NUTRITIONAL AND ORGANOLEPTIC QUALITIES OF VALUE ADDED PRODUCTS FROM BREADFRUIT

[*Artocarpus altilis* (Park) Fosberg]

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Nutritional and organoleptic qualities of value added products from breadfruit** [*Artocarpus altilis* (Park) **Fosberg]"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis, entitled **"Nutritional and organoleptic qualities of value added products from breadfruit [*Artocarpus altilis* (Park) Fosberg]"** is a record of research work done independently by **Sharon, C.L.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Food processing industry can play a significant role for India's development because of the vital linkages between the two pillars of the economy, the industry and agriculture. It will give India the potential to become number one in food production with sustained efforts. The growth potential of this sector is enormous and it is expected that the food production will double in the next 10 years, making improvement in consumption of value added foods (Saigal, 2001).

Demand for processed food is rising exponentially, since consumer food preferences especially in the urban areas are changing rapidly with people becoming more adventurous and unrestrained by cultural or social eating habits. In a way, the spirit of activity in the processed food industry has been brought about primarily due to the conveniences demanded by changing life-styles.

Food processing will have to play an increasing market role, as demand created both by population growth and by requirement for improved nutrition generates a need for an estimated 60 per cent increase in available food stuffs (Walker, 1993).

In order to improve food supplies it is not only sufficient to increase food production, but also to harvest, handle, process and store food stuffs with least possible losses (Potty, 1993).

Agricultural produce are perishable and do not command as much price compared to processed products. Hence, the challenge to agriculture has been to add economic value to fresh produce to assist rural farmers to cope up with changes in the economy, world trade, weather and disease. Value added agricultural products are increasing the economic value and consumer appeal of an agricultural commodity. Alternative production and marketing strategy are required to better understand the rapidly changing food industry and food safety issues, consumer preferences, business savvy and teamwork. Genetics, post harvest approaches storage, processing, and packaging are some of the ways of adding value to agriculture.

Breadfruit belonging to family Moraceae is a tropical crop suited for the homesteads of Kerala. Breadfruit is not consumed in the ripe stage in the popular sense of the term 'fruit'. The mature green fruit is used as a vegetable for cooking boiled, fried or roasted.

Breadfruit incidentally is having very low keeping quality, as fruits ripen and soften within 2 to 3 days of harvest. Such ripe fruits have no commercial value, as consumers purchase only mature green fruits of a firm texture.

It is a fast ripening climacteric fruit resulting in faster depletion of stored food reserves. Besides the high ambient temperature prevailing in most tropical conditions, heat build up, moisture loss, faster respiration rate and breakdown of cellular organisation leads to softening, color development and other biochemical changes associated with the ripening, making it unfit to use as a vegetable.

One method to overcome this problem is to produce value added products from breadfruit. Breadfruit has received little attention in the field of value addition. By value addition and creation of new products the popularity of breadfruit can be increased. Hence, the present study entitled "Nutritional and organoleptic qualities of value added products from breadfruit [*Artocarpus altilis* (Park) Fosberg] is proposed with the following objectives.

1. To standardize value added products of breadfruit.
2. To evaluate the nutritional and organoleptic qualities and shelf life of the products.

Review of Literature

2. REVIEW OF LITERATURE

2.1 BREADFRUIT - COUNTRIES AND CULTIVATION

Breadfruit, *Artocarpus altilis* belongs to the mulberry family, Moraceae. Earlier the fruit was known as *Artocarpus communis* forst, *Artocarpus incisus* Linn (Barrau, 1957) but the most widely accepted once now is *Artocarpus altilis* (Park) Fosberg (Stone, 1974).

Breadfruit tree is fast growing, 8 to 18 meters high and begins bearing fruits after about 6 years. It produces fruit over 50 years. Breadfruits are picked at the mature green stage (Barrau, 1957). The fruits are usually oblong, cylindrical, ovoid, rounded or pear shaped. Breadfruit is not consumed in the ripe stage in the popular sense of the term 'fruit'. The fully mature but unripe fruit is used as a vegetable (Bowers, 1981). It is a climacteric fruit of extreme perishability (Sankat and Maharaj, 1993).

The breadfruit is believed to be native to a vast area extending from New Guinea through the Indo Malayan Archipelago to Western Micronesia (Bose and Mitra, 1990). It is said to have been widely spread in the pacific area by migrating Polynesians and Hawaiians believed that it was brought from the Samoan island of Upalu to Oahu in the 12^{th} century AD (Nero, 1992). It is said to have been first seen by Europeans in the Marquises in 1595, then in Tahiti in 1006. Breadfruit is a very popular fruit in the islands of the Caribbean (Sankat and Maharaj, 1993).

There are two main types, the normal wild type (cultivated in some areas) with seeds and little pulp and the 'cultivated' (most widely grown) seedless type (Worrell and Carrington, 1996).

There is good evidence that the fresh navigator Sonnerat in 1772 obtained the seeded breadfruit from the Philippines and brought it to the French West Indies. In some areas only the seedless type is grown, in others particularly Haiti, the seeded is more common. Jamaica, is the leading producer of the seedless type, followed by St Lucia, In New Guinea only the seeded type is grown for food (Morton, 1987). In Jamaica, a variety 'Yellow heart' is grown which is best among all (Thamburaj, 2001).

The breadfruit is more tropical in its requirements (Singh, 1969) and is not much grown in India. It flourishes on the West coast of south India and off the islands of that coast (Hayes, 1970). It is seen in lower Palani hills, Wyanad, Courtallam and in Annamalais (Thamburaj, 2001).

Breadfruit is the most widely distributed species and exhibits great variability. Hundreds of cultivars have been named and described with more than 200 vernacular names recorded from 22 island groups of Pacific Distinctions are based on bearing season, fruit shape, colour, presence of seeds, cooking or storage qualities of fruit, tree form, leaf shape and horticultural requirements (Rangone, 1995).

2.2 VALUE ADDITION OF HORTICULTURAL COMMODITIES

Processing of foods can be derived as adding value to conventional and innovative food items through various formation and combination providing protection, preservation, packing, convenience, carriage and disposability (Rao, 1991). Roy (1993) stated that surplus production of perishable fruits and vegetables during the seasonal glut could be converted into durable products in order to avoid wastage.

Nwankezi *et al.* (1994) pointed out that the search for alternative use of perishable horticultural commodities to maximize their utilization and reduce losses is virtually important.

Sethi (1996) emphasized that all the future thrust in research should be aimed at developing simple technologies which could be easily adopted to conserve and preserve perishable commodities and minimize both their qualitative and quantitative losses, so that the gap between the production and availability of horticultural crops is slowed down.

2.2.1 Flours

2.2.1.1 Breadfruit flour

Breadfruits are considered as substitute for bread and many tasty dishes are prepared out of it (Singh *et al.*, 1963).

The dried breadfruit fruit has been made into flour. The breadfruit flour is much richer than wheat flour in lysine and other essential amino acids (Wootton and Tumaalii 1984).

Under ripe breadfruits are used in preparations of soups and ripe fruits are combined with coconut milk, salt, sugar and baked to make pudding. Breadfruit is also candied or sometimes prepared as a sweet pickle (Morton, 1987).

According to Esuoso and Bamiro (1995) wheat flour can be supplemented with 50 per cent breadfruit flour. Breadfruit flour indicated a high starch content of 80.9 per cent, 4.2 per cent crude fiber and 1.6 per cent ash content, 4.5 per cent protein. Blends recorded best pasting characteristics in terms of starch stability, gelatinisation index and set back values.

Breadfruit flour can be used instead of wheat flour in many recipies (Worrell and Carrington, 1997).

Full fat African breadfruit flour was used to replace 70 per cent of sweet potato flour. Composite flours had good foaming capacity but lacked foaming stability. It is suggested that low bulk density of the composite flour will be an advantage in the preparations of weaning food formulations (Akubor, 1997).

The seeds of breadfruits are boiled, steamed, roasted over a fire and eaten with salt (Mathews, 1998). African breadfruit seeds are either boiled or roasted and then milled into flour (Giami *et al.*, 2000).

Badifu and Akubor (2001) reported that African breadfruit seeds were cleaned parboiled (98°) for 15 minutes, drained, dehulled, sun dried, milled and sieved into flour. The flour was used to supplement food products.

Pillai (2001) had standardised the preparation of breadfruit flour. Breadfruits were first washed, peeled, chipped to 4 x 3 x 2 cm^3 size and blanched at 90° water with 0.3 per cent citric acid and 1500 ppm SO_2 for five minutes and sun dried. The dried chips were ground and sieved through a 40-mesh size to get a uniform flour.

A fermented product from breadfruit called 'Madrai' and a paste called 'Pakakur' was developed in the pacific. It can be sliced, dried and made into flour (Amusa *et al.*, 2002).

Ayodele and Oginni (2002) reported the utilization of breadfruit flour in the preparation of bread, cake, buttered biscuits and pancake.

Since the literature on breadfruit flour and chips is meager, literature on other sources of fruit flour and chips is incorporated to support the present investigation.

2.2.1.2 Jackfruit flour

According to Singh (1983) the fruit of jackfruit, varika variety were peeled, seeds were removed and flakes made into small pieces of 2.0-2.5 cm thickness. This was soaked in water containing 2000 ppm KMS for 2 hours and then mechanically dried at 65 ± 5°C for 24 hours and powdered to get flour. This flour remained unspoiled up to 130 days in polypropylene bags. The flour contained 47 per cent TSS, 29.5 per cent total sugar and 16.4 per cent reducing sugar.

Srirajarajeshwari and Prakash (1999) removed the outer part of jackfruit seeds and they were pound, dried and powdered and two products namely 'Khara sev' and 'Jamun' were prepared using this flour.

Jackfruit is known as a close relative of breadfruit and various part of this fruit is utilized for value addition (Falcao, 2001).

2.2.1.3 Mango powder

Sharma *et al.* (1974) studied the production and storage behaviour of spray dried mango powder. They reported that during the storage period of one year at room temperature of 31 ± 1°C there was no perceptible change in colour, flavour and reconstitution of the product but there was progressive increase in free-fat content, volatile fatty acids and acidity value.

It was reported by Gangopadhyay *et al.* (1976) that mango powder could be used for preparing chutney and beverage.

Dabhade and Khedkar (1980) observed that the raw mango powder or amchur, as it is commonly called in northern India, is widely used as a condiment for acidifying and flavoring a variety of culinary preparations. Mangoes are first washed, peeled, sliced, blanched, dehydrated and then powdered to get the flour. A drying time of 10 hrs in a cabinet dryer or 15 hrs in sun is necessary to reduce moisture content to 2-3 per cent.

Singh (1983) standardized the preparation of mango powder. Uniformly matured Neelum mangoes were harvested, peeled, sliced into pieces of 2.5 to 3.5 cm thickness and mechanically dried at 65 ± 5°C. Powdering was done with the help of a grinder. The flour was stored and remained in good condition up to 190 days in PE and PP bags. The mango powder contains 28.5 per cent TSS, 23.15 per cent total sugar and 12 per cent reducing sugar. The powder was utilized for the preparation of payasam.

2.2.1.4 Banana flour

Banana flour was standardized by Snehalatha (1985). Unripe banana fruit Nendran was peeled and then sliced and dried at an oven temperature of 60°C. When the fruit was completely dried, it was powdered and sieved. According to Rao (1999) banana flour can be prepared from unripe and ripe fruits.

Patil and Magen (1976) analysed banana powder prepared from 3 varieties (Basrai, Rajeli, safea volchi) and found considerable variations in moisture content, starch, sugars and protein. Banana powder contained important minerals viz. potassium, phosphorus, magnesium and vitamins like thiamin, niacin and ascorbic acid.

The study of Suntharlingam and Ravindran (1993) revealed that banana flour contained 70 per cent starch, 1.3 per cent fat, 3.2 per cent crude fibre and 3.7 per cent ash content. Mota *et al.* (2000) reported that banana flour contained 2.6-3.5 per cent ash, 0.3-0.8 per cent lipid and 2.2-3.3 per cent protein.

Prasad (1988) conducted a study to develop a weaning food based on banana flour, which was nutritious, low cost and acceptable. The banana flour was supplemented with horse gram, sesame and skin milk powder to improve the nutritive value.

In Kerala, banana flour is prepared from fully mature banana especially Kunnan and Nendran varieties and used as a weaning food (Singh and Uma, 1994). Banana flour prepared from raw fruit is a highly nutritive baby food (Thajudeen *et al.*, 1996).

A technique was developed for producing banana flour enriched with degreased soybean flour, vitamins and minerals. The mixture was considered to be suitable as a food for infants (Giraldo, 2000).

According to Muyonga (2001) banana flour produced with predehydration and steaming gives pastes of low paste bulk density, which is desirable for weaning and supplementary foods.

According to Narayanan and Mustaffa (2001) banana biscuits prepared from banana powder had good consumer acceptance.

2.2.1.5 Cassava flour

The preparation of cassava flour was standardized by Chellammal (1995). Cassava tubers were first washed to remove impurities then peeled, chipped to a thickness ranged from 0.5-0.7 cm. The fresh chips were sun dried for 4 days, and milled to obtain the flour. The flour was sieved through 100 mesh size. The cassava flour thus obtained contained 9.8 per cent moisture, 1.60 per cent total ash, 0.10 per cent acid insoluble ash, 79 per cent starch and 2 per cent crude fibre.

Yoshi and Garcia (1979) studied the suitability of cassava flour substitution in the preparation of puttu. Palomos *et al.* (1980) reported that based on cost analysis, root crop flour is a good substitute for wheat flour and substitution of wheat flour (20%) with cassava flour in bread making is explained by them. The cassava flour was mixed in soups and used in making pancakes, biscuits and bread. It is also excellent for gravies and pudding as it is not glutinous like wheat flour (Siviero *et al.*, 1984). The possibility of incorporating cassava flour into some traditional Kenyan foods was studied by Imungi (1990) and he found that cassava flour upto 50 per cent could be incorporated in the recipes. Cassava flour and starch provide an excellent raw material for extended foods and breakfast cereals (Eldash and Chang, 1990).

The feasibility of developing marconi based on cassava flour was also studied by Chellammal (1995) and Mathan (1997). Cassava flour was combined with soy flour, maida, rice flour, black gram flour or milk powder to improve the quality of composite flour used for processing vermicelli.

2.2.1.6 Potato flour

In developed countries potato flour is produced commercially using sophisticated methods such as drum drying and spray drying of precooked mashed potatoes (Willard, 1975).

Processing of potatoes into flour is perhaps the most satisfactory method of creating a product that is not only nutritionally adequate, but also remain for an extended period without damage than the raw tubers (Hadziyev and Steele, 1979).

Vaidehi and Sunanda (1982) reported that potato flour could be safely stored in polyethylene pouches for 6 months without any fungal or insect infestation and also there occurred no changes in colour, odor and flavour.

Potato flour is now a days widely used in the food industries, specially the baking industry in the preparation of bread and biscuits (Talburt and Smith, 1987).

Raw potato flour made by slicing, blanching, sulphitation and drying in a hot air dehydrator and were compared for proximate and functional properties (Kulkarni *et al.*, 1988).

According to Kabira *et al.* (1990) potatoes were washed, peeled, sliced, immersed in water and soaked in KMS. Then it was dehydrated at 60°C in a cabinet air flow dehydrator for 3 hours. The dehydrated slices were ground to yield flour of 70-mesh size. The flour obtained contained 8.22 per cent moisture, 10.80 per cent protein, 1.0 per cent total lipids, 2.19 per cent ash, 1.63 per cent crude fiber, 70.82 per cent starch, 0.90 per cent total sugar and 41 mg vitamin C.

Potato flour is rich in starch and so can improve the functional properties of several food products (Woolfe, 1990).

Potato flour can be used advantageously in pastries, yeast raised doughnuts, cake and cake mixes (Kulkari *et al.*, 1996). Sagar and Roy (1997) reported safe storage of potato flour in PE bags for 6 months at room temperature and for 9 months at low temperature.

Potato flour can be used as a thickening - flavouring agent in products such as dehydrated soups, gravies, sauces and baby foods (Marwaha and Sandhu, 1999).

Boiled potatoes were peeled, grated and dried in tray drier at 55°C for 24 h. After drying, ground in an electric grinder and powdered in a Brabender unit. The flour stored safely upto 6 months both in room and refrigerated temperatures. The flour was used in various recipes and food products instead of fresh potatoes especially during the off season (Misra and Kulshretha, 2002).

2.2.1.7 *Sweet potato flour*

In Peru, sweet potato flour is a common item in the grocery stores and used for many preparations as reported by Martin (1984).

Sweet potato flour as raw material was used in preparations of candy drops, icecreams, sausage, bread, biscuits, cake and juice (Bouwkamp, 1985). While Datta *et al.* (1986) revealed that sweet potato flour could totally replace wheat flour in soy sauce production.

Zozima (1992) opined that since the price of sweet potato is several times cheaper than wheat flour, it could be used as a substitute to wheat flour in bread making. Ono and Hirano (1992) have reported the utilization of sweet potato flour for the preparation of noodles, baby foods pies and a range of other products in China.

Chellammal (1995) standardized the preparation of sweet potato flour. The sweet potato tubers were washed peeled, chipped and then sundried for 4 days and finally milled. The ground flour was sieved through a sieve of 100 mesh. This flour along with soyflour and milk powder in the ratio 2:1:1 was used for the preparation of weaning food. Noodles and wafers were also prepared from sweet potato flour with suitable blending materials.

The flour contained 8.5 per cent moisture, 2 per cent ash, 8 per cent starch, 6 per cent total sugar and 3.80 per cent crude fibre.

Seralathan and Thirumaran (1999) studied the effect of incorporation of sweet potato flour in South Indian and baked recipes.

According to Osundahunsi *et al.* (2003) white sweet potato flour had high amylase content (32-34%).

2.2.1.8 *Taro flour*

Greenwall (1947) reported that taro flour can be prepared from raw or precooked tubers, and flour that obtained from precooked tubers is considered better.

The flour can be mixed in soup and in making pancakes, biscuits and bread. It is excellent for gravies and puddings, as it is not glutinous like wheat flour. Tarolactin and taromalt prepared from flour is said to form good infant and invalid foods.

Taro flour was mixed with hot water to a smooth thick paste and eaten with rich vegetable soup (Lyongo, 1980).

Moy *et al.* (1980) reported that taro flour mixed with 15 per cent winged bean flour or 15 per cent Soya protein has been extruded into rice, noodle and macaroni in Hawaii.

Siviero *et al.* (1984) evaluated taro flour as an additive to a wide range of bakery products including breads, cakes and biscuits and found that up to 15 per cent, taro flour can be successfully incorporated in bread, 30 per cent in cakes and 20 per cent in biscuits.

Ghosh *et al.* (1988) has described a process for the production of taro flour. Taro corms are washed, peeled cut in to 6 mm thick slices, washed thoroughly to remove mucilage and kept immersed in 0.75 per cent KMS solution for 3 hours. The slices were blanched in hot water for 5 minutes, sun dried and tunnel dried at 57-60°C. It is then ground, sieved and packed. This flour produced can be used in weaning foods and taro based bread.

Liya (2001) standardised another method for the production of taro flour. The corms were washed, peeled and chips of uniform size and thickness were made and sun dried. The dried chips were ground and sieved through 40-mesh size to get uniform flour. The flour obtained was made into secondary products viz. murukku, wafers and papads with standard blending materials. According to her the cultivar, drying periods and temperatures had a significant effect on the starch content, total sugar, moisture and colour of the flour. The starch content varied from 47.48-50.18%, total sugars 1.58-1.84% and moisture 1.15-2.53%. The flour dried at 75°C for 18 hours was judged as the best because it exhibited fairly low moisture content and good colour.

2.2.1.9 Mushroom powder

Dehydration of mushrooms may be done either in the sun or in mechanical dehydrator and stored in airtight container or ground and used as mushroom powder. Dehydrated mushroom powder can be used for making mushroom soups and also as flavoring agent in other foods (Sethi and Anand, 1984).

Whole or sliced mushrooms can be sun dried after treatment with an effective discoloration retardants. Sulphurdioxide is added in permissible concentration to avoid bacterial attack. Dried mushroom can be stored in tightly closed containers and packet of silica gel should be kept in it to keep the mushroom dry. Dried mushrooms can be easily rehydrated by boiling in water and this can be used for any recipe (Chandra, 1980).

Dehydrated powders can be mixed with flour for preparation of chapathi, wafers and other baked products like biscuits (Rangaswamy, 1993).

Hema (1995) dehydrated mushroom as standardized by National Center for Mushroom Research and Training at Solon. The dried mushroom was finely powdered and kept in dry bottles and preserved in refrigerator. Mushroom flour in combination with black gram flour in ratio 25:75 was found to be suitable for the preparation of wafers. According to her the powder contained 26.72-47 per cent protein, 12 per cent moisture, 13 per cent fiber, 0.2 per cent fat, 1.6 gm calcium, 0.12 g iron, 3.25 gm potassium and 0.125 g Zn.

2.2.1.10 Other flours from horticultural crops

Gvozdenovic *et al.* (1983) reported that optimum quality retention of tomato powder was achieved with paper/polyethylene/aluminum foil/polyethylene laminate. The packaging retained the nutrient contents in a better way.

Pacheco and Portillo (1990) reported that enrichment of commercial white corn flour with amaranth flour prior to the preparation of arepas, a popular snack of Venezuela is highly acceptable.

Lazoas (1992) reported the use of defatted pumpkinseed flour as a potential food because of its high protein content (61.4%).

Aruna *et al.* (1998) has standardized a method for preparing cereal-based papaya powder. Wheat flour and homogenized papaya pulp was mixed thoroughly and heated at 80-85°C in a drier till the moisture reduced to 5 per cent. Then this was powdered in a mill and sieved through 100-mesh size. The use of this powder was found acceptable in preparations like ice cream, custard, weaning mixture and other processed products.

Sebio and Chang (2000) reported the use of yam flour for preparing extruded foods. It was successfully used in the preparation of futu (pre cooked compact dough) a yam based food, popular in Western Africa.

El-Adawy and Taha (2001) studied the protein solubility index, water and fat absorption capacities, and emulsification properties and foam stability in water melon and pumpkinseed kernel flour. The flour samples could be potentially added to food systems such as bakery products and ground meat formulations not only as a nutrient supplement but also as functional agent.

2.2.2 Chips

2.2.2.1 Breadfruit chips

Breadfruit can be made into chips by sun drying or artificial drying which remains in good condition for 2 or 3 years if stored in air tight containers (Barrau, 1957).

According to Morton (1987) soft or over ripe breadfruit is best for making chips and these are being manufactured commercially in Trinidad and Barbados.

Bates *et al.* (1991) reported that the chips made out of raw breadfruit were stable, crisp with lipid stability compared to potato chips.

According to Pillai (2001) microwave oven dried breadfruit chips (dehydrated) treated with citric acid and KMS and packed in polyethylene and polypropylene films prevented moisture reabsorption.

2.2.2.2 *Banana chips*

The most common form of processing plantains is plantain chips from thinly sliced green finger in vegetable oil. The shelf life of plantain chips was six months (Nieva *et al.*, 1975).

Hameed (1981) investigated the suitability of flexible packages and inert gas packing in sealed tins for the storage of fried 'Nendran' banana chips. It was found that for banana chips fried in fresh coconut oil, and 300 gauge high density polyethylene bag packaging are satisfactory up to two months, while packing in tin under CO_2 is satisfactory up to six months at room temperature. Chips fried in groundnut oil and packed under similar conditions were inferior.

Satyarati *et al.* (1981) reported that banana chips fried in fresh coconut oil and packed in 300 gauge HDPE and 400 guage LDPE bags packaging are satisfactory up to two months.

Banana chips is one of the processed products that can be prepared easily and if proper packaging are provided will store well for months together (Khader *et al.*, 1985).

According to Uma *et al.* (1999) banana chips made from Nendran is best. Thirteen cultivars of banana were evaluated for the preparation of chips by Kishan *et al.* (2000) and indicated that Dakhnisagar is the best cultivar to prepare chips and the other suitable varieties are Bersian and Gauria.

In a study conducted on the physicochemical and sensory characteristics of deep fat fried banana chips, fresh bananas with higher firmness and carbohydrate content gave banana chips with higher crispness and oil absorption (Ammawath *et al.*, 2001).

Narayanan and Mustaffa (2001) observed a shelf life of 30 days for the chips and antioxidants like citric acid and propylene glycol were found to be effective in checking the rise of acid value and peroxide value in nendran banana chips.

2.2.2.3 Taro chips

Murray (1977) reported that in United States taro is peeled, sliced and deep fat fried in the same manner as in the manufacture of potato chips.

According to a study conducted by Liya (2001) taro chips were prepared by fresh frying and parboiling and frying. Freshly fried chips had a higher moisture content than parboiled fried chips. Thinner chips scored higher for organoleptic qualities than thicker chips while parboiled chips scored higher than freshly fried chips. She also reported that glass bottles and pet jars were better for storage than LDPE bags. The chips stored in LDPE bags lost their crisp texture gradually due to absorption of moisture and turned rancid towards the later periods of 75 and 90 days.

2.2.2.4 Potato chips

Balasubramanyam and Anandaswamy (1979) studied the packaging requirements for fried potato chips and found potato chips had 15 days storage life in 100 guage HDPE and 200 guage LDPE and cello/poly laminate.

According to Anand *et al.* (1982) the quality of potato chips are based on the moisture content, oil content and colour.

Potato having high dry matter content are considered suitable for the preparation of chips as high dry matter content is associated with mealiness, crispness and reduced oil uptake in fried products (Grewal and Uppal, 1989).

According to Waghmare *et al.* (1990) shelf life of chips increased by increasing antioxidant level and improving storage conditions.

Sandhu and Kaur (1992) reported that blanching for 1 minute at 80°C followed by dipping in 0.2 per cent KMS solution (5 min) and dipping in 0.25 per cent $CaCl_2$ solution at 90°C and slice thickness of 1.44 mm in providing the colour index of chips is effective.

Out of 24 varieties of potatoes 13 varieties produced chips of acceptable colour at the harvest time. Kufri Lauvkar and Kufri Sherpa were found to be the best for chip processing (Peshin, 1998).

Among chips, potato chips are the most popular. Potatoes are washed, peeled and sliced to a thickness of 1-1.5 mm. The chips are fried at 180-190°C until moisture content reduced to 2 per cent. Product should be light yellow colour, and posses pleasing desirable flavour and crispy texture (Peshin and Marwaha, 1999).

Mozolewski (1999) reported that with the lapse of storage time, the starch content increased while the quantity of soluble sugars remained unchanged. The quality of chips produced was acceptable and did not change with duration of storage.

Potato chips are made by deep fat frying of potato slices in hot oil. Blanching slices in hot water lowers the reducing sugars and improve the colour (Pokharkar and Mahale, 2002).

2.2.2.5 Cassava chips

In India cassava is used as a fresh root, as chips and flour (Nair, 1976).

Prema *et al.* (1982) have developed different recipes based on fresh cassava and cassava chips.

Van Den (1991) reported that the dried cassava chips could be stored in glass jars and tin cans for 6 months without affecting eating quality while fried chips could be stored in glass jars for one week only.

In Kerala both the fried chips and parboiled fried chips are very popular (Gosh, 1992).

2.2.2.6 Sweet potato chips

The colour of fried products particularly chips, is the most important quality character, which is dependent upon the quality of reducing sugars in the tubers, since they can combine with free amino acids at the processing temperature to cause non enzymatic browning (Collins and Waller, 1982).

Sweet potato can be prepared into fried chunks and chips (Alkuno and Trouyn, 1987).

Datta and Opario (1992) has developed successfully the technology for processing sweet potato chips. Widodo *et al.* (1993) also observed that sweet potato is suitable for the preparation of chips.

2.2.2.7 Jackfruit chips

According to Singh (1983), jackfruit chips stored in polythene and polypropylene bags were good up to 15 days.

Jackfruit chips are prepared by frying ripe or sometimes unripe fruits (Bose *et al.*, 1999).

2.2.3 WAFERS

Wafers are one of the popular snack foods. Snack foods can be defined as 'Ready to eat' (RTE) foods consumed between the main meals of the day. Papads are thin wafer like products prepared from a variety of base ingredients. These are mostly prepared at home or in cottage scale industry (Arya, 1992).

According to Chadha (1990) the ripe carpls of jackfruit can be made into papads. In addition to the use of bitter gourd for curry preparations it can be sun dried and consumed as fried wafer along with meals (Veenakumari, 1992).

Arya (1992) prepared a stiff dough from a mixture of black gram flour and colocasia flour in equal proportions with a little water. It was then rolled into thin discs by means of rolling pins and dried to a level, so that it still remained pliable. The papads were deep fried in coconut oil before consumption.

Hema (1995) prepared wafers from mushroom powder. Mushroom powder along with black gram flour in the ratio 25:75 was mixed along with salt and chilly powder. It was cooked and spread on sheet and sun dried and stored. It can be fried in coconut oil.

According to Padmaja *et al.* (1999) fried wafers were prepared using sweet potato flour and refined wheat flour (maiḍa) in varying proportions, which was found to be very acceptable.

Liya (2001) prepared wafers from taro flour in combinations with black gram flour and rice flour. The starch content, in wafers stored in glass and pet bottles declined towards the last 30 days of storage. While starch content of LDPE stored wafers declined after 45 days of storage while total sugars increased with the duration of storage.

Materials and Methods

3. MATERIALS AND METHODS

The methods followed and the materials used in the evaluation of nutritive value, organoleptic qualities and shelf life of breadfruit products are given under the following heads.

3.1	Collection of the sample
3.2	Selection of judges for acceptability studies
3.3	Development of score cards
3.4	Research methods
3.4.1	Preparation of primary products
3.4.1.1	Preparation of breadfruit chips
3.4.1.2	Preparation of breadfruit flour
3.4.2	Preparation of secondary products
3.5	Statistical analysis

3.1 COLLECTION OF THE SAMPLE

Fully matured firm breadfruits were collected from a local household. All the fruits were collected from the same tree.

3.2 SELECTION OF JUDGES FOR ACCEPTABILITY STUDIES

A series of acceptability trials were carried out using simple triangle test as suggested by Jellinek (1985) to select a panel of 20 untrained judges which included 10 college students and 10 technical experts.

3.3 DEVELOPMENT OF SCORE CARDS

Separate score cards were developed for different products depending on the quality attributes to be assessed and is given as Appendix-I, II and III Sensory evaluation was carried out using score cards based on a five point hedonic scale.

3.4 RESEARCH METHODS

3.4.1 Preparation of primary products

3.4.1.1 Preparation of breadfruit chips

Breadfruits after harvest were individually washed using running tap water to remove solid particles and dirt. Peeling was done manually with sharp knives. During chipping the core of the fruit was discarded. Chips of uniform size with 1 mm thickness were prepared using two techniques. After slicing they were divided into two lots, one lot was freshly fried in coconut oil and the other lot was blanched in 90°C water for 5 minutes, sun dried and fried in coconut oil. Salt was added to taste.

3.4.1.1.1 Moisture content and organoleptic qualities of chips

The freshly fried chips and blanched fried chips were evaluated for their organoleptic qualities such as appearance, color, flavour, texture and taste and over all acceptability, with the panel of selected judges using score cards. Moisture content of the chips was estimated by the method of AOAC (1980).

To determine the moisture content 10g of sample was taken in a petridish and dried at 60-70°C in a hot air oven, cooled in a desiccator and weighed. The process of heating and cooling was repeated till constant weight was achieved. The moisture content of the sample was calculated from the loss in weight during drying.

3.4.1.1.2 Shelf life of chips

Both types of chips were packed in pet jars and polyethylene bags (250 gauge) and were stored for 2 months. Sample size was 100 g. Observations were taken for 2 months at an interval of 15 days for organoleptic evaluation and analysis of moisture content as mentioned before.

3.4.1.2 Preparation of breadfruit flour

Dehydrated breadfruit chips was prepared as standardized by Pillai (2001). The breadfruits were first cleaned, peeled and sliced into pieces of 4 x 3 x 2 cm^3 size and blanched at 90°C water with 0.3 per cent citric acid and 1500 ppm SO_2 for five minutes and sun dried. The dried chips were ground and sieved through a 40 mesh size to get uniform flour.

3.4.1.2.1 Chemical composition of breadfruit flour

1. Moisture

The moisture content of breadfruit flour was estimated by using the method of AOAC (1980) as described before.

2. Starch

The starch content was estimated calorimetrically using anthrone reagent, as suggested by Sadasivam and Manikam (1992).

0.5 g of the sample was extracted with 80 per cent ethanol to remove sugars. Residue was repeatedly extracted with hot 80 per cent ethanol to remove the sugars completely. The residue was dried over a water bath and added 5 ml water and 6.5 ml 52 per cent perchloric acid and extracted in the cold for 20 minutes. Centrifuged the sample and re-extracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made upto 1 ml with water and added 4 ml of anthrone reagent, heated for 8 minutes, cooled and read the OD at 630 nm.

A standard graph was prepared using serial dilutions of standard glucose solution. From the graph, glucose content of the sample was obtained.

3. Protein

The estimation of the protein content, was done by using the method of AOAC (1980).

0.3 g of the sample was digested with 6 ml con H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5 g K_2SO_4 in a digestion flask until the colour of sample is converted to green. After digestion it was diluted with water and 25 ml of 40 per cent NaOH was pumped. The distillate was collected in 2 per cent boric acid containing mixed indicators and then titrated with 0.2 N HCl.

4. Total soluble sugars

The total carbohydrate was analysed calorimetrically using phenol sulphuric acid method as suggested by Sadasivam and Manikam (1992) and from this the total soluble sugars was calculated.

Hundred milligram of the sample was hydrolyzed by keeping in a boiling water bath with 5 ml of 2.5 N HCl and cooled and neutralized with sodium carbonate till the effervescence ceases. The volume was made upto 100 ml and centrifuged. Pipetted out 0.1 and 0.2 ml of supernatant and made upto 1 ml with water and added 1 ml phenol solution and 5 ml sulphuric acid and shook well, placed in a water bath at 25-30°C for 20 minutes and read the OD at 490 nm.

5. Fibre

The crude fibre content was estimated by acid-alkali digestion method as suggested by Chopra and Kanwar (1978).

Two gram of sample was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Repeated the filteration through muslin cloth and washed with sulphuric acid, water and alcohol in a sequential manner. Transferred the residue to a pre-weighed ashing dish. The residue was ignited for 30 minutes in a muffle furnace at 250°C, cooled in a desicator and weighed. The fibre content of the sample was calculated from loss in weight on ignition.

6. Calcium

The calcium content was estimated using titration method with EDTA as suggested by Page (1982).

Five ml of diacid extract made upto 100 ml was taken and added 100 ml water, 10 drops of hydroxylamine, 10 drops of triethanol amine and 2.5 ml of NaOH and 10 drops of calcone were added. Then it was titrated with EDTA till the appearance of permanent blue colour. It was expressed in mg per 100 g of sample.

7. Phosphorus

The method suggested by Jackson (1973) was followed for the estimation of phosphorus content calorimetrically after preparing a diacid extract by vandomolybdophosphoric yellow colour method in nitric acid medium.

One gram of sample was pre-digested with 12 ml of 9:4 diacid and volume made upto 100 ml. 5 ml of aliquot were pipetted into 50 ml volumetric flask and 5 ml of nitric acid vandate molybdate reagent was added and made upto 50 ml with water. After 10 minutes the OD was read at 470 nm.

A standard graph was prepared using serial dilution of standard phosphorus solution.

8. Iron

Iron content was estimated by the Atomic Absorption Sectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982).

3.4.1.2.2 Organoleptic qualities of breadfruit flour

Organoleptic qualities such as appearance, flavour, colour, texture, taste and over all acceptability of the flour was assessed with the panel of selected judges.

3.4.1.2.3 Microbial count

The total plate count of fungi, bacteria, yeast in the breadfruit flour was estimated by routine procedure of serial dilution and plate count method to determine the microbial load of the sample. Nutrient agar medium, potato dextrose medium and malt dextrose medium was used for estimating the count of bacteria, fungi and yeast respectively.

3.4.1.2.4 Shelf life of breadfruit flour

The prepared breadfruit flour was packed in pet jars and was stored for three months and observations were taken for every month for changes in chemical composition, organoleptic qualities and microbial contamination as described before.

3.4.2 Preparation of secondary products

3.4.2.1 The wafers

The flour prepared from breadfruit was made into secondary products viz. wafers. Eight combinations of raw ingredients were standardized in the preparation of wafers and the proportion of ingredients used is as detailed below.

The proportion of various raw ingredients used.

Ingredients (g)	T1	T2	T3	T4	T5	T6	T7	T8
Breadfruit flour	100	80	80	80	50	40	40	40
Tomato paste	-	20	-	10	-	20	-	10
Ginger garlic paste	-	-	20	10	-	-	20	10
Rice flour	-	-	-	-	50	40	40	40

Breadfruit flour and rice flour were mixed and sieved. Water (6 times volume of flour) was added and was made into a batter without any lumps. Tomato paste, ginger garlic paste and salt were added in the respective combinations. It was cooked on a slow flame for 25 minutes. After cooling it was spread thinly (0.3 mm to 0.5 mm thickness) on plastic sheets and sun dried. Before consumption the wafers were deep fried in coconut oil.

3.4.2.1.2 Organoleptic qualities of wafers

Organoleptic qualities such as appearance, flavour, colour, texture, taste, overall acceptability of fried wafers were assessed with the panel of selected judges.

3.4.2.1.3 Shelf life of wafers

The prepared wafers were packed in polyethylene bags (250 gauge) and were stored for 3 months and organoleptic evaluation was conducted for every month after frying in coconut oil.

3.5 Statistical analysis

Statistical analysis was done using Duncan's Multiple Range Test.

Results

4. RESULTS

The results pertaining to the study entitled 'Nutritional and organoleptic qualities of value added products from breadfruit [*Artocarpus altilis* (Park) Fosberg]' are presented under the following headings.

1. Moisture content, organoleptic qualities and shelf life evaluation of breadfruit chips.
2. Chemical composition of breadfruit flour.
3. Organoleptic evaluation of breadfruit flour at monthly intervals.
4. Microbial count of breadfruit flour.
5. Organoleptic and shelf life evaluation of breadfruit wafers at monthly intervals.

4.1 MOISTURE CONTENT, ORGANOLEPTIC QUALITIES AND SHELF LIFE EVALUATION OF BREADFRUIT CHIPS

4.1.1 Moisture

The moisture content of the fresh chips and blanched chips and the effect of storage period in pet jars and polyethylene bags in the moisture content is given in Table 1.

Table 1. Moisture content of fresh and blanched breadfruit chips

	Polyethylene bag (g/100 g)					Pet jar (g/100 g)			
	Initial	15 days	30 days	45 days	60 days	15 days	30 days	45 days	60 days
Fresh chips	3.94	4.38	4.92	5.62	5.88	4.52	5.01	5.91	6.24
Blanched chips	2.02	2.57	3.01	3.56	3.97	2.84	3.40	3.88	4.21

As observed in Table 1 the moisture content of both the samples were found to be gradually increasing with storage period in both polyethylene bag and pet jars. The initial moisture content of fresh chips was 3.94 g 100 g^{-1}. With a storage period of 60 days in polyethylene bag, the moisture content increased up to 5.88 g 100 g^{-1} and 6.24 g 100 g^{-1} when stored in pet jar. The initial moisture content of blanched chips was 2.02 g100 g^{-1} which increased to 3.97 g 100 g^{-1} after 60 days of storage in polyethylene bag and 4.21 g 100 g^{-1} when stored in pet jar.

Statistical analysis was conducted to find out the variation in moisture content of fresh and blanched chips with respect to storage containers, storage period, storage period and storage containers and storage period, storage containers and type of chips and the results are given in Table 2, 3, 4 and 5 respectively.

Table 2. Moisture content of fresh and blanched breadfruit chips in different storage containers

Storage containers	Moisture (g/100 g)	
	Fresh	Blanched
Polyethylene bag	4.94^{b}	3.03^{d}
Pet jar	5.13^{a}	3.27^{c}

Values having different superscripts differ significantly at 5% level

Table 3. Moisture content of fresh and blanched breadfruit chips with respect to storage period

Storage period in days	Moisture (g/100 g)		Mean
	Fresh	Blanched	
0	3.94^{f}	2.02^{j}	2.98^{E}
15	4.44^{d}	2.71^{i}	3.57^{D}
30	4.95	3.21^{h}	4.08^{C}
45	5.76^{b}	3.72^{g}	4.74^{B}
60	6.06^{a}	4.10^{e}	5.07^{A}

Values having different superscripts differ significantly at 5% level

Table 4. Moisture content of breadfruit chips with storage period and storage containers

Storage period in days	Moisture (g/100 g)		Mean
	Polyethylene bag	Pet jar	
0	2.98^{g}	2.98^{g}	2.98^{E}
15	3.41^{f}	3.68^{f}	3.55^{D}
30	3.97^{e}	4.21^{d}	4.08^{C}
45	4.52^{c}	4.93^{c}	4.74^{B}
60	4.92^{b}	5.23^{a}	5.07^{A}

Values having different superscripts differ significantly at 5% level

As given in Table 2 fresh chips were found to have significantly higher moisture content after the storage period when compared to blanched chips (Fig. 1). With regard to storage containers moisture content was significantly low in both types of chips stored in polyethylene bags. With regard to storage period as revealed in Table 3, there was a significant increase in the moisture content of stored chips even for a storage period of 15 days (Fig. 2).

Table 5. Moisture content of breadfruit chips with respect to storage period, storage containers and type of chips

Storage period in days	Moisture (g/100 g)			
	Fresh		Blanched	
	Polyethylene bag	Pet jar	Polyethylene bag	Pet jar
0	3.94^{h}	3.94^{h}	2.02^{p}	2.02^{p}
15	4.35^{f}	4.52^{g}	2.58^{n}	2.83^{o}
30	4.88^{d}	5.01^{e}	3.01^{l}	3.40^{m}
45	5.61^{b}	5.91^{c}	3.55^{j}	3.88^{k}
60	5.85^{a}	6.25^{b}	3.97^{h}	4.21^{i}

Values having different superscripts differ significantly at 5% level

The effect of storage period and packaging system in the moisture content of chips revealed that (Table 4) there was a significant increase in the moisture content of chips stored in both pet jars and polyethylene bags during storage but when the packaging systems were compared there was no significant variation in moisture content of chips stored for 15 days and for 45 days. Significant increase in moisture

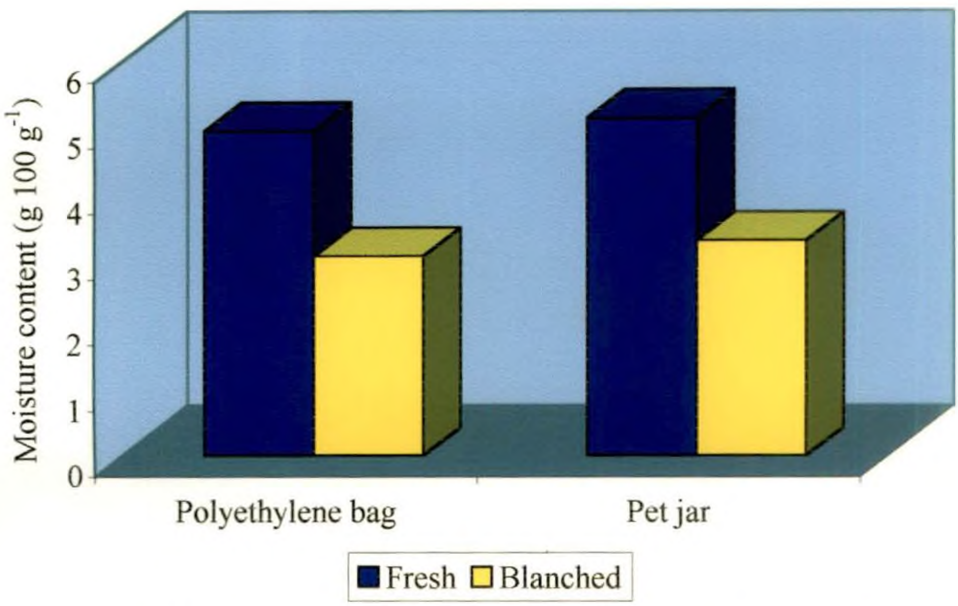

Fig. 1. Moisture content of fresh and blanched breadfruit chips in different storage containers

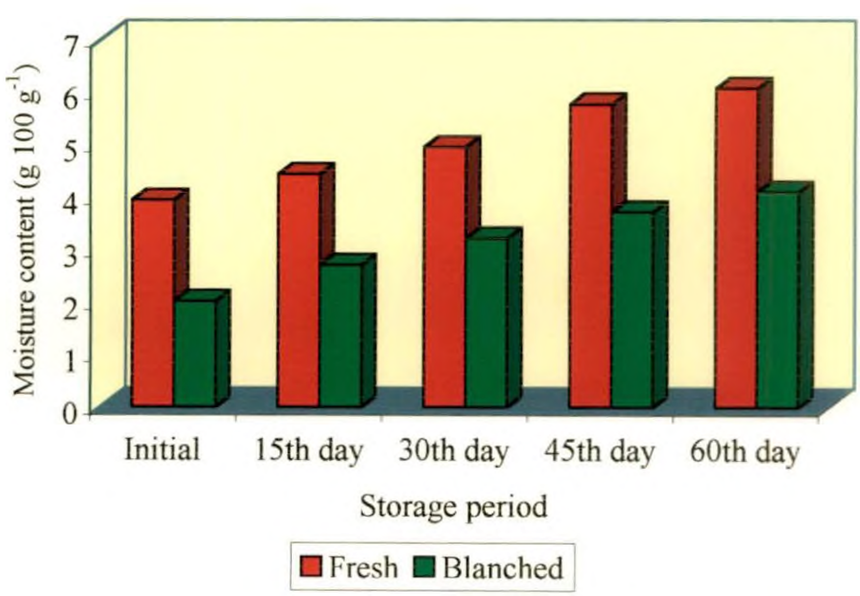

Fig. 2. Moisture content of fresh and blanched breadfruit chips with respect to storage period

content was observed in chips stored for 30 days and for 60 days. Moisture content was significantly high in chips stored for 30 days and 60 days in pet jars (Fig. 3).

Statistical analysis on the effect of storage period, storage containers and the type of chips in the moisture content as revealed in Table 5, indicated that moisture content of blanched chips stored in polyethylene bags was significantly low during all storage periods, when compared to the fresh chips. Among the fresh chips stored, chips stored in polyethylene bag was found to be significantly low when compared to the chips stored in pet jars during all storage periods (Fig. 4).

4.1.2 Organoleptic evaluation of chips

The mean scores obtained for the organoleptic evaluation of the fresh and blanched chips for the different quality attributes, stored for a period of 60 days in pet jars and polyethylene bags are presented in Table 6 and Table 7.

As revealed in Table 6, the appearance of fresh chips had a maximum initial score of 4.15 (Plate 1) and it decreased with storage time. A minimum score of 3.7 on 60^{th} day was obtained when stored in polyethylene bag and a minimum score of 3.6 when stored in pet jar. A significant change in the appearance of fresh chips was seen on the 45^{th} day of storage in both pet jars and polyethylene bags. Up to 30 days of storage there was no significant change in the appearance of chips stored in both pet jars and polyethylene bags.

The colour of fresh chips had maximum initial score of 4.65 and a least score of 4.4 on 60^{th} day in polyethylene bag and 4.2 in pet jar. There was no significant change in colour of fresh chips stored in polyethylene bags due to storage period but fresh chips stored in pet jars showed a significant reduction in the scores for colour from 45^{th} day of storage.

The characteristic flavour of fresh chips had a maximum initial score of 4.25 which gradually decreased to 3.75 by the 60^{th} day of storage in polyethylene bag

Table 6. Mean scores for organoleptic evaluation of fresh chips

Character \ Storage period	Polyethylene bag					Pet jar				
	Initial	15 days	30 days	45 days	60 days	Initial	15 days	30 days	45 days	60 days
Appearance	4.15^{a}	4.10^{a}	4.10^{a}	3.70^{b}	3.70^{b}	4.15^{a}	4.10^{a}	4.10^{a}	3.60^{b}	3.60^{b}
Color	4.65^{a}	4.65^{a}	4.50^{a}	4.40^{a}	4.40^{a}	4.65^{a}	4.60^{a}	4.55^{a}	4.25^{b}	4.20^{b}
Flavour	4.25^{a}	4.20^{a}	4.20^{a}	4.15^{a}	3.75^{b}	4.25^{a}	4.25^{a}	4.20^{a}	3.65^{b}	3.60^{b}
Texture	4.35^{a}	4.30^{a}	4.30^{a}	4.15^{a}	3.75^{b}	4.35^{a}	4.25^{a}	4.25^{a}	3.75^{b}	3.55^{b}
Taste	4.10^{a}	4.10^{a}	4.00^{a}	4.00^{a}	3.95^{b}	4.10^{a}	4.05^{a}	4.00^{a}	4.00^{a}	3.70^{b}
Overall acceptability	4.55^{a}	4.50^{a}	4.45^{a}	4.40^{a}	3.85^{b}	4.55^{a}	4.45^{a}	4.40^{a}	4.40^{a}	3.35^{b}
Total score	26.05	25.85	25.55	24.75	23.40	26.05	25.70	25.10	23.25	22.00

Values having different superscript differ significantly at 5% level

DMRT row wise comparison

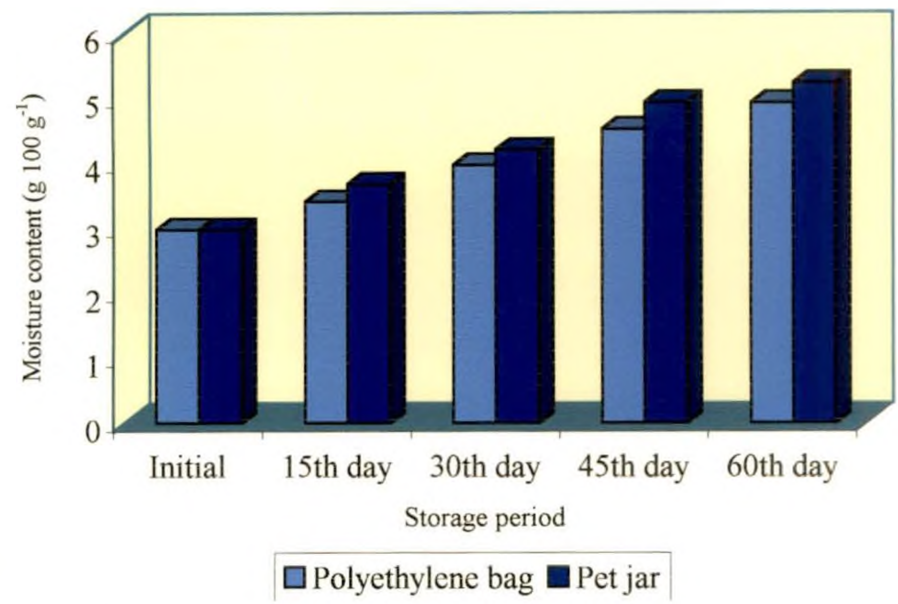

Fig. 3. Moisture content of breadfruit chips with respect to storage period and storage containers

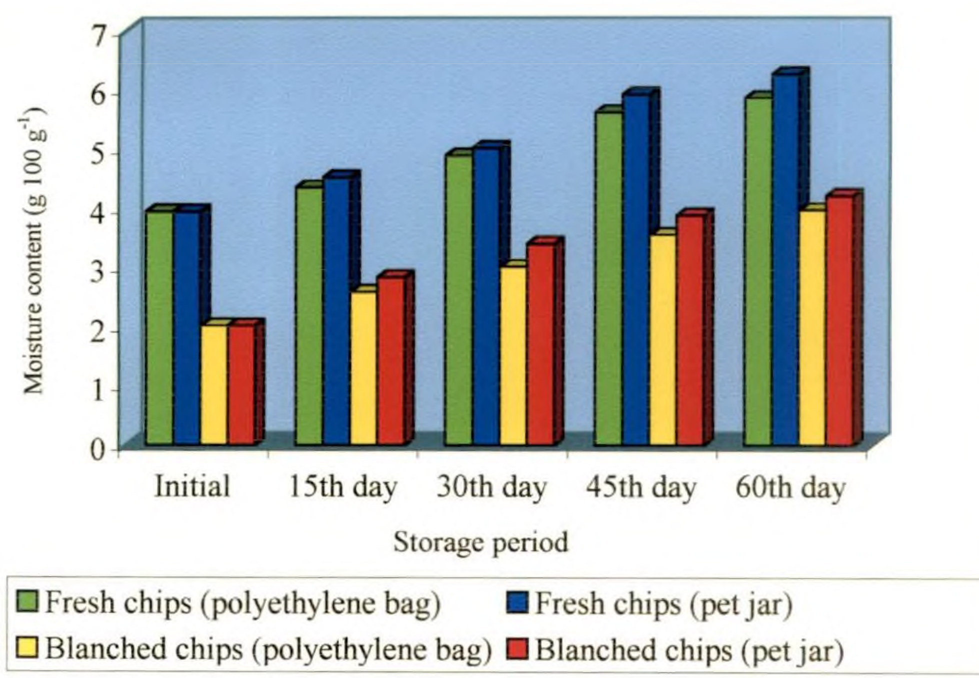

Fig. 4. Moisture content of breadfruit chips with respect to storage period, storage containers and type of chips

and a minimum of 3.6 in pet jar. There was no significant reduction in flavour due to storage in polyethylene bag up to 45 days of storage and significant reduction was observed only for the 60th day of storage. But fresh chips stored in pet jar showed significant reduction in flavour from the 45th day of storage. In both types of containers there was no significant difference in flavour during the 60th day of storage.

The attribute texture of fresh chips scored a maximum of 4.35, which decreased to a minimum of 3.75 in polyethylene bag and 3.55 when, stored in pet jars. In fresh chips stored in polyethylene bag significant changes in the texture of the product was observed only during the 60th day of storage. Chips stored in pet jars showed significant textural changes from 45th days of storage itself. But during the 60th day of storage of fresh chips, textural changes observed in the chips was not significant.

The taste of fresh chips had a maximum score of 4.1 initially and after 60 days of storage the scores gradually decreased to a minimum of 3.95 in polyethylene bag and 3.7 when stored in pet jar. In both polyethylene bag and pet jar significant change in taste was observed only on the 60th day of storage.

The fresh chips had an initial over all acceptability score of 4.55 and a least score of 3.85 when stored in polyethylene bag for 60 days and 3.35 in pet jar. There was a significant reduction in the overall acceptability of fresh chips when stored for 60 days in polyethylene bags and pet jars.

According to the results revealed in Table 7. The appearance of blanched chips had maximum initial score of 1.95 (Plate 2) which decreased with storage time to reach a minimum score of 1.8 on 60th day when stored in polyethylene bag and 1.7 in pet jar. There was no significant change in the appearance of blanched chips stored in both pet jars and polyethylene bags throughout the storage period.

The colour of blanched chips had a maximum initial score of 2.6 which droped to a minimum of 2 on 60th day when in polyethylene bag and 1.95 in pet jar.

Table 7. Mean scores for organoleptic evaluation of blanched chips

Storage period / Character	Polyethylene bag					Pet jar				
	Initial	15 days	30 days	45 days	60 days	Initial	15 days	30 days	45 days	60 days
Appearance	1.95^{a}	1.95^{a}	1.90^{a}	1.80^{a}	1.80^{a}	1.95^{a}	1.95^{a}	1.90^{a}	1.70^{a}	1.70^{a}
Color	2.60^{a}	2.55^{a}	2.30^{ab}	2.15^{b}	2.00^{b}	2.60^{a}	2.55^{a}	2.30^{ab}	2.15^{b}	1.95^{c}
Flavour	2.25^{a}	2.20^{a}	2.20^{a}	2.15^{a}	2.10^{a}	2.25^{a}	2.20^{a}	2.15^{a}	2.10^{a}	2.05^{a}
Texture	2.40^{a}	2.40^{a}	2.35^{a}	2.15^{ab}	1.80^{b}	2.40^{a}	2.40^{a}	2.35^{a}	2.05^{ab}	1.70^{b}
Taste	2.00^{a}	2.00^{a}	1.90^{a}	1.90^{a}	1.80^{a}	2.00^{a}	2.00^{a}	1.90^{a}	1.80^{a}	1.70^{a}
Overall acceptability	2.20^{a}	2.20^{a}	2.10^{ab}	2.00^{ab}	1.80^{b}	2.20^{a}	2.20^{a}	2.10^{a}	1.90^{ab}	1.65^{b}
Total score	13.40	13.30	12.75	12.15	11.30	13.40	13.30	12.70	11.70	10.75

Values having different superscript differ significantly at 5% level
DMRT row wise comparison

Plate 1. Breadfruit chips (Fresh)

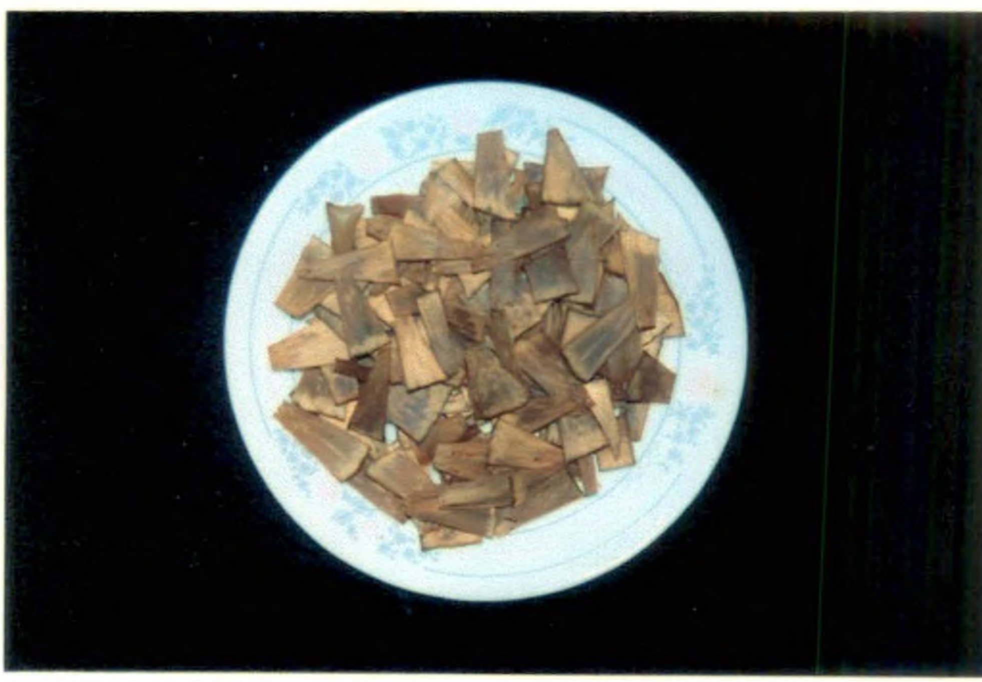

Plate 2. Breadfruit chips (Blanched)

There was no significant change in colour of blanched chips stored in polyethylene bag and pet jar up to 15 days but there was a significant reduction in the scores of colour after 30^{th} day of storage.

The characteristic flavour of blanched chips had a maximum initial score of 2.25, which decreased to a minimum of 2.1 in polyethylene bag and 2.05 in pet jar. There was no significant difference in the flavour of blanched chips throughout the storage period.

The attribute texture of blanched chips had a maximum initial score of 2.4 which decreased to a minimum of 1.8 in polyethylene bag and 1.7 when stored in pet jars. A significant change in the texture of blanched chips was observed from the 45^{th} day of storage in both pet jars and polyethylene bag. Up to 30 days of storage there was no significant change in the texture of chips stored in pet jars and polyethylene bags.

The character taste of blanched chips scored a maximum of 2.0 initially and after 60 days of storage the scores gradually decreased to a minimum of 1.8 in polyethylene bag and 1.7 when stored pet jar. There was no significant difference in the taste of blanched chips throughout the storage period in both the containers.

The blanched chips had an initial overall acceptability of 2.2 and a least score of 1.8 in polyethylene bag and 1.65 in pet jar. There was a significant reduction in the overall acceptability of blanched chips from 30 days of storage in polyethylene bag and in pet jars.

The over all acceptability of both fresh and blanched chips were compared with respect to storage period and storage containers and is presented in Table 8.

As revealed from the table the overall acceptability of fresh chips was found to be high when compared to the blanched chips, with respect to both storage period and storage containers. In fresh chips the initial overall acceptability of 4.55

Table 8. Comparison of overall acceptability of fresh and blanched chips with respect of storage period and storage containers

	Polyethylene bag					Pet jar				
	Storage period in days					Storage period in days				
	Initial	15 days	30 days	45 days	60 days	Initial	15 days	30 days	45 days	60 days
Fresh	4.55	4.50	4.45	4.40	3.85	4.55	4.45	4.40	4.40	3.35
Blanched	2.20	2.20	2.10	2.00	1.80	2.20	2.20	2.1	1.90	1.65

was decreased to 3.85, when stored in polyethylene bag for 60 days. In blanched chips the initial overall acceptability was only 2.2 which further decreased to 1.8 when stored in polyethylene bags for 60 days. When stored in pet jars the overall acceptability was 3.35 for fresh chips after 60 days of storage but for blanched chips the overall acceptability was only 1.65 after 60 days of storage (Fig. 5).

4.2 CHEMICAL COMPOSITION OF BREADFRUIT FLOUR

Chemical composition of the breadfruit flour and the changes in chemical composition of breadfruit flour such as moisture, starch, protein, total soluble sugar, fibre, calcium, phosphorus and iron on storage is presented in Table 9.

Table 9. Changes in the chemical composition of breadfruit flour in storage

Sl. No.	Constituents	Initial	Storage period		
			1st month	2nd month	3rd month
1	Moisture (g 100^{-1})	7.30	7.71	8.62	8.90
2	Starch (g 100^{-1})	65.67	65.11	64.38	63.53
3	Protein (g 100^{-1})	4.53	4.45	4.32	4.25
4	Total soluble sugar (g 100^{-1})	5.53	5.72	5.97	6.16
5	Fibre (g 100^{-1})	4.28	4.28	4.25	4.21
6	Calcium (mg 100^{-1})	82.20	81.00	79.97	77.77
7	Phosphorus (mg 100^{-1})	67.25	64.88	62.91	60.67
8	Iron (mg 100^{-1})	5.30	5.13	5.06	4.97

4.2.1 Moisture

The initial moisture content of breadfruit flour was 7.3 g 100 g^{-1} which reached a maximum of 8.9 g 100 g^{-1} within a period of 3 months of storage. The moisture content of flour was found to be gradually increasing with storage period (Fig. 6).

4.2.2 Starch

The starch content of the flour was found to be 65.67 g 100 g^{-1} initially. The starch content registered a decreasing trend from initial to the third month of

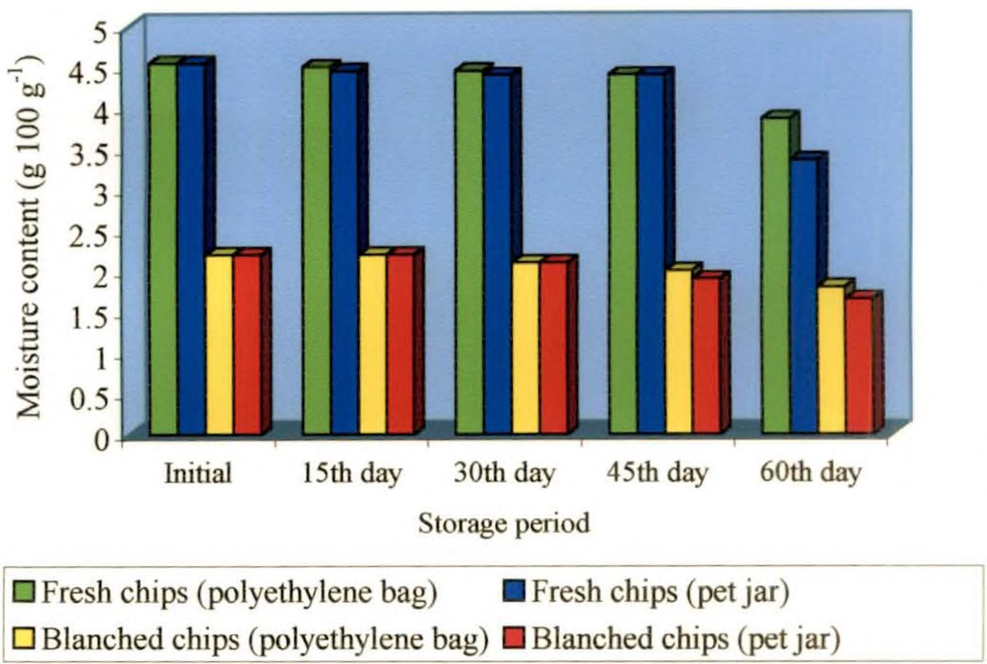

Fig. 5. Comparison of overall acceptability of fresh and blanched chips with respect to storage period and storage containers

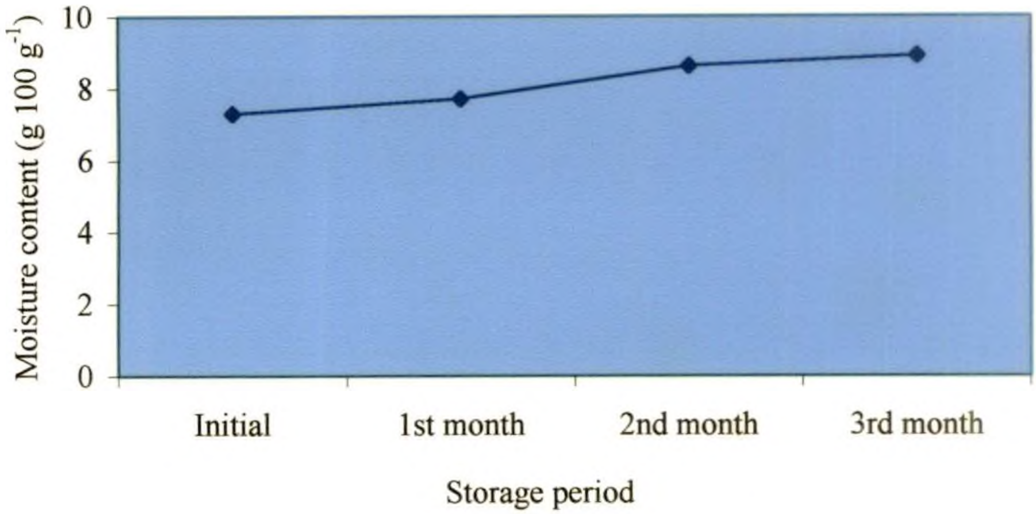

Fig. 6. Effect of storage period on the moisture content of breadfruit flour

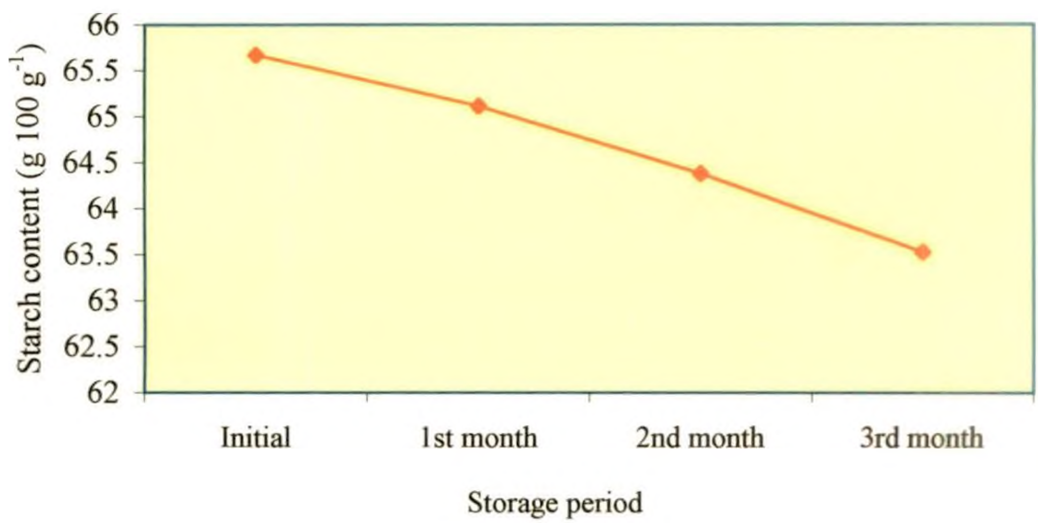

Fig. 7. Effect of storage period on the starch content of breadfruit flour

storage. After 3 months of storage starch content was found to be the least of 63.53 g 100 g^{-1} (Fig. 7).

4.2.3 Protein

The fresh flour had a protein content of 4.53 g 100 g^{-1}. This showed a decreasing trend with storage and after 3 months it decreased to reach a minimum of 4.25 g 100 g^{-1} (Fig. 8).

4.2.4 Total soluble sugars

The TSS of the flour was 5.53 g 100 g^{-1}. The TSS in the flour was found to be gradually increasing with storage. The maximum TSS in the flour was 6.16 g 100 g^{-1} after 3 months of storage (Fig. 9).

4.2.5 Fibre

The fibre content of the flour did not show much variation with storage. The fibre content in fresh flour was 4.28 g 100 g^{-1}, which was the same for the first month, and on the 3rd month it was decreased to 4.21 g 100 g^{-1} (Fig. 10).

4.2.6 Calcium

The initial calcium content of the flour was 82.2 mg 100 g^{-1}, which decreased gradually on storage, and on the 3rd month it was 77.7 mg 100 g^{-1}, which was the minimum (Fig. 11).

4.2.7 Phosphorus

As calcium, the phosphorus content in the flour was also found to be decreasing with storage period. The phosphorous content of fresh flour was 67.25 mg 100 g^{-1}, which reached a minimum of 60.67 mg 100 g^{-1} of the 3rd month (Fig. 12).

4.2.8 Iron

Iron content in the fresh flour was 5.30 mg 100 g^{-1}, which was found to be gradually decreasing with storage. By the 3rd month the iron content of the flour decreased to 4.97 mg 100 g^{-1} (Fig. 13).

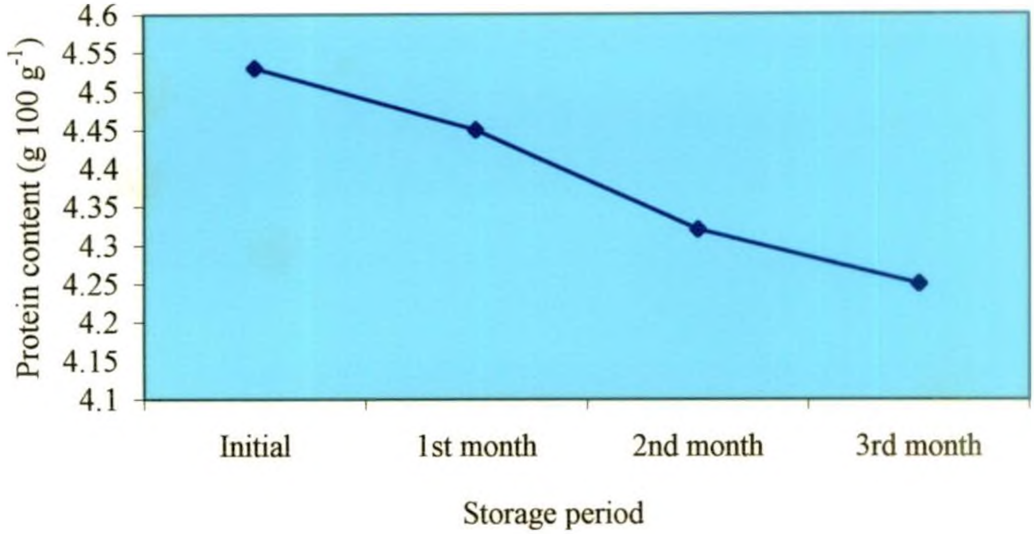

Fig. 8. Effect of storage period on the protein content of breadfruit flour

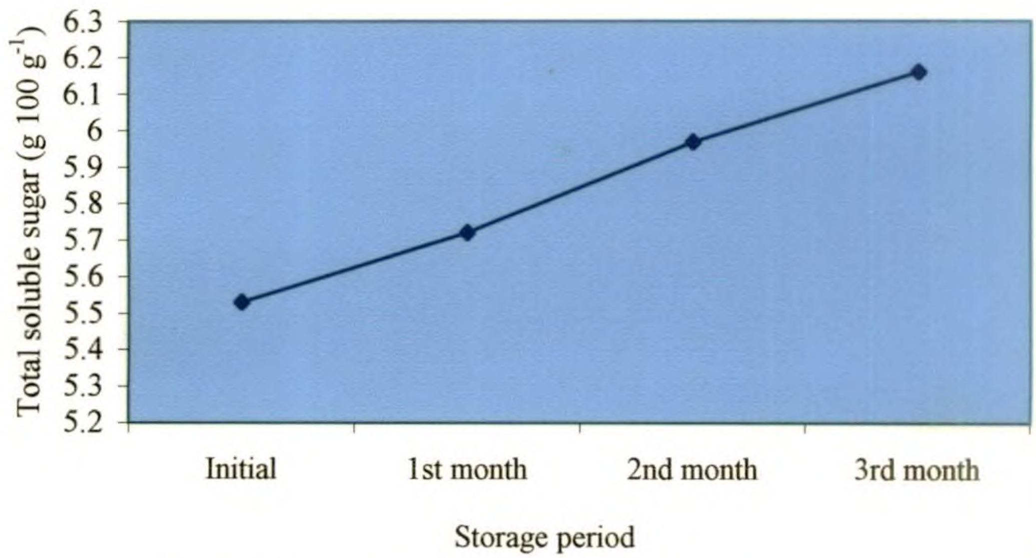

Fig. 9. Effect of storage period on total soluble sugar of breadfruit flour

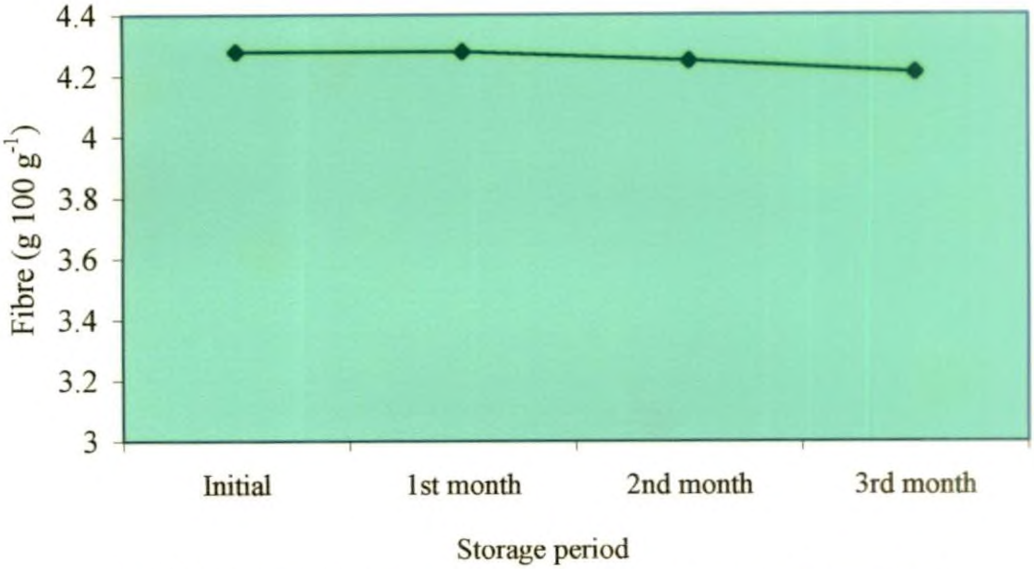

Fig. 10. Effect of storage period on fibre content of breadfruit flour

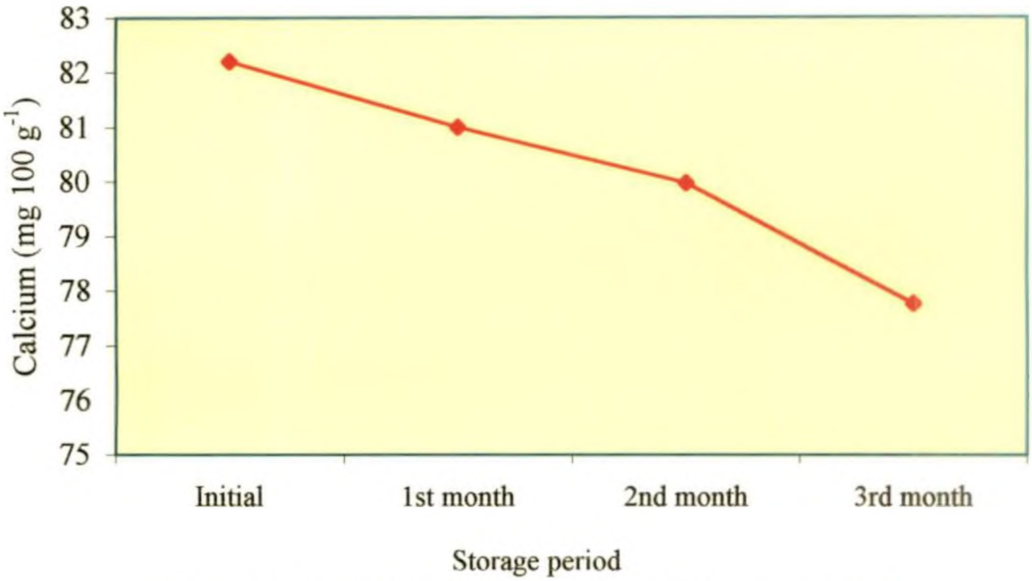

Fig. 11. Effect of storage period on calcium content of breadfruit flour

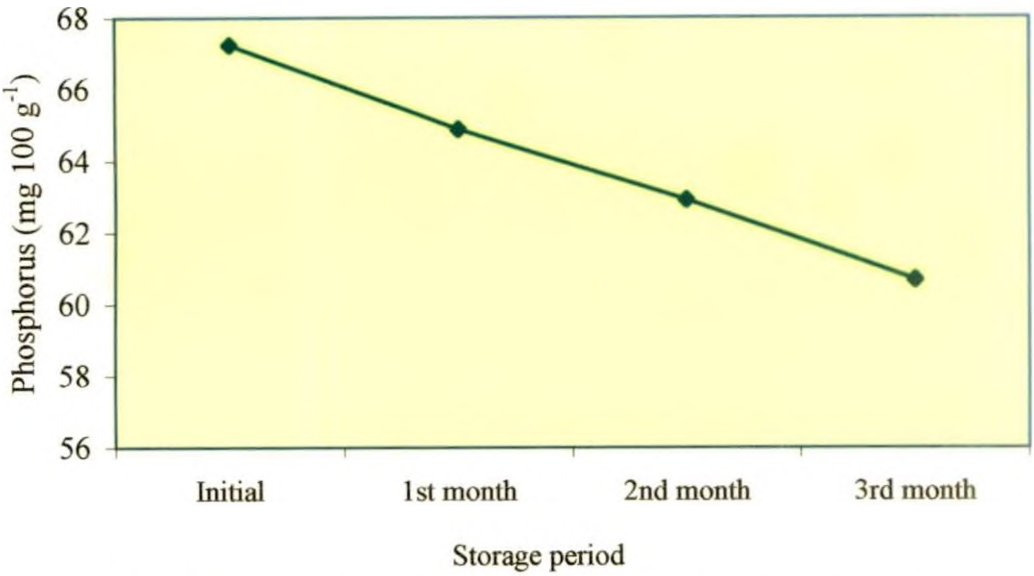

Fig. 12. Effect of storage period on phosphorus content of breadfruit flour

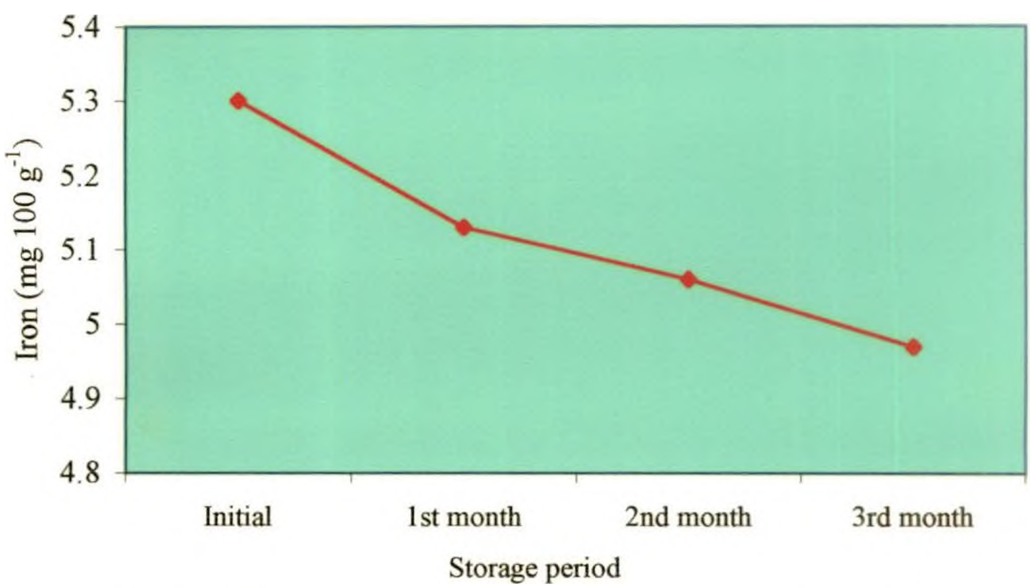

Fig. 13. Effect of storage period on iron content of breadfruit flour

4.3 ORGANOLEPTIC EVALUATION OF BREADFRUIT FLOUR AT MONTHLY INTERVALS

The scores obtained for the organoleptic evaluation of the breadfruit flour for the different quality attributes stored for a period of 3 month is presented in Table 10.

Table 10. Mean scores for organoleptic evaluation of breadfruit flour stored for 3 months

Storage period / Character	Initial	1st month	2nd month	3rd month
Appearance	4.25	4.25	4.20	4.10
Colour	3.65	3.60	3.50	3.50
Flavour	3.20	3.10	2.80	2.65
Texture	4.20	4.15	4.15	4.00
Taste	2.80	2.65	2.40	2.30
Total score	18.10	17.75	17.05	16.55

The characteristic appearance of the fresh flour scored a maximum of 4.25 (Plate 3), which did not show any change during the first month but by third month the scores decreased to a minimum of 4.1.

The colour of the flour scored maximum during the initial period (3.65). This gradually decreased with the storage period and at the end of the 3rd month the scores obtained for colour was 3.5. The attribute flavour of the breadfruit flour scored a maximum of 3.2 which decreased to a minimum of 2.65 on the 3rd month.

The texture of the flour remained almost the same throughout the storage period. The maximum score of texture of the fresh flour was 4.2 and it come to 4 by the end of third month.

Mean score for the taste of the flour was 2.8, which was maximum in the initial period which decreased to reach a minimum of 2.3 after 3 months of storage. There observed a gradual reduction of the total score, which was highest (18.10) initially and the least (16.55) after 3 months of storage (Fig. 14).

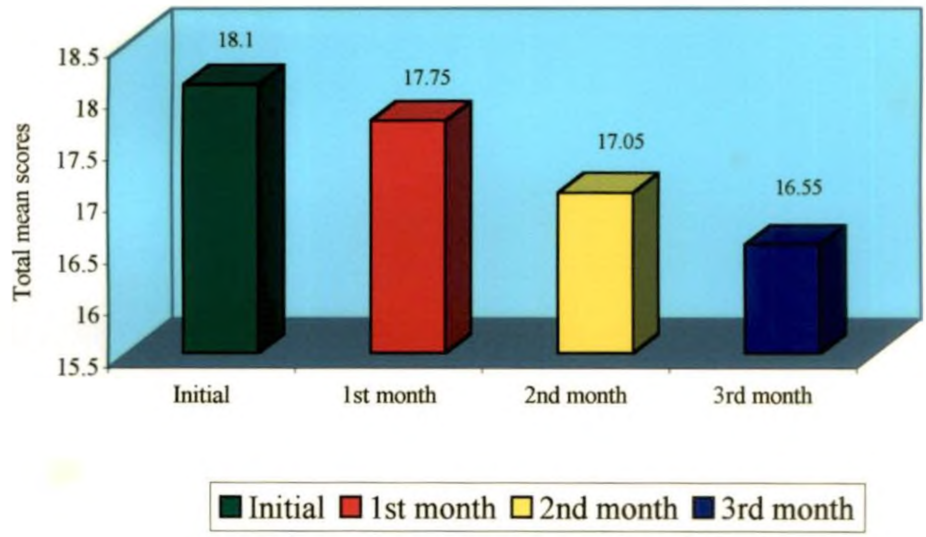

Fig. 14. Total mean score for organoleptic evaluation of breadfruit flour stored for three months

Plate 3. Breadfruit flour

The results of the statistical analysis obtained for the breadfruit flour for the different quality attributes studied for a period of 3 months is presented in Table 11.

Table 11. Changes in scores of the various parameters of flour over the periods of storage

Storage period / Character	Appearance	Color	Flavour	Texture	Taste
Period I	0.000[a] (1.400)	-0.050[a] (1.374)	-0.100[a] (1.210)	-0.050[a] (1.389)	-0.150[a] (1.338)
Period II	-0.050[a] (1.374)	-0.100[a] (1.358)	-0.300[a] (1.180)	0.000[a] (1.405)	-0.0250[a] (1.287)
Period III	-0.100[a] (1.363)	-0.650[b] (1.086)	-0.200[a] (1.283)	-0.150[a] (1.352)	-0.100[a] (1.349)

Part I - first month
Part II - second month
Part III - third month
Figures in paranthesis are $\sqrt{x+2}$ transferred
Values having different superscript differ significantly at 5% level
DMRT columnwise comparison

As revealed in the table above the character viz., appearance, flavour, texture and taste had no significant variations on storage but there was a significant reduction in the color of flour on storage.

4.4 MICROBIAL COUNT IN BREAD FRUIT FLOUR

The microbial population of the flour was assessed at monthly intervals for a period of 3 months and the results are presented in Table 12.

Table 12. Microbial count in breadfruit flour

Period of storage in months	Microbial population (cfu g^{-1})		
	Bacteria (x 10^6)	Fungi (x 10^4)	Yeast
Initial	5.2	4.6	-
1st month	7.1	7.0	-
2nd month	7.7	7.3	-
3rd month	8.9	8.3	-

As revealed in the table the microbial load increased with storage. The initial bacterial load was found to be 5.2×10^6 cfu g^{-1}, which increased gradually to 8.9×10^6 cfu g^{-1} during the 3rd month. The first and second month had 7.1×10^6 cfu g^{-1} and 7.7×10^6 cfu g^{-1} respectively.

The initial fungal load was 4.6×10^4 cfu g^{-1}, which gradually increased to 7×10^4 cfu g^{-1} and 7.3×10^4 cfu g^{-1} and 8.3×10^4 cfu g^{-1} during the first, second and third months respectively.

There was no traces of yeast found throughout the storage period.

4.5 ORGANOLEPTIC AND SHELF LIFE EVALUATION OF BREADFRUIT WAFERS AT MONTHLY INTERVALS

Eight combinations of raw ingredients used for standardization of wafers are given below.

T_1 - Breadfruit flour
T_2 - Breadfruit flour + Tomato paste
T_3 - Breadfruit flour + Ginger garlic paste
T_4 - Breadfruit flour + Tomato paste + Ginger garlic paste
T_5 - Breadfruit flour + Rice flour
T_6 - Breadfruit flour + Rice flour + Tomato paste
T_7 - Breadfruit flour + Rice flour + ginger garlic paste
T_8 - Breadfruit flour + Rice flour + Tomato paste + Ginger garlic paste

The mean scores obtained for the organoleptic evaluation of wafers made by different combinations and stored for a period of 3 months is given in Table 13.

As revealed in the table appearance of T_1 (Plate 4) had maximum initial score of 3, which decreased with storage time to a minimum of 2.70 on the 3rd month of storage. Similarly the colour also decreased from a maximum score of 3.1 to a minimum score of 2.85. The flavour had a maximum initial score of 3.25, which reduced to a minimum of 3 on the 3rd month of storage. The texture had a maximum initial score of 4.1, which did not change much with the storage time. On the 3rd month the score obtained for texture was 4. The taste of T_1 decreased with storage time from

Table 13. Scores for the organoleptic evaluation of wafers on storage

Treatments	Appearance				Colour				Flavour				Texture				Taste				Overall acceptability			
	Storage period in months																							
	P0	P1	P2	P3	P0	P1	P2	P3	P0	P1	P2	P3	P0	P1	P2	P3	P0	P1	P2	P3	P0	P1	P2	P3
T_1	3.00	2.90	2.75	2.70	3.10	3.00	2.90	2.85	3.25	3.20	3.10	3.00	4.10	4.10	4.00	4.00	2.80	2.75	2.65	2.65	2.90	2.90	2.70	2.65
T_2	4.10	4.05	3.90	3.85	4.20	4.15	4.15	4.05	3.90	3.80	3.75	3.65	4.25	4.25	4.20	4.20	3.10	3.00	2.90	2.90	3.00	3.00	2.85	2.80
T_3	4.00	4.00	3.90	3.85	4.30	4.20	4.15	4.05	3.80	3.70	3.6	3.55	4.35	4.35	4.30	4.30	3.15	3.05	3.05	3.00	3.05	3.00	2.90	2.85
T_4	4.20	4.15	4.05	4.00	4.15	4.05	4.00	3.95	3.80	3.80	3.70	3.65	4.35	4.35	4.30	4.25	3.35	3.25	3.15	3.05	3.10	3.10	3.00	2.90
T_5	4.40	4.35	4.25	4.20	4.30	4.25	4.15	4.00	4.00	4.00	3.90	3.85	4.45	4.40	4.30	4.30	4.20	4.15	4.10	4.00	4.55	4.50	4.45	4.40
T_6	4.30	4.20	4.20	4.15	4.20	4.10	4.10	4.05	4.10	4.00	3.80	3.75	4.40	4.35	4.35	4.30	4.10	4.05	4.00	4.00	4.00	4.00	3.90	3.85
T_7	4.20	4.15	4.10	4.00	4.10	4.00	4.00	3.95	4.20	4.10	4.05	4.00	4.30	4.30	4.25	4.20	4.30	4.20	4.15	4.10	4.75	4.75	4.65	4.60
T_8	4.15	4.00	4.00	4.00	4.15	4.10	4.00	3.90	4.15	4.10	4.00	3.90	4.25	4.25	4.20	4.10	4.20	4.10	4.05	4.00	4.15	4.15	4.10	4.05

P0 - Initial period of storage
P1 - 1st month of storage
P2 - 2nd month of storage
P3 - 3rd month of storage

a maximum of initial score of 2.8 to a least of 2.65. Thus, the Overall acceptability of T_1 was found to decrease gradually from an initial score of 2.9 to 2.65 by the third month of storage.

For the combination T_2 also the appearance reduced with storage time. The maximum initial score for appearance was 4.1 (Plate 5) which reduced to 3.85 on the 3rd month. The colour and flavour also decreased with storage, which had a maximum score of 4.2 and 3.9 and a minimum score of 4.05 and 3.65 respectively. The texture of T_2 did not change much, the maximum score for texture was 4.25 and on the 3rd month the score was 4.2. The taste of T_2 reduced gradually with storage from a maximum score of 3.1 to a minimum of 2.9 on the 3rd month. The overall acceptability of T_2 also reduced gradually with storage from a maximum score of 3.0 to a minimum of 2.8.

The appearance of T_3 (Plate 6) recorded a maximum score of 4, which decreased with storage time to a minimum of 3.85 on the 3rd month of storage. The colour of T_3 also decreased from a maximum score of 4.3 to a minimum score 4.05. The flavour had a maximum initial score of 3.8, which reduced to a minimum of 3.55 on the 3rd month of storage. The texture had a maximum initial score of 4.35, which reduced to 4.3 on the 3rd month of storage. The taste had a maximum initial score of 3.15, which decreased with storage time to a minimum of 3. The overall acceptability of T_3 scored a maximum of 3.05, which, with storage time reduced to 2.85 by the 3rd month.

The characteristic appearance of T_4 (Plate 7) had a maximum initial score of 4.2, which gradually decreased to 4 by the 3rd month of storage. The colour of T_4 had a maximum initial score of 4.15, which reduced gradually to 3.95 by the 3rd month of storage. The flavour of T_4 also decreased with storage from a maximum initial score of 3.8 to a minimum of 3.65. The texture of T_4 had a maximum initial score of 4.35, which gradually decreased to 4.25 by the 3rd month of storage. The taste also decreased gradually from a maximum initial score of 3.35 to a minimum of 3.05 on the 3rd month of storage. The initial overall acceptability of T_4 was 3.1, which reduced with storage, and on the 3rd month the score was 2.9.

Plate 4. Wafer T_1 (100% Breadfruit flour)

Plate 5. Wafer T_2 (Breadfruit flour + tomato paste)

Plate 6. Wafer T_3 (Breadfruit flour + ginger garlic paste)

Plate 7. Wafer T_4 (Breadfruit flour + tomato paste + ginger garlic paste)

The appearance of T_5 (Plate 8) had a maximum initial score of 4.4, which gradually decreased to 4.2 by the 3rd month of storage. The colour of T_5 had maximum initial score of 4.3, which reduced gradually to 4 by the 3rd month of storage. The flavour of T_5 also decreased with storage from a maximum initial score of 4 to a minimum of 3.85. The texture of T_5 had a maximum initial score of 4.45, which gradually decreased to 4.3 on the 3rd month of storage. The taste also decreased gradually from a maximum initial score of 4.2 to a minimum of 4 on the 3rd month of storage. The overall acceptability of T_5 was 4.55 initially which reduced with storage and on the 3rd month the score was 4.40.

The appearance of T_6 (Plate 9) had a maximum initial score of 4.3, which gradually decreased to 4.15 on the 3rd month of storage. The colour of T_6 had a maximum initial score of 4.2, which reduced gradually to 4.05 on the 3rd month of storage. The flavour of T_6 also decreased with storage from a maximum initial score of 4.1 to a minimum of 3.75. The texture of T_6 had a maximum initial score of 4.4, which gradually decreased to 4.30 on the 3rd month of storage. The taste of T_6 also decreased gradually from a maximum initial score of 4.1 to a minimum of 4 on the 3rd month of storage. The initial overall acceptability of T_6 was 4.0, which reduced with storage and on the 3rd month it was 3.85.

The appearance of T_7 (Plate 10) had a maximum initial score of 4.2, which gradually decreased to 4.0 on the 3rd month of storage. The color of T_7 had a maximum initial score of 4.1, which reduced gradually to 3.95 on the 3rd month of storage. The flavour of T_7 also decreased with storage from a maximum initial score of 4.2 to a minimum of 4. The texture of T_7 had a maximum initial score of 4.3, which gradually decreased to 4.2 on the 3rd month of storage. The taste also decreased gradually from a maximum initial score of 4.3 to a minimum of 4.1 on the 3rd month of storage. The initial overall acceptability of T_7 was 4.75, which reduced with storage, and on the 3rd month the score was 4.60.

The appearance of T_8 (Plate 11) had a maximum initial score of 4.15, which gradually decreased to 4 on the 3rd month of storage. The color of T_8 had a

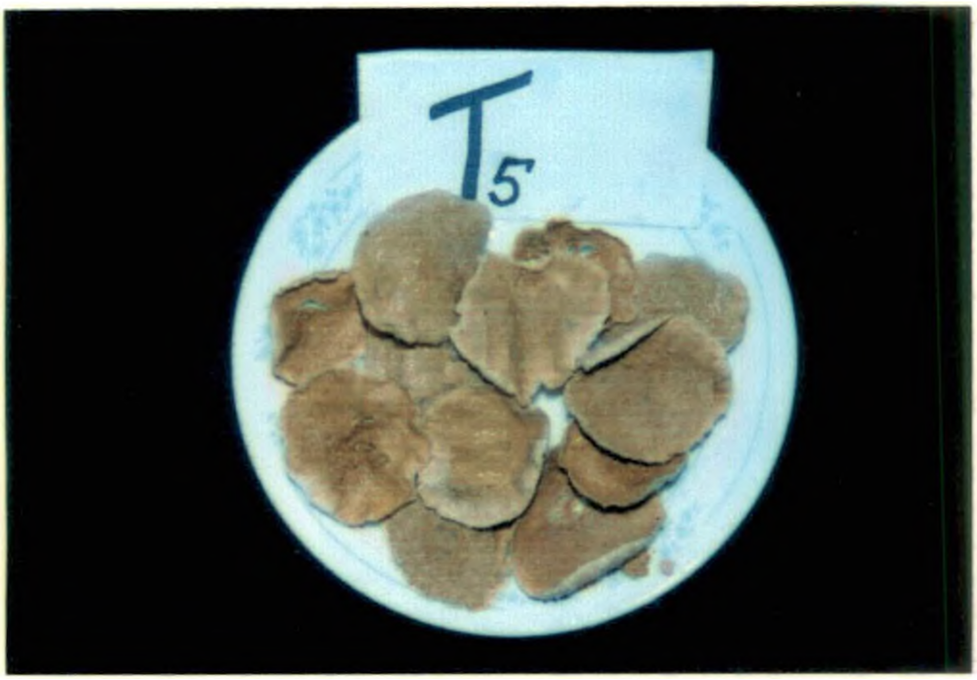

Plate 8. Wafer T_5 (Breadfruit flour + rice flour)

Plate 9. Wafer T_6 (Breadfruit flour + rice flour + tomato paste)

Plate 10. Wafer T_7 (Breadfruit flour + rice flour + ginger garlic paste)

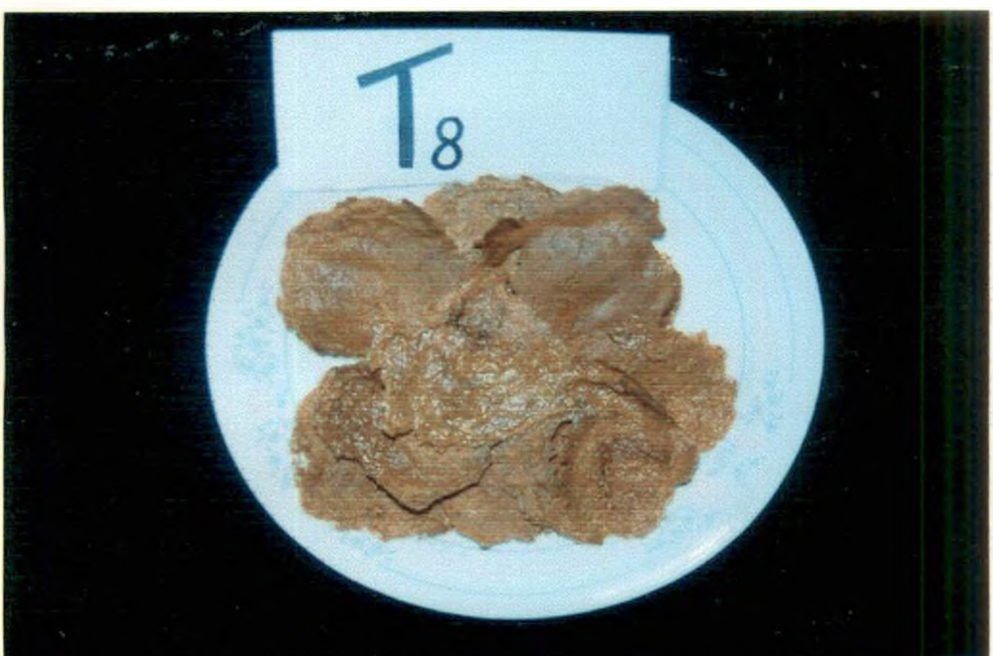

Plate 11. Wafer T_8 (Breadfruit flour + rice flour + tomato paste + ginger garlic paste)

maximum initial score of 4.15, which reduced gradually to 3.9 on the 3rd month of storage. The flavour of T_8 also decreased with storage from a maximum initial score of 4.15 to a minimum of 3.9. The texture of T_8 had a maximum initial score of 4.25, which gradually decreased to 4.10 on the 3rd month of storage. The taste also decreased gradually from a maximum initial score of 4.2 to a minimum of 4.0 on the 3rd month of storage. The initial overall acceptability of T_8 was 4.15, which reduced to 4.05 on the 3rd month of storage.

Statistical analysis was conducted to find out the effect of different treatments and the effect of storage periods on the acceptability of wafers and the results are given in Table 14 and Table 15 respectively.

Table 14. Effect of treatments on the acceptability of wafers

Character / Treatment	Appearance	Color	Flavour	Texture	Taste	Overall acceptability
T_1	2.84^{e}	2.96^{d}	3.14^{c}	4.05^{d}	2.71^{g}	2.79^{g}
T_2	4.08^{c}	4.14^{ab}	3.78^{ab}	4.23^{bc}	2.96^{f}	2.91^{f}
T_3	3.94^{d}	4.18^{a}	3.66^{b}	4.33^{a}	3.06^{e}	2.95^{f}
T_4	4.10^{bc}	4.04^{c}	3.74^{b}	4.31^{a}	3.20^{d}	3.00^{e}
T_5	4.30^{a}	4.18^{a}	3.93^{ab}	4.36^{a}	4.11^{b}	4.48^{b}
T_6	4.21^{ab}	4.11^{b}	3.91^{ab}	4.35^{a}	4.03^{c}	3.94^{d}
T_7	4.11^{bc}	4.01^{c}	3.84^{ab}	4.26^{b}	4.19^{a}	4.69^{a}
T_8	4.06^{c}	4.04^{c}	4.04^{a}	4.20^{c}	4.09^{b}	4.11^{c}

Values having different superscript differ significantly at 5% level
DMRT coloum wise comparison

Table 15. Effect of storage on the acceptability of wafers

Character / Strage period	Appearance	Color	Flavour	Texture	Taste	Overall acceptability
P_0	4.04^{a}	4.06^{a}	3.90^{a}	4.31^{a}	3.65^{a}	3.69^{a}
P_1	4.03^{a}	3.98^{b}	3.84^{ab}	4.29^{a}	3.57^{b}	3.66^{a}
P_2	3.89^{b}	3.93^{c}	3.78^{c}	4.24^{b}	3.51^{c}	3.57^{b}
P_3	3.84^{b}	3.85^{d}	3.67^{bc}	4.21^{b}	3.46^{d}	3.51^{c}

Values having different superscript differ significantly at 5% level
DMRT coloum wise comparison

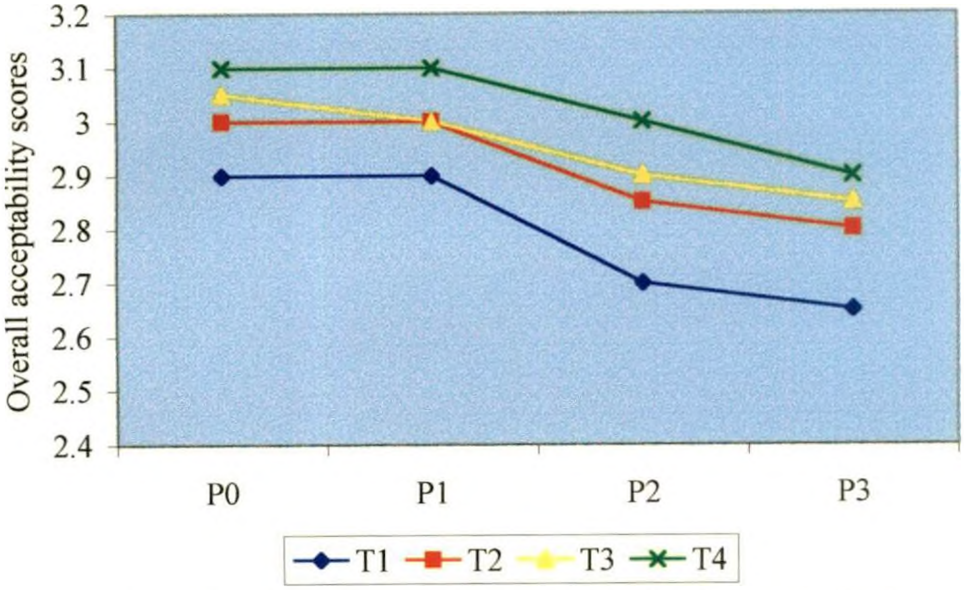

Fig. 15a. Overall acceptability scores for the organoleptic evaluation of wafers on storage

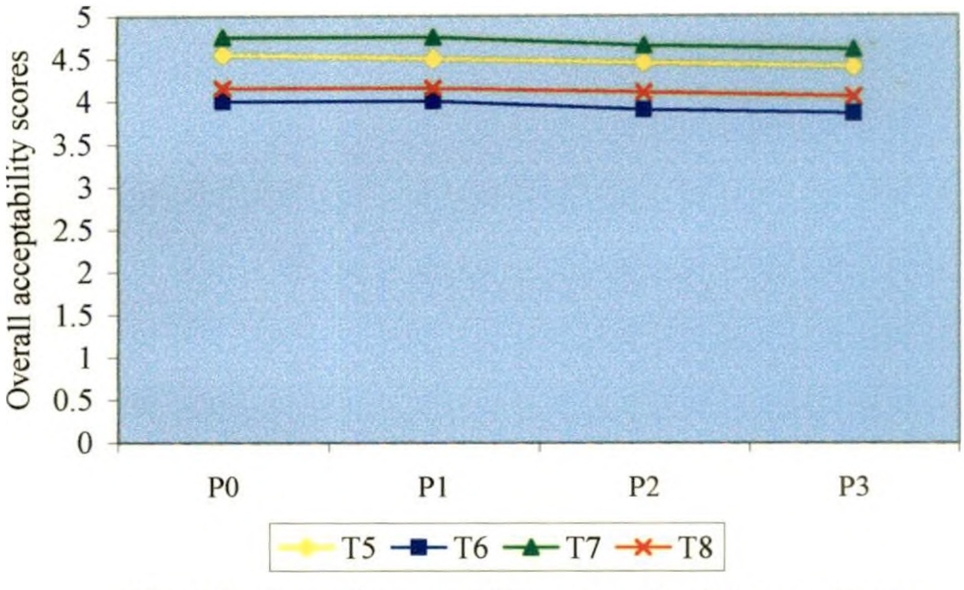

Fig. 15b. Overall acceptability scores for the organoleptic evaluation of wafers on storage

As revealed in Table 14 there is significant difference in the appearance of the products due to different treatments. Maximum score for appearance was for T_5 (4.3) and the minimum score was for T_1 (2.84). T_6 had a score of 4.21, which is not statistically different from T_5. T_7 had a score of 4.11 for appearance, which is comparable to T_6 and T_4. Significant difference in the appearance was observed between T_1, T_2, T_3, T_4 and T_5.

The color of the products also showed a significant difference with regard to treatments. Maximum score for color was for T_3 and T_5 (4.18) and the minimum score was for T_1 (2.96). T_2 had a score of 4.14, which is not statistically different from T_3 and T_5. T_6 had a score of 4.11, which is comparable to T_2. There was no significant difference in color for T_4, T_7 and T_8. A significant difference in color was observed between T_1, T_3, T_4 and T_6.

The maximum score for flavour was for T_8 (4.04) and the minimum score was for T_1 (3.14). A significant variation in flavour was not observed between T_2, T_3, T_4, T_5, T_6 and T_7.

The maximum score for texture was for T_5 (4.36) and the minimum score was for T_1 (4.05). No significant variation in texture was observed between T_3 (4.33), T_4 (4.31), T_5 (4.36) and T_6 (4.35).

The maximum score for taste was for T_7 (4.19) and the minimum score was for T_1 (2.71). T_5 had a score of 4.11, which was comparable to T_8. Significant difference in the taste was observed between T_1, T_2, T_3, T_4, T_5, T_6 and T_7.

The overall acceptability was maximum for T_7 which had a score of 4.69 and the minimum was for T_1 which had a score of 2.79. A significant difference in the overall acceptability was observed between all the treatments.

Statistical analysis on the effect of storage period on the quality attributes of the wafers (Table 15) indicated that the appearance of wafers did not show any significant difference when stored for one month but during the 2^{nd} month onwards there was a significant changes in the appearance. P_2 had a score of 3.89, which is not statistically different from P_3. Significant difference in appearance was observed between P_0 and P_2.

The colour of wafers scored a maximum of 4.06 for P_0 and least score was for P_3 (3.85). There was significant difference in colour throughout the storage period.

The flavour of wafers scored a maximum for P_0 (3.90) and least for P_3 (3.67). P_0 had a score, which is not statistically different from P_1. P_2 had a score 3.78 which is not statistically different from P_3 (3.67). There is significant difference in flavour upto one month of storage.

The texture of wafers scored a maximum for P_0 (4.31) and minimum for P_3 (4.21). There was no significant difference between P_0 and P_1. P_2 is not significantly different from P_3. Significant difference was observed between P_0 and P_2.

The taste of wafers scored a maximum for P_0 (3.65) and a minimum for P_3 (3.46). Significant difference was observed in the taste of the products on storage.

The overall acceptability was maximum for wafers stored upto one month, later the acceptability scores were found to be decreasing significantly.

Discussion

5. DISCUSSION

The discussion pertaining to the study is explained under the following headings.

5.1 MOISTURE CONTENT, ORGANOLEPTIC QUALITIES AND SHELF LIFE EVALUATION OF BREADFRUIT CHIPS

The moisture content of both types of chips (blanched) and also the effect of storage period of chips in pet jars and polyethylene bags in the moisture content was evaluated.

5.1.1 Moisture

Moisture content of chips was found to be influenced by the method of processing, storage containers and storage periods. Freshly fried chips expressed a higher moisture content (3.94 g $100g^{-1}$) than blanched fried chips (2.02 $g100g^{-1}$). This can be explained by the fact that blanched chips are dried first and then fried so that at the time of frying they might have a lower moisture content, whereas freshly fried chips are not dried before frying thereby having more initial moisture content. Liya (2002) also observed that the freshly fried taro chips had higher moisture content than the blanched fried chips. Anand (1982) observed that an important criterion that governs the quality of potato chips is the moisture content of the chips.

The moisture content of both types of chips increased significantly when stored in polyethylene bags and pet jars. However, storage in polyethylene bag was found to be better for chips than pet jars with regard to the absorption of moisture. The moisture content of fresh chips was 4.94 g 100 g^{-1} when stored in polyethylene bags, but when stored in pet jars moisture content was found to be 5.13 g 100 g^{-1} which is significantly high when compared. Similarly the moisture content of blanched chips stored in polyethylene bags was 3.03 g $100g^{-1}$ but when stored in pet jars moisture content was found to be 3.27 g 100 g^{-1} which is significantly high when compared. This can be due to the fact that pet jars are moderate barrier to water vapour when compared to polyethylene bag (Balasubramanyam, 1995).

With regard to storage period (Table 3) the moisture content increased significantly in both types of chips due to storage period (60 days). But when compared to fresh chips, moisture content was significantly low in blanched chips throughout the storage period. This low moisture content of blanched chips in storage may be due to the following factors. Fresh chips are directly fried in oil so that no significant changes occur to starch granules. Normal starch granules have more loosely packed regions that are amorphous and they exist between the miscelles in each concentric shell in the starch granule. Water can easily enter the amorphous regions of the grain. But during parboiling restricted type of swelling pattern of starch granules are exhibited suggesting strong bonding forces within the starch granule (Cheng *et al.*, 1982). This may be the reason for the decreased absorption of moisture by the blanched chips during storage.

Moisture content with regard to storage period and storage containers (Table 4) revealed that there was no significant difference in the moisture content of chips stored in polyethylene bag (3.41 g 100 g^{-1}) and pet jar (3.68 g 100 g^{-1}) up to 15 days of storage but by the end of storage period more moisture was observed in chips stored in pet jars indicating that polyethylene bags are more suitable for packing breadfruit chips. Premalatha *et al.* (1999) was also of the view that polypropylene packaging is the most suitable packaging system for the long term storage of fruit based products. Anjankar and Kalaivanan (2000) opined that polypropylene and its copolymers are safe and save cost of storage and transportation of food products.

Satyarati *et al.* (1981) and Hameed (1981) reported that banana chips packed in 300 gauge HDPE and 400 gauge LDPE remained satisfactory up to two months.

Thus, as observed (Table 5) in this study moisture content of blanched chips stored in polyethylene bags was significantly low during all storage periods, when compared to fresh chips. Among fresh chips, moisture content was low in those stored in polyethylene bags during all storage periods.

5.1.2 Organoleptic qualities in breadfruit chips

Organoleptic qualities such as appearance and taste of fresh chips stored in polyethylene bags and pet jars were comparable (Table 6) without any significant difference during the storage period. A significant change in the color of fresh chips stored in pet jars was observed after 45 days of storage. This brown discoloration may be due to the high moisture content of chips stored in pet jars, which might have facilitated Maillard reaction. Pigment formation is the result of polymerization of the many highly reactive compounds that are formed during the Maillard reactions, especially the unsaturated carbonyl compounds and furfural, the later yielding water insoluble brown products. The commence of Maillard reaction is strongly influenced by the reaction conditions such as temperature, duration of storage and on water activity in the food being inhibited by very high and very low water activity (Mauron, 1989).

A change in the flavour of fresh chips was observed only towards the end of the storage period (60 days) in polyethylene bag where as the change in flavour was observed during 45th day of storage in pet jars. This can also be attributed to the high moisture content of fresh chips that too stored in pet jars which is only a moderate barrier for water vapour when compared to polyethylene bags. The flavour loss in chips due to storage might be due to rancidity brought out by the high moisture content. Towards the end of the storage period, the texture of fresh chips stored in polyethylene bag was found to be unacceptable. Where as fresh chips stored in pet jars, became unacceptable by 45 days of storage. The products lost their crispness due to moisture absorption and became very tough and leathery in texture. As reported by Labuza *et al.*, 1977), polymerization of compounds in Maillard reaction definitely lead to toughening of the stored food products. Thus, for fresh chips there was significant changes in quality criteria's only after 45 days of storage in polyethylene bags where as in pet jars significant changes was observed after 30 days of storage.

The acceptability of fresh chips was good compared to that of blanched chips. The blanched chips had a poor colour and a hard texture. According to Padmaja

(1994) the blanched cassava chips were harder than plain chips due to partial gelatinisation and fusion of starch granules. The acceptability of blanched chips stored in polyethylene bag scored high when compared to pet jars. The organoleptic qualities of blanched chips showed no significant changes for the initial 30 days of storage.

5.2 CHANGES IN CHEMICAL COMPOSITION OF BREADFRUIT FLOUR

In the present study, the moisture content of the flour was found to be increased during storage period. The increase in moisture is probably because as suggested by Balasubramanyam (1995). Pet jars are only moderate barrier proof for water vapour transmission. The moisture pick up can be expected to increase with the advancement in storage period; especially when the relative humidity is higher around the storage vicinity. The dehydrated breadfruit chips when powdered to flour reported a high moisture pick up with storage (Pillai, 2001). This was similar to the findings of Chellammal (1995) in sweet potato flour and Liya (2001) in taro flour.

As per the analysis it was found that breadfruit flour contained a starch content of 65.67 g 100 g^{-1}. The values obtained are close to the value reported by Pillai (2001). The results obtained were slightly lesser than those obtained by Esuoso and Bamiro (1995) who reported a starch content of 80.9 per cent in breadfruit flour. The gradual decrease in starch content of the flour with advancement in storage period may be due to the conversion of starch to sugars that support the findings of Pillai (2001).

The prepared breadfruit flour exhibited a protein content of 4.53 g $100g^{-1}$. The result obtained is in line with the findings of Esuosa and Bamiro (1995) and Morton (1987) in breadfruit flour. The protein content showed a gradual decrease on storage may be due to browning reaction.

As per the result the TSS of the flour was 5.53 $g100g^{-1}$which is slightly lower than the findings of Pillai (2001). The TSS in the flour was gradually increasing with the advancement in storage and this may be due to the breakdown of starch to sugars as evidenced by a decrease in starch content of breadfruit flour on storage. The starch having been formed in the storage cells and tissues may become transformed in to sugars particularly sucrose, glucose and fructose during the post harvest period. This change is largely dependent upon the conditions of storage such as temperature and time. The increase in TSS with storage was also reported by Pillai (2001) in dehydrated breadfruit chips.

The fibre content of the flour was found to be 4.28 g $100g^{-1}$ which is in line with the findings of Morton (1987) and Esuosa and Bamiro (1995) and Pillai (2001). The crude fibre content was found to decrease with advancement of storage period. The decrease in crude fibre content may be due to the degradation of hemicellulose and other structural polysaccharide materials during storage.

The mineral content viz., calcium, phosphorus and iron were found to be gradually decreasing with storage.

5.3 ORGANOLEPTIC EVALUATION OF BREADFRUIT FLOUR

There was a gradual reduction in the total mean scores obtained for each quality criteria evaluated during storage of breadfruit flour. Statistical analysis revealed that there was no significant variations in sensory qualities such as appearance, flavour, texture and taste on storage but there was a significant reduction in the color of the flour due to storage. The dark brown discoloration of the flour towards the end of storage period may be due to browning reaction. Bhaskar(2000) revealed that banana flour when stored showed a slight discoloration during the later periods of storage due to enzymic browning and ascorbic acid browning.

The taste of the flour was not much acceptable to almost all members of the assessment panel due to slight astringency.

5.4 MICROBIAL COUNT OF BREADFRUIT FLOUR

The bacterial and fungal load in the breadfruit flour was found to be gradually increasing with storage. The bacterial count ranged from 5.2×10^6 cfu g^{-1} to 8.9×10^6 cfu g^{-1} and the fungal contamination ranged from 4.6×10^4 cfu g^{-1} to 8.3×10^4

cfu g^{-1}. This might be due to the increase in the moisture content in the flour. Bhaskar (2000) reported the bacterial load in banana powder to be to 6 x 10^6 cfu g^{-1}. The microbiological examination of sweet potato flour samples revealed a considerable increase in fungal count during storage (Kapoor and Kapoor, 1990).

There was no trace of yeast in the flour throughout the storage period.

5.5 ORGANOLEPTIC AND SHELF LIFE EVALUATION OF BREADFRUIT WAFERS

The wafers made by different combinations showed a significant difference in their overall acceptability (Table 14). The different treatments and the duration of storage had an influence on the organoleptic qualities of the wafers. Wafer T_7 had a highest score (4.6) when the overall acceptability was considered followed by T_5 (4.40), T_8 (4.05) and T_6 (3.85). In general wafers prepared with rice flour as an ingredient was found to be more acceptable than that with breadfruit flour alone. Wafers made with breadfruit flour alone was found to be least acceptable with respect to all quality criteria's evaluated. Among the wafers prepared with rice flour as an ingredient, the overall acceptability was maximum for T_7, a combination of breadfruit flour, rice flour and ginger garlic paste in the proportion of 40:40:20. Next most acceptable product was T_5, a combination of breadfruit flour and rice flour in the proportion of 50:50.

Breadfruit flour had a slightly brown color and astringent taste that may be due to enzymic browning reaction. Besides, breadfruit flour when gelatinized produced a waxy gel which indicates the presence of more of amylopectin in breadfruit starch. Waxy starches form a soft thick mass rather than stiff gels. This characteristic together with translucence and slow retrogradation make breadfruit flour alone unacceptable in wafer preparation. But when supplemented with rice flour, which is rich in amylose, it makes an ideal combination for making highly acceptable wafers.

The organoleptic qualities of wafers varied significantly in the later periods of storage (Table 15). Up to one-month storage no significant changes occurred in the organoleptic qualities. The changes in organoleptic characters may be due to the moisture pick up. As reported by Liya (2001) the increase in moisture content, total sugars and decline in the starch content with storage can effect the organoleptic qualities of taro wafers. Studies conducted by Hema (1995) revealed that wafers made from mushroom flour in combination with black gram flour remained acceptable up to five months of storage in polyethylene bags.

Summary

6. SUMMARY

The study on the Nutritional and organoleptic qualities of value added products from breradfruit [*Artocarpus altilis* (Park) Fosberg] was undertaken to standardize value added products of breadfruit and to evaluate the nutritional and organoleptic qualities and shelf life of the products. Full-matured firm breadfruits were collected from a local household for the study.

Two types of breadfruit chips namely, the fresh and blanched were made and the effect of storage of chips in polyethylene bags and pet jars on the moisture content and organoleptic qualities were studied for a period of 60 days. The results indicated that the moisture content increased with the advancement of the storage period. There was significant variation among the types of chips, storage containers and time of storage with respect to the moisture content. Moisture content was significantly high in fresh chips (3.9 g100g^{-1}) when compared to blanched chips (2.02 g 100g^{-1}). The study indicated that the best packaging system for breadfruit chips is polyethylene bag (250 gauge) compared to pet jars. Moisture content with regard to storage period and storage containers revealed that there was no significant difference in the moisture content of chips stored in polyethylene bag (3.60 g 100g^{-1}) and pet jar (3.55 g 100g^{-1}) up to 15 days of storage but by the end of storage period more moisture was observed in chips stored in pet jars indicating that polyethylene bags are more suitable for packing breadfruit chips. The moisture content of blanched chips stored in polyethylene bags was significantly low during all storage periods when compared to fresh chips. Among fresh chips moisture content was low in those stored in polyethylene bags during all storage periods.

With regard to the organoleptic qualities of the chips the fresh chips was found to be more acceptable (4.55) than the blanched fried chips (2.20).

Organoleptic qualities such as appearance and taste of fresh chips stored in polyethylene bags and pet jars were comparable without any significant difference during the storage period. A significant change in the color of fresh chips stored in pet jars was observed after 45 days of storage. A change in the flavour of fresh chips was observed only towards the end of the storage period (60 days) in polyethylene bag where as the change in flavour was observed during the 45th day of storage in pet jars. Thus, in fresh chips significant changes in quality criteria were observed only after 45 days of storage in polyethylene bags where as in pet jars significant changes were observed after 30 days of storage indicating the suitability of polyethylene bags (250 gauge) for packing breadfruit chips.

The breadfruit flour was prepared and stored for a period of 3 months and the chemical constituents, organoleptic qualities and the microbial load was analyzed at monthly intervals. Initially the flour contained 7.30 g 100g^{-1} moisture, 65.67 g 100g^{-1} starch, 4.53 g 100g^{-1} protein, 5.53 g 100g^{-1} TSS, 4.28 g 100g^{-1} fibre, 82.20 mg 100g^{-1} calcium, 67.25 mg 100g^{-1} phosphorus and 5.30 mg 100g^{-1} iron. The moisture content and TSS increased where as the starch, protein, fibre, calcium, iron and phosphorus reduced with the storage period.

With regard to the shelf life studies there was a gradual reduction in the total mean scores obtained for each quality criteria evaluated during storage of breadfruit flour. Statistical analysis revealed that there was no significant variations in sensory qualities such as appearance, flavour, texture and taste on storage but there was a significant reduction in the color of the flour due to storage. The taste of the flour was not much acceptable to almost all members of the assessment panel due to slight astringency.

Regarding the microbial count, the bacterial and fungal load in the flour was found to be gradually increasing with storage. The bacterial count ranged from 5.2 x 10^{6} cfu g^{-1} to 8.9 x 10^{6} cfu g^{-1} and the fungal contamination ranged from 4.6 x 10^{4} cfu g^{-1} to 8.3 x 10^{4} cfu g^{-1}. There was no traces of yeast in the flour throughout the storage period.

The wafers made by different combinations showed a significant difference in their overall acceptability. The different treatments and the duration of storage had an influence on the organoleptic qualities of the wafers. Wafer T_7 which is a combination of breadfruit flour, rice flour and ginger garlic paste in the proportion of 40:40:20 had a highest score (4.6) followed by T_5 (4.40), T_8 (4.05) and T_6 (3.85). In general wafers prepared with rice flour as an ingredient was found to be more acceptable than that with breadfruit flour alone.

The organoleptic qualities of wafers varied significantly with the storage period. Up to one-month storage in polyethylene bag (250 gauge) no significant changes occurred in the overall acceptability.

Hence, from the present study we can come to a conclusion that among the primary products with breadfruit, the fresh fried chips was acceptable when stored in polyethylene bags (250 gauge) which remained acceptable for more than 45 days of storage. Breadfruit flour is a good source of starch and can be used as a composite flour for the preparation of wafers, it remained acceptable up to one month when stored in pet jars under ambient conditions. Among the different combinations of wafers prepared T_7 was the best followed by T_5, T_8 and T_6. The overall acceptability was maximum for wafers stored upto one month, later the acceptability scores were found to be decreasing significantly.

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* Originals not seen

Appendices

APPENDIX-I

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BREADFRUIT CHIPS

Sl.No.	Character	Description	Score	1	2	3	4	5
1	Appearance	Excellent Good Fair Poor Very poor	5 4 3 2 1					
2	Colour	Light Brown Medium Brown Dark Brown Brownish Black Black	5 4 3 2 1					
3	Flavour	Excellent Good Fair Poor Very poor	5 4 3 2 1					
4	Texture	Very crisp Crisp Mildly soggy Soggy Hard	5 4 3 2 1					
5	Taste	Excellent Good Fair Poor Very poor	5 4 3 2 1					
6	Overall acceptability	Like extremely Like moderately Neither like nor dislike Dislike moderately Dislike extremely	5 4 3 2 1					

Name:

Date:

Signature:

APPENDIX-II

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BREADFRUIT FLOUR

Sl.No.	Character	Description	Score	1	2	3	4	5
1	Appearance	Excellent Good Fair Poor Very poor	5 4 3 2 1					
2	Colour	White Cream Creamish yellow Creamish brown Brown	5 4 3 2 1					
3	Flavour	Excellent Good Fair Poor Very poor	5 4 3 2 1					
4	Texture	Fine powder Powder Coarse powder Grainy Clumpy	5 4 3 2 1					
5	Taste	Excellent Good Fair Poor Very poor	5 4 3 2 1					
6	Overall acceptability	Like extremely Like moderately Neither like nor dislike Dislike moderately Dislike extremely	5 4 3 2 1					

Name:

Date: Signature:

APPENDIX-III

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BREADFRUIT WAFERS

Sl.No.	Character	Description	Score	1	2	3	4	5
1	Appearance	Excellent Good Fair Poor Very poor	5 4 3 2 1					
2	Colour	Excellent Good Fair Poor Very poor	5 4 3 2 1					
3	Flavour	Excellent Good Fair Poor Very poor	5 4 3 2 1					
4	Texture	Very crisp Crisp Mildly soggy Soggy Hard	5 4 3 2 1					
5	Taste	Excellent Good Fair Poor Very poor	5 4 3 2 1					
6	Overall acceptability	Like extremely Like moderately Neither like nor dislike Dislike moderately Dislike extremely	5 4 3 2 1					

Name:

Date:

Signature:

NUTRITIONAL AND ORGANOLEPTIC QUALITIES OF VALUE ADDED PRODUCTS FROM BREADFRUIT
[*Artocarpus altilis* (Park) Fosberg]

By

SHARON, C. L.

ABSTRACT OF THE THESIS

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ABSTRACT

Breadfruit, *Artocarpus altilis* belonging to the family, Moraceae is most widely distributed species and exhibits great variability. It is a fast ripening climacteric fruit resulting in faster depletion of stored food reserves. Hence the present study on the nutritional and organoleptic qualities of value added products from breadfruit was aimed at developing simple technologies which could be easily adopted to conserve and preserve perishable commodity and minimize both their qualitative and quantitative losses.

Fully matured firm breadfruits were collected from a local household for the study. Two types of breadfruit chips namely, the fresh fried and blanched fried was made and was analyzed for moisture, organoleptic qualities and effect of storage containers at 15 days interval for a period of 60 days. There was a significant variation among the types of chips, storage containers and time of storage with respect to the moisture content. The moisture content increased with advancement of storage and polyethylene bag (250 gauge) was found to be a better packaging system than pet jar. With regard to the organoleptic qualities of the chips the fresh chips was found to be more acceptable than the blanched fried chips. No significant changes in the quality criteria's were observed in fresh chips stored in polyethylene bags upto 45 days.

The prepared breadfruit flour was stored for a period of 3 months and the chemical constituents, organoleptic qualities and the microbial load was analyzed at monthly intervals. The moisture content and TSS increased whereas the starch, protein, fibre, calcium, phosphorus and iron reduced gradually with the advancement of storage period. Statistical analysis revealed that there was no significant variations in sensory qualities of the flour such as appearance, flavour, texture and taste on storage but there was a significant reduction in the colour of the flour due to storage. A gradual increase in the bacterial and fungal load with storage of breadfruit flour was also observed whereas there was no traces of yeast found throughout the storage period.

The organoleptic qualities of wafers showed a significant difference with respect to the different treatments and storage period. The wafer T_7 (combination of breadfruit flour, rice flour and ginger garlic paste in the ratio 40:40:20) was the best followed by T_5 (combination of breadfruit flour and rice flour in the ratio 50:50), T_8 (combination of breadfruit flour, rice flour, ginger garlic paste and tomato paste in the ratio 40:40:10:10) in the ratio and T_6 (combination of breadfruit flour, rice flour and tomato paste in the ratio 40:40:20). The overall acceptability was maximum for wafers stored up to one month, later the acceptability scores were found to be decreasing significantly.