UTILIZATION OF MINOR TUBERS FOR THE DEVELOPMENT OF BAKED PRODUCTS

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DECLARATION

I here by declare that this thesis entitled **" Utilization of minor tubers for the development of baked products"** 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Utilization of minor tubers for the development of baked products"** is a record of research work done independently by Ms. Darshana.T (2002-16-02) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVATIONS

c	Control Sample
CD	Critical Difference
cms	centimetres
et al	and others
Fig	Figure
g	grams
g/100g	gram per 100 gram
g/kg	gram per kilogram
hrs	hours
mg	milligram
min	minutes
ml	millilitre
MT1	Arrowroot
MT2	Taro
MT3	Elephant foot yam
MT4	Yam
MT5	Coleus
MT6	*Nanakizhangu*
MT7	*Cherukizhangu*
PET	Poly Ethylene Terephthalate
Rs	Rupees
SE	Standard Error
sp	species

Introduction

1. INTRODUCTION

Food is an integral part of all living things as the very survival depends on a minimum intake of balanced foods for meeting the energy and other needs of the body. Current Indian population is more than one billion, 36 per cent of them is below the poverty line and about 210 million people (21 per cent) are under nourished. Non availability of adequate nutritious food for the fast growing population is a challenging problem.

India is the second largest food producer in the world and the food requirement is 215 million tonnes. Cereals and pulses are staple food of India. Roots and tubers are the most important food crops of man after cereals. Tuber crops have the potentiality to produce significantly high amount of food per unit area. This group of crop can substitute for cereals owing to its higher carbohydrate and calorie content

The tuber crops put together occupy an area of 48 million hectares with an yield of 12 tonnes per hectare in the world. In India they are cultivated in an area of 1.4. million hectares with a yield potential of 16 tonnes per hectare.

Food processing is very important for prosperity of India. Food processing industry helps to avoid post harvest losses of agricultural produce. In India, the value addition of food production is only 7 per cent, compared to 23 per cent in China, 45 per cent in Philippines and 88 per cent in United Kingdom (Mallaya, 2003). Perishable nature of roots and tubers calls for research works on the possibility of developing various value added food products.

The demand for diverse use of products such as bread, biscuits, noodles, cakes and pasta products has increased tremendously in recent years. Fresh horticultural produce is highly perishable, which needs to be marketed immediately or processed into varied value added products. Improved value addition to agricultural crops, is necessary to ensure sustainability and prosperity through agriculture. In most of the developed countries the agricultural produces are processed, packaged and marketed. There is a need for minimally processed foods and the food industry is focusing its research on the technologies that offer potential for preserving the wholesomeness of food.

Sethi (1996) emphasized that all 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.

The utilization of minor tubers is restricted to its use as a vegetable in India. Some tuber crops are called minor tuber crops due to their less popular cultivation. They are cultivated in the backyard or kitchen gardens and at times in small areas of one or two cents only. Minor tuber crops with a potential yield of 10 to 15 tonnes per hectare has tremendous scope to be used for preparation of commercial food products which can be distributed on a wider scale. There is much scope for including the minor tuber crops in the manufacture of processed or semiprocessed foods. The change in day to day life of an average Indian due to urbanization, increased per capita income, change in life style and increase in working women population has resulted in an increase in the consumption of processed foods. Today many value added products such as fructose syrup, alcohol, extruded products, confectionary products, cosmetic powders, pharmaceutical preparations and biodegradable plastics are manufactured industrially using tuber crops.

Recent efforts towards increased production of tuber crops have necessitated opening up new vistas for processing to develop a variety of value added convenience foods of nutritional significance. Information on the suitability of minor tubers for production of value added food is extremely limited and hence the present study is proposed with the objective to develop value added baked products utilising minor tubers and to evaluate the quality of the developed products.

Review of Literature

2. REVIEW OF LITERATURE

This chapter describes the earlier research findings under the head "Utilization of minor tubers for the development of baked products", presented under the following sections.

2.1. Use of minor tubers in Indian dietaries

2.2. Nutritional significance of minor tubers

2.3. Medicinal properties of minor tubers

2.4. Value addition and processing of minor tubers

2.1. USE OF MINOR TUBERS IN THE DIETARIES OF INDIANS

Tropical tubers, which are known as the energy banks of nature serves either as a primary or secondary staple to meet the calorie needs of about one fifth of the world population. According to a study conducted by FAO (1997) roots and tubers are plants yielding starchy roots, tubers, rhizomes, corms and stems. They are used mainly for human consumption, for animal feed and for manufacturing starch, alcohol and fermented beverages (Sreenivas *et al.,* 1998.)

A number of edible tubers, roots and corms form an important part of the diet of many people in different parts of the world. In tropical countries, cassava, sweet potatoes, taro, yams, lesser yams and arrowroot are the most important in this class. These food crops are relatively easy to cultivate and give high yields per hectare (Michael, 1997)

Thompson (1996) opined that minor tubers form the major staple in some parts of tropics and contribute as major source of carbohydrate in the diet.

Arrowroot has been identified as a minor tuber. One species *Maranta arundinacea* has been cultivated for the edible rhizomes. It has been widely distributed throughout the tropical countries like India, Sri Lanka, Indonesia, Philippines and Australia.

Arrowroot is mostly cultivated by the tribals and marginal farmers for the edible tubers, which contains good quality starch. CTCRI (2003) reported that arrowroot is valued for its starch.

Taro (*Colocasia esculenta* (L) Schott), which is one of the most ancient food crops, is a herbaceous tuber bearing plant belonging to the family *aracea*. A world wide estimate by FAO (1998) described that taro was cultivated in an area of 1.08 million hectare, and the production was 6.60 million tonnes of tubers. Santha *et al.* (1999) found that taro is cultivated in India in almost all the states, right from the foot hills of Himalayas to the Southern plains of the Peninsula.

Narzary and Rajendran (1999) reported that taro (*Colocasia*) along with other root crops like cassava, sweet potato and yam have assumed great importance in Indian agriculture due to their yield potential and adaptation to varied environmental conditions.

CTCRI (1993) reports also showed that taro is cultivated almost all over India for their underground tubers. The tuber and leaves are used as a vegetable. Maga (1992) stated that taro is a root crop that has been the staple food in many areas of tropical and subtropical world.

Anigbogu (1996) reported that the matured corms and young shoots of taro are mostly used as a vegetable boiled , roasted or fried. Roasted or boiled corms are mashed and used as weaning diet. Mature edible aroids are also processed into flour. Tomling *et al.* (2000) found that the taro flour can be stored for a considerable period and can be reconstituted with hot water to form a paste or dough. The colour of the paste or dough is light to dark brown.

Another minor tuber, elephant foot yam (*Amorphophallus paeoniifolius*) is the best among the tubers (Raghu *et al.*, 1999). It belongs to the *aroidea* family. CTCRI (1999) reported that there are a number of varieties of elephant foot yam under cultivation in our country having cream to reddish flesh. A high yielding variety for general cultivation 'Gajendra' has been released from West Bengal, and a variety 'Sree Padma' has been released from CTCRI, Trivandrum.

Tindall (1994) stated that elephant foot yam is boiled and used as a vegetable. The calcium oxalate crystals present in the elephant foot yam is responsible for the itching and irritation. This is removed by extensive boiling. The corms are carefully cleaned and stored in heaps preferably in well ventillated sheds. They may lose up to 25 per cent of their weight during the first month of storage but may be successfully stored for several months at 10°C. Raghu *et al.* (1999) has reported that elephant foot yam in Kerala is eaten as vegetable in curries.

Yam (*Dioscorea* sp.) is another important minor tuber that has a place in the Indian dietaries (Prema *et al*., 1994). There are edible species of yams namely *Dioscorea esculenta, Dioscorea alata and Dioscorea rotundata* popularly cultivated in India for the underground tubers. Opara (1999) stated that yams are mainly grown for direct human consumption and are marketed as fresh produce in all the growing areas. These are primarily used as a vegetable. CTCRI (1993) reported that yams are consumed in various forms such as boiled, roasted, fried, pounded, flour and chips. Yams are second to cassava as the most important tropical root crops.

Attaie *et al.* (1998) found that yam tubers remain dormant during the unfavourable agro climatic conditions. Thus the fresh tuber, has a longer shelf life than other roots and tubers. Tubers are also often dried for longer storage and later milled into flour for reconstituting into a stiff paste which is eaten with soup. The development of yam based products could further promote this tuber. Research on the quality characteristics of yam starch done by Berthaud *et al.* (1998) revealed that the starch may identify additional market segments beyond those for fresh roots.

Coleus is used as a vegetable having special flavour and taste (Mandal, 1993). A high yielding variety CP-11 has been developed at CTCRI, Thiruvananthapuram (CTCRI 2002)

Lesser yam (*Dioscorea esculenta* (Lour) Burk) is among the most ancient species of the genus *dioscorea*, which has been cultivated in China since second century AD. It has been originated from India, Vietnam, Papua New Guinea and Philippines. It is widely distributed throughout the tropics. IPGRI (1994) stated that in India lesser yams are cultivated in Bihar, Tamil Nadu and Kerala.

2.2 NUTRITIONAL SIGNIFICANCE OF MINOR TUBERS

Roots and tubers are the most important food crops after cereals Chadha (1993). They possess many nutritional components and are available at a relatively cheaper rate. He also reported that roots and tubers derive reasonable importance in view of the fact that six per cent of worlds dietary energy is provided by them. This group of crop can easily substitute for cereals owing to their higher carbohydrate and calorie content.

Mandal (1993) opined that tropical tubers viz., cassava, sweet potato, yams, elephant foot yam and arrowroot are used as the major source of non conventional cheap supplementary starchy food in the diet of about 450 million people of the humid tropics.

According to Edison (1999) tuber crops constitute an important food crop of man from time immemorial sustaining people during the days of famine or when there is shortage in food. Ahn *et al*. (1998) reported that among these crops, the most important are cassava, sweet potato, yam and aroids and they form the most important staple or subsidiary food for about 20 per cent of worlds population. Edison (1999) also opined that tuber crops have high biological efficiency and highest dry matter production than all other crops. Most striking aspect is that they supply a cheap source of food energy to the weaker sections of the people.

Arrowroot is well known for its high starch content. According to Heinz (1993) arrowroot is somewhat fibrous and has of 19.20 per cent starch, one to two percent protein and some sugar. Arbizu (1994) stated that arrowroot stores starch in the root stocks, the edible types have more fleshy rhizomes with better flavour and taste and low fibre and tannin content.

Seralathan and Thirumaran (1999) reported that among minor tuber crops, *colocasia* was found to have highest thiamine content. *Amorphophallus* was found to be an excellent source of carotene (260 mg per 100g).

Balagopalan (2000) opined that like other tuber crops, calcium content is high in *colocasia* and *alocasia,* while *amorphophallus* is poor in calcium. *Colocasia* and *amorphophallus* are fair source of iron and all aroids have high amounts of phosphorus (49.00 - 60.00 mg per 100g fresh weight) and the leaves of colocasia are exceptionally rich in minerals, vitamins and protein. He has also opined that starch is the major component of the dry matter of edible aroids and ranges from 18.00 to 28.00 per cent of fresh weight in *colocasia* and 15.00 to 20.00 per cent in *amorphophallus.*

Moy *et al.* (1993) reported that taro starch, because of its good protein and vitamin content, could provide a good cereal substitute. Liya (2002) reported that the total sugar content of taro flour was found to increase during the storage period (3 months). This was supported by Chellammal (1995) who opined that the conversion of starch to sugar during storage may be the reason for the increase in sugar content of stored products.

Apart from these nutritional constituents, some minor tubers including taro contains some non nutritional constituents such as trypsin inhibitors. Padmaja *et al.* (1999) reported that boiling and/or baking could inactivate these inhibitors in sweet potato, taro and swamp taro. Vinas *et al.* (1999) also reported that heat treatment removes the acrid, irritating property of the raw corms. James (1994) stated that *dioscorea* sp has superior flavour and contained no toxic substances.

Sheela and Abraham (1994) conducted a study on lesser yams and found that these tubers were less fibrous and had good palatability, soft texture, than most larger yams and were free of toxins. They had a starch content of 29.66 per cent and sugar content of 47.41 per cent.

According to Raja and Ramakrishana(1990) the reducing sugar content of *amorphophallus* was reduced by 0.99 to 0.23 per cent on parboiling. Balagopalan (2000) reported that the dietary fibre in *amorphophallus* is 1.5g per 100g, in *colocasia* 4.3g per 100g, *alocasia* 1.9 g per 100g and in *xanthosoma* 3.6g per 100g. He also cited that aroids especially *amorphophallus* has good protein content ranging from 1.50 to 4.00 per cent of fresh weight.

Baked products especially cake, biscuit and bread are highly liked by all segments of population. According to Wayre (1994) consumption pattern of baked products has increased many folds as they serve as a vehicle for nutrients.

According to Mathew and Nanda (1999) among the baked products bread still dominates as staple food since it is extremely convenient in that it requires no further preparation once purchased. Its keeping quality, convenience of transportation and suitability for enrichment with vitamins, minerals and protein concentrates are the special advantages.

Hasmukh *et al.* (2003) stated that bread provides important amounts of protein, starch, iron and whole wheat bread provides almost all the natural vitamins and minerals including niacin, riboflavin, thiamine, vitamin E, iron and calcium. Whole wheat bread also contains bran and important source of fibre, white bread has little fibre.

Lunning and Rooze (1991) reported that increasing lipoxygenase in bread dough can improve its rheological characteristics, nutritional quality and shelf life.

In the case of biscuit, Agarwal (1994) opined that biscuits have an important role to play in diet supplements for both adults and children. Pratima *et al.* (2000) reported that during recent years considerable interest has been developed in high protein baked products especially biscuits.

Gallagher *et al.* (2003) stated that biscuits made using whey protein as a fat replacer resulted in acceptable sensory quality and high protein content compared to control.

According to Gandhi *et al.* (2001) biscuits are very convenient and inexpensive food products and are becoming popular among both rural and urban population of India. These baked products have about 6.00 to 7.00 per cent protein. There is an evergrowing demand for high protein biscuits of therapeutic value.

Hou and Yamamoto (1996) reported that wheat flours with weak gluten strength and softer wheat grain have been specified for good biscuit making quality. Gandhi *et al.* (2001) stated that the enrichment of protein may be achieved through incorporation of protein rich ingredients.

2.3 MEDICINAL PROPERTIES OF MINOR TUBERS.

Minor tubers are rich in their nutritional content, at the same time most of them possess medicinal properties. Minor tubers are low cost, calorie dense food which are suitable in the Indian situation to alleviate calorie malnutrition.

Manjula *et al* (1999) stated that *Maranta arundinacea* Linn (Arrowroot) is an important medicinal herb of the family *Marantaceae.*

The dried and powdered tuber is a nourshing food for infants, convalescents and invalids.

According to Vimala (1995) arrowroot starch values as a food especially for invalid and convalescents. It possesses demulcent properties and are given in bowel complaints. It is used as a suspending agent in the preparation of barium meals and the starch is preferred in tablet making since it produces rapid disintegration.

Warrier *et al.* (1994) reported that the tuber of arrowroot are used in medicine as remedy for diarrhoea, bronchitis, cough and dyspepsia.

Taro also possesses some medicinal properties. Balagopalan (2000) opined that the *colocasia* tubers are generally low in sodium and hence can be advantageously used in low salt diets prescribed for patients with high blood pressure.

According to Gosh (1994) *Colocasia esculenta* and *Dioscorea alata* is gradually becoming the only source of calories for diabetic patients. He also suggested that the most remarkable quality of taro is its acceptance by people who are allergic to some other sources of carbohydrates.

Sahai and Jackson (1999) reported that taro malt prepared from taro flour is considered as a good infant and invalid food. Halawatan *et al.* (1998) stated that the tubers of taro is used in the treatment of indigestion. The leaf is used to treat asthma.

Amorphophallus paeoniifolius (elephant foot yam) is described in Ayurveda in connection with dietetics and medicinal uses. Raghu *et al.* (1999) reported that elephant foot yam is widely used in the ancient alchemy. It cures piles, gastric disorders, liver disorders and stimulates liver secretion and is an excellent laxative. The use of this tuber is not only limited to scientific ayurvedic treatment, but also as detoxifying agent.

Balagopalan (2000) reported that some species of *amorphophallus* contain appreciable amounts of glucomannans. The presence of glucomannans could be the prime reason for employing *amorphophallus* tuber for certain ayurvedic preparation for piles and dysentry.

The *dioscorea* species is also used in pharmaceuticals and folk medicine. Heinz (1993) found out that *dioscorea* sp contain small amounts of sapogenin (diosgenin) and alkaloid (dioscorine) which are used as medicine.

According to Abraham (1994) the tubers of lesser yams has medicinal properties and reported to be used as an application for swellings.

De Souza (1991) reported that although clinical traits are lacking there are references of coleus being used for weight loss.

According to Nema *et al.* (2003) fermentation imparts flavour and texture to the foods. Apart from this it makes food easily digestible. Bread is prepared through fermentation. Torre *et al*. (1996) found that high quality gluten free bread with good taste and appearance are suitable for celiac patients. This bread was prepared from a mixture of corn starch, rice flour and cassava starch with a percentage contribution of corn starch 74.20 per cent, rice flour 17.20 per cent and cassava starch 8.60 per cent.

2.4 VALUE ADDITION AND PROCESSING OF MINOR TUBERS.

Generally root crops are utilized as fresh food or home consumption, processed food products, animal feed and sources of industrial starch for food and textile industries, for the manufacture of glucose, and adhesives and for the production of laundry starches.

Many value added products can be prepared from roots and tubers such as dehydrated chips, fermented products like alcohol and wine, extruded products like chunks, semolina, macroni and girts and baked products like cake, biscuits,bread and cookies. Generally these value added products are prepared from the flour of tubers.

Kamenan *et al*. (1999) pointed out that an effective procedure against storage loss is to convert the fresh tubers to flour soon after harvest.

In this way tubers would be available throughout the year through the processed products.

Shorab (1995) reported that though food processing was not given due importance in earlier time, since last few years a change has taken place in this area. Now a days the growth of technology has made many of the basic foods in to processed items and with people opting for life on a fast lane, these processed foods has come to the market as a blessing in disguise.

Mauro (1996) explained that tuber starch plays an important role in controlling the aesthetic and organoleptic characteristics of processed foods. The unique properties of starch make it an ideal agro material that can be converted into value added products.

Scott *et al.* (2000) found that the root and tuber crops produce large quantities of starch in relatively less time than other crops. This starch content endowed these crops with an extra ordinary range of potential uses. He also cited that roots and tubers are employed in manufacturing sorbitol, mannitol and noodles in China.

Many value added products can be prepared from cassava which include sago, liquid glucose used in the preparation of toffees, soft drinks and jams. Anantharaman *et al.* (1996) had reported that cassava porridge mix, cassava rava are value added products developed at CTCRI. Chellammal (1995) reported that noodles, macroni, weaning mix and wafer prepared from cassava had good acceptability and shelf life.

Augustine (1999) reported that value added products namely dehydrated chips, flour, toffee, doughnuts, cakes and biscuits could be prepared from sweet potato with good consumer acceptability. Roopa (2002) reported that jam, leather and wine prepared from sweet potato and fruit pulp blends were highly acceptable to the consumers.

Baking is a field of much importance in value addition. Baking is the primary method of cooking used in the preparation of breads, cookies, cakes, biscuits and other pastries. Baking is cooking by surrounding the item with dry heat in an oven. According to Dorko and Penfield (1993) bakery products have mostly been formulated for baking in a commercial oven. Devariya (1996) explained that the baking time will vary depending upon the size of the ingredients used.

Krishnappa (2002) explained that during baking physical and chemical changes such as expansion of the dough mass, gelatinisation of starch granules, caramelisation of sugar and gluten coagulation takes place. Hoda *et al.* (2002) reported that baked products prepared in a microwave oven prevented over heating and had a good colour. But the aroma of products prepared in hot air oven was better than those prepared in microwave oven.

According to Rao (1993) the popularity of baked products is due to their ready to eat nature, unique taste and ready availability at reasonable cost in different parts of the country including remote and rural areas. Rajani *et al.* (2000) opined that the main reason for the purchase of baked products was to save time.

Thirumaran (1993) reported that increasing industrialization and urbanisation in developing countries have brought with them a much greater use of bread because of its convenience for workers eating away from home. According to Kala *et al.* (2002) the bakery products like bread, bun, toast or biscuits are widely consumed as a source of nutrients including calories throughout the world. Bharti *et al.* (2001) reported that cakes, biscuits and bread are the major baked products used by the consumers.

Agarwal (1994) reported that biscuits are amongst the lowest cost processed foods in the country when compared to Indian sweet meats. Biscuits apart from offering good taste is a snack item with substantial energy having good shelf life and affordable price.

Sewa *et al.* (2001) opined that biscuit industry is the largest constituent of food processing industry. Jane and Enuma (1998) reported that biscuits are ready to eat convenient and inexpensive food product containing digestive and dietary principles of vital importance. Biscuits owing to their long shelf life are considered useful for nutritional enrichment in feeding programmes.

Campos (1997) reported that bread is the most widely consumed food. It provides a larger share of people's energy and protein than any other food and is often called the "stuff of life". According to Gopal (1993) the accepted term for baked foods made of flour, sugar, shortening, salt and liquid and leavened by the action of yeast is known as bread.

Gabriel *et al.* (2001) was of the opinion that bread consumption in India is steadily increasing as it offers convenience and relief from the drudgery in food preparation. They reported that the present production of bread in India is 9.58 lakh tonnes and the estimated growth rate is 9.70 percent per annum.

Several attempts have been made to prepare different varieties of baked products using roots and tubers (Tomling *et al.*, 2000).

2.4.1 Value Addition in Arrowroot (*Maranta arundinacea*).

Arrowroot is valued for starch particularly for invalids and infants. Arrowroot fetches high price in the market and has immense industrial value. Edible arrowroot grown are used commercially for starch before cassava came to prominence. CTCRI (2003) reported inspite of the wide application of arrowroot starch it is rather neglected in the homesteads with little care and management.

John *et al.* (2002) cited that arrowroot enjoys as a specialty starch in paper, pharmaceutical and cosmetic industry. Herman *et al.* (1997) stated that the arrowroot starch is used to make highly popular noodles in parts of

Vietnam and China. Vimala (1995) found that arrowroot starch is used in the preparation of biscuits, cakes, puddings and jellies.

Baking of arrowroot is not a new concept. Hermann (1994) reported that arrowroot has made the jump from traditional to modern use in Colombia where it is processed into starch and then into biscuits and widely consumed as local snack food. Vimala (1995) opined that arrowroot is eaten boiled or roasted and made into pastries.

Arbizu (1994) stated that bakery products prepared from arrowroot starch are much lighter, crispier and spongier than wheat products. Briggs *et al.* (2002) reported that because of the easy digestibility, arrowroot flour is used as an ingredient in cookies intended for infants and young children. The cookie is prepared using two parts of refined flour with one part of arrowroot flour.

2.4.2 Value Addition in Taro (*Colocasia esculenta* (L) Schott)

Taro starch and flour are used in the production of value added products. Recent research done by Arnaud and Lorenz (1999) revealed that plastic can be made biodegrdable by adding starch grains.

Mannan *et al.* (1991) prepared Sevian (Murukku) with *colocasia.* Halavatan *et al.* (1998) opined that taro products include taro chips, taro bread, taro cheese cake and taro biscuits.

Tindall (1994) found that a steamed pudding 'Poi" prepared from grated coconut and taro is popular in Hawai. He also stated that taro is peeled and used as cooked vegetable being added to soups and stews

Besides purchasing taro root in its natural state use for cooking purposes, many manufacturers have developed food products that incorporate the use of taro root as an ingredient. These include taro chips, cookies, vegetarian taro burgers. Preethi (2001) reported that all these items are available for immediate consumption. Because of its diversity the taro root can easily be used as a healthy alternative to potatoes and other tubers.

Gosh *et al.* (1988) reported that flour prepared from aroids like taro has been used to produce noodles, flakes, cookies, biscuits, infant foods and puddings. Padmaja (1994) reported that taro starch because of its extremely fine size, is superior to other starches such as corn, tapioca and potato. As this starch is not allergic it is used extensively in the production of baby foods.

Gubag *et al.* (1996) reported that ‘sapal’is a traditional fermented food made by mixing, cooked grated taro corm with coconut cream and allowing it to ferment at ambient temperature. Green Well (1994) reported that taro flour can be prepared from raw or pre cooked tuber and flour that obtained from pre cooked tuber is better. The flour can be mixed in soups and for making pan cakes, biscuits and bread. It is excellent for gravies and puddings as it is not glutinous like wheat flour.

According to Wang (1990) dehydrated taro was used in combination with skim milk and other ingredients to prepare infant gruel and drinks, similar to chocolate flavoured beverage powders.

Gahlawat and Sehgal (1998) reported that starch prepared from taro is considered to be highly digestible and the flour made from cooked and dried corms is used in the preparation of soups, biscuits, bread and beverages.

Okorie *et al.* (2002) stated that breads can be prepared using potato and taro flour which contained more carbohydrate, crude fiber, ash and minerals than wheat flour. They also found that potato and taro flours showed less oil content than wheat flour and this explained the reduced occurrence of oxidative rancidity in composite, breads from non wheat flours.

According to Sahai and Jackson (1999) taro flour has been evaluated as an additive to a wide range of bakery products, where up to 15.00 per cent taro flour could be successfully incorporated in bread, 30.00 per cent in cakes and 20.00 per cent in biscuits. Moy *et al.* (1993) opined that taro starch could be included in a number of manufactured foods such as noodles, biscuits and bread. In many parts of the world wheat flour is replaced by 10.00-15.00 per cent of starch from root crops.

Portgeiler and Reiley (1998) found that 20.00 per cent taro flour could be substituted with wheat flour during baking. They also found that taro flour could be reconstituted to fresh unfermented 'poi' (a popular Hawaiian dish)

2.4.3 Value Addition in Elephant Foot Yam (*Amorphophallus paeoniifolius*)

Seralathan and Thirumaran (1999) reported that in India the *amorphophallus* tubers are popularly consumed in Kerala and the southern parts of Tamil Nadu. The tubers are boiled and fried and used in common preparation like 'poriyal', 'kolumbu', 'morekolumbu' and 'kootu'.

CTCRI (2000) reported that to increase market, home front technologies will enable the producer to develop low cost value added products like yam sauces, pickles, starches and instant drinks can be prepared from elephant foot yam.

Value added products such as chips, murukku, papads and wafers were prepared from elephant foot yam in a study conducted by Sini (2000). It was found that the chips made from *amorphophallus* contains a good amount of starch, low oil uptake and fairly high acceptability scores.

2.4.4 Value Addition in Yam (*Dioscorea* sp.)

Yam is consumed in various forms such as boiled, roasted, fried, pounded, flour and chips.

Thirumaran and Seralathan (1999) have found that value added products can be prepared by using novel recipes like sweet stuffed parathas, tuber mashed bitsoy could be prepared from fresh tubers, *dioscorea* *esculenta and dioscorea alata.* Wafer, cripples and biscuits prepared from *dioscorea alata* tubers were found to have good acceptability.

Prema *et al.* (1994) opined that yams are prepared as a boiled vegetable and is widely used in the preparation of fufu a popular West African dish made of yam flour. Ramesh *et al.* (2002) reported that yams are second to cassava as the most important tropical root crop. Yams are mainly grown for direct human consumption and are marketed as fresh produce in all the growing areas. Common methods of preparation of yam include boiling, baking or frying.

Attempts were made to prepare some Indian snacks like yam vegetable, yam vada, yam bonda and yam vegetable cutlet, from fresh tubers of *dioscorea esculenta.* (Naik *et al.,* 1993), It was found that all the products were well accepted by the consumers with a greater acceptance for yam bonda.

CTCRI (1999) reported that yams are prepared for consumption in a variety of ways including boiling baking or frying.

Substitution of wheat flour by yam flour at 20.00 per cent level in breads has been shown by Martin and Robert (1997) to give a satisfactory product while with other bakery products such as pancakes and cup cakes acceptable at 50.00 per cent.

Sulit (1999) suggested that the starch or flour obtained from yam can be used in the preparation of liquid starches or baked goods. Chellammal and Augustine (2003) reported that yam biscuit prepared by partial substitution of yam flour with refined flour had greater consumer acceptability.

2.4.5 Value Addition in Coleus (*Solanostemon rotundifolius*)

Desouza (1991) reported that as part of a long standing tradition in India coleus roots have been used as a marinated food such as pickle that is commonly eaten as part of a vegetarian meal.

Several value added products such as cutlet, chips, bonda, halwa and vadai were prepared from a mixture of tuber flours containing coleus flour and *dioscorea* flour (Balagopalan 1993). The result revealed that bonda prepared from *dioscorea* and coleus flour scored the maximum acceptability among the consumers. He explained that this may be due to the suitability of *dioscorea* to potato and excellent flavour of coleus.

Palomar (1992) reported that based on cost analysis of root crop flour is a good substitute for wheat flour (20.00 per cent).

Materials and Methods

3. MATERIALS AND METHODS

The study entitled “Utilization of minor tubers for the development of baked products” was conducted at the Department of Home Science, College of Agriculture, Vellayani.

PLAN OF ACTION

The plan of action comprises of

3.1 Selection of minor tubers

3.2 Processing and preparation of flour from minor tubers.

3.3 Quality assessment of flours prepared from minor tubers.

3.4 Product development.

3.5 Quality assessment of developed products.

3.6 Selection of best products.

3.1 SELECTION OF MINOR TUBERS

Though a number of tuber crops have been cultivated, not much attention has been paid to the development of suitable post harvest technologies for utilization of these tuber crops for production of value added products in India.

Minor tubers selected for the study included arrowroot (*maranta arundinacea*.L), taro (*colocasia esculenta* (L) Schott), elephant foot yam (*amorphophallus paeoniifolius*), yam (*dioscorea rotundata* Poir), coleus (*solanostemon rotundifolius*) and lesser yams *(Nanakizhangu and Cherukizhangu).*

3.2 PROCESSING AND PREPARATION OF FLOUR FROM MINOR TUBERS

There is a vast potential to tap the under exploited fruits, vegetables and tubers in the country. Need arises to process these indigenous raw materials to nutritious value added diversified products.

3.2.1 Preparation of Flour from Minor Tubers

Processing the tubers into flour lessens the post harvest loss, especially during the glut season. Preparation of flour from minor tubers is the initial step in processing. The method of flour preparation is detailed in the flow chart (Fig. 1).

Fig. 1. Flow chart showing the processing of minor tubers

Fresh tubers
↓
Cleaning
↓
Peeling
↓
Washing
↓
Chipping
↓
Drying
↓
Flouring
↓
Sieving
↓
Storing of flour

3.3 QUALITY ASSESSMENT OF FLOURS PREPARED FROM MINOR TUBERS

3.3.1 Fresh flours were analysed for moisture, acidity, reducing sugar, fibre and protein. Table: 1 depicts the details of analysis and methods followed

Table 1. Analysis of chemical constituents of fresh tuber flour

Constituents	Method
Moisture	Sadashivam and Manickam, 1992.
Acidity	Thyagaraja *et al.*1992.
Reducing Sugar	Renganna 2001.
Crude fibre	Sadashivam and Manickam, 1992
Protein	Thimmaih, 1999

3.3.2 Functional Quality Analysis

Functional qualities such as water absorption index, volume expansion, change in weight, processing loss and yield ratio of the fresh and stored minor tuber flours were studied.

3.3.2.1Water Absorption Index

Water absorption index is the quantity of water absorbed by a known quantity of the food sample. This is mainly used to assess the rehydration capacity of the flour. Fifty grams of the fresh tuber flour was taken in a glass beaker, 100ml of water was added to it. The water was drained off after 10 minutes. The weight of the hydrated sample was recorded. The water absorption index was calculated by weight of hydrated sample minus weight of the raw sample.

Water absorption index = weight of hydrated sample - weight of raw sample

3.3.2.2Change in Weight

Change in weight was found out from the difference in weight of fresh tuber and dried tuber.

Change in weight = weight of fresh tuber - weight of dried tuber.

3.3.2.3Yield Ratio

The yield ratio was calculated for both the tuber flour as well as for the baked products such as cake, biscuit and bread. Yield ratio of tuber flours was calculated using the formula

$$\text{Yield ratio of tuber flour} = \frac{\text{Weight of tuber flour}}{\text{Weight of raw edible tuber before drying and flouring}}$$

3.3.2.4 Processing Loss

The processing loss was calculated as the weight of food ingredients as purchased (Ap w.t) minus that of the edible portion. (Ep wt) and the ratio of processing loss was calculated using the formula.

$$\text{Processing loss} = \frac{\text{Ap wt.-Ep wt.}}{\text{Ap wt.}}$$

3.3.2.5Colour

The colour of the flours was examined and noted soon after flouring and changes after three months storage.

3.3.3 Shelf Life Qualities of the Tuber Flour

According to Thakur *et al.* (1995) chemical and sensory changes are influenced by storage period and containers used for storage. The tuber flours were stored in poly ethylene terephthalate [PET] containers and poly proplylene covers at ambient conditions for three months.

The moisture content and water absorption index were found out after the storage period of 3 months.

3.3.3.1Insect Infestation in Stored Tuber Flour

Insects are responsible for enormous losses to stored tuber flour and their products. They destroy a substantial quantity by spoilage and contamination with their droppings, urine and body hair. Observations on the insect infestation in stored tuber flours were recorded after three months by visual examination.

3.3.3.2 Microbial Growth in Stored Tuber Flour

The stored tuber flours were assessed for their microbial growth at the end of three months. Serial dilution plate technique was used to assess the microbial growth (Johnson and Curl, 1972). Nutrient agar medium was used for bacteria, yeast extract was used for yeast and Martins media was used for the estimation of fungal growth. The composition of media used is given in Appendix IV.

3.4 PRODUCT DEVELOMENT

Baked products developed in the present study include cake, biscuit and bread. Products were prepared by blending flours of minor tubers with selected ingredients following standard techniques. Under each category of products two variations were tried out.

3.4.1 Cakes

Good quality cakes can be prepared by using maida, sugar, eggs, fat, baking powder, salt, and flavour compounds. Different varieties of cakes can be prepared by changing the ingredients (Sharma *et al.,* 2003).

Cakes using minor tuber flour were prepared with 15.00 per cent and 20.00 per cent substitution of refined flour, using standard recipe. The procedure is given in the flow chart (Fig. 2).

Tuber flour + Maida + Baking powder (15g and 20g) (85g and 80g) (1g)

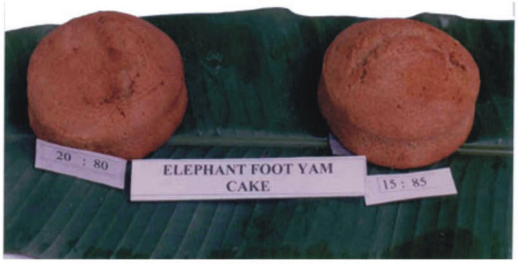
Blending and fluffing of powdered sugar (100 g) and dalda (60 g)
↓
Addition of whipped egg (2)
↓

Blending of the mixture
↓
Mixture poured into greased cake mould
↓
Baking for 30 min. at 180°C
↓
Cooling
↓
Wrapping in butter paper
↓
Storing

Fig - 2 Flow chart for the processing of cake

ARROWROOT CAKE

TARO CAKE



ELEPHANT FOOT YAM CAKE

YAM CAKE

COLEUS CAKE

NANAKIZHANGU CAKE

CHERUKIZHANGU CAKE

Plate 1. Cakes prepared from minor tuber flours

3.4.2 Biscuit

Biscuit industry is the largest constituent of food processing industry (Sewa *et al*., 2001). The ingredients used for the preparation of biscuits are refined flour, sugar, salt, solid fat or unsalted butter.

Each minor tuber flour was used in the preparation of two variations of biscuit, with 15 per cent and 20 per cent substitution of refined flour. The procedure is given in the flow chart (Fig. 3).

Tuber flour (15g and 20g) + Maida (85g and 80g) + Baking powder (1g)

↓

Sifting

↓

Addition of
Sieved powdered sugar + Dalda + Salt
(150 g) (100g) (1 pinch)

↓

Blending

↓

Making dough

↓

Spreading the dough

↓

Cutting into desired shape with a biscuit cutter

↓

Baking for 15 min. at 210°C

↓

Cooling

↓

Packing in poly propylene covers

↓

Storing

Fig - 3 Flow chart for the processing of biscuit

3.4.3 Bread

Breads are made from refined flour, yeast, sugar, salt, shortening and water. The mix is made into a dough by adding water and kept for rising.

ARROWROOT BISCUITS

TARO BISCUITS

ELEPHANT FOOT YAM BISCUITS

YAM BISCUITS

COLEUS BISCUITS

Plate 2. Biscuits prepared from minor tuber flours

Dough is divided into pieces of lime size balls and are allowed to rest for 10 - 30 minutes and baked in a proper mould in an oven at 230°C for about 30 minutes (Sharma *et al.* 2003)

Breads were prepared by the substitution of refined flour with tuber flour with two variations (15 per cent and 20 per cent) and the procedure is given in the flow chart (fig. 4)

Tuber flour + Maida + Water + Salt + Yeast + Sugar + Shortening
(15g and 20g)(85g and 80g) (1/2 cup) (10g) (20g) (10g) (40g)

↓

Mixing and making dough

↓

Dough Fermentation (11/2 hrs)

↓

Moulding and Loaf shaping

↓

Baking for 20 min. at 230°C

↓

Cooling

↓

Packing in butter paper

↓

Storing

Fig - 4 Flow chart for the processing of bread

3.5. QUALITY ASSESSMENT OF DEVELOPED PRODUCTS

Products such as cakes, biscuits and bread made from various tuber flour were subjected to organoleptic and functional quality evaluation.

3.5.1 Organoleptic Evaluation of Baked Products

Sensory quality is one of the criteria that determines the acceptability of any food product by the consumer. The organoleptic evaluation was done by scoring using a 5 point score card that includes the parameters appearance, colour, flavour, texture and taste.

ARROWROOT BREAD

TARO BREAD

ELEPHANT FOOT YAM BREAD

YAM BREAD

COLEUS BREAD

***NANAKIZHANGU* BREAD**

***CHERUKIZHANGU* BREAD**

Plate 3. Breads prepared from minor tuber flours

3.5.2 Functional Quality Evaluation

3.5.2.1 Volume Expansion

Volume expansion of the baked products were calculated by the difference in height of the batter or dough before baking and height of the products after baking.

3.5.2.2 Yield Ratio

The yield ratio of the baked products were calculated using the formula

$$\text{Yield ratio} = \frac{\text{Baked weight of the products}}{\text{Weight before baking}}$$

3.5.2.3 Loaf Volume

The appearance and texture of bread is influenced by loaf volume and loaf weight. In the case of bread the loaf volume was found out by comparing the change in height of the dough after fermentation and baking.

3.5.2.4 Porosity

Porosity of bread was found out by applying ink on the surface of bread loaf after cooling the fresh bread and taking its impression on paper. Porosity of the cake was found out by applying ink on the surface of cake pieces and taking its impression on the paper.

3.5.3 Other Parameters Studied

Baking time and cost of the baked products were studied.

3.5.3.1 Baking Time

Time required for baking cake, biscuit and bread were noted by recording into the time required for the raw batter or dough to be baked.

3.5.3.2 Economic Feasibility

Economic feasibility of the baked products were analysed by adding the actual cost of the ingredients used along with 10 per cent overhead charges.

3.6 SELECTION OF BEST PRODUCTS

Based on the organoleptic quality assessment, best baked products were selected and compared with ISI specifications.

3.6.1 Shelf Life Qualities of the Selected Baked Products

The shelf life qualities of selected baked products (cakes, biscuit, and bread) were studied separately. The baked products were packed in poly propylene covers for the study.

3.6.2 ISI Type Tests to Assess the Commercial Viability

The Bureau of Indian Standard has specified type tests for various processed food products to maintain quality during processing and marketing. Type tests specified by ISI to the requirement of cake (IS: 9712 - 1981), biscuit (IS: 1011 - 1992) and bread (IS: 1483 - 1988) were carried out mainly by analysing moisture, acidity and ash using standard techniques.

Results

4. RESULTS

Salient findings of the study entitled "Utilization of minor tubers for the development of baked products" are presented under the following heads.

4.1 Selection and procurement of minor tubers

4.2 Processing of minor tubers

4.3 Quality assessment of minor tuber flours

4.4 Product development and quality assessment of developed products

4.5 Selection of best products

4.1 SELECTION AND PROCUREMENT OF MINOR TUBERS

Simpson and Weiner (1989) defined a tuber as an underground structure consisting of a solid thickened portion or outgrowth of a stem or rhizome of a more or less rounded form and bearing eyes or buds from which new plants may arise.

Cassava, sweet potato, yam, taro, lesser yams, elephant foot yams and coleus are the roots and tubers mostly cultivated in Kerala. In the present study minor tubers such as arrowroot, taro, elephant foot yam, yam, coleus and lesser yams (*nanakizhangu* and *cherukizhangu*) were selected.

Due to the ease of cultivation, most of these minor tubers are raised in the homesteads of Kerala. Required quantity of minor tubers were procured from local markets and government farms.

Yams were procured from the Instructional farm, College of Agriculture Vellayani and coleus from the Central Tuber Crops Research Institute Sreekariyam. Arrowroot and lesser yams (*nanakizhangu and cherukizhangu*) were collected from the local markets of Kattakada and taro was purchased from Chalai bazar. The fresh tubers were procured in bulk during the season.

4.2 PROCESSING OF MINOR TUBERS

In the present study value added baked products such as cake, biscuit and bread were standardised by partial replacement of major ingredients with minor tuber flour. For this the tubers were primarily processed into flour. The method of flour making is shown in the flow chart (Fig.I) given in Chapter III

4.3 QUALITY ASSESSMENT OF TUBER FLOURS

The flour developed from the minor tubers had a soft texture. They had pleasant flavour and acceptable colour.

The colour of tuber flour varied from pure white to light brown. Pure white colour was observed for fresh flour of arrowroot, *nanakizhangu* and *cherukizhangu*, while greyish white colour was observed for taro and coleus flours. Light brown colour was seen for flour of elephant foot yam and yam flours.

After three months storage a slight variation in colour was observed for arrowroot and elephant foot yam flours. All the other tuber flours maintained fresh colour.

4.3.1 Quality assessment of fresh tuber flour was done by chemical analysis . The results obtained are presented in Table 2.

Table. 2 Quality characteristics of flours prepared from different minor tubers

Tuber flour	Moisture (Per cent)	Acidity	Reducing Sugar	Crude Fibre (g/100g)	Protein (g/100 g)
Arrowroot (MT1)	9.73	0.546	2.434	3.000	4.316
Taro (MT2)	9.43	0.268	1.933	1.166	2.566
Elephant foot yam (MT3)	9.53	0.596	1.266	1.166	3.500
Yam (MT4)	11.43	0.389	1.213	1.666	2.683
Coleus (MT5)	9.53	0.666	2.033	1.266	3.616
Nanakizhangu (MT6)	9.97	0.502	1.890	1.000	3.033
Cherukizhangu (MT7)	10.37	0.444	1.880	1.100	3.150
SE	0.06668	0.03106	0.0377	0.1453	0.2494
C.D (0.05)	0.20228	0.09421	0.10541	0.4407	0.75668

The moisture content in the flours ranged from 9.43 to 11.43 per cent. The highest moisture content was found in MT4 flour (11.43 per cent) and the lowest moisture content was found in MT2 flour (9.43 per cent). The moisture content of MT2 flour (9.43 per cent), MT3 flour (9.53 per cent) and MT5 flour (9.53 per cent) were on par. It was also noted that significant difference in moisture content was observed between MT7 flour and all other minor tuber flours. Significant difference was observed between MT4 flour with other minor tuber flours except flour of MT7; and flour of MT6 with MT1, MT2, MT3 and MT5; also significant difference was observed between flour of MT1 and MT2. The results showed a significant difference in moisture content was observed between the tuber flours.

Acidity of minor tuber flours ranged from 0.268 to 0.666. Statistical analysis showed that the acidity of flours of minor tubers differed significantly. Highest acidity was observed in MT5 flours (0.666) which was on par with MT3 flour (0596). The least value of acidity was found in MT2 flour (0.268). Comparison between tuber flours revealed significant difference in acidity of MT5 flour with flours of all other tubers except MT3. Flours of MT1 and MT3 significantly differed from the flours of MT7, MT4 and MT2; MT2 flour with MT4, MT6 and MT7.

The analysis of reducing sugar content revealed that MT1 flour had the highest reducing sugar content (2.434) and a lower value for MT4 flour (1.213). The reducing sugar content of MT4 flour (1.213) and MT3 flour (1.266) were on par. While comparing the reducing sugar content between flours of minor tubers significant difference was seen between MT1 flour with all other flours, MT5 flour with flours of other tubers, except MT1 and MT2. Flours of MT3 and MT4 were significantly different from MT2, MT6 and MT7.

The crude fibre content of flours ranged between 1.00 to 3.00g per 100g. Statistical analysis showed that there is significant difference in the crude fibre content of minor tuber flour. The highest crude fibre content was found in MT1flour (3.00g) and MT6 flour had the lowest crude fibre content (1.00g) which was on par with MT2 flour (1.66g), MT3 flour (1.16g) and MT7 flour (1.10g). Fibre content between flours of minor tubers were compared and significant difference was observed between MT1 flour with all other minor tuber flours. Fibre content of MT4 flour was significantly different from flours of MT3, MT6 and MT7.

Analysis of data showed significant difference in the protein content of minor tuber flours. MT1flour had the highest protein content of 4.316g per 100g. MT2 flour had a lower protein content of 2.566g per 100g which was on par with MT4 flour (2.683g), MT6 flour (3.033g) and MT7 flour (3.15g). Comparison between flours of minor tubers showed significant difference in protein content between MT1 flour with other flours except MT5. Significant difference in protein content was observed between MT2 and MT4 with flours of MT3 and MT5.

4.3.2 Functional qualities of tuber flours

The functional qualities which included water absorption, volume expansion, change in weight, processing loss and yield ratio were studied for different minor tuber flours The results are presented in Table 3

Table 3. Functional qualities of flours prepared from different minor tubers

Tuber flour	Change in weight (g/kg)	Processing loss (g/kg)	Yield ratio	Water absorption index
MT1	0.662	0.080	0.279	10.633
MT2	0.611	0.093	0.325	9.603
MT3	0.687	0.120	0.218	9.673
MT4	0.653	0.130	0.249	9.806
MT5	0.707	0.150	0.167	10.303
MT6	0.573	0.105	0.359	9.793
MT7	0.527	0.093	0.418	10.056
SE	0.0128	0.00936	0.00823	0.0227
C D (0.05)	0.041557	0.01461	0.017989	0.068997

The change in weight was found out by the weight change of fresh tuber and dried tuber. The change in weight was due to loss of moisture from the fresh tuber on drying. The difference in the weight before drying and the weight after drying gave the change in weight. Results revealed that MT5 flour had the highest change in weight of 0.707. The change in weight of MT5 flour (0.707) and MT3 flour (0.687) were on par, but significant difference was seen between other tuber flours. Flour of MT7 had a change in weight of 0.527. Significant difference was observed between flours of

MT3, MT1 and MT4 with flours of MT2, MT6 and MT7. Flour of MT7 was significantly different from MT2 and MT6.

Processing loss is another factor which can influence the economic feasibility of a product. Processing loss was calculated by determining the difference between purchased weight of the tuber and their edible portion. Details regarding processing loss is presented in Table 3. The loss accounted was mainly due to the removal of unwanted portions of the minor tubers. Statistical analysis revealed that MT5 flour had a processing loss of 0.150, which was significantly different from all other minor tuber flours. MT1 flour had a processing loss of 0.080, which was on par with MT2 flour (0.093)and MT7 flour (0.093). Significant difference were observed between MT4 flour with all minor tuber flours except MT3 flour. Significant difference was also observed between the flours of MT6 and MT1.

The yield ratio of minor tubers gave an estimate of the amount of flour obtained from a known quantity of fresh tuber after cleaning and drying. Analysis of data showed that there is significant difference in the yield ratio of different minor tuber flours. MT7 had a highest yield ratio of 0.418. The lowest yield ratio was observed in the flour of MT5 (0.167).

Water absorption index gives an estimate of the amount of water absorbed by a given sample. Statistical analysis of water absorption index of different minor tuber flours showed that there is significant difference among the tuber flours. MT1 flour had the highest water absorption index of 10.633. MT2 flour had the lowest value of 9.603. Significant difference in water absorption index was noted between minor tuber flours except MT4 and MT6 flour.

4.3.3 Shelf life qualities of the minor tuber flours

The shelf life quality of minor tuber flours was assessed by estimating the moisture content and water absorption index of the flours after a storage period of three months.

Moisture is one of the important parameter which determined the shelf life of any substance. Moisture content of different minor tuber flours stored for three months in PET (Poly Ethylene Terephthalate) containers and poly propylene covers in comparison to the fresh flour is given in Table 4.

Table 4 Moisture content of stored tuber flours

Tuber flour	Initial moisture (per cent)	Moisture content			
		PET container (per cent)	Per cent increase	Poly propylene cover (per cent)	Per cent increase
MT1	9.73	10.13	0.40	10.53	0.80
MT2	9.43	10.53	1.10	11.13	1.70
MT3	9.53	11.70	2.17	13.16	3.63
MT4	11.43	12.40	0.97	12.76	1.33
MT5	9.53	11.26	1.73	13.63	4.10
MT6	9.97	10.33	0.36	12.13	2.16
MT7	10.37	10.53	0.16	10.56	0.19
SE	0.06668	0.1247		0.09107	
CD (0.05)	0.20228	0.3784		0.27628	

The result revealed that there is an increase in the moisture content of stored minor tuber flours kept in PET containers and polypropylene covers. Compared to the moisture content of flours stored in PET containers, moisture content was more in minor tuber flours stored in polypropylene covers. Among tuber flours stored in PET containers, highest moisture content was observed in MT4 flour (12.40 per cent). MT1 flour had a lower moisture content of 10.13 per cent which was on par with MT6 flour (10.33 per cent).

When the moisture content of fresh and stored minor tuber flours were compared MT3 flour had a greater increase in the moisture content (2.17 per cent) and MT7 flour had least increase in moisture content of 0.16 per cent. Other tuber flours increase in moisture content was as follows:

MT1 flour 0.40 per cent, MT2 flour 1.10 per cent, MT4 flour 0.97 per cent, MT5 flour 1.73 per cent and MT6 flour 0.36 per cent.

Analysis of data showed that there is significant difference in the moisture content of minor tuber flours stored in polypropylene covers. MT5 flour had the highest moisture content of 13.63 per cent and MT1 flour had a lower moisture content of 10.53 per cent which was on par with the moisture content of MT7 flour (10.56 per cent).

In comparison with the moisture content of fresh tuber flour and tuber flour stored in polypropylene covers it was observed that MT5 flour had the highest increase in moisture content (4.10 per cent). Other flours showed an increase in moisture content in descending order, MT3 (3.63 per cent), MT6 (2.16 per cent), MT2 (1.70 per cent), MT4 (1.33 per cent), MT1 (0.80 per cent) and MT7 (0.19 per cent).

Water absorption index was also found out for the minor tuber flours stored in PET containers and poly propylene covers. Table 5 depicts the results obtained.

Table 5. Water absorption index of stored minor tuber flours

Tuber flour	Initial water absorption index	Water absorption index			
		PET container	Per cent difference	Poly propylene cover	Per cent difference
MT1	10.633	9.996	-0.637	9.673	-0.96
MT2	9.603	9.600	-0.003	9.59	-0.013
MT3	9.673	9.616	-0.057	9.533	-0.140
MT4	9.806	9.633	-0.173	9.610	-0.196
MT5	10.303	10.033	-0.27	9.596	-0.707
MT6	9.793	9.643	-0.150	9.553	-0.24
MT7	10.056	9.910	-0.146	9.680	-0.376
SE	0.02274	0.01524		0.00816	
CD (0.05)	0.068997	0.056925		0.02737	

The results revealed that the water absorption index of the stored minor tuber flours decreased on storage. Indepth investigation on water absorption index of flours stored in PET containers and polypropylene covers, revealed that the water absorption was more in those tubers stored in polyproylene covers. It was found that as the moisture content increases there is a decrease in the water absorption index.

Analysis of data on water absorption index of tuber flours stored in PET containers showed that MT5 flour had the higher water absorption index of 10.033 which was on par with MT1 flour (9.996). Lower water absorption index was seen in MT2 flour (9.600) which was on par with flours of MT3 (9.616), MT4 (9.633) and MT6 (9.643). The water absorption index of MT5 and MT1 flours were significantly different from all other minor tuber flours. Also significant difference was observed in the water absorption index of MT7 flour with all other minor tuber flours.

Among the tuber flours stored in polypropylene covers the water absorption index was higher for MT7 (9.680) which was on par with MT1 (9.673). Lower values for water absorption index was found in MT3 flour (9.533) which was on par with MT6 flour (9.553). The water absorption index of MT7 and MT1 flour were significantly different from all other tuber flours. Significant difference in water absorption index was observed between the flours of MT6 and MT3 with MT4, MT5 and MT2 flours.

4.3.4 Evaluation of insect infestation in stored tuber flours

The incidence of insect attack in stored minor tuber flours was assessed after three months storage. No insect was found in any of the stored samples both in PET containers and poly propylene covers.

4.3.5 Microbial growth analysis in stored tuber flours

Inorder to assess the quality of fresh as well as stored tuber flour, microbial analysis was done for bacteria, yeast and fungi using nutrient agar, yeast extract agar and Martins media, this was done by the serial dilution methods. (Johnson and Curl (1972)). The media were kept for one week and colony count was taken every day. The results are depicted in Table 6.

Table 6 Microbial growth analysis in stored tuber flours

Tuber flour	PET container no: of colonies of			Polypropylene covers no: of colonies of		
	Bacteria	Yeast	Fungus	Bacteria	Yeast	Fungus
MT1	3	0	0	3	8	0
MT2	0	7	1	1	9	2
MT3	2	4	1	2	6	0
MT4	0	0	0	2	8	0
MT5	1	7	0	2	9	2
MT6	1	0	0	1	0	4
MT7	1	2	1	3	2	1
SE	0.01875	0.008727	0.009932	0.01246	0.024216	0.008079
CD (0.05)	0.04648	0.02472	0.03514	0.04259	0.0629	0.03048

The result revealed that in all the media, fresh samples were not affected by any of the micro organisms. Among the stored samples yeast growth was more compared to bacteria and fungi. Statistical analysis of the data revealed that there is significant difference in the number of microbial colonies in stored tuber flours.

MT1 flour stored in PET containers and poly propylene covers showed three colonies of bacterial growth. Fungal colonies were nil and about eight colonies of yeast were found in flour stored in poly propylene cover.

MT2 flour stored in PET containers did not show any bacterial growth, but those stored in polypropylene covers showed one colony of bacteria. MT2 flour stored in PET container had one colony of fungus and those in cover showed two fungal colonies. There were seven and nine colonies of yeast in MT2 flour stored in PET and poly propylene covers respectively.

MT3 stored in PET container and cover showed two colonies of bacteria, one colony of fungus was seen in flour stored in PET container. Yeast growth of four and six colonies were noted in flours stored in PET container and polypropylene covers respectively.

In the case of MT4 flour there was no bacterial growth in PET container, but those stored in polypropylene covers showed two colonies of bacteria. There was no fungal growth but eight colonies of yeast were seen in MT2 flour stored in polypropylene covers.

The microbial analysis done on MT5 flour revealed that flours stored in PET containers and polypropylene covers showed one and two colonies each of bacteria and seven and nine colonies of yeast respectively. In the case of fungus there were two colonies in flour stored in polypropylene covers.

MT6 flour stored in PET containers showed one colony of bacteria. There were four fungal colonies in the flour stored in polypropylene covers and no colonies of yeast in both containers.

MT7 flour stored in PET containers and polypropylene cover had one and three colonies of bacteria respectively. It had one colony each of fungus in both the storage containers and two colonies each of yeast in both the storage containers.

The results of microbial analysis revealed that among the seven tuber flour, MT6 flour was least affected by microbial attack followed by MT4 flour and MT1 flour. For all the tuber flours, PET containers were found suitable for long period of storage.

4.4 PRODUCT DEVELOPMENT AND QUALITY ASSESSMENT OF THE DEVELOPED PRODUCTS

Although a number of tuber crops have been cultivated not much attention has been paid to the development of suitable post harvest technologies for utilization of these tuber crops for production of value added products in India. The development strategy for roots and tubers need a new orientation with a thrust on product diversification, value addition and marketing.

The baked products developed from minor tubers for the present study included cake, biscuit and bread. The products were developed by partial substitution of refined flour with minor tuber flour.

Any new product developed should be assessed for its acceptability among the consumers. The baked products standardised viz. cake, biscuit and bread were assessed for acceptability.

A panel of fifteen judges were selected for the organoleptic evaluation of the baked products through triangle test. The triangle test was conducted employing three samples of sugar solution at different concentrations in which two were identical and one was different. All the three samples were presented simultaneously to the panelists and were asked to determine the odd sample.

Parameters like appearance, colour, flavour, texture and taste of developed baked products were assessed through a score card (Appendix I, II and III) of 5 point scale and compared with the control sample.

4.4.1 Quality Assessment of Cakes

Cakes are not only rich and sweet but also light and delicate among all the baked products. As part of the study cakes were standardised in two variations with partial substitution of refined flour with tuber flour at 15 and 20 per cent level. Other ingredients used were powdered sugar, egg, shortening (dalda) and baking powder. The mean scores of organoleptic parameters for cakes is given in Table 7 (Fig. 5 and 6).

4.4.1.1 Appearance of Cake

The first impression of food is usually visual and a major part of willingness to accept a food depends on its appearance.

The mean score for appearance of two variations (I and II) of cake is given in table 7. The mean score for appearance of cake variation I (15:85) ranged from 3.60 to 4.33 and variation II (20:80) ranged from 3.66 to 4.33 and compared with control sample. Statistical analysis of first variation (15:85) of cake revealed that the control sample had the highest score for appearance of 4.60 which was on par with MT1 (4.33) and MT6 (4.26). The score for appearance was lower for MT3 (3.60) which was on par with MT4 (3.93) MT2 (4.00), MT5 (4.00) and MT7 (4.06). It was also observed that the mean score for appearance was significantly different from control sample and cakes made from MT7, MT5, MT2, MT4 and MT3; MT1 and MT6 with MT3.

Statistical analysis of cake variation II revealed that the highest score for appearance was obtained for arrowroot (MT1) cake (4.33) which was on par with control sample, cake made from MT6 (4.26). The lower score for appearance was obtained for cake made from MT3 (3.66) which was on par with cakes made from MT4 (3.80), MT7 (4.00) MT5 (4.00) and MT4 (4.06). While significant difference was observed between control cake with cakes made from flours of MT2, MT5, MT7, MT4 and MT3 and also MT3 with MT1 and MT6.

4.4.1.2 Colour of Cake

Colour one of the important visual attributes, has been used to judge the overall quality of foods for a very long time. If the colour is unattractive, a potential consumer may be not impressed by any other attributes. The scores to colour of cake its depicted in Table 7.

Table 7 Quality assessment of cake

Tuber flour	Appearance		Colour		Flavour		Texture		Taste	
	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II
Control	4.60	4.60	4.60	4.60	4.26	4.26	4.73	4.73	4.66	4.66
MT1	4.33	4.33	4.40	4.20	4.33	4.13	4.20	3.93	4.46	4.26
MT2	4.00	4.06	4.00	3.80	4.13	3.80	3.80	3.86	4.13	3.93
MT3	3.60	3.66	3.20	3.53	3.46	3.66	3.73	3.60	3.60	3.73
MT4	3.93	3.80	3.66	3.66	4.00	3.93	4.00	3.93	4.06	4.06
MT5	4.00	4.00	3.53	3.93	4.06	3.73	4.00	3.93	4.13	4.00
MT6	4.26	4.26	4.06	3.66	3.46	3.60	3.86	3.80	3.73	3.66
MT7	4.06	4.00	3.86	3.73	3.66	3.60	3.86	3.80	3.86	3.73
SE	0.18473	0.1894	0.18473	0.18687	0.16856	0.19128	0.14254	0.16158	0.18856	0.17817
CD (0.05)	0.51728	0.53035	0.51728	0.52326	0.47199	0.5356	0.39913	0.45247	0.52799	0.49891

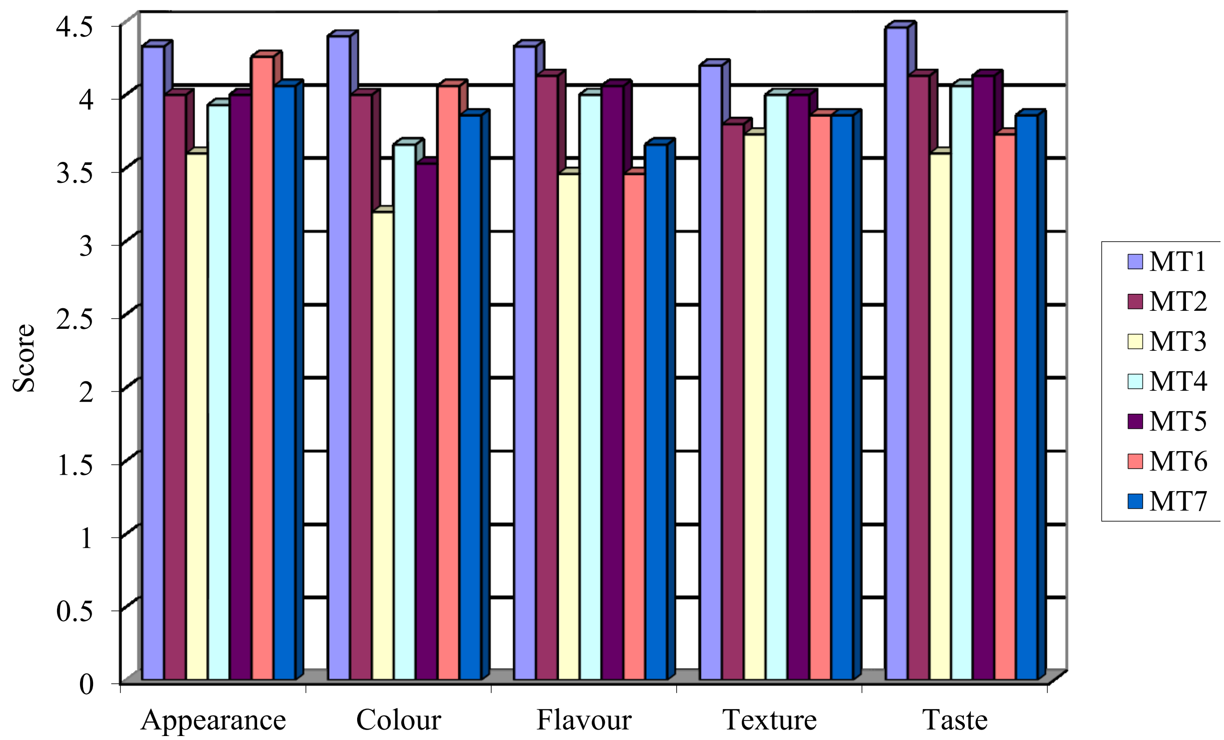


Fig. 5. Organoleptic parameters of cake vaiation I

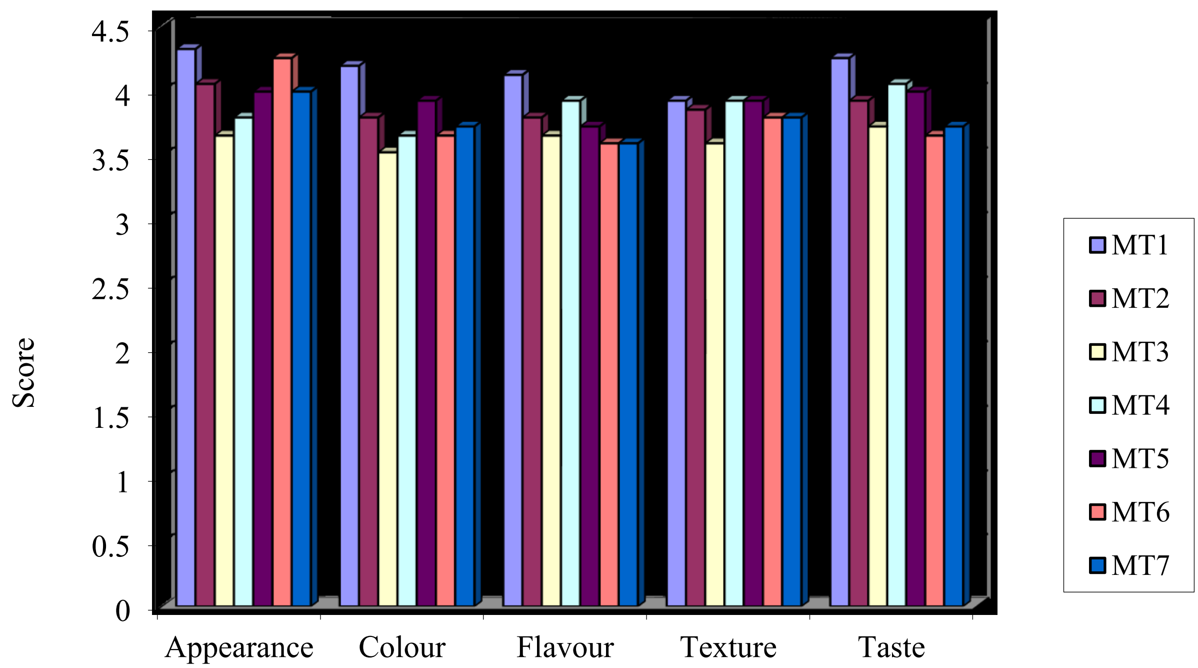


Fig. 6. Organoleptic parameters of cake variation II

Statistical analysis done on colour of the cakes of variation I and II showed that the MT1 cake has the highest score of 4.40. The mean score for colour of cake variation I ranged from 3.20 to 4.40, with the highest score for MT1 cake (4.40) which was on par with control sample (4.60). While a significant difference was observed with cake made from all the other minor tuber flours. Also significant difference was observed for colour between MT1 cake and cakes made from MT7, MT4, MT5 and MT3. The lower score for colour was obtained for MT3 cake (3.20) which was on par with cakes made from MT4 (3.66) and MT5 (3.53) Significant difference was observed for colour between cake made from MT6 with MT5 and MT3, MT2 and MT7 cake with cake made from MT3.

Statistical analysis for colour of cake variation II showed that the mean scores ranged from 3.53 to 4.20 with the higher score for MT1 cake (4.20) which was on par with control sample (4.60). Lower scores were observed for MT3 cake (3.53) which was on par with cakes made from all other minor tuber flours.

Significant difference was observed for colour between control cake and all the other cakes except MT1 cake. Significant difference was also noted between arrowroot cake with cake made from MT4, MT6 and MT3.

4.4.1.3 Flavour of Cake

Odour preference is generated by stimulation of the sensory cells by specific volatile compounds present in the food. The flavour of the developed cake was found out by sensory evaluation and the details are given in Table 7.

Analysis of data on flavour of cake revealed that MT1 cake had obtained the highest score of 4.33 in variation I and 4.00 in variation II . The score for MT1 cake of variation I (4.33) were on par with control cake (4.26) and cake made from MT2 (4.13), MT5 (4.06) and MT4 (4.00). The lower score was obtained for MT6 (3.46) which was on par with cakes made from MT3 (3.46) and MT7 (3.66). Significant difference was observed in the mean scores for flavour between MT1 cake and cakes made from the flours of MT7, MT3 and MT6. The flavour of cakes made from MT7, MT3 and MT6 were significantly different from control sample; flavour of MT2 cake differed significantly from cakes made from flour of MT3 and MT6, and also between cakes made from the flours of MT5 and MT4 with cakes made from MT3 and MT6.

Statistical analysis done for flavour of cake (variation II) showed that MT1 had the highest score of 4.13 which was on par with control sample (4.26) and cake made from MT4 (3.93), MT2 (3.80) and MT5 (3.73) and significantly different from cakes made from MT3, MT6 and MT7. The lower score for flavour was obtained for MT6 and MT7 (3.60) which was on par with cakes made from the flours of MT3 (3.66), MT5 (3.73), MT2 (3.80), MT4 (3.93) and MT1 (4.13).

4.4.1.4 Texture of Cake

Texture constitute a physical property of food stuffs apprehended by the eyes, the skin and muscle senses located in the mouth. The scores obtained for the texture of cake is detailed in Table 7.

Statistical analysis done on texture of cake variation I ranged from 3.73 to 4.20 and variation II ranged from 3.60 to 3.93. The highest score for texture of cake (variation I) was obtained for MT1 cake 4.20. The lower score for texture was obtained for MT3 cake which was on par with cakes made from flour MT2 (3.80), MT7 (3.86), MT6 (3.86), MT4 (4.00) and MT5 (4.00). Significant difference was observed between MT1 cake and cakes made from the flour of MT2 and MT3.

Analysis of data on texture of cake variation II revealed that the highest score was obtained for MT1 (3.93). The mean score of texture for control sample was 4.73 which was significantly different from the scores obtained for all the other cakes. The lower scores for texture was obtained for MT3 (3.60) which was on par with the scores obtained for all the other cakes except the control. The scores obtained were 3.93 for cakes made from MT1, MT4 and MT5; 3.86 for MT2 and 3.80 for MT7 and MT6.

4.4.1.5 Taste of Cake

Taste is the major attribute which determines the acceptability of a food. It is not only a sensory response to soluble materials but also aesthetic appreciation of the mouth. The sensory quality evaluation of cake for taste is given in Table 7.

The mean score for taste of cake variation I ranged from 3.60 to 4.46 and variation II ranged from 3.66 to 4.26. Data analysis showed that the highest score for taste of cake variation I was for MT1 cake (4.46). The mean score for taste for control sample was (4.66) which on par with the score obtained for MT1 (4.46) and significantly different with the cakes made from all other minor tuber flours. Lower score was for MT3 (3.60) which was on par with cakes made from the flours of MT6 (3.73), MT7 (3.86) and MT4 (4.06). Significant difference was observed with the scores for taste between MT1 and with MT7, MT6 and MT3. The mean score for taste of MT3 cake was significantly different from MT2 and MT5.

Statistical analysis done for the taste in variation II of cake showed that MT1 had the highest score (4.26). The score for control sample (4.60) was on par with MT1 and significantly different from the cakes made from all the other tuber flours. The mean score for taste of MT1 also showed significant difference with the scores obtained for MT3, MT7 and MT6. Lower scores for taste was obtained for MT6 (3.66) which was on par with the cakes made from MT7, MT3 and MT2.

4.4.2 Quality Assessment of Biscuit

Biscuit, a cereal based snack food, is highly liked by all segments of population. Biscuits and biscuit like products such as cookies and crackers have been consumed for thousands of years. Starchy ingredients are often used in the preparation of biscuits. Flour, sugar, salt, baking powder and fat comprises the major ingredients of biscuit.

In the present investigation, two variations of biscuits were prepared by partial substitution of refined flour with tuber flours at 15 and 20 per cent level. The mean scores for organoleptic parameters for biscuits is given in Table 8 (Fig. 7 and 8).

4.4.2.1 Appearance of Biscuit

Appearance is an important visual parameter that determines the acceptance or rejection of food. Mean scores for appearance of biscuits are given in Table 8.

The mean score of appearance for biscuit variation I ranged from 3.73 to 4.73 and variation II ranged from 3.86 to 4.53. The mean score of appearance for variation I biscuit was higher for MT1 (4.73) which was on par with control (4.60) and MT2 (4.46). The poor score for appearance was obtained for MT5 (3.73) which was on par with biscuit made from flours of MT6 (3.80), MT4 (3.80), MT7 (3.86) and MT3 (4.06). Statistical analysis also revealed a significant difference in appearance between MT1 and biscuit made from flours of MT3, MT7, MT4, MT6 and MT5 and also between control biscuit and biscuits made from flours of MT3, MT7, MT4, MT6 and MT5.

The statistical analysis done on the appearance of second variation of biscuit revealed that the highest score was obtained for MT1 biscuit (4.53) which was on par with control sample (4.60) and biscuit made from MT2 (4.26), MT3 (4.06) and MT4 (4.06). The lowest score was obtained for biscuits made from flours MT7 (3.80) which was on par with biscuit made from MT6 (3.86), MT5 (4.00), MT4 (4.06), MT3 (4.06) and MT2 (4.26) while significant difference for appearance was observed between control sample and biscuits made from MT5, MT6 and MT7 and also between arrowroot biscuit (MT1) and biscuits made form flours of MT6 and MT7.

Table 8 Quality assessment of biscuit

Tuber flour	Appearance		Colour		Flavour		Texture		Taste	
	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II
Control	4.60	4.60	4.66	4.66	4.40	4.40	4.60	4.60	4.73	4.73
MT1	4.73	4.53	4.40	4.40	4.33	4.53	4.33	4.26	4.26	4.26
MT2	4.46	4.26	4.26	4.20	4.40	4.33	4.26	4.20	4.20	4.33
MT3	4.06	4.06	3.73	3.53	4.13	4.06	4.06	4.13	3.80	4.06
MT4	3.80	4.06	3.60	4.66	4.13	4.26	4.26	4.20	4.13	4.20
MT5	3.73	4.00	3.80	3.93	4.33	4.26	4.06	4.13	4.06	4.20
MT6	3.80	3.86	3.80	3.93	4.06	4.06	4.00	4.00	3.46	3.20
MT7	3.86	3.86	4.00	3.93	4.06	4.00	4.13	4.33	3.46	3.33
SE	0.19313	0.19558	0.18126	0.19334	0.13183	0.13887	0.17994	0.18279	0.19334	0.18687
CD (0.05)	0.54081	0.54766	0.50756	0.54138	0.36916	0.38886	0.5038771	0.5118419	0.54138	0.523264

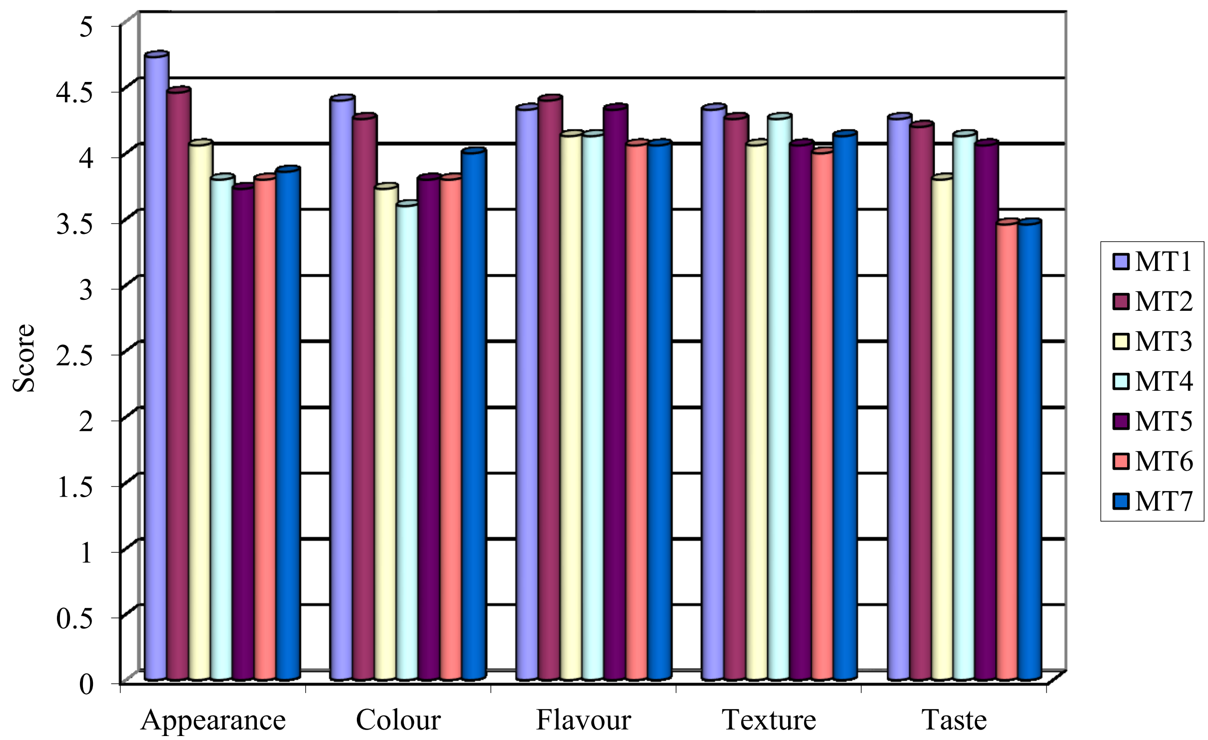


Fig. 7. Organoleptic parameters of biscuit vaiation I

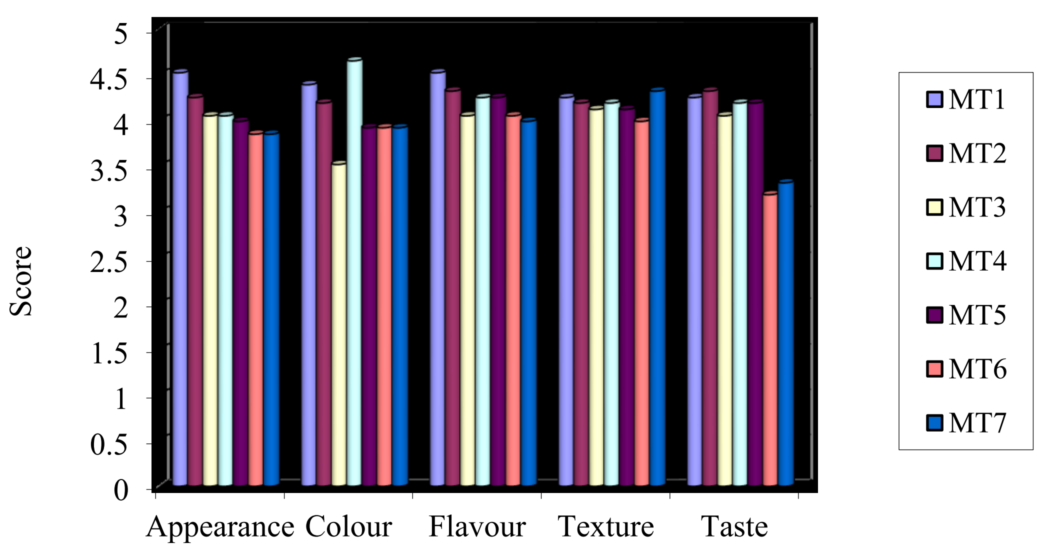


Fig. 8. Organoleptic parameters of biscuit variation II

4.4.2.2 Colour of Biscuit

Colours of food contribute to one's appreciation of the food. Table 8 depicts the details of the scores obtained for colour for biscuits.

The mean score for colour of variation I biscuit ranged from 3.60 to 4.40, with the highest score for MT1 biscuit (4.40) which was on par with control sample (4.66) and biscuit made from MT2 (4.26). The lower score for colour was obtained for MT4 biscuit (3.60) which was on par with biscuit made from MT5 (3.80), MT6 (3.80) and MT3 (3.73). Significant difference was observed in the scores for colour between control sample with all other biscuits except for MT1 and MT2 biscuit. There was also significant difference between MT1 biscuit with biscuit made from MT5, MT6, MT3 and MT4 and MT2 biscuit with biscuits made from MT3 and MT4.

Statistical analysis showed that the mean score for colour for biscuit variation II was higher for MT1 biscuit (4.40) which was on par with control sample (4.66) and MT2 (4.20) biscuit. Lower score for colour was obtained for MT3 biscuit (3.53) which was on par with biscuits made from MT7 (3.93), MT6 (3.93), MT5 (3.93) and MT4 (4.06). Significant difference was observed for scores of colour between control sample and biscuits made from the flours of MT4, MT5, MT6, MT7 and MT3; MT1 and MT2 biscuit with biscuit made from MT3.

4.4.2.3 Flavour of Biscuit

Flavour is a sensory phenomenon depending upon taste, odour, appearance, temperature and texture of food. Mean scores for flavour of biscuits are given in Table 8.

Data analysis done for the flavour of biscuit revealed that there is no significant difference in the scores for biscuits made at 15:85 variation. The scores for biscuits at variation II (20:80) showed that the highest score for flavour was obtained for MT1 (4.53) which was on par with control (4.40) and biscuit made from MT2 (4.33) MT4 (4.26) and MT5 (4.26).

Comparable scores were obtained for biscuits made out of other minor tuber flours MT6 (4.06), MT3 (4.06), MT7 (4.26), MT4 (4.26) and MT2 (4.33). Significant difference was observed in MT1 with biscuit made from MT3, MT6 and MT7 and also between control and MT7.

4.4.2.4 Texture of Biscuit

The textural properties of foods include the hardness, chewiness, crispness and elasticity. Table 8 depicts the details of scores obtained for texture of biscuits.

The mean score for texture of biscuit (variation I and variation II) ranged from 4.00 to 4.33. The highest score for variation I biscuit was obtained for MT1 biscuit 4.33 and in variation II biscuit made from flour of MT7 (4.33). Statistical analysis for variation I biscuit revealed that the control biscuit with the score of 4.60 was on par with biscuits made from the flours of MT1 (4.33), MT2 (4.26) MT4 (4.26) and MT7 (4.13) and was significantly different from MT3, MT5 and MT6. Lower scores for texture was obtained for MT6 which was on par with biscuits made of MT5 (4.06), MT3 (4.06) MT6 (4.13), MT4 (4.26), MT2 (4.26) and MT1 (4.33).

Statistical analysis showed that the highest score for texture for biscuit variation II was obtained for MT1 (4.26) which was on par with control sample (4.60), MT7 (4.33), MT2 (4.20), MT4 (4.20), MT3 (4.13) and MT5 (4.13) and MT6 (4.00). The lower score for texture was obtained for MT6 which was on par with all the other biscuit except the control.

4.4.2.5 Taste of Biscuit

The sense of taste refers to the ability of the taste organs to perceive and recognize the four basic tastes - sweet, sour, salty and bitter. The mean scores for taste of biscuit is depicted in Table 8.

Mean score for taste of biscuits (variation I) ranged from 3.46 to 4.26 and for (variation II) it ranged from 3.20 to 4.26 Statistical analysis showed that for both the variation biscuit prepared from MT1 had the highest score (4.26). The score for control sample (4.73) was on par with MT1 (4.26) and MT2 (4.20). Lower scores for taste were obtained for MT7 (3.46) and MT6 (3.46) which was on par with biscuit made from MT3 (3.80) and significantly different from the scores of all biscuits except MT3. Significant difference was also observed between the scores of control sample with biscuits made from the flours of minor tubers.

In the case of biscuit variation II the score for control sample (4.73) was on par with the scores obtained for MT2 (4.33) and MT1 (4.26) and significantly different from the biscuits made from all other minor tuber flours. Lower score was obtained for MT6 which was on par with MT7 and significantly different from biscuits made from all other minor tuber flours.

4.4.3 Quality Assessment of Bread

Bread is one of the convenient breakfast foods consumed world wide. It is a fermented baked product of flour, salt, sugar, yeast, fat or shortening and water.

In the present study refined flour was partially substituted with tuber flours at 15 and 20 per cent level for the standardisation of bread. The mean scores of organoleptic parameters for bread is given in Table 9 (Fig. 9 and 10).

4.4.3.1 Appearance of Bread

Appearance is the criterion for the desirability of any food product. Mean scores for appearance of bread is depicted in Table 9.

Analysis of data done for the appearance of variation I bread revealed that the arrowroot (MT1) bread had got the highest score (4.26) which was on par with control sample (4.46), MT4 (4.20) and MT2 (4.13). The lower score for appearance was found for MT7 bread (3.53) which was on par with breads made from MT6 (3.80) and MT3 (3.93). Also significant difference was observed between control sample with breads made from MT4, MT5, MT3, MT6 and MT7; MT1 bread with breads made from MT6 and MT7 and also between MT5 and MT7.

The mean score for appearance of bread (variation II) ranged from 3.40 to 4.26 statistical analysis revealed that MT1 bread obtained the highest score of (4.26) which was on par with control sample (4.46) and MT4 (4.20). Significant difference was observed between control sample and breads made from MT5, MT2, MT3, MT6 and MT7 and also between MT1 with breads made from MT3, MT6 and MT7. Scores obtained for MT4 was significantly different from MT6 and MT7. The lower score for appearance was obtained for MT7 bread (3.40) which was on par with bread made from MT6 (3.46). While significant difference was observed between MT5 bread with breads made from MT6 and MT7; scores of bread made from the flours of MT2 and MT3 were significantly different from the breads made from MT6 and MT7.

4.4.3.2 Colour of Bread

Colour of food serves as a useful criterion for measurement of its quality. Mean score for colour of bread is given in Table 9.

The mean score for colour of bread variation I ranged from 3.53 to 4.20 with the higher score for MT1 bread (4.20) which was on par with control sample (4.46) and bread made from MT2 (4.20) and MT6 (3.93). MT1 bread was significantly different from bread made from MT4, MT7, MT5 and MT3. The lower scores for colour was obtained for breads made from MT3 (3.53) which was on par with bread made from MT6 (3.93), MT4 (3.80) MT7 (3.80) and MT5 (3.73).

Statistical analysis done on colour for variation II bread revealed that MT1 bread had the highest score for colour (4.13) which was on par with control sample (4.46) and bread made from MT2 (4.00) and MT4 (4.00) and significantly different from MT6, MT5, MT7 and MT3. The lower scores for colour was observed for MT3 bread (3.66) which was on par with bread made from MT7 (3.73), MT5 (3.73), MT6, (3.93), MT4, (4.00) and MT2 (4.00).

Table 9 Quality assessment of bread

Tuber flour	Appearance		Colour		Flavour		Texture		Taste		Crumblingnature		Masticability	
	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II
Control	4.46	4.46	4.46	4.46	4.60	4.60	4.53	4.53	4.53	4.53	4.46	4.46	4.53	4.53
MT1	4.26	4.26	4.20	4.13	3.93	4.00	3.86	3.73	3.93	3.93	4.33	4.20	3.93	3.80
MT2	4.13	3.93	4.20	4.00	3.73	3.73	3.80	3.60	3.73	3.80	3.93	3.93	3.66	3.26
MT3	3.93	3.86	3.53	3.66	3.26	3.60	3.53	3.46	2.86	3.13	3.60	3.86	3.33	3.20
MT4	4.20	4.20	3.80	4.00	3.73	3.86	3.73	3.73	3.53	3.80	4.06	3.93	3.66	3.40
MT5	4.00	4.06	3.73	3.73	3.80	3.93	3.86	3.93	3.53	3.80	4.00	3.86	3.66	3.60
MT6	3.80	3.46	3.93	3.93	2.93	3.06	3.13	2.93	2.86	2.93	3.53	3.40	2.93	2.93
MT7	3.53	3.40	3.80	3.73	3.00	3.06	3.40	2.75	2.80	2.86	3.40	3.46	3.06	3.00
SE	0.15404	0.12909	0.19354	0.18192	0.19920	0.18366	0.15736	0.16134	0.2054	0.18301	0.1333	0.15507	0.2009	0.19760
CD (0.05)	0.43135	0.3614	0.5419	0.5094	0.5578	0.51427	0.44063	0.45178	0.5753	0.5124	0.3733	0.43422	0.5628	0.5533

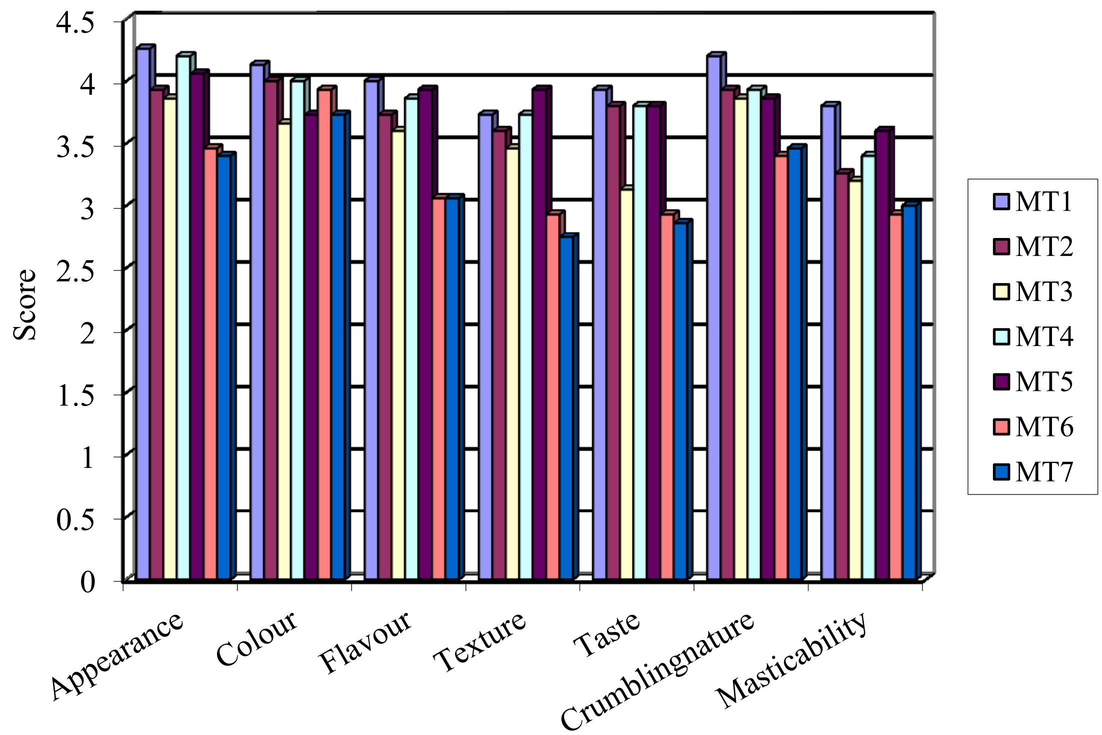


Fig. 9. Organoleptic parameters of bread vaiation I

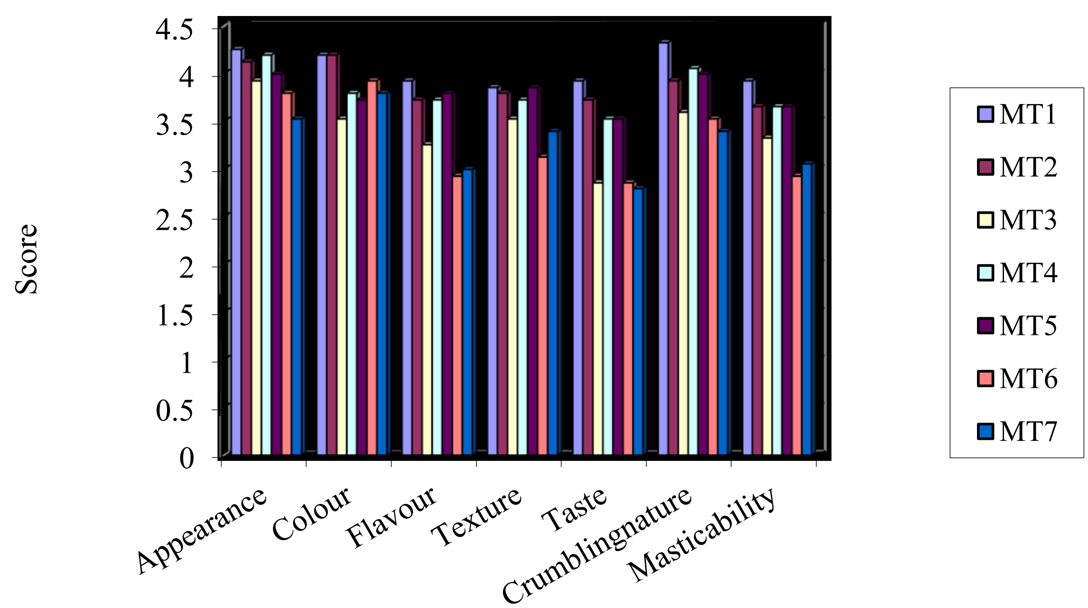


Fig. 10. Organoleptic parameters of bread variation II

4.4.3.3 Flavour of Bread

Flavour of a food contributes much to the acceptance of a food. The mean scores for flavour of bread is given in Table 9.

In the case of bread, the scores for flavour of variation I bread revealed that the highest score was obtained for MT1 bread (3.90). There was significant difference in the scores for flavour of control sample with all other breads. The score obtained for MT6 bread was on par with breads made from the flours of MT7 (3.00) and MT3 (3.26). Significant difference was observed in the mean scores of flavour between bread made from MT1 and breads made from MT3, MT7 and MT6. Significant difference was observed between breads made from the flours of MT5, MT2 and MT4 with breads made from MT6 and MT7.

The mean scores for flavour for bread variation II ranged from 3.06 to 4.00 with a highest score for MT1 (4.00). There was significant difference in the mean scores between control and all the breads made of other minor tuber flours. The lowest score was obtained for MT6 and MT7 with a score 3.06, which was significantly different from all the other samples of bread made from minor tuber flours.

4.4.3.4 Texture of Bread

Texture is an organoleptic parameter that determines the quality of the finished products. Mean scores for texture of bread is given in Table 9.

The mean score for texture of variation I bread ranged from 3.13 to 3.86 and variation II ranged from 2.75 to 3.93. The highest score was obtained for MT1 bread 3.86. Statistical analysis showed that control sample had a score of 4.53 for texture which was significantly different from all other breads made from minor tuber flour. The lower scores for texture was obtained for MT6 bread which was on par with breads made from MT7, MT3 and significantly different from breads made from MT4, MT2, MT1 and MT5. Significant difference in the score for texture was also observed between bread made from flour of MT7 with bread made from MT1 and MT5.

Statistical analysis revealed that the mean score for texture of bread (20:80 variation) was highest for MT5 bread (3.93). The score for control sample was 4.53 which was significantly different from all the other breads. Lower scores of texture was obtained for MT7 (2.75) which was on par with bread made from MT6 (2.93). Significant difference in texture was observed between bread made from MT5 with bread made from MT3, MT6 and MT7; scores obtained for bread made from MT4, MT1, MT2 and MT3 were significantly different from the bread made from MT6 and MT7.

4.4.3.5 Taste of Bread

Qualities of foods are evaluated by sensory organs - eyes, nose and mouth of which taste is the most important and unavoidable aspect. Mean scores for taste of bread is given in Table 9.

The mean score for taste of bread variation I varied from 2.80 to 3.93 with the highest score for MT1 (3.93). The score for control sample was (4.53) which was significantly different from the scores obtained for the breads made from all minor tuber flours. Lower scores for taste was obtained for MT7 (2.80) which was on par with the breads made from MT6 (2.86) and MT3 (2.86). The scores obtained for breads made from other minor tuber flour were significantly different from the breads made from MT3, MT6 and MT7.

Analysis of data showed that the mean score for taste of bread variation II was highest for MT1 (3.93). The score for control sample (4.53) was significantly different from the breads made from the minor tuber flours. Bread made from the flour of MT6 obtained the lower score for taste (2.86) which was on par with breads made from MT7 (2.93) and MT3 (3.13). Significant difference was observed between breads made from the flours of MT3, MT6 and MT7 with breads made from other minor tuber flours.

Crumbling nature and masticability of bread were assessed through five point scale along with other organoleptic parameters.

4.4.3.6 Crumbling Nature and Masticability of Bread

Crumbling nature measures whether the crumb of bread is fine or coarse. To see whether bread is sticky or not when chewed was ascertained through the parameter masticability. Table 9 depicts the details regarding the crumbling nature and masticability of bread made from flours of minor tubers.

The mean scores for the crumbling nature of variation I bread ranged from 3.40 to 4.46. Statistical analysis showed that the highest score for crumbling nature was obtained for control sample (4.46) which was on par with MT1 (4.33) and significantly different from all other breads. Lower scores for crumbling nature was obtained for MT2 which was on par with the breads made from MT6 and MT3 was significantly from different the scores obtained for MT1, MT4 and MT5.

Data analysis of variation II bread revealed that the mean score for crumbling nature was highest for control sample (4.46) which was on par with MT1 (4.20) and significantly different from breads made from all other minor tuber flour. The lower scores for crumbling nature was observed for MT6 (3.40) which was on par with the score obtained for MT7 (3.46) and significantly different from all other minor tuber flours.

Statistical analysis of masticability of variation I of bread revealed that the score was higher for control sample which was significantly different from breads made of all other minor tuber flours. The lower scores were obtained for MT6 (2.93) which was on par with MT7 (3.06) and MT3 (3.33). Significant difference was observed in the scores for masticability between MT1 and MT3, MT6 and MT7 breads. Breads made from the flours of MT2, MT4 and MT5 had the similar score for masticability (3.66) and was significantly different from the scores of MT6 and MT7.

The mean score for masticability of variation II bread ranged from 2.93 to 4.46 with the highest score for control sample (4.46), which was significantly different from the scores obtained for breads made from all other minor tuber flours. Lower scores for masticability was obtained for MT6 (2.93) which was on par with the scores of MT7 (3.00), MT3 (3.20) and MT2 (3.26). Significant difference in the scores of masticability was observed for MT1 with MT3, MT6 and MT7 and also between MT5 with MT6 and MT7.

4.4.4 Functional Quality Evaluation of Baked Products

The parameters studied under functional quality evaluation of baked products involved volume expansion, yield ratio, loaf volume, porosity and baking time.

4.4.4.1 Volume Expansion

Volume expansion of baked products gave the difference in the height of the raw dough or batter to the height of the baked product. The results of volume expansion of different baked products is detailed in Table 10.

Table 10. Volume expansion of baked products (cms)

Tuber flour	Cake		Biscuit		Bread	
	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II
Control	2.50	2.50	0.60	0.60	2.63	2.63
MT1	1.87	1.40	0.40	0.30	1.60	1.36
MT2	1.22	1.30	0.37	0.27	1.30	1.30
MT3	1.53	1.30	0.30	0.27	1.00	0.93
MT4	0.70	0.87	0.27	0.20	1.26	1.13
MT5	1.10	1.30	0.23	0.30	1.43	1.26
MT6	1.13	0.97	0.37	0.13	1.33	1.20
MT7	0.73	0.77	0.17	0.17	1.33	1.33
SE	0.09651	0.09651	0.06667	0.06667	0.09699	0.09699
CD (0.05)	0.2787	0.2787	0.19252	0.19252	0.2801	0.2801

Analysis of data revealed that higher values for volume expansion was obtained for cakes made from the flour of MT1. In the first variation of MT1 cake 1.87 cms increase in volume expansion was seen, which was significantly different from the values obtained for other cakes. An increase of 2.5 cms was obtained for control sample which was also significantly different from all other cakes. Lower values of volume expansion was noted for cake made from the flour of MT4(0.70 cms) which was on par with cake made from the flour of MT7(0.734 cms) and was significantly different from cakes made from MT2, MT3, MT4 and MT5

The mean value of volume expansion of cake variation II revealed that MT1 obtained a higher value of 1.40cms. Volume expansion of control sample was 2.5 cms which was significantly higher than the values obtained for all other cakes. Lower values for volume expansion was noted for cake made from the flour of MT7 (0.77 cms) which was on par with cakes made from the flour of MT4 (0.87 cms) and MT6 (0.97 cms) and significantly different form the cakes made from all other minor tuber flours.

The statistical analysis done for the volume expansion of biscuit revealed that in variation I and II, MT1 biscuit attained the highest value 0.40 cms. The mean score for volume expansion of MT1 biscuit was 0.40 cm which was significantly different from the value obtained for biscuit made from MT7 . The lower value for volume expansion was obtained for biscuit made from the flour of MT7(0.17cms) which was on par with the biscuit made from the flours of MT5(0.23 cms), MT4(0.27 cm) and MT3 (0.30cms) and significantly different from the value obtained for control sample (0.60 cms) which was significantly different from the values obtained for all other biscuits made from minor tuber flours.

For the variation II biscuit the value of volume increase was highest for biscuit made from the flour of MT1 (0.30cms) and MT5(0.30cms) which was on par with biscuits made from all the other minor tuber flours. The value obtained for the control sample was 0.60 cms which was significantly different from the values obtained for all biscuits made from minor tuber flours.

The mean value for volume expansion of bread made at variation I and II revealed that MT1 bread had the highest value. The value for volume expansion at variation I of MT1 bread was 1.43 cms. The control sample obtained 2.63 cms increase which was significantly different from the values obtained for breads prepared from other minor tuber flours. The lower value for volume expansion was obtained for bread made from the flour of MT3(1.00cm) which was on par with bread made from the flour of MT4(1.26cm) and significantly different from the breads made from the flours of MT1, MT5, MT6, MT7 and MT2.

Analysis of data pertaining to volume expansion of variation II bread revealed that the highest value has obtained for MT1 bread(1.36cm). In the control sample value increase was 2.63 cms which was significantly different from the values obtained for the breads made from minor tuber flours. Lower value of volume expansion was obtained for bread made from MT3 (0.93cms) which was on par with the values obtained for breads made from the flours of MT4(1.13 cms) and MT6 (1.20 cms) and significantly different from the values obtained for breads made from other minor tuber flours.

4.4.4.2 Yield Ratio

The product yield ratio gave an estimate of the amount of baked product obtained from utilising known quantity of raw materials. The yield ratio of developed baked products is given in Table 11.

Table 11 Yield ratio of cake, biscuit and bread.

Tuber flour	Cake		Biscuit		Bread	
	Variation I	Variation II	Variation I	Variation II	Variation I	Variation II
Control	0.980	0.980	0.980	0.980	0.970	0.970
MT1	0.980	0.973	0.983	0.970	0.950	0.936
MT2	1.020	1.033	0.966	0.963	0.923	0.916
MT3	0.936	0.966	0.990	0.980	0.970	0.970
MT4	0.943	0.923	0.966	0.926	0.920	0.926
MT5	0.973	0.926	0.926	0.930	0.936	0.926
MT6	0.976	0.990	0.990	0.953	0.940	0.930
MT7	0.930	0.926	0.920	0.933	0.920	0.930
SE	0.01471	0.01471	0.01198	0.0198	0.01256	0.01256
CD (0.05)	0.04247	0.04247	0.034611	0.034611	0.03278	0.03278

Statistical analysis done on yield ratio of cake revealed that cakes made from the flour of MT2 attained the highest yield ratio of 1.020 which was on par with the value obtained for control sample and MT1(0.980) and significantly different from all other cakes. Yield ratio obtained for control sample and MT1 were (0.980) which was significantly different from the values obtained for cakes made from the flours of MT3 and MT7. Lower values for yield ratio was obtained for cake made from MT7(0.930) which was on par with the values obtained for cakes made from MT3(0.936) and MT4(0.943). Significant difference was observed between the cakes made from MT5and MT6 with MT7

In the case of second variation cake, highest value (1.033) was obtained for cake made from MT2 which was on par with the cake made from MT6(0.90). The control sample obtained an yield ratio of 0.980 which was significantly different from the values obtained for cakes made from MT7, MT5 and MT4. Significant difference was observed in the yield ratio of MT2 with other cakes. Yield ratio of variation II cake, MT4 obtained

0.923 which was on par with the values obtained for cakes made from the flours of MT5 (0.926) and MT7 (0.926).

Analysis of data for yield ratio of variation I biscuit revealed that MT3 and MT6 obtained 0.990 which was on par with the scores obtained for control (0.980), MT1(0.983), MT2 (0.966) and MT4(0.966). Values for yield ratio of MT7(0.920) which was on par with MT5(0.926) and significantly different from the values obtained for all other biscuits.

Biscuits made at variation II, MT3 and control obtained the highest value (0.980) which was on par with MT1 (0.970), MT2 (0.963) and MT6 (0.953). Yield ratio was lower for MT4 (0.926) which was on par with the scores obtained for MT5 (0.936) MT6 (0.953) and MT7 (0.933). Values for yield ratio of control sample, MT3 and MT1 was significantly different from the yield ratio of MT7, MT5 and MT4. Significant difference was observed between MT2 and MT4.

Statistical analysis done for yield ratio of bread revealed that MT3 had the highest yield ratio. Bread prepared at variation I of MT3 and control had yield ratio of 0.971 which was on par with the value obtained for breads prepared from the flours of MT1 (0.95) and MT6 (0.94) and significantly different from the values obtained for breads prepared from the flours of MT2, MT4, MT5 and MT7.

Lower values of yield ratio was found for breads of MT4 and MT7 (0.920) which was on par with the breads prepared from the flours of MT1 (0.950), MT2 (0.923), MT5 (0.936) and MT6 (0.940)

Values for bread variation II ranged from 0.916 to 0.970 with the highest value for bread made from the flour of MT3 and control sample (0.97). Significant difference was observed with the values obtained for MT3 and control sample with other breads. Lower values for yield ratio was noted for bread of MT2 (0.916) which was on par with breads prepared from all minor tuber flours except MT3.

4.4.4.3Loaf Volume

The loaf volume for bread gave the rate of fermentation that has taken place in the bread dough. Loaf volume was found out by taking the difference in the height of baked bread to that of the height of fermented dough. The results are depicted in Table 12.

Table 12 Loaf volume of bread (in cms)

Tuber flour	Baked bread	
	Variation I	Variation II
Control	1.80	1.80
MT1	1.00	0.83
MT2	0.70	0.87
MT3	0.70	0.69
MT4	0.66	0.57
MT5	0.93	0.73
MT6	0.60	0.60
MT7	1.03	0.83
SE	0.077931	0.077931
CD (0.05)	0.248789	0.248789

Data analysis done on the loaf volume of bread variation I revealed that bread made from the flour of MT7 had the highest increase in loaf volume 1.03 cms followed by bread made from the flour of MT1 with an increase of 1.00 cm. Control sample had loaf volume of 1.80 cm which was significantly different from the loaf volume of other breads. The lower value of loaf volume was seen in bread made from the flour of MT6 (0.60cm) which was on par with breads made from MT4 (0.66cm) MT2

(0.70cm) and MT3 (0.70cm). Significant difference was observed in the loaf volume of bread from the flours of MT7 and MT1 with breads made from the flours of MT3, MT2, MT4 and MT6; and also significant difference was seen between MT5 with MT4 and MT6.

In the second variation of bread the highest increase in loaf volume was observed for MT2 (0.867). Which was significantly different from the loaf volume of breads made from the flours of MT6 and MT4. Control sample obtained the loaf volume of 1.80 cm which was significantly different from the loaf volume of bread made from minor tuber flours. Lower value of loaf volume was found for bread made from the flour of MT4 (0.57 cm) which was on par with the loaf volume of breads made from the flours of MT6 (0.60 cm), MT5 (0.73 cm) and MT3 (0.69 cm) and significantly different from the loaf volume of bread made from the flour of MT7 and MT1.

4.4.4.4 Porosity

Porosity gives the number of pores formed in cakes and bread during the process of baking. The porous nature of bread decides the softness of bread.

The porosity was estimated on the basis of number of tunnels or holes in the baked product. The ink impression of porous nature of different variations of cakes and breads are depicted in Fig. 11 and 12.

4.4.4.5 Baking Time and Temperature

Baking time and temperature of developed products were assessed separately. Baking time gave the extent of time required by each product to be well cooked. Table 13 shows the baking time and temperature of different products.

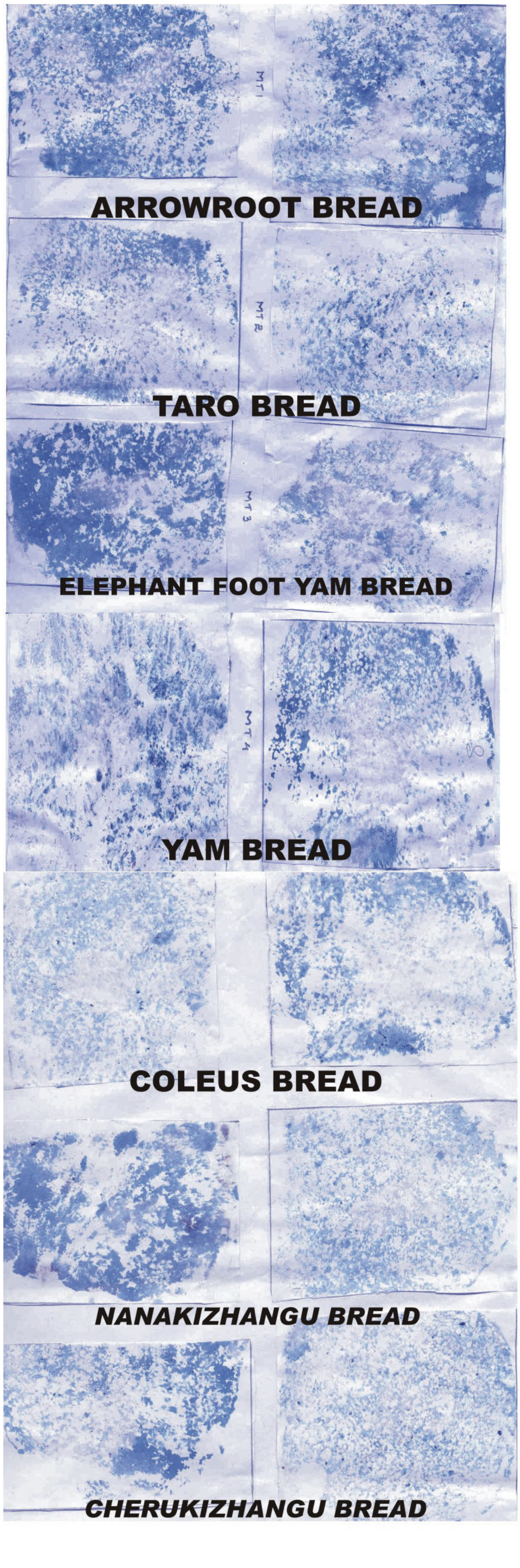


Fig. 12. Porosity of bread

Fig. 11. Porosity of cake

Table 13 Baking time and temperature of different products

Product	Baking time (min)	Baking temperature (°C)
Cake	30	180
Biscuit	25	210
Bread	30	230

The baking time and temperature varied with the type of products. It was observed that thirty minutes was required for baking cake at 180°C, for biscuits the required time was twenty five minutes. The temperature for baking biscuit was 210°C. Breads required thirty minutes time for baking at 230°C.

4.4.5 Economic Feasibility of the Developed Baked Products from Minor Tubers

The cost of the developed baked products were assessed through input cost and output cost. Input cost was calculated from the cost of the ingredients (Minor tuber flour, refined flour, shortening and thickening agents, leavening agents and other food additives) and output cost was the total of input cost and added ten per cent of overhead charges. Cost of production of one kilogram of the baked product was worked out and is presented in Table 14.

Table 14 Cost of one kilogram of baked product

Tuber	Cake		Biscuit		Bread	
	Variation I (Rs.)	Variation II (Rs.)	Variation I (Rs.)	Variation II (Rs.)	Variation I (Rs.)	Variation II (Rs.)
MT1	27.00	28.00	19.80	20.50	27.00	28.00
MT2	26.00	27.00	19.00	19.50	25.00	26.00
MT3	26.00	27.00	19.50	20.00	26.00	27.00
MT4	25.00	26.00	18.50	19.00	24.00	24.40
MT5	27.00	28.00	20.00	21.00	27.50	29.00
MT6	25.00	27.00	19.00	20.00	25.00	26.00
MT7	26.00	26.00	19.00	19.25	24.00	25.00
Market Price	60.00		50.00		28.00	

The cost of first variation of cakes varied from Rs.25.00to Rs 27.00 and variation II varied from Rs.26.00 to Rs. 28.00. Lower price was found for cake made from the flour MT4 (yam) and higher price was observed for cakes made from the flours of MT1 (arrowroot) and MT5 (coleus) in both the variation. Compared to the market price the price of cake made from minor tubers were found to be economically feasible. The market price of cake was Rs. 60.00 per kilogram and the price of cakes made from minor tuber flours ranged from Rs. 25.00 to Rs28.00 and about fifty percent profit was observed.

The price of biscuit variation I ranged from Rs 18.50 to Rs 20.00, with lower cost for biscuits made from the flour of MT4 (yam) and higher cost for biscuits made from the flour of MT5 (coleus). The cost of variation II biscuits ranged from Rs. 19.00 to Rs. 21.00, with lower cost for biscuits made from yam flour and higher cost of Rs. 21.00 for biscuits made from the flour of MT5. Market price of one kilogram biscuit was Rs. 50.00, and the cost of one kilogram of biscuit made from minor tuber flour ranged from Rs. 18.50 to Rs. 21.00

The cost of variation I bread ranged from Rs.24.00 to Rs. 27.50, with the lower cost for breads made from the flours of MT4 (yam) and MT7 (*cherukizhangu*) and higher cost for bread made from the flour of MT5 (coleus). The price of variation II bread ranged from Rs.24.00 to Rs.29.00 with lower and higher prices for breads made from the flours of MT4 and MT5 respectively. The market price of one kilogram of bread was found to be Rs. 28.00 and the cost of one kilogram of bread made from minor tuber flours ranged from Rs.24.00 to Rs.29.00, and it was observed that there was no cost benefit with regard to breads of minor tubers and breads purchased from market.

4.4.6 Overall Acceptability

Overall acceptability is the most important parameter to evaluate the acceptability of a product. This is the mean of the sum total of scores of 15 judges obtained for appearance, colour, flavour texture and taste. Overall acceptability of bread was calculated by adding the scores of crumbling nature and masticability along with that of the other organoleptic parameters. Table 15 depicts the mean scores for overall acceptability of cake, biscuit and bread. (Fig. 13 and 14)

Table 15. Overall acceptability of cake, biscuit and bread

Tuber flour	Cake				Biscuit				Bread			
	Variation I	Rank	Variation II	Rank	Variation I	Rank	Variation II	Rank	Variation I	Rank	Variation II	Rank
Control	4.63	c	4.63	c	4.63	c	4.63	c	4.5	c	4.5	c
MT1	4.40	**1**	4.26	**1**	4.47	**1**	4.45	**1**	4.06	**1**	4.04	**1**
MT2	4.08	**2**	3.98	**2**	4.46	**2**	4.40	**2**	3.87	**2**	3.79	4
MT3	3.64	5	3.74	6	4.10	**3**	4.06	5	3.46	5	3.54	5
MT4	4.02	**3**	3.96	**3**	4.06	4	4.23	**3**	3.80	**3**	3.86	**2**
MT5	4.02	**3**	3.98	**2**	4.10	**3**	4.16	4	3.78	4	3.84	**3**
MT6	3.93	4	3.87	4	3.93	6	3.93	6	3.35	6	3.27	6
MT7	3.93	4	3.85	5	3.98	5	3.93	6	3.31	7	3.26	7
SE	0.0643		0.0915		0.0835		0.0661		0.0853		0.0595	
CD (0.05)	0.1739		0.2258		0.3043		0.1683		0.3714		0.1150	

Analysis of the data on the overall acceptability scores for variation I - cake revealed that control sample had the highest score of 4.63. Cake prepared from the flour of MT1 attained a score of 4.40. Lowest score was obtained for cake prepared from the flour of MT3. Significant difference was observed in the scores of overall acceptability obtained for MT1 cake and cakes prepared from all other minor tuber flours. Score obtained for MT2 cake differed significantly from the scores obtained for cakes prepared from the flour of MT6, MT7, and MT3. Score obtained for MT3 cake differed significantly from the scores obtained for cakes made from MT6 and MT7.

Analysis of data on overall acceptability of cake variation II revealed that control sample obtained the highest score of 4.63. Cake prepared from the flour of MT1 had a score of 4.26 which differed significantly from the scores obtained for all other cakes. Lower score for overall acceptability was obtained for MT3 cake (3.74) which was on par with the scores obtained for cakes prepared from the flours of MT7 (3.85) and MT6 (3.87). Significant difference was observed in the scores obtained for cakes prepared from the flours of MT2 and MT3.

Statistical analysis done on the overall acceptability scores of biscuit variation I revealed that the control sample attained the highest score of (4.63) which was on par with biscuits prepared from the flours of MT1 (4.47) and MT2 (4.46). Lower scores for overall acceptability was obtained for MT6 biscuit (3.93) which was on par with the scores obtained for biscuits made from the flours of MT7 (3.98), MT4 (4.06), MT5 (4.10) and MT3 (4.10) and significantly different from the scores obtained for control sample and biscuits made from the flours of MT1 and MT2 .

Analysis of data regarding the overall acceptability scores of biscuit variation II revealed that the control sample attained the highest score of 4.63 which differed significantly from the scores attained for biscuits prepared from minor tuber flours. MT1 biscuit attained a score of (4.45) which was on par with the score attained for MT2 biscuit (4.23) and significantly different from the scores obtained for all other biscuits. Lower scores for overall acceptability was obtained for biscuits prepared from the flours of MT6 (3.93) and MT7 (3.93) which was on par with the scores obtained for biscuits prepared from the flours of MT3 (4.06). Significant difference was observed in the scores of overall acceptability of MT5 biscuit with biscuits made from the flour of MT6 and MT7.

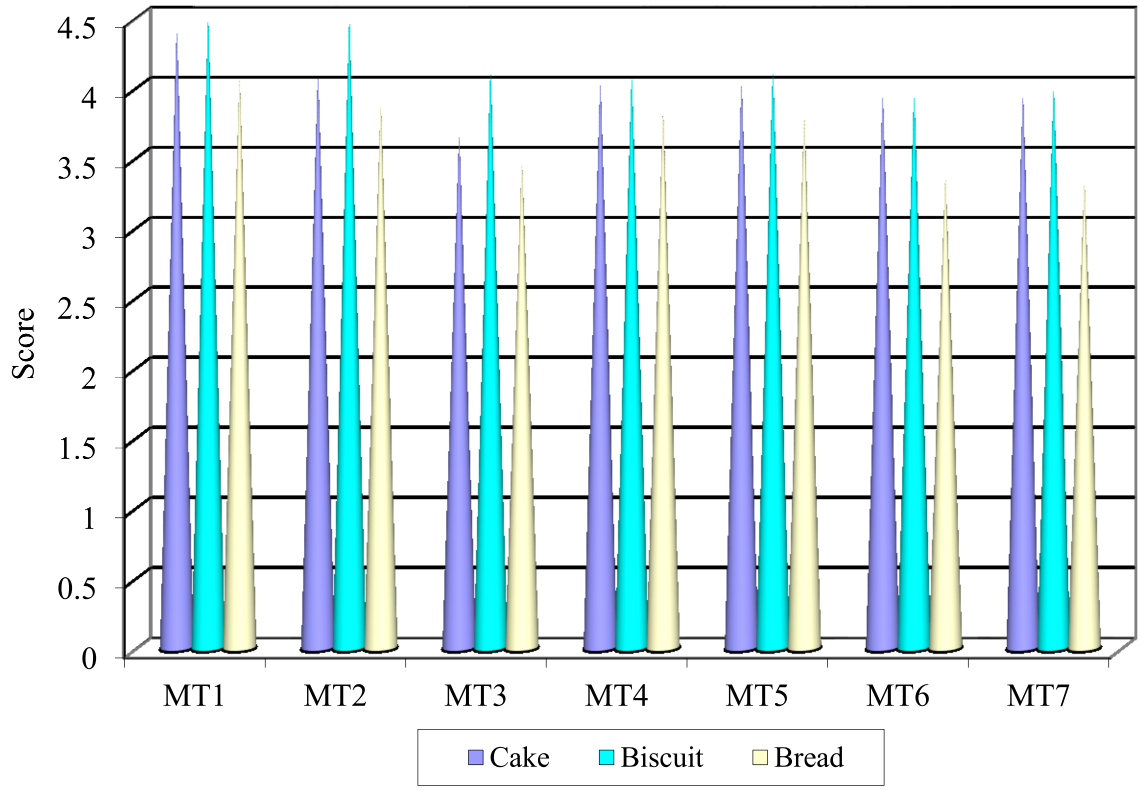


Fig. 13. Overall acceptability of baked products (Variation I)

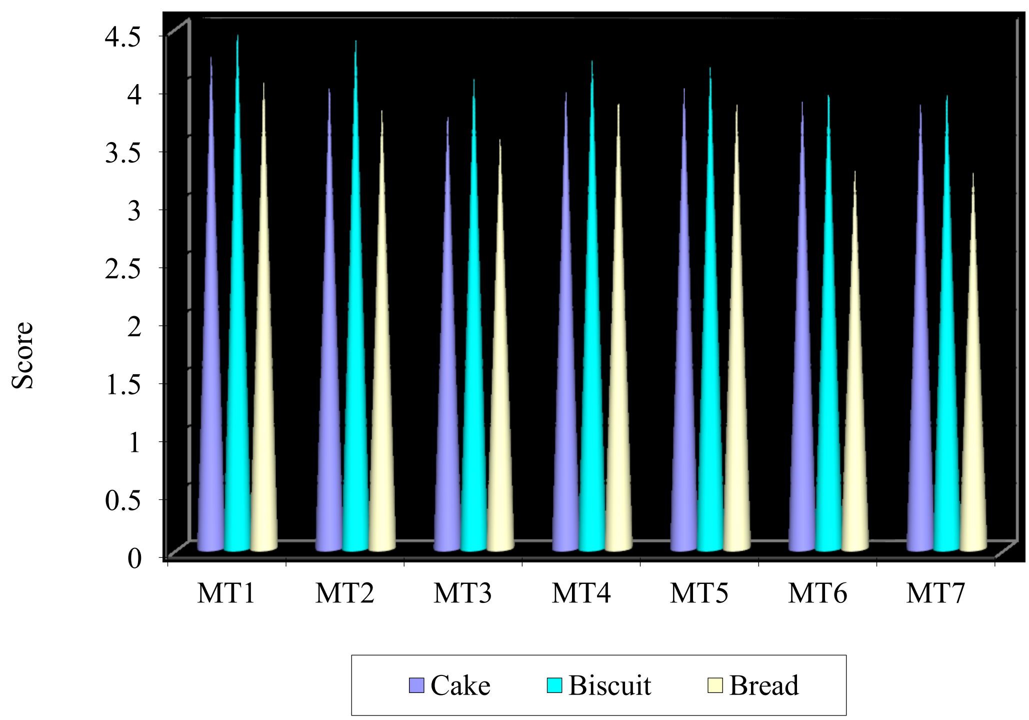


Fig. 14. Overall acceptability of baked products (Variation II)

Analysis of data on the overall acceptability of bread variation I revealed that control sample had the highest score of (4.50) which was on par with the score obtained for MT1 bread (4.06). Lower score of overall acceptability was obtained for bread prepared from the flour of MT7 (3.31) which on par with the scores of bread prepared from the flours of MT6 (3.35) and MT3 (3.46). Significant difference in the overall acceptability scores was observed between control sample and all other breads except MT1 bread. Overall acceptability scores of MT1 and MT2 breads were significantly different from the scores obtained for breads prepared from the flours of MT3, MT6 and MT7. It was also observed that the scores obtained for overall acceptability of breads made from MT4 and MT5 differed significantly from the scores obtained for MT6 and MT7.

Statistical analysis done on the overall acceptability of bread variation II revealed that the highest score was obtained for control sample (4.5). Bread made from the flour of MT1 attained a score of (4.04). Lower score of acceptability was obtained for bread prepared from the flour of MT7 (3.26) which was on par with the score of bread prepared from the flour of MT6 (3.27). Significant difference was observed in the overall acceptability scores obtained for MT6 and MT7 bread with breads prepared from all other tuber flours. Significant difference in acceptability scores was observed in control sample and all other breads. Statistical analysis revealed that the scores of acceptability of MT1 bread differed significantly with the scores obtained for all other breads.

4.5 SELECTION OF BEST PRODUCTS

For the selection of best baked product from among the minor tubers, ranks were allotted based on the organoleptic quality evaluation. It was observed that MT1 (arrowroot) got first rank for cake, biscuit and bread in both the variation. MT2 (taro) availed second rank for cake and biscuit and variation I of bread. Bread made at variation II using the flour of MT4 (yam) also obtained second rank. Baked products prepared from the flours of MT4 (yam) and MT5 (coleus) obtained third rank. Baked products prepared from all other minor tuber flour acquired lower ranks for overall acceptability.

4.5.1 Shelf Life Qualities of the Developed Baked Products

Processed food developed should be assessed for its shelf life qualities. Based on the overall acceptability scores, best baked products were selected for shelf life study. The shelf life of the baked products were assessed by storing the products in polypropylene covers at room temperature. Moisture content of the stored products were estimated to assess the shelf stability. Moisture content of fresh sample and after one week storage were analysed. Microbial growth was also examined daily by observation of the sample product. Table 16 depicts the moisture content of different baked products.

Table 16 Moisture content of the baked products

Tuber flour	Cake			Biscuit			Bread		
	Initial	8^{th} day	Per cent increase	Initial	8^{th} day	Per cent increase	Initial	8^{th} day	Per cent increase
MT1	19.03	19.18	0.15	4.43	4.47	0.04	29.96	36.89	6.93
MT2	17.25	17.41	0.16	3.90	4.00	0.10	28.9	36.70	7.8
MT4	20.60	20.82	0.22	4.13	4.28	0.15	31.5	40.78	9.28
MT5	18.73	18.39	0.16	3.93	4.07	0.08	28.73	37.88	9.15

It was found that there was an increase in moisture content in all the stored baked products; cake, biscuit and bread. The increase in moisture content was more in breads; than in cakes and biscuits.

The moisture per cent increase was found to be higher in cake made from the flour of MT4 with 0.22 per cent increase.

Biscuits had a longer shelf life than cakes and bread and the per cent increase in moisture was less. Moisture increase was found high in MT4 biscuit with 0.15 per cent, followed by biscuit made from the flour of MT2 (taro) 0.10 per cent increase. The increase in moisture per cent was lower in biscuit made from the flour of MT1 (arrowroot) with an increase of 0.04 per cent.

The moisture rise in breads was within the ISI specified value of 35.00 per cent. There was about 6.93 to 9.28 per cent rise in moisture, after one week with the highest rise in breads prepared from the flour of MT4 (yam).

Along with moisture estimation, microbial growth was also observed on stored baked products. On the twelfth day of storage mold growth was observed on cake. Biscuits had a longer shelf life of about one month. Mold growth was seen on the twenty seventh day of storage. By the fifth day mold growth was seen on bread samples. Breads had a shorter shelf life than cakes and biscuits.

4.5.2 ISI Type Test to Assess the Commercial Viability

The quality of processed products is controlled by the government through the ISI specification. The baked products prepared by partial substitution of refined flour with minor tuber flours, were analysed for ISI type tests. Estimation of moisture, total ash and acidity were the major type tests prescribed for baked products. ISI type tests were administered to the best products selected through the rank and overall acceptability scores. Type tests of product administered to cake (IS:9712-1981), biscuit (IS:1011-1992) and bread (IS:1483-1988) are depicted in Table 17.

Table 17 ISI type tests done on baked products

Tuber	Moisture (per cent)			Acid insoluble ash (per cent)			Acidity (per cent)		
	Cake	Biscuit	Bread	Cake	Biscuit	Bread	Cake	Biscuit	Bread
ISI value	**15.25**	**5.00**	**35.00**	**0.10**	**0.05**	**0.10**	**1.00**	**1.20**	**1.50**
MT1	19.03	4.40	29.96	0.73	0.70	0.63	1.60	1.00	1.62
MT2	17.26	3.90	28.90	0.58	0.80	0.73	1.80	1.70	1.60
MT4	20.60	4.13	31.50	0.56	0.46	0.64	0.90	1.60	1.80
MT5	18.73	3.93	28.70	0.96	0.90	0.93	2.06	1.18	2.00

Moisture content of cake, biscuit and bread were according to the ISI specification. The moisture content of cakes were MT1 (19.03 per cent), MT2 (17.26 per cent) MT4 (20.60 per cent) and MT5 (18.73 per cent), while the ISI specification was between 15 and 25 per cent. Moisture content of biscuits were MT1 (4.40 per cent), MT2(3.90 per cent), MT4 (4.13 per cent) and MT5 (3.93 per cent) while the ISI has specified a maximum limit of 5.00 per cent. Breads made from the flours of MT1, MT2, MT4 and MT5 had a moisture content of 29.96, 28.9, 31.5 and 28.70 per cent respectively. ISI has specified a maximum limit of 35.00 per cent for breads. It was observed that the moisture content of baked products were within the limits of ISI specification.

The acid insoluble ash content of the baked products were above the ISI specification. It might be due to the excess mineral and fibre content of minor tubers. The ash content of cakes were MT1 (0.13), MT2 (0.58) MT4 (0.56) and MT5 (0.96). The highest ash content was observed in cakes made from the flour of MT5 while the ISI specification for acid insoluble ash for cakes were 0.1.

The estimated value for acid insoluble ash of biscuits were MT1 (0.70) MT2 (0.80) MT4 (0.46) and MT5 (0.90). The ISI specification of acid insoluble ash of biscuits were 0.05. Breads made from the flour of MT1, MT2, MT4 and MT5 had acid insoluble ash content of 0.63, 0.73, 0.64 and 0.93 respectively while the ISI specification for acid insoluble ash of breads were 0.10.

Acidity of cakes were found to be MT1 (1.60), MT2 (1.80), MT4 (0.90) and MT5 (2.06), while the acidity for cakes specified by ISI was 1.00 per cent. The acidity for biscuit were found to be MT1 (1.00), MT2 (1.70), MT4 (1.60) and MT5 (1.18). The ISI specification for acidity of biscuits were 1.20 per cent. The estimated value for acidity of breads were MT1 (1.62), MT2 (1.60), MT4 (1.80) and MT5(2.00) while the ISI specified value was 1.50 per cent. It was noted that the acidity was higher for baked products prepared from the flour of MT5.

Discussion

5. DISCUSSION

The current study entitled "Utilization of minor tubers for the development of baked products" are discussed under the following heads.

5.1 Processing of minor tubers

5.2 Quality assessment of minor tuber flours.

5.3 Functional quality analysis of minor tuber flours.

5.4 Shelf life qualities of minor tuber flours.

5.5 Product development and quality assessment of the developed products

5.6 Selection of best product

5.1 PROCESSING OF MINOR TUBERS

Processing is a method of reducing post harvest loss of perishable foods like fruits, vegetables, roots and tubers. Processed products are of immense value and technologies were developed to increase the shelf life of tubers and to develop various value added processed products from roots and tubers. Cassava, sweet potato and yams are the major root crops and arrowroot, taro, elephant foot yam and lesser yams are considered as minor tubers just because they are cultivated in small area. Research on value addition and utilization of these minor tubers is limited. The present study is an attempt to process these minor tubers for the development of baked products. Flours of these minor tubers were used for processing of products.

5.2 QUALITY ASSESSMENT OF MINOR TUBER FLOURS

It is necessary to assess the quality of the raw materials before developing it into various products. In the present study, minor tuber flours were assessed for its functional quality characteristics with regard to moisture content acidity, reducing sugar, crude fibre and protein.

Significant difference was observed in moisture content, acidity, reducing sugar, crude fibre and protein content of fresh flour of minor tubers.

Moisture content of minor tuber flours ranged from 9.43 per cent (taro) to 11.43 per cent (yam). The ISI specification for flour used in the preparation of baked products is 13.00 per cent (maximum). Moisture content of elephant foot yam (MT3) flour was 9.53 per cent. Sini (2002) reported that the moisture content of elephant foot yam flour ranged from 10 to 13.93 per cent. In the present study the value was lower than the values obtained by Sini. The moisture content of taro flour was 9.43 per cent and Liya (2002) had reported similar values of moisture content. Chellammal (1995) found that the moisture content of cassava flour as 9.80 percent and sweet potato flour as 8.50 per cent.

Acidity of coleus flour (MT5) was highest (0.666) among the minor tuber flours and lowest acidity was recorded for taro (MT2) flour (0.268). The sugar present in the flour is hydrophilic which enhances the absorption of water. This hygroscopic property of sugar is an important factor affecting the quality and acceptability of baked products. Reducing sugar content of arrowroot flour (MT1) was higher than that of other minor tuber flours, reducing sugar content of yam (MT4) flour (1.213) was low. Jos *et al.* (1990) reported that the reducing sugar content of roots and tubers ranged from 0.5 to 2.5 per cent.

The low fibre content in minor tubers is an advantage in the preparation of various value added products. Hence this quality characteristics were assessed. The crude fibre content of arrowroot (MT1) flour was highest among the minor tuber flours with 3.00 g which was in line with the findings of Veena (2000) who reported a value of 2.6 g in arrowroot. Ramesan (1991) obtained a low value for crude fibre content of arrowroot. Sini (2002) reported that the crude fibre content of different varieties of fresh elephant foot yam corms ranged from 0.84 per cent to 1.10 per cent. In the present study the fibre content of elephant foot yam (MT3) flour was 1.16 per cent. The crude fibre content of taro (MT2) flour was 1.16 per cent while Liya (2002) opined that crude fibre content of fresh taro corm as 0.85 per cent. Earlier findings by Gopalan *et al.* (1997) and Lila *et al.* (1998) showed the fibre content in fresh taro as 0.35 per cent to 1.00 per cent. The crude fibre content of yam (MT4) flour was 1.66g which was in line with the findings of Jos *et al*. (1990). The crude fibre content of cassava and sweet potato flour was 2.00 and 3.80 per cent respectively (Chellammal, 1995). Karuna *et al.* (1990) found that the crude fibre content of cassava flour was 2.00 per cent. Less fibre in minor tubers is advantageous to use it in variety of products.

Flour protein is of prime importance in the development of baked products. Protein content was highest for arrowroot (MT1) flour with 4.3 g. This was supported by the findings of Veena (2000) who opined that the protein content of different varieties of fresh arrowroot ranged from 3.12 to 6.48 per cent per 100g. Maheswarappa *et al.* (1997) also reported high protein content in arrowroot. Ramesan (1991) reported a lower value for protein content in arrowroot.

Taro flour (MT2) had a protein content of 2.56 g which was in accordance with the values obtained by Liya (2002). She reported that the protein content of taro ranged from 2.32 to 2.65 g. However Seralathan and Thirumaran (1999) observed a higher value of 3.2 per cent.

The protein content of elephant foot yam (MT3) flour was 3.5g which was in accordance with the values arrived by Balagopalan (2000). Sini (2002) reported that the protein content of corms of elephant foot yam as 3.7 per cent. Gosh *et al.*(1988) found that the protein content of tubers ranged from 1 to 4 per cent. Lila *et al.* (1998) observed that the protein content of elephant foot yam was 3.0 per cent. Seralathan and Thirumaran (1999) obtained a protein content of 2 per cent for elephant foot yam.

The BIS specification of moisture content of flours used in the preparation bakery products is 13.00 per cent and the moisture content of minor tubers confines to this value. It was observe that the reducing sugar, fibre and protein content was highest for arrowroot (MT1) flour which makes it more suitable for the development of baked products.

5.3 FUNCTIONAL QUALITY ANALYSIS OF MINOR TUBER FLOURS

Functional qualities namely; change in weight, processing loss, yield ratio and water absorption index of minor tuber flours were studied. The change in weight due to loss of moisture from fresh tuber on drying was accounted for different minor tubers. It was shown that coleus (MT5) flour had the highest change in weight of 0.707 while *cherukizhangu* (MT7) flour recorded the lowest value (0.527).

Processing loss is another factor which was analysed from purchased weight and edible portion of the tuber. Processing loss was highest for coleus (MT5) flour (0.150) and lowest for arrowroot (MT1) flour (0.080).

Significant difference in flour yield ratio of minor tuber flours were observed *nanakizhangu* (MT6) flour had higher yield ratio of 0.350 and the lowest yield ratio was observed for coleus (MT5) flour (0.167).

Highest water absorption index was observed for arrowroot flour (MT1) 10.633. Manay and Sadhaksharaswamy (2002) reported that the sugar present in the flour enhances the water absorption. In the present study it was noted that arrowroot (MT1) flour had the highest reducing sugar content, this might be the reason for the high water absorption index.

5.4 SHELF LIFE QUALITIES OF MINOR TUBER FLOUR

Shelf life qualities are essential parameters to be assessed since it determines the suitability of a particular ingredient for product development (Livingstone *et al.,* 1993) Varsany (1993) reported that the mechanism and kinetics of the food deterioration can be controlled by the storage techniques applied. According to Shankar (1993) several factors such as raw material quality, storage temperature, storage containers, process employed and the environment in which it is processed will have an effect on the quality of the food material. In the present investigation minor tuber flours were stored in PET containers and poly propylene covers for three months with an objective to find out the shelf stability of flours at ambient conditions. Moisture content and water absorption index were analysed after the storage period of three months inorder to asses the quality of the stored minor tuber flours.

Moisture is an important aspect which affects the shelf life of a products. The moisture content of the stored minor tuber flours increased after three months of storage with a more specific increase of moisture was detected in the flours stored in polypropylene covers.

Among the tuber flours stored in polypropylene covers, coleus flour (MT5) had the highest moisture increase of 4.1 per cent, followed by elephant foot yam (MT3) flour (3.63 per cent). The least increase was observed in *cherukizhangu* (MT7) flour (0.19 per cent).

Sini (2002) and Liya (2002) had also reported that the moisture content of stored elephant foot yam flour and taro flour increased on storage and the increase was found to be more profound in the flours stored in polypropylene covers. They opined that polypropylene covers appeared to have allowed the flour to absorb more moisture and suggested that glass bottles and PET containers can provide longer shelf life for amorphophallus and taro flours than polypropylene covers. Chellammal (1995) and Augustine (1999) were also of the same opinion.

The water absorption index of the stored tuber flours decreased after three months of storage with a profound decrease in flours stored in polypropylene covers. Among the tuber flours stored in PET containers, (coleus) MT5 had the highest water absorption index and (taro) MT2 had the lowest water absorption index. Among the tuber flours stored in polypropylene covers, *(cherukizhangu)* MT7 had the highest water absorption index and (elephant foot yam) MT3 had the lowest water absorption index.

5.4.1 Insect Infestation and Microbial Analysis of Minor Tuber Flours.

The deterioration of stored foods is caused by damage due to bacterial, fungal and insect infestations. Damage due to insects may be considerable since they not only consume stored food but also contaminate the food with insect fragment and metabolic products. There were no incidence of insect attack in any of the stored minor tuber flours both in PET containers and poly propylene covers. Similar results were reported by Augustine (1999), Liya (2002) and Sini (2002) on different tuber flours.

According to Leela *et al.*(1993), processed foods and other food materials provide ample scopes for contamination with spoilage and pathogenic micro organisms, thus necessitating microbiological quality assessment as an integral part of processing.

Microbial analysis of fresh as well as stored minor tuber flours were conducted by the serial dilution technique. No microbial growth was observed in any of the fresh minor tuber flours and similar result was reported by Chellammal (1995), Augustine (1999). Among the stored samples, yeast growth was seen. Bacterial growth were observed in all minor tuber flours stored in polypropylene covers as well as in PET containers. The number of colonies were more in poly propylene covers when compared to PET containers. Chellammal (1995) also opined that macroni and noodles stored in polypropylene covers had more microbial contamination than the products stored in PET containers.

5.5 PRODUCT DEVELOPMENT AND QUALITY ASSESSMENT OF THE DEVELOPED PRODUCTS

Baking is one of the processing method for product development. In the present investigation, cakes, biscuits and bread were developed by partial substitution of refined flour with minor tuber flour in two variations (15 and 20 per cent level).

5.5.1 Sensory Quality Evaluation of Baked Products

The baked products developed were subjected to quality assessment by sensory evaluation. According to Herrington (1991) sensory evaluation technology is a method using skilled management and trained panelists to provide confirmation on the acceptability of the product in terms of product profile, consumer acceptability and consistency. Mc Dermott (1992) reported that sensory method in which palatability is evaluated by a panel of judges is essential to every standardisation procedure because they answer all important questions of the food; taste, smell, look and feel. Rajalekshmi (1993) described sensory analysis as a scientific discipline used to evoke, measure, analyse and interpret reaction to those characteristics on food materials as perceived by the sense of sight, smell, taste, touch and hearing.

In present study, appearance, colour, flavour, texture and taste were the quality parameters assessed. Johns (1993) had stated that for consumers the perceivable sensory attributes, colour, appearance, feel, aroma, taste and texture are the deciding factors of food acceptance.

5.5.1.1 Sensory Assessment of Cake

Consumer preference to appearance is one of the major factors leading to the demand of a product. Appearance of the cake made from different minor tuber flours were comparable with the control sample which was made out of refined flour. In both the variations cakes made from the flours of arrowroot (MT1), taro (MT2), yam (MT4), coleus (MT5), *cherukizhangu* (MT7) and *nanakizhangu* (MT6) obtained a mean score of 4 and above out of 5. The lower score for MT3 cake was due to the dull colour of fresh elephant foot yam flour.

Dorko and Penfield (1993) reported that the aesthetic, safety, sensory characteristics and acceptability of foods are all affected by colour. Colour is one of the important characteristic for judging the quality of a product. The light brown colour of cake made from the flour of arrowroot (MT1) was more acceptable and comparable with the control sample than other cakes made from the flours of taro (MT2) and *nanakizhangu* (MT6).

Brue *et al.* (1991) had stated that the important factors in the marketing of products are its cooking, eating and processing qualities. This include the flavour, texture and appearance of the product. Flavour of cake prepared from arrowroot (MT1) was comparable with the control sample. Cakes prepared from arrowroot (MT1), taro (MT2), yam (MT4) and coleus (MT5) at variation I obtained score of 4 and above for flavour.

Nikolaidis and Labuza (1996) opined that texture is an important sensory attribute for many cereal based foods and the loss of desired texture results in a loss of product quality and a reduction in shelf life. Texture of cakes prepared from the flour of arrowroot (MT1), yam (MT4) and coleus (MT5) of variation I obtained scores of 4 and above.

Sharma *et al.* (1995) stated that taste is the primary and most important quality among various attributes. Taste of cakes prepared from the flour of arrowroot (MT1), yam (MT4) and coleus (MT5) were comparable with the control sample and obtained higher scores.

5.5.1.2 Sensory Assessment of Biscuits

Almedia and Noguiria (1995) stated that organoleptic properties determine acceptance of food by the consumer with appearance being the first factor that determine the acceptance or rejection of a food. In the case of biscuits made from different minor tuber flours the score for appearance was comparable with the control sample. Arrowroot (MT1) biscuit variation I scored 4.73, which was more than the score obtained for control sample (4.60). Biscuits made from arrowroot (MT1), taro (MT2) and elephant foot yam (MT3) variation I obtained scores above 4 and in variation II all biscuits except those made from the flours of *nanakizhangu* (MT6) and *cherukizhangu* (MT7).

According to Sharma *et al.* (1995) colour scores were significantly related with acceptability. When the colour attribute was taken into consideration, scores obtained for biscuits were comparatively better than that of cakes and bread. Similar result was obtained by Augustine (1999). Biscuits, both the variation I and II prepared from arrowroot (MT1) and taro (MT2) were comparable with control sample.

Flavour of bakery products is a very important quality attribute. Flavour is the unique character of odour and taste. Appearance of food is important but it is flavour that ultimately determines the quality and acceptability of foods. Flavour of biscuits were better than the control sample. All biscuits made from the flour of minor tubers obtained score of 4 and above for flavour. While a score of 4.53 was obtained for flavour of biscuit made from arrowroot (MT1) variation II. The baked flavour of arrowroot was highly acceptable. The nature of ingredients used and the method of preparation of biscuits gave a higher score than cakes and breads.

Texture is the property of food which is associated with the sense of feel or touch experienced by the finger or the mouth (Renganna, 2001). The scores obtained for texture of biscuits were comparable with the control sample. All biscuits prepared from the minor tuber flours scored a high value of 4 and above out of 5 for texture. The surface area of biscuit was smooth and the texture was very crisp and this quality must have contributed for the highest score.

Wayre (1994) stated that taste is not only a sensory response to soluble materials but also aesthetic appreciation of the mouth. The taste of biscuits prepared from arrowroot (MT1), yam (MT4) and coleus (MT5) were comparable with the control sample and obtained higher scores, than biscuits prepared from taro (MT2) and elephant foot yam (MT3) which were moderately acceptable. Low scores of MT6 and MT7 biscuits were due to the mild bitter taste of the *nanakizhangu* and *cherukizhangu* flour.

5.5.1.3 Sensory Assessment of Bread

The appearance of breads made from arrowroot (MT1), taro (MT2) and yam (MT4) variation I were comparable with the control sample and in variation II the scores obtained for breads made from arrowroot (MT1) and yam (MT4) were comparable with the control sample. Score of 4 and above were obtained for breads made from arrowroot (MT1), taro (MT2), yam (MT4) and coleus (MT5).

Colour is the fundamental characteristic of appearance. Jellinick (1986) reported that the first impression of food is usually visual and major part of our willingness to accept a food depends upon its colour. The scores obtained for breads were lower than cakes and biscuits. In both the variations breads prepared from arrowroot (MT1) and taro (MT2) recorded a score of 4 and above. According to Sinha *et al*. (1993) the type and proportion of ingredients added has a direct effect on colour formation in baked products.

The flavour of processed food is probably the most important single quality factor of concern to the food technologist. A higher score of 4 was obtained for variation II of arrowroot bread (MT1) than variation I. Augustine (1999) reported that breads made up of sweet potato flour also obtained lower scores for flavour than cakes and biscuits.

Jack *et al.* (1995) reported that texture is a sensory attribute resulting from interaction between food and its consumer. It is the physical property of food stuffs apprehended by the eye, the skin and the mouth.

Texture of breads prepared from different minor tubers were not comparable with the control sample. Lower scores were obtained for minor tuber breads. Similar result was reported for sweet potato bread (Augustine, 1999). According to Rao and Malini (1991) addition of bran, cassava flour and full fat soya flour are reported to affect the texture of the crumb adversely.

The scores obtained for taste of bread prepared from different minor tubers were low compared to scores obtained for cakes and biscuits. The taste of minor tubers were prominent in the case of bread and this was preferred only by a small percentage of panelists, hence the score was low for bread Among the different minor tubers, only arrowroot (MT1) bread had attained a higher score. Almazan (1990) reported that variation in taste exist as the amount of cassava flour increased in bread.

Shalstrom *et al.* (1999) stated that the gluten and starch content in the flour, quantity of water added, kneading process for dough preparation and the type of yeast used all affect the taste and texture of the breads.

Crumbling nature of bread determines the quality of bread. It is the nature of pores or holes in the crumb of bread. A soft bread was obtained from arrowroot (MT1) flour which was comparable with the control sample. The breads made from yam (MT4) and coleus (MT5) at 15 per cent level (variation I) attained higher scores. Lower scores were obtained for breads prepared from all other minor tuber flours. Augustine (1999) reported that the lower scores of crumbling nature in sweet potato based bread was due to the lower binding capacity of sweet potato flour.

Gabriel *et al.* (2001) opined that addition of optimum amount of fat improves the loaf volume and crust and crumb characteristics of bread. According to He and Hoseney (1990) moisture play an important role in crumb firming. Higher moisture of crumb resulted in slower firming rate and lower equilibrium firmness.

Masticability is the parameter used to ascertain the quality of bread. Lower score were obtained for masticability of tuber flour based breads. Ferris *et al.* (2001) reported that the addition of tuber flours such as yam, cassava and arrowroot produced a very gummy crumb in breads.

5.5.2 Functional Quality Evaluation of Baked Products

Parameters such as volume expansion, yield ratio, loaf volume and porosity were studied. Baking time and temperature of the developed products were also noted.

5.5.2.1 Volume Expansion

Volume expansion is an important aspect to assess the quality of baked products. The volume increase is due to the quality of fat and the aeration of the dough or batter during mixing.

Cakes prepared from arrowroot (MT1) had the highest volume expansion and cake prepared from yam (MT4) and *cherukizhangu* (MT7) had the least volume expansion. Arunepanlop *et al.* (1996) opined that the cake volume increases at higher levels of emulsifiers and oxidants and lower water concentrations. Wong *et al.* (1996) reported that pasteurization reduced cake volume.

Volume expansion was found to be higher for biscuit prepared from the arrowroot (MT1) flour which was very crisp and smooth than the biscuit prepared from *cherukizhangu* (MT7) which was the least accepted. Patel *et al.* (2003) reported that addition of leavening agent to the biscuit dough increases the volume and makes biscuit more porous and crisp and more palatable.

Highest volume expansion was found in breads prepared from the flour of arrowroot (MT1). Okorie *et al.* (2002) opined that substitution of refined flour with potato flour and taro flour up to 15 per cent resulted in highest bread volume and substitution after 15 percent reduced the volume expansion. The present study was in line with the findings of Okorie *et al.* (2002).

5.5.2.2 Yield ratio

Yield ratio of different baked products prepared from minor tuber flours were ascertained. Among cakes the yield ratio was maximum for cake made from the flour of taro (MT2) and minimum for cakes made from the flour of *cherukizhangu* (MT7). In the case of biscuits and bread the highest yield ratio was observed in the products prepared from the flour of elephant foot yam (MT3). Sharma and Chauhan (2002) reported that the loaf weight of bread increased with the addition of flours other than refined flour.

5.5.2.3 Loaf Volume

Loaf volume of breads gave the rate of puffing in the bread that has taken place during fermentation. Breads from arrowroot (MT1) and *cherukizhangu* (MT7) had the highest loaf volume. Sindhu (1995) reported that the duration of fermentation had a direct effect on loaf volume. She also suggested that addition of tapioca flour reduced the loaf volume of bread. Bakshi and Nanda (1990) were also of the same opinion. Swason and Sanderson (1999) were of the opinion that incorporation of milk powder in bread mixtures increases the loaf volume, flavour and texture. Sharma and Chauhan (2002) reported that addition of bran reduced the loaf volume of breads were as the addition of fenugreek increased the loaf volume of breads.

5.5.2.4 Baking Time and Temperature

Food products are considered as convenient foods because of their three proven advantages in time, labour and fuel saving and these factors play a desirable role in conditioning their popularity among consumers (Chellammal 1995). This calls for the necessity to assess the baking time and temperature of cakes, biscuits and breads.

The time required for baking cake was 30 minutes at 180°C, for biscuits it was 25 minutes at 210°C and bread took 30 minutes to bake at 230°C. Similar range of time and temperature were reported by Kale *et al.* (2002)

5.5.3 Economic Feasibility of the Developed Baked Products

High cost is unavoidable in food processing and hence the challenge in developing new food products is to keep the cost to a minimum (Amla, 1993). According to Nagarajan (1993) the strategies for the development of food products have to be based on affordable price and cost effectiveness.

In the present study, the price of cakes prepared from the flours of minor tubers ranged from Rs. 25.00 to Rs. 28.00. Cakes prepared from arrowroot (MT1) and coleus (MT5) had higher price (Rs. 28.00) with an increase of Rs. 3.00 than the lower price of cake prepared from yam flour (MT4) Rs. 25.00. The cost variation is mainly due to the cost difference of the minor tubers.

Biscuits had a comparatively lower cost than cakes and bread. Lower cost was found in biscuits prepared from the flour of yam (MT4) and higher cost for biscuits prepared from the flour of coleus (MT5). The cost of bread was lowest for yam (MT4) and highest for coleus (MT5).

It was observed that the products (cake, biscuit, bread)prepared from the flour of yam (MT4) was economically feasible, due to less raw material cost and higher yield ratio.

5.5.4 Overall Acceptability

Overall acceptability of a product depends on the concentration or amount of particular ingredients, the nutritional and other hidden attributes of a food and its palatability or sensory quality.

Result for overall acceptability revealed that baked products prepared from arrowroot (MT1) was highly acceptable followed by taro (MT2), yam (MT4) and coleus (MT5).

Cakes prepared from arrowroot (MT1) was highly acceptable followed by taro (MT2), yam (MT4) and coleus (MT5).

Biscuits prepared from minor tubers were acceptable to the panel members. Higher acceptability was obtained for biscuits prepared from the flour of arrowroot (MT1). Martin and Robert (1995) reported that bakery products can be prepared with good acceptability by substitution of wheat flour with yam flour at 50 per cent or even 100 per cent.

Overall acceptability scores were higher for breads prepared from arrowroot (MT1) followed by taro (MT2). Okorie *et al.* (2002) reported that bread made by the substitution. of wheat flour with potato and taro flour (10 to 40 per cent) compared well with control bread (refined flour) in appearance, taste, crust colour and overall acceptability.

The assessment of the organoleptic qualities of the developed baked products by partial substitution of refined flour with flours of minor tubers revealed that biscuits were the most acceptable product and bread the least accepted product. The poor scores for sensory quality parameters of bread contributes to the less acceptability of bread than cakes and biscuits.

Sharma and Chauhan (2002) found that among the different baked products prepared from rice bran-fenugreek blends, biscuits attained higher acceptability and breads with lower acceptability. Similar results were obtained in the present investigation, were minor tuber flours were blended with refined flour for product development. Good quality biscuits were obtained while the quality of bread was not as good as cakes and biscuits.

5.6 SELECTION OF BEST PRODUCTS

The bakery products like bread, cakes sweet buns and biscuits are widely consumed as source of nutrients including calories throughout the world. The quality of these products are influenced by ingredients, baking conditions and storage.

In the present study best baked products were selected based on the organoleptic quality evaluation. High values of overall acceptability scores were obtained for arrowroot (MT1) products and hence selected as best one, followed by the products prepared from the flours of taro (MT2) , yam (MT4) and coleus (MT5).

5.6.1 Shelf Life Qualities of the Developed Baked Products

Bakery foods are perishable, they undergo physico chemical, sensory and microbial changes. In India, breads, biscuits, cakes, pastry, buns, fruit pies and pizza bases are popular items of bakery industry. Most of these items are subjected to microbial deterioration limiting their shelf life to a few days.

Arya (2003) reported that the rate of deterioration of baked products are influenced by intrinsic food related factors such as moisture content and level of preservatives and extrinsic factors such as temperature, relative humidity and gaseous environment surrounding the product. The shelf life qualities were ascertained by estimating the moisture content and microbial growth analysis of the stored product.

Estimations of moisture content is the primary step in the assessment of shelf life of any products. Considering the moisture content of the baked products developed from minor tuber flours, it could be observed that there was an increase in the moisture content throughout the storage period. Bread was found to have the highest moisture content than cakes and biscuit. Due to this factor the storage life of bread was lower than other products. According to Black *et al.* (1993) the packaging incorporated with ethicap doubled the shelf life of bread. Seiler and Russel (1993) reported that ethanol at 1 per cent level by product weight delayed the on set of ropiness caused by growth of Bacillus subtilis in bread.

In the present study the shelf life of bread was up to five days. This is in line with the finding of Augustine (1999) and Arya (2003).

Cakes had a high moisture content after the 8th day of storage. Arya (2003) reported that bakery products including cakes and bread had shelf life of 2 to 5 days. Vaidehi and Varalekshmi (1992) reported that the shelf life of cake, bread and puffs were 4-5 days.

The moisture content of biscuit increased slowly and spoilage occurred at the 27th day of storage. This was in line with the findings of Augustine (1999). Vaidehi and Varalekshmi (1992) reported a lower storage life of biscuits for 9 days. Arya (2003) reported that biscuits of all types have a shelf life of 3-4 months.

In the present study it was observed that biscuits had the better shelf life than compared to breads and cakes. Moisture content in biscuit was less compared to other products, which is the determining factor of shelf life (Kaur, 2002).

5.6.2 ISI Type Test to Assess the Commercial Viability

Implementation of quality system standards for the food products would result in several benefits. Estimated values of different type tests were compared with the ISI specification. Type tests were conducted in terms of moisture, acid insoluble ash and acidity of the developed products.

The results showed that among the different type tests, the moisture content was low in all the baked products. The lower moisture content of the products is beneficial since it may improve the keeping quality of the products. Similar results were reported by Augustine (1999) who obtained a moisture content of 20 to 30 per cent for cake, (ISI specification 15-25 per cent), 7-1 for biscuit (ISI specification 6.00 per cent) and 34.66 per cent for bread (ISI specification 35.00 per cent).

Acid insoluble ash content were higher than the ISI specifications. Augustine (1999) reported that the increased mineral content of the products were the reason for the higher value of ash. According to Chellammal (1995) the acid insoluble ash in sweet potato based extruded food was higher than the ISI specification.

Acidity of extracted fat were also higher than the ISI specifications. Similar results were reported by Augustine (1999).

Summary

6. SUMMARY

The present investigation entitled "Utilization of minor tubers for the development of baked products", was an attempt to develop baked products from minor tubers. Flours were prepared from arrowroot (MT1), taro (MT2), elephant foot yam (MT3), yam (MT4), coleus (MT5), *nanakizhangu* (MT6) and *cherukizhangu* (MT7) and utilized for the development of baked products viz., cake, biscuit and bread. The prepared tuber flours were assessed for its quality characteristics by estimating the moisture, acidity, reducing sugar, crude fibre, and protein.

Estimation of quality characteristics of minor tuber flours revealed that yam (MT4) had the highest moisture content. Acidity was higher for coleus (MT5) flour. Reducing sugar, crude fibre and protein content was highest for arrowroot (MT1) flour.

Investigation of functional qualities of minor tuber flours revealed that the change in weight and processing loss was highest for coleus (MT5). *Nanakizhangu* (MT6) had the highest yield ratio and arrowroot (MT1) had the highest water absorption index.

The shelf life quality of the minor tuber flours were also analysed by estimating the moisture content and water absorption index of tuber flours by storing them in PET containers and poly propylene covers for a period of three months.

It was observed that PET containers are suitable for longer storage of minor tuber flours than storing in polypropylene covers. Flours of arrowroot (MT1), taro (MT2), yam (MT4), *nanakizhangu* (MT6) and *cherukizhangu* (MT7) exhibited better storage qualities. There were no incidence of insect attack in any of the stored minor tuber flours both in PET containers and polypropylene covers.

Fresh tuber flours were free of microbes while stored tuber flours showed microbial colonies, with more number of colonies in flours stored in polypropylene covers. *Nanakizhagu* (MT6) flour and yam (MT4) flour were least affected by microbes.

Quality assessment of minor tuber flours were followed by product development. Tuber flours were blended with refined flour in two variations (15 and 20 per cent). Three baked products; cake, biscuit and bread were processed from minor tuber flour. The acceptability of the products were assessed through sensory evaluation.

The appearance of all the baked products were good and were comparable with the control sample prepared from 100 per cent refined flour.

Products prepared from arrowroot (MT1) and taro (MT2) had better colour than the products prepared from other minor tuber flours.

Cakes prepared from the flour of arrowroot (MT1), taro (MT2), yam (MT4) and coleus (MT5) had better flavour than other cakes. Biscuit and bread prepared from arrowroot (MT1) attained highest scores for flavour.

Texture of cakes prepared from arrowroot (MT1), yam (MT4) and coleus (MT5) were better than the cakes prepared from other minor tuber flours. Biscuits prepared from all minor tuber flours were good in texture. Breads prepared from minor tuber flours had poor texture.

Arrowroot products were very good in taste. Products prepared from yam (MT4), taro (MT2) and coleus (MT5) also got better scores for taste. The scores obtained for bread for the attribute taste were comparatively lower than cakes and biscuits.

Crumbling nature of bread prepared from arrowroot (MT1) was comparable with the control sample. Masticability of breads prepared from minor tuber flours were poor.

The developed products were also subjected to functional quality evaluation, cost analysis and ISI type tests. The cost computation was done as per the market price of the ingredients.

Functional quality parameters including volume expansion, yield ratio and loaf volume were studied in the baked products. Products prepared from arrowroot flour (MT1) had the highest volume expansion. Cakes prepared from taro (MT2) and biscuits and bread prepared from elephant foot yam (MT3) had the highest yield ratio. Loaf volume of breads prepared from arrowroot (MT1) and *cherukizhangu* (MT7) were highest.

Cost analysis of the different baked products revealed that, those products prepared from yam (MT4) flour were of low cost.

The overall acceptability scores of products prepared from arrowroot (MT1) was higher followed by taro (MT2), yam (MT4) and coleus (MT5). The baked products of arrowroot, taro, yam and coleus were selected as best products and subjected for shelf life study.

Shelf life studies of baked products revealed that breads had the lowest storage life of five days. Cakes remained fresh for eight days and biscuits had a longer shelf life of twenty seven days.

The developed baked products were subjected to ISI type tests with regard to moisture, acid insoluble ash and acidity.

It was observed that the moisture content was less than the ISI specification. This indicated better storage life of the products developed. The acid insoluble ash and acidity of the products were higher than the ISI values. The presence of more mineral content in tuber flours were the reason for the increased acid insoluble ash content.

In conclusion, minor tubers can be utilized for the development of organoleptically acceptable, economically feasible baked products with good storage life. Products of minor tubers especially from arrowroot, taro, yam and coleus were exceptionally good for making biscuits and cakes.

Modification of these standard recipes into variety recipes by adding dried fruits, cocoa powder, nuts and other suitable ingredients can produce commercially acceptable products. Entrepreneurs in baking can take up these products as a small scale income generating profession.

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UTILIZATION OF MINOR TUBERS FOR THE DEVELOPMENT OF BAKED PRODUCTS

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ABSTRACT

The present study entitled "Utilization of minor tubers for the development of baked products" was carried out to explore the suitability of minor tubers for the development of baked products. The study comprised of the quality assessment of minor tuber flours, product development and assessing the organoleptic and shelf life qualities of the developed products.

Minor tubers are crops with tremendous potential. They have the highest yield potential per hectare. In the present study minor tubers, *viz*., arrowroot (MT1), taro (MT2), elephant foot yam (MT3), yam (MT4), coleus (MT5), *nanakizhangu* (MT6) and *cherukizhangu* (MT7) were selected and processed into flour.

The flour prepared from minor tubers were analysed for moisture, acidity, reducing sugar, crude fibre and protein and revealed that yam (MT4) flour had the highest moisture content and coleus (MT5) flour had the highest acidity. Reducing sugar, crude fibre and protein content were highest for arrowroot (MT1) flour.

Functional quality analysis, of minor tuber flours observed that the water absorption index was highest for arrowroot (MT1) flour. Coleus (MT5) flour had the highest change in weight and processing loss. *Cherukizhangu* (MT6) flour had the highest yield ratio.

Evaluation of shelf life qualities of minor tuber flours revealed that flours of arrowroot (MT1) , taro (MT2), yam (MT4), *nanakizhangu* (MT6) and *cherukizhangu* (MT7) exhibited better storage qualities.

Insect infestations was not observed in any of the stored minor tuber flours. Fresh flours were free of microbes. Many microbial colonies were found in flours stored in polypropylene covers and very few number of colonies in PET containers. *Nanakizhangu* (MT6) flour and yam (MT4)

flour were least affected by microbial attack. The shelf life quality evaluation revealed that PET containers are suitable for long period of storage of minor tuber flour.

The flours of minor tubers were utilized for the development of baked products *viz*., cake, biscuit, and bread. The acceptability of the products were assessed through organoleptic evaluation, which revealed that all products prepared from the flour of arrowroot (MT1) flour were highly acceptable among the panel members. Products prepared from the flours of taro (MT2), yam (MT4) and coleus (MT5) were also found to be acceptable.

Functional qualities of the baked products were also studied. Cake, biscuit and bread prepared from arrowroot (MT1) had the highest volume expansion. Yield ratio of cake was highest for taro (MT2) cake. Biscuits and bread prepared from MT3 attained highest yield ratio. Loaf volume was highest for breads prepared from the flour of arrowroot (MT1).

Cost analysis done on the baked products revealed that cake, biscuit and bread prepared from yam (MT4) were economically feasible. The cost of baked products prepared from minor tuber flours were lower than the price of their counterparts in the market .

Based on the evaluation of organoleptic parameters, products prepared from arrowroot (MT1), taro (MT2), yam (MT4), and coleus (MT5) were selected as best ones.

The shelf life of the products were examined by packing them in polypropylene covers. Biscuits had the highest shelf life of about one month; cakes remained fresh for 8 days and bread had a shelf life of 5 days.

ISI type tests were administered to the products and the moisture content was within the limits of the ISI values, acid insoluble ash and acidity were slightly above the ISI specifications.

Appendices

APPENDIX - I

Score card for cake

1.	Appearance	Score
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
2.	Colour	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
3.	Flavour	
	Highly Acceptable	5
	Acceptable	4
	Moderately acceptable	3
	Less acceptable	2
	Unacceptable	1
4.	Texture	
	Very Soft	5
	Soft	4
	Neither soft nor hard	3
	Hard	2
	Very hard	1
5.	Taste	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1

APPENDIX - II

Score card for Biscuit

1.	Appearance	Score
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
2.	Colour	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
3.	Flavour	
	Highly Acceptable	5
	Acceptable	4
	Moderately acceptable	3
	Less acceptable	2
	Unacceptable	1
4.	Texture	
	Very crisp	5
	Crisp	4
	Less crisp	3
	Slightly crisp	2
	Very soft	1
5.	Taste	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1

APPENDIX - III

Score card for Bread

		Score
1.	Appearance	Score
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
2.	Colour	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
3.	Flavour	
	Highly Acceptable	5
	Acceptable	4
	Moderately acceptable	3
	Less acceptable	2
	Unacceptable	1
4.	Texture	
	Very Soft	5
	Soft	4
	Sticky	3
	Hard	2
	Very hard	1
5.	Taste	
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Very Poor	1
6.	Crumbling Nature	
	Highly acceptable	5
	Acceptable	4
	Moderately acceptable	3
	Less acceptable	2
	Unacceptable	1
7.	Masticability	
	Smoothy	5
	Non Sticky	4
	Moderately Nonsticky	3
	Moderately Sticky	2
	Very sticky	1

APPENDIX - IV

Composition of media used for microbial evaluation

1. Composition of martins media

Peptone	5g
Dextrose	10g
Potassium dihydrogen phosphate	1g
Magnesium sulphate	0.50g
Agar agar	15.00g
Rose Bengal	1part in 30,000 part of the medium
Streptomycin	30mg
Distilled water	1000ml

2. Composition of nutrient agar

Beef extract	3g
Peptone	5g
Agar agar	17g
Distilled water	1000ml

3. Composition of Yeast extract agar

Yeast extract	30 g
Peptone	5g
Agar agar	20g
Distilled water	1000ml