999		0.0499	0.9537	0.3480	0.9537
3	0.3480	0.0499		0.1925	0.7999	0.1925
4	0.9979	0.9537	0.1925		0.7999	1.0000
5	0.9537	0.3480	0.7999	0.7999		0.7999
6	0.9979	0.9537	0.1925	1.0000	0.7999	

Annexure-III

Statistical analysis of the data with SAS 9.3 for 120 days

Observed Data

Obs	Rep	Pack	Temp	a_w	TSS	TS	pH	Acidity	Colour	TBC	TMC
1	1	MPP	CT	0.744	24.3	27.8066	3.18	1.088	6.9215	4	0.8
2	1	MPP	RT	0.747	26.6	29.9491	3.16	1.152	10.8014	5	1.1
3	1	PET	CT	0.738	24.0	29.7511	3.20	1.408	6.9883	4	1.0
4	1	PET	RT	0.750	24.2	30.3500	3.19	1.408	11.0590	5	1.2
5	1	HDPE	CT	0.746	22.1	27.3145	3.22	1.152	8.1262	5	0.9
6	1	HDPE	RT	0.749	24.2	29.5559	3.20	1.408	11.1799	6	1.2
7	2	MPP	CT	0.735	25.2	28.6248	3.20	1.088	7.4058	4	0.9
8	2	MPP	RT	0.735	24.2	31.5109	3.21	1.152	11.9493	5	1.2
9	2	PET	CT	0.740	24.0	30.0924	3.21	1.408	8.1506	5	0.9
10	2	PET	RT	0.737	24.2	30.4196	3.17	1.344	12.3020	6	1.3
11	2	HDPE	CT	0.738	25.5	29.6038	3.21	1.408	8.5309	5	1.0
12	2	HDPE	RT	0.740	25.1	29.5829	3.19	1.216	12.4682	7	1.3
13	3	MPP	CT	0.728	26.0	29.0934	3.20	1.152	7.8902	5	1.0
14	3	MPP	RT	0.751	25.5	30.2343	3.20	1.088	12.0972	6	1.3
15	3	PET	CT	0.723	22.6	29.0757	3.16	1.408	8.8130	5	0.9
16	3	PET	RT	0.735	23.1	30.9989	3.20	1.280	13.5450	6	1.4
17	3	HDPE	CT	0.728	24.5	27.7435	3.22	1.344	9.4356	6	1.0
18	3	HDPE	RT	0.732	25.1	30.5957	3.17	1.408	13.7565	8	1.5

Water activity on 120th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00022400	0.00004480	0.61	0.6938
Error	12	0.00088000	0.00007333		
Corrected Total	17	0.00110400			

R-Square	Coeff Var	Root MSE	Value Mean
0.202899	1.159317	0.008563	0.738667

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.00002433	0.00001217	0.17	0.8490
Temp	1	0.00017422	0.00017422	2.38	0.1492
Pack*Temp	2	0.00002544	0.00001272	0.17	0.8428

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000073
Critical Value of t	2.17881
Least Significant Difference	0.0108

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	0.740000	6	MPP
A			
A	0.738833	6	HDPE
A			
A	0.737167	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000073
Critical Value of t	2.17881
Least Significant Difference	0.0088

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	0.741778	9	RT
A			
A	0.735556	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	0.73733333	0.00901850

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**RT**	**3**	0.74033333	0.00850490
MPP	**CT**	**3**	0.73566667	0.00802081
MPP	**RT**	**3**	0.74433333	0.00832666
PET	**CT**	**3**	0.73366667	0.00929157
PET	**RT**	**3**	0.74066667	0.00814453

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.73733333	1
HDPE	**RT**	0.74033333	2
MPP	**CT**	0.73566667	3
MPP	**RT**	0.74433333	4
PET	**CT**	0.73366667	5
PET	**RT**	0.74066667	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9977	0.9999	0.9089	0.9940	0.9962
2	0.9977		0.9824	0.9911	0.9241	1.0000
3	0.9999	0.9824		0.8101	0.9997	0.9763
4	0.9089	0.9911	0.8101		0.6562	0.9940
5	0.9940	0.9241	0.9997	0.6562		0.9089
6	0.9962	1.0000	0.9763	0.9940	0.9089	

TSS on 120th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	8.98666667	1.79733333	1.65	0.2216
Error	12	13.09333333	1.09111111		
Corrected Total	17	22.08000000			

R-Square	Coeff Var	Root MSE	Value Mean
0.407005	4.269330	1.044563	24.46667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	7.86333333	3.93166667	3.60	0.0595
Temp	1	0.88888889	0.88888889	0.81	0.3845
Pack*Temp	2	0.23444444	0.11722222	0.11	0.8990

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.091111
Critical Value of t	2.17881
Least Significant Difference	1.314

t Grouping		Mean	N	Pack
	A	25.3000	6	MPP
	A			
B	A	24.4167	6	HDPE
B				
B		23.6833	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	1.091111
Critical Value of t	2.17881
Least Significant Difference	1.0729

t Grouping	Mean	N	Temp
A	24.6889	9	RT
A			
A	24.2444	9	CT

Level of	Level of	N	Value

Pack	Temp		Mean	Std Dev
HDPE	**CT**	**3**	24.0333333	1.74737899
HDPE	**RT**	**3**	24.8000000	0.51961524
MPP	**CT**	**3**	25.1666667	0.85049005
MPP	**RT**	**3**	25.4333333	1.20138809
PET	**CT**	**3**	23.5333333	0.80829038
PET	**RT**	**3**	23.8333333	0.63508530

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	24.0333333	1
HDPE	**RT**	24.8000000	2
MPP	**CT**	25.1666667	3
MPP	**RT**	25.4333333	4
PET	**CT**	23.5333333	5
PET	**RT**	23.8333333	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9395	0.7649	0.5896	0.9901	0.9999
2	0.9395		0.9976	0.9722	0.6792	0.8585
3	0.7649	0.9976		0.9995	0.4384	0.6345
4	0.5896	0.9722	0.9995		0.2935	0.4590
5	0.9901	0.6792	0.4384	0.2935		0.9991
6	0.9999	0.8585	0.6345	0.4590	0.9991	

Total solids on 120th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	15.29643255	3.05928651	5.49	0.0074
Error	12	6.68545585	0.55712132		
Corrected Total	17	21.98188840			

R-Square	Coeff Var	Root MSE	Value Mean
0.695865	2.523994	0.746406	29.57240

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Pack	2	3.31012054	1.65506027	2.97	0.0895
Temp	1	11.03244522	11.03244522	19.80	0.0008
Pack*Temp	2	0.95386679	0.47693340	0.86	0.4492

The GLM Procedure

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.557121
Critical Value of t	2.17881
Least Significant Difference	0.9389

Means with the same letter are not significantly different.

t Grouping		**Mean**	**N**	**Pack**
	A	30.1146	6	PET
	A			
B	A	29.5365	6	MPP
B				
B		29.0660	6	HDPE

The GLM Procedure

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.557121
Critical Value of t	2.17881
Least Significant Difference	0.7666

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**Temp**
A	30.3553	9	RT

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Temp**
B	28.7895	9	CT

Level of Pack	**Level of Temp**	**N**	**Value**	
			Mean	**Std Dev**
HDPE	**CT**	**3**	28.2205795	1.21693360
HDPE	**RT**	**3**	29.9115150	0.59269308
MPP	**CT**	**3**	28.5082419	0.65128197
MPP	**RT**	**3**	30.5647978	0.83169213
PET	**CT**	**3**	29.6397052	0.51741987
PET	**RT**	**3**	30.5895418	0.35624731

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	**Temp**	**Value LSMEAN**	**LSMEAN Number**
HDPE	**CT**	28.2205795	1
HDPE	**RT**	29.9115150	2
MPP	**CT**	28.5082419	3
MPP	**RT**	30.5647978	4
PET	**CT**	29.6397052	5
PET	**RT**	30.5895418	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	**1**	**2**	**3**	**4**	**5**	**6**
1		0.1301	0.9963	0.0220	0.2549	0.0205
2	0.1301		0.2644	0.8834	0.9972	0.8672
3	0.9963	0.2644		0.0487	0.4693	0.0455
4	0.0220	0.8834	0.0487		0.6605	1.0000
5	0.2549	0.9972	0.4693	0.6605		0.6373
6	0.0205	0.8672	0.0455	1.0000	0.6373	

pH on 120th day

The GLM Procedure
Dependent Variable: Value

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	0.00196111	0.00039222	1.16	0.2216
Error	12	0.00406667	0.00033889		
Corrected Total	17	0.00602778			

R-Square	**Coeff Var**	**Root MSE**	**Value Mean**
0.325346	0.576380	0.018409	3.193889

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Pack	2	0.00057778	0.00028889	0.85	0.4506
Temp	1	0.00067222	0.00067222	1.98	0.1844
Pack*Temp	2	0.00071111	0.00035556	1.05	0.3803

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000339
Critical Value of t	2.17881
Least Significant Difference	0.0232

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**Pack**
A	3.20167	6	HDPE
A			
A	3.19167	6	MPP
A			
A	3.18833	6	PET

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.000339

Critical Value of t	2.17881
Least Significant Difference	0.0189

t Grouping	Mean	N	Temp
A	3.200000	9	CT
A			
A	3.187778	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	CT	3	3.21666667	0.00577350
HDPE	RT	3	3.18666667	0.01527525
MPP	CT	3	3.19333333	0.01154701
MPP	RT	3	3.19000000	0.02645751
PET	CT	3	3.19000000	0.02645751
PET	RT	3	3.18666667	0.01527525

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	3.21666667	1
HDPE	RT	3.18666667	2
MPP	CT	3.19333333	3
MPP	RT	3.19000000	4
PET	CT	3.19000000	5
PET	RT	3.18666667	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.3975	0.6408	0.5144	0.5144	0.3975
2	0.3975		0.9973	0.9999	0.9999	1.0000
3	0.6408	0.9973		0.9999	0.9999	0.9973
4	0.5144	0.9999	0.9999		1.0000	0.9999
5	0.5144	0.9999	0.9999	1.0000		0.9999
6	0.3975	1.0000	0.9973	0.9999	0.9999	

Acidity on 120th day

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.22846578	0.04569316	7.44	0.0022
Error	12	0.07372800	0.00614400		
Corrected Total	17	0.30219378			

R-Square	Coeff Var	Root MSE	Value Mean
0.756024	6.157935	0.078384	1.272889

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.21890844	0.10945422	17.81	0.0003
Temp	1	0.00000000	0.00000000	0.00	1.0000
Pack*Temp	2	0.00955733	0.00477867	0.78	0.4813

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.006144
Critical Value of t	2.17881
Least Significant Difference	0.0986

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	1.37600	6	PET
A			
A	1.32267	6	HDPE
B	1.12000	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.006144
Critical Value of t	2.17881
Least Significant Difference	0.0805

t Grouping	Mean	N	Temp
A	1.27289	9	CT
A			
A	1.27289	9	RT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	CT	3	1.30133333	0.13322662
HDPE	RT	3	1.34400000	0.11085125
MPP	CT	3	1.10933333	0.03695042
MPP	RT	3	1.13066667	0.03695042
PET	CT	3	1.40800000	0.00000000
PET	RT	3	1.34400000	0.06400000

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	CT	1.30133333	1
HDPE	RT	1.34400000	2
MPP	CT	1.10933333	3
MPP	RT	1.13066667	4
PET	CT	1.40800000	5
PET	RT	1.34400000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.9825	0.0906	0.1540	0.5752	0.9825
2	0.9825		0.0298	0.0522	0.9093	1.0000
3	0.0906	0.0298		0.9993	0.0056	0.0298
4	0.1540	0.0522	0.9993		0.0097	0.0522
5	0.5752	0.9093	0.0056	0.0097		0.9093

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
6	0.9825	1.0000	0.0298	0.0522	0.9093	

Colour on 120days

The GLM Procedure

Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	79.36598700	15.87319740	18.16	<.0001
Error	12	10.49046818	0.87420568		
Corrected Total	17	89.85645517			

R-Square	Coeff Var	Root MSE	Value Mean
0.883253	9.276689	0.934990	10.07892

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	3.48437017	1.74218509	1.99	0.1789
Temp	1	75.62935902	75.62935902	86.51	<.0001
Pack*Temp	2	0.25225780	0.12612890	0.14	0.8671

The GLM Procedure
t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.874206
Critical Value of t	2.17881
Least Significant Difference	1.1762

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	10.5829	6	HDPE
A			
A	10.1430	6	PET
A			

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	9.5109	6	MPP

The GLM Procedure
t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.874206
Critical Value of t	2.17881
Least Significant Difference	0.9603

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	12.1287	9	RT
B	8.0291	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	8.6975833	0.67041687
HDPE	**RT**	**3**	12.4681693	1.28831219
MPP	**CT**	**3**	7.4058312	0.48437785
MPP	**RT**	**3**	11.6159577	0.70932812
PET	**CT**	**3**	7.9839696	0.92372336
PET	**RT**	**3**	12.3019856	1.24297783

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	8.6975833	1
HDPE	**RT**	12.4681693	2
MPP	**CT**	7.4058312	3
MPP	**RT**	11.6159577	4
PET	**CT**	7.9839696	5
PET	**RT**	12.3019856	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.0036	0.5607	0.0229	0.9296	0.0051
2	0.0036		0.0003	0.8656	0.0008	0.9999
3	0.5607	0.0003		0.0014	0.9698	0.0004
4	0.0229	0.8656	0.0014		0.0048	0.9396
5	0.9296	0.0008	0.9698	0.0048		0.0011
6	0.0051	0.9999	0.0004	0.9396	0.0011	

Total bacteria count on 120th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	12.94444444	2.58888889	5.83	0.0059
Error	12	5.33333333	0.44444444		
Corrected Total	17	18.27777778			

R-Square	Coeff Var	Root MSE	Value Mean
0.708207	12.37113	0.666667	5.388889

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	5.77777778	2.88888889	6.50	0.0122
Temp	1	6.72222222	6.72222222	15.12	0.0022
Pack*Temp	2	0.44444444	0.22222222	0.50	0.6186

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.444444
Critical Value of t	2.17881
Least Significant Difference	0.8386

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	6.1667	6	HDPE

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Pack**
B	5.1667	6	PET
B			
B	4.8333	6	MPP

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.444444
Critical Value of t	2.17881
Least Significant Difference	0.6847

Means with the same letter are not significantly different.			
t Grouping	**Mean**	**N**	**Temp**
A	6.0000	9	RT
B	4.7778	9	CT

Level of Pack	**Level of Temp**	**N**	**Value**	
			Mean	**Std Dev**
HDPE	**CT**	**3**	5.33333333	0.57735027
HDPE	**RT**	**3**	7.00000000	1.00000000
MPP	**CT**	**3**	4.33333333	0.57735027
MPP	**RT**	**3**	5.33333333	0.57735027
PET	**CT**	**3**	4.66666667	0.57735027
PET	**RT**	**3**	5.66666667	0.57735027

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	**Temp**	**Value LSMEAN**	**LSMEAN Number**
HDPE	**CT**	5.33333333	1
HDPE	**RT**	7.00000000	2
MPP	**CT**	4.33333333	3
MPP	**RT**	5.33333333	4
PET	**CT**	4.66666667	5

Pack	Temp	Value LSMEAN	LSMEAN Number
PET	RT	5.66666667	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.0818	0.4798	1.0000	0.8172	0.9880
2	0.0818		0.0038	0.0818	0.0105	0.2139
3	0.4798	0.0038		0.4798	0.9880	0.2139
4	1.0000	0.0818	0.4798		0.8172	0.9880
5	0.8172	0.0105	0.9880	0.8172		0.4798
6	0.9880	0.2139	0.2139	0.9880	0.4798	

Total mold count on 120th day

The GLM Procedure
Dependent Variable: Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.56944444	0.11388889	11.39	0.0003
Error	12	0.12000000	0.01000000		
Corrected Total	17	0.68944444			

R-Square	Coeff Var	Root MSE	Value Mean
0.825947	9.045226	0.100000	1.105556

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pack	2	0.03111111	0.01555556	1.56	0.2508
Temp	1	0.53388889	0.53388889	53.39	<.0001
Pack*Temp	2	0.00444444	0.00222222	0.22	0.8040

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.01
Critical Value of t	2.17881
Least Significant Difference	0.1258

Means with the same letter are not significantly different.

t Grouping	Mean	N	Pack
A	1.15000	6	HDPE
A			
A	1.11667	6	PET
A			
A	1.05000	6	MPP

The GLM Procedure

t Tests (LSD) for Value

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.01
Critical Value of t	2.17881
Least Significant Difference	0.1027

Means with the same letter are not significantly different.

t Grouping	Mean	N	Temp
A	1.27778	9	RT
B	0.93333	9	CT

Level of Pack	Level of Temp	N	Value	
			Mean	Std Dev
HDPE	**CT**	**3**	0.96666667	0.05773503
HDPE	**RT**	**3**	1.33333333	0.15275252
MPP	**CT**	**3**	0.90000000	0.10000000
MPP	**RT**	**3**	1.20000000	0.10000000
PET	**CT**	**3**	0.93333333	0.05773503
PET	**RT**	**3**	1.30000000	0.10000000

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Pack	Temp	Value LSMEAN	LSMEAN Number
HDPE	**CT**	0.96666667	1
HDPE	**RT**	1.33333333	2
MPP	**CT**	0.90000000	3

Pack	Temp	Value LSMEAN	LSMEAN Number
MPP	**RT**	1.20000000	4
PET	**CT**	0.93333333	5
PET	**RT**	1.30000000	6

Least Squares Means for effect Pack*Temp
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Value

i/j	1	2	3	4	5	6
1		0.0075	0.9588	0.1139	0.9981	0.0148
2	0.0075		0.0020	0.5945	0.0038	0.9981
3	0.9588	0.0020		0.0294	0.9981	0.0038
4	0.1139	0.5945	0.0294		0.0584	0.8172
5	0.9981	0.0038	0.9981	0.0584		0.0075
6	0.0148	0.9981	0.0038	0.8172	0.0075	

Instrument foto

Plate.3.1. Fresh Ginger (Cv. Suprava)

Plate.3.2. Hand operated sealing machine(DMT, Impulse sealer, Divya machine tools)

Plate.3.3. Freshly prepared ginger paste in different packaging material

Plate.3.4. Water Activity Meter(Make: Labswift-a_w Model: Novasina AG)

Plate.3.5. Brix Meter (Pocket Refractometer, Atago)

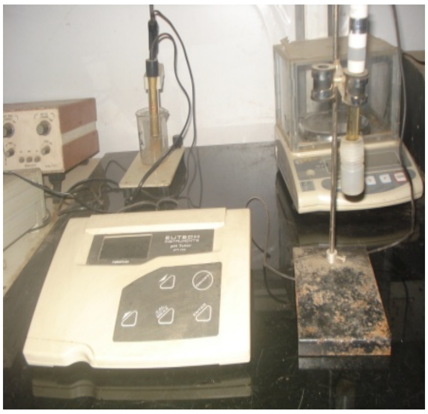

Plate.3.6. Digital pH meter (EUTECH Instruments)

Plate.3.7. Acidity measurement (Titration method)

Plate.3.8. Hunter Lab colorimeter (Model: ColorFlex, Hunter Lab, USA)

Plate.3.9. Laminar flow chamber for microbial analysis

Plate.3.10. Incubator

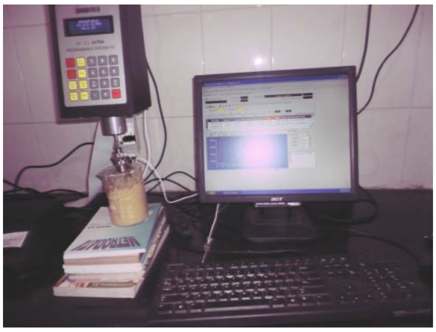

Plate.3.11. Rheometer (Make: Brookfield Model: LVDV-III Ultra)

Plate.4.18. 60th day storage of (A) PET (B) HDPE (C)MPP at room temperature

Plate.4.19. 60th day storage of (A) PET (B) HDPE (C)MPP at cold room.

Plate.4.20. 90th day storage of (A) PET (B) HDPE (C)MPP at room temperature

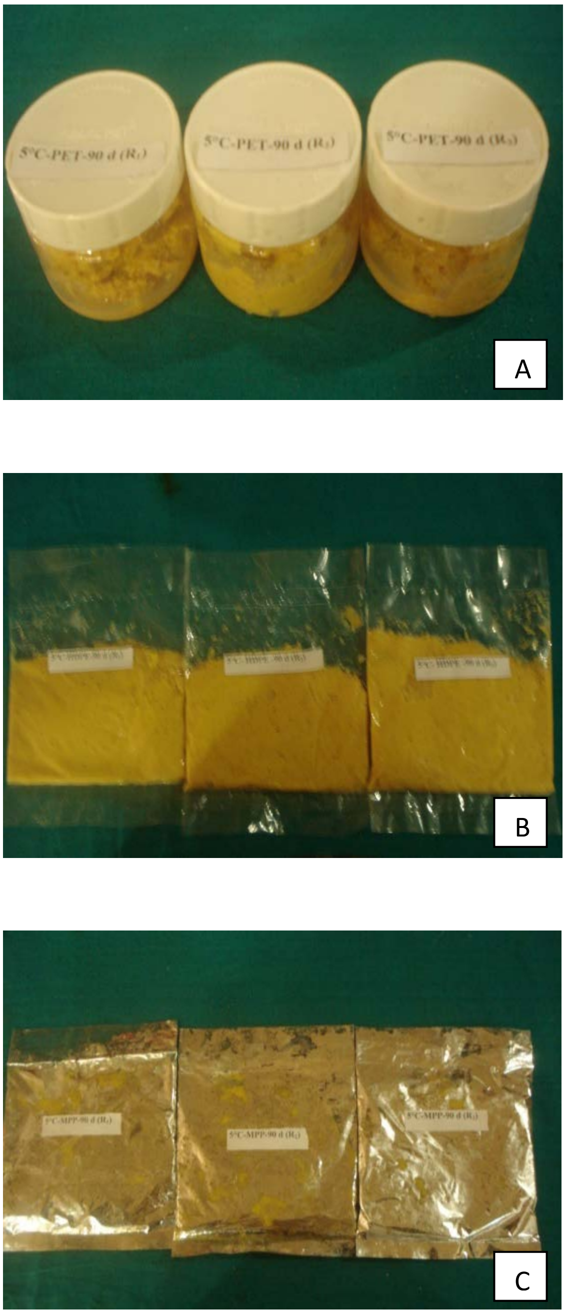

Plate.4.21. 90th day storage of (A) PET (B) HDPE (C)MPP at cold room.

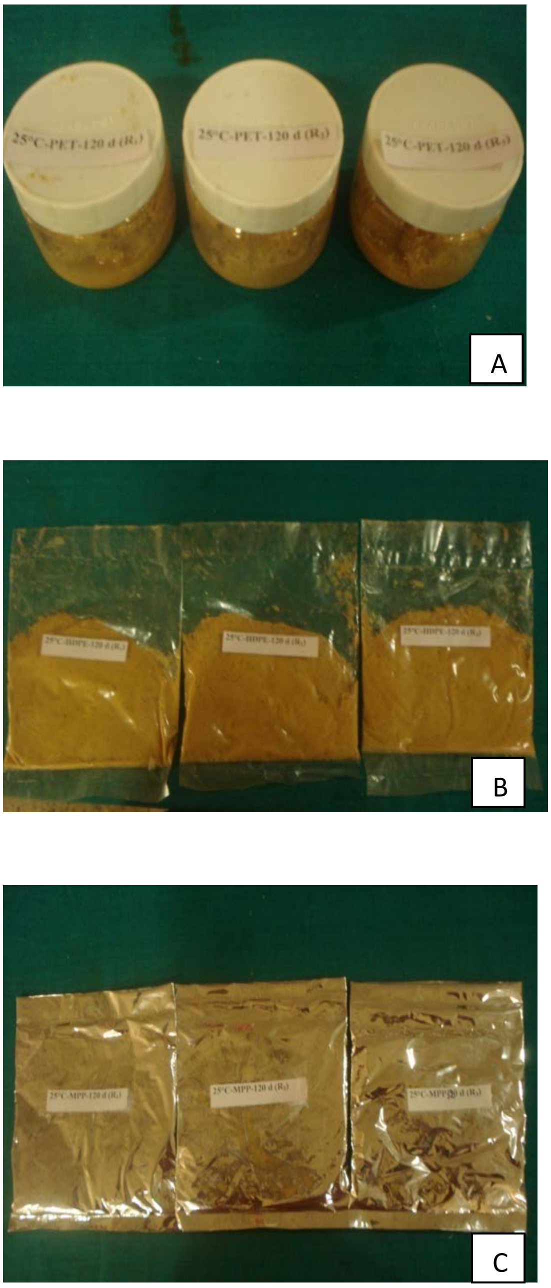

Plate.4.22. 120th day storage of (A) PET (B) HDPE (C)MPP at room temperature

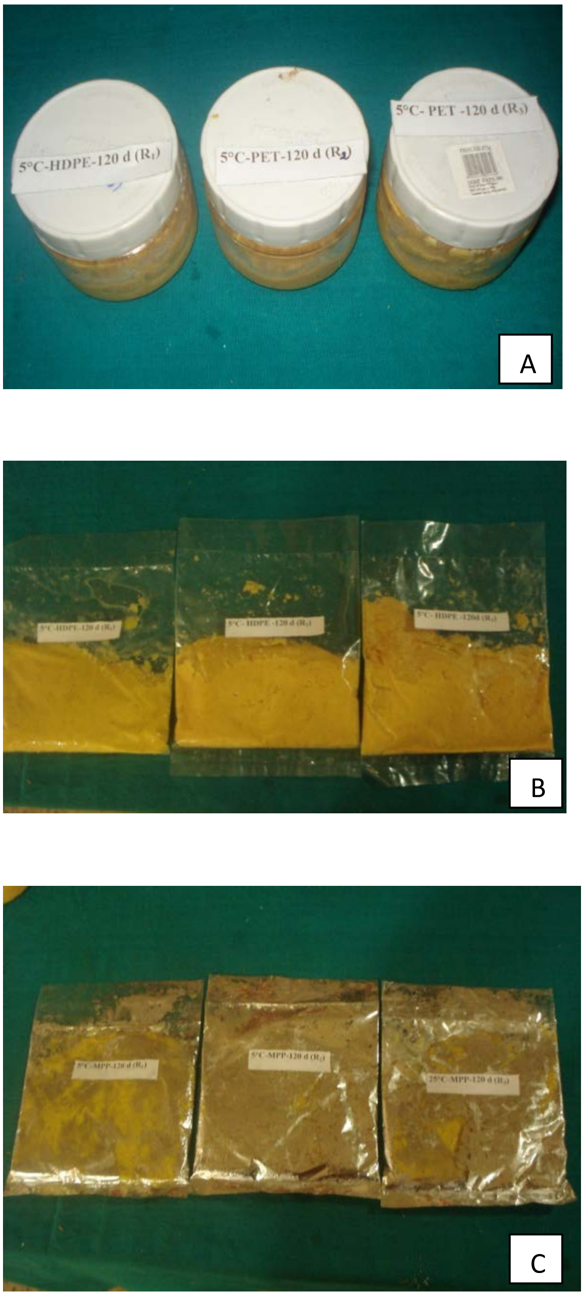

Plate.4.23. 120th day storage of (A) PET (B) HDPE (C)MPP at cold room.

LIST OF SYMBOLS AND ABBREVIATION

%	Percentage
^0B	Degree Brix
^0C	Degree Celsius
a_w	Water activity
cfu/g	Colony forming unit/gram
CT	Cold room temperature
g	Gram
g/l	Gram/litre
ha	Hectare
HDPE	High Density Polyethylene
IU	International Unit
K	Consistency coefficient
kCal	Kilo calorie
kg	Kilogram
KMS	Potassium Metabisulphate
mg	Milligram
min	Minute
ml	Milliliter
MPP	Materialized Poly Propylene
MT	Metric tonnes
n	Flow behavior index
NA	Nutrient Agar
NaOH	Sodium hydro oxide
Pa	Pascal
PDA	Potato Dextrose Agar
PET	Polyethylene Terepthalate
ppm	Parts per million
R^2	Regression coefficient
rad/s	Radian/sec
rpm	Revolution per minute
RT	Room Temperature
s	Second
SE	Standard error
TBC	Total Bacterial Count
TMC	Total Mould Count
TS	Total Solids
TSS	Total Soluble Solids
γ	Shear rate
τ	Shear Stress
τ_0	Yield stress