PHYSICO-CHEMICAL PROPERTIES, NUTRITIONAL QUALITY AND VALUE ADDITION TO QUALITY PROTEIN MAIZE (*Zea mays* L.)

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I. INTRODUCTION

Maize (*Zea mays* L.), the American Indian word for corn, means literally "that which sustains life". It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and more recently, fuel. Presently world produces around 638.04 million tonnes of maize and is grown in an area of about 140 million hectares (Anon, 2004). Over 43 million ha of maize is grown in Asia producing 166 million tons with an average yield of 3.8 t/ha (Anon, 2004). India ranks eighth in terms of production and shares about 1.85 per cent of the total maize production of the world. Other major maize producing countries are China, Brazil, Mexico, France, Argentina, Romania, Italy and Canada. In India the production of maize is 14.13 million tonnes and the total area under this crop is 7.55 million hectares (Anon., 2005). Major maize growing states are Bihar, Gujarat, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh and Karnataka. The maize production in Karnataka is 12.44 lakh tonnes and the total area under this crop is 6.18 lakh hectares for the year 2004.

World-wide with its high content of carbohydrate, fats, proteins, some of the important vitamins and minerals, maize has acquired a well deserved reputation as a poor man's nutricereal. It is estimated that several million people, particularly in the developing countries derive their protein and calorie (11.1 g and 342 Kcal/day) requirement from maize (Gopalan *et al.*, 1999). Another estimate indicates that maize grain accounts for about 15 to 56 per cent of the total daily calories in diets of people in about 25 developing countries (Prasanna, 2001). Besides this, it is also used as industrial starches and in pharmaceuticals as dextrose, maltose, ethanol and corn oil. A variety of maize based fast foods both the domestic and international super markets are found world over.

Maize endosperm, consisting of approximately 9-12 per cent protein is however deficient in two essential amino acids. This leads to poor net protein utilization and low biological value of traditional maize varieties. Discovery of maize mutants in the mid-1960s containing the opaque-2 gene which enhances levels of lysine and tryptophan in the endosperm protein, opened a new era in breeding for improvement of quality in maize. However these mutants also came with several undesirable traits such as, opaque and chalky grain texture, low grain yield, higher levels of ear rot, slow dry down and increased incidence of stored product pests. Through an inter-disciplinary research involving breeders, biochemists and other disciplinary scientists, International Maize and Wheat Improvement Center (CIMMYT) researchers developed Quality Protein Maize (QPM). This special type of maize has exactly the same qualities as normal maize in grain texture, taste and colour but possess almost double the levels of lysine and tryptophan, high yield and tolerance to biotic and abiotic stresses. Several QPM hybrids have been released for cultivation in the developing world. From less than 4 countries that grew QPM in 1997, today more than 23 countries have released and are producing QPM in the developing world. Three decades of research at CIMMYT has led to the development of QPM cultivars that possess high- yield and better quality that can lead to nutritional security among developing world poor.

In 2001, India released two QPM white hybrids Shaktiman-1 (CML142 x CML150) x CML186 and Shaktiman-2 (CML176 x CML186) using tropical and subtropical combinations. Scientists at Directorate of Maize Research, Karnal, released two new yellow QPM hybrids HQ-1 and HQ-2 in 2003 using CML 161 and CML 193. Replacement of normal maize hybrids with QPM hybrids would ensure better income to the farmers and higher nutrition to the consumers. This would contribute to food and nutrition security of the poor and tribal communities where maize is consumed as staple food (Anon, 2004).

In the present dissertation an attempt has been made to study the nutritional composition of quality protein maize and to elucidate some of their properties which are beneficial to the human beings. Keeping this in view the present study was undertaken with the following specific objectives.

1. To explore the physical characters of maize varieties
2. To assess the chemical composition of maize
3. To investigate the functional properties of maize flours
4. To evaluate the nutritional quality of maize
5. To develop value added maize products

II. REVIEW OF LITERATURE

A conceptual frame work for the study based on the ideas and concepts gathered from review work of existing literature of both theoretical and empirical nature will facilitate planning the study in a comprehensive manner. It also helps to know the previous research work carried out in the area and acts as a torch for new research.

An attempt is made here to put together some of the closely related research findings on Quality Protein Maize (QPM) from food and nutrition perspectives.

2.1 UTILIZATION OF MAIZE

Maize as a crop has multiple uses and can be used as food at its various stages of development and it is not necessary to wait for the crop to reach maturity. Maize is used as food, as feed for livestock and as raw material for industry. As a food, the whole grain, either mature or immature, may be used; or the maize may be processed by dry milling techniques to give a relatively large number of intermediary products, such as grits of different particle size, meal, flour and flakes. These materials in turn have a great number of applications in a large variety of foods.

In developed countries more than 60 percent of the production is used in compounded feeds for poultry, pigs and ruminant animals. The by-products of dry milling include the germ and the seed-coat. The former is used as a source of edible oil of high quality. The seed-coat or pericarp is used mainly as a feed, although in recent years interest is developed in it as a source of dietary fibre. In industries maize is wet milled to manufacture starch and by-products such as maize gluten are used as a feed ingredient. The maize germ processed to produce oil gives a by-product maize germ meal, used as an animal feedstuff. Fermentation also provides some alcoholic beverages.

Maize is consumed in many forms in different parts of the world, from maize grits, *polenta* and corn bread to popcorn and products such as maize flakes. The grain is fermented to give *ogi* in Nigeria and other countries in Africa. In Egypt maize flat bread, *aish merahra*, is widely produced. A similar product called *markouk* is eaten in Lebanon. Maize is also widely used to make beer. In Benin, malt is obtained by germinating the grain for about five days. A dough prepared from lime cooked maize is the main ingredient for many popular dishes such as *atole*, a beverage with a great variety of flavors, and *tamalitos*, made by wrapping the dough in maize husks and steam-cooking it for 20 to 30 minutes to gelatinize the starch. The dough is also used for *tamales*, a more complex preparation because of the number of ingredients it contains, in most cases with chicken or pork meat added to the gelatinized dough. It is also used to provide support for *enchiladas*, *tacos* (folded tortillas containing meat, etc.). Maize is also in preparation of *pupusas*, with fresh cheese placed between two layers of dough and baked like tortillas. When the dough is fried and flavoured, it yields foods such as chips and *chilaquiles*. Dough is allowed to ferment for two days, wrapped in banana or plantain leaves, to make *pozol* from which a number of drinks are made. Acid porridges usually made from fermented raw or heat-treated maize include pozol in Mexico and Guatemala, *ogi* in Nigeria, *uji* in Kenya and *kenkey* in Ghana. *Ogi* has a number of other names such as *akamu* or e*kogbona*, *agidi* and *eko* tutu. The nixtamal, or cooked maize without the seed-coat, is ground to coarse dough which is shaped into balls by hand, then wrapped in banana leaves to avoid drying and are allowed to ferment for two to three days, or more if necessary. Another major food made from decorticated, degermed and precooked maize, is *arepa* - maize bread without yeast, is round in shape consumed daily in Colombia and Venezuela,

Ahenkora *et al*. (1999) documented methods of preparation of some Ghanaian *maize based foods. Kenkey* was prepared by steeping the grains for 24 hrs at 25-26℃ steeped grains were wet milled and kneaded with 1:2 meals: water. It was allowed for fermentation for 3 days at 25-27℃. Slurry was cooked and made into dough (*Kenkey* mass). The dough was molded and wrapped with corn husks to get *ga kenkey*. It was boiled for two hours, sliced into pieces and dried for 24 hrs at 65℃ to form *Kenkey*. To obtain fante *kenkey* the balls were wrapped in plantain leaves. For *thozafi* the maize was dry milled and mixed with water at 1:4 ratios and cooked with continuous stirring for 50 to 60 min to obtain a solid consistency.

2.2 PHYSICAL CHARACTERISTICS

Physical characteristics are some of the determinants of consumer acceptability. The size, shape and appearance of the grain, influence the marketability of any food commodity. The kernels are often white or yellow in colour, although black, red and a mixture of colors is also found. There are a number of grain types, distinguished by differences in the chemical compounds deposited or stored in the kernel.

A comparative study of the new QPM hybrids with normal maize was conducted by Szaniel *et al*. (1984). It was reported that colour of QPM white hybrid was better than normal maize. The QPM hybrids were bigger in size and kernel hardness was improved, due to thick pericarp. QPM kernel cells are tightly packed with relatively few air spaces around the starch granule, resulting in increased hardness (Anon., 1988).

A study was conducted by Sproule *et al*. (1988) to assess the characteristics of QPM with those of standard food grade maize. It was observed that QPM kernel had dark yellow colour with a greater amount of corneous endosperm and larger proportion of germ compared to food grade maize. Also, QPM recorded significantly greater test weight (61.5 lbs/bu) and density (1.40 g/cc) over food grade maize (60.2 lbs/bu; 1.33 g/cc respectively).

Lopes and Larkins (1991) reported that QPM and normal maize genotypes showed similar kernel densities (1.11-1.16 and 1.09-1.12 g/ml, respectively) and were nearly 10 per cent denser than typical 02 mutants (0.97-1.02 g/ml). QPM hybrids are observed to consist of hard, vitreous endosperm (Moro *et al*., 1996).

A comparative study of QPM and normal maize was conducted by Martinez *et al*. (1996) to evaluate wet milling interaction. It was observed that water soluble solids were higher in QPM (81-90 g/kg) than in normal maize (79-80 g/kg). Further, water soluble solids were positively correlated to kernel size, test weight and density. Test weight of QPM was higher (74.3-80.8 kg/hl) than normal maize (73.1-74.4 kg/hl).

Gibbon *et al*. (2003) reported that altered starch structure was associated with endosperm modification in QPM. Proteomic analysis of QPM showed increased levels of granule bound starch synthase I in the soluble non-zein protein fraction. It was reported that increased extraction of this enzyme reflected a change in starch structure, which was manifested as shorter amylopectin branches and increased starch granule swelling. In mature kernels, these alterations in starch structure were associated with inter connections between starch granules that resulted in a vitreous kernel phenotype.

A study on storage protein and its impact on nutritional quality of QPM were conducted by Gupta *et al*. (2003). It was reported that SDS-PAGE pattern of unalkylated zein from QPM, opaque-2 and normal maize showed similarity in polypeptide bonding despite significant quantitative differences amongst these cultivars. In normal unalkylated zein polypeptide of 20 KDa was absent but was found in unalkylated opaque-2. However, polypeptide of low molecular weight of 24 KDa of unalkylated zein and 22 KDa of alkylated zein of normal and one QPM cultivars, were found more intense compared to opaque-2 and other QPM cultivars and were responsible for endosperm vitreousness. Zein proteins were known to impart endosperm vitreousness and hardness and were not only reduced in all the QPM cultivars but also differed in their complexity and sub units as compared with opaque-2 and normal maize. It was concluded that ratio of tryptophan and ratio of non-zein to zein were higher in opaque-2 and QPM as compared to normal maize.

2.3 NUTRIENT COMPOSITION

Cereal proteins have poor nutritional value for monogastric animal including humans. Cereals are low in essential amino acids such as lysine, tryptophan and threonine, lysine being the most limiting. Protein fraction such as albumins, globulins, zein, and glutelin also differ in cereals. Varietal differences in nutrient composition within the hybrids of maize were reported by several investigators.

Angel and Sotelo (1982) evaluated cereal legume mixtures for their nutrient content. It was reported that protein content in the opaque-2 maize was higher (11.42 g/100 g) than normal maize (10.81 g/100 g) especially the hard endosperm opaque maize (10.81 g/100 g). There was no differences in the other nutrients such as fat (4.87, 5.32 and 5.19 g/100 g), carbohydrate (77.95, 76.44 and 75.82 g/100 g) and ash (1.64, 2.00 and 1.78 g/100 g) among the three types of maize normal, soft endosperm opaque-2 and hard endosperm opaque-2, respectively. It was also reported that genetically improved soft and hard endosperm corn varieties contained higher amounts of lysine (5.64 and 6.45 g/16 g N, respectively) and tryptophan (0.70 and 0.76 g/16 g N, respectively) as compared to normal corn (3.04 and 0.51 g/16 g N, respectively). However, the leucine content in both opaque-2 corns was lower (9.14 and 7.92 g/16 gN, respectively) than that of the normal corn varieties (18.85 g/16 gN).

The protein fractions of maize varieties were reported to increased for fraction 1-albumins, globulins, nitrogen components about 6.65 mg of protein, fraction v-true glutelin about 5.74 mg of protein in QPM compared to normal maize as reported by Ortega *et al*. (1986). The authors also reported that QPM hybrid contains higher amounts of lysine by 33-35 per cent, tryptophan by 60-66 per cent and threonine by 18-30 per cent. Leucine to isoleucine ratio was low in QPM hybrids, an advantage as it helps to liberate more tryptophan for more niacin biosynthesis thus helping to combat pellagra.

Several investigators have reported that proximate composition of QPM was similar to that of normal maize. However, QPM tended to have higher levels of crude protein (9.11 to 11.3% Vs 8.92 to 11.0%), ether extract (4.3 to 5.12% Vs 4.2 to 4.48%), crude fibre (2.6 to 3.5% Vs 1.93to 2.14%) and carbohydrates (71.37 to 75.4% Vs 71.52 to 72.8%), as reported by Sproule *et al*. (1988), Graham *et al*. (1990), Ahenkora *et al*. (1995) and Osei *et al*. (1999).

Bressani *et al*. (1990) compared QPM with 11 common maize types for fat, protein, total dietary fibre, Calcium, Magnesium, Sodium and Potassium. It was reported that protein content in common maize was 9.4 per cent and in QPM it was 10.2 per cent. Ether extract was more in QPM (5.5%) compared to common maize (4.7%). Ash content varied from 1.1-1.4 per cent among the common maize. Calcium, Magnesium, Sodium and Potassium contents were lower in QPM (23.7, 104.4, 15.5 and 361.9 mg/100 g respectively) compared to common maize (32.0, 128.4, 22.8 and 366.9 mg/100 g, respectively).

An investigation on chemical composition of QPM and normal maize was carried out by Martinez *et al*. (1996). It was reported that QPM contained higher amounts of protein, fat, dietary fibre and ash (10.56, 3.56 and 1.72%, respectively) when compared to normal maize (10.44, 2.66 and 1.28%, respectively). Starch content was lower in QPM than normal maize (82.6 Vs 84.2%). However, QPM showed better lysine content (42 g/kg of protein) than normal maize (35 g/kg of protein). Similar higher lysine content of QPM varieties was reported by Ahenkora *et al*. (1999). A range 3.7 to 4.2 g/100 g of protein was reported which was significantly higher than that of normal maize (2.6 to 3.1 g/100 g protein).

A study was conducted by Omueti and Morton (1996) to evaluate the nutrient content of soya-maize extruded snacks named *soyabari*. It was prepared by adding pepper, onion, salt, palm oil, plantain and banana in different proportions. It was observed that protein content in soya and maize grits extrudates was higher (24.06%) followed by extrudates containing plantain (22.75%) and banana (20.13%). The banana containing extrudates gave the highest crude fat and available carbohydrate content (14.2 and 40.3%, respectively) than the extrudates prepared from soya-maize grits (2.9 and 38.5%, respectively). It was also reported that the crude fibre content of all the extrudates were less (1.1-1.7%) than market sample (3.5%). Total ash content was higher in extrudates containing plantain (4%) followed by maize-soya grits products (3.6%) and banana extrudates (2.1%). The gross energy of the extrudates ranged between 4 and 5 kcal/g and maize soya grits extrudates exhibited low energy value of 4 Kcal/g.

A comparative study on QPM cultivars and commercial maize varieties was conducted by Zarkadas *et al*. (2000). It was observed that QPM genotypes contained high levels of lysine (3.43 to 4.21 g/100 g of protein) compared to commercial maize varieties which ranged from 2.9 to 3.1 g/100 g of protein.

Sharma *et al.* (2002) conducted an investigation on five improved genotypes of maize namely Paras, Prabhat, PAC 776, Bio 9637 and Prakash. The grains were analyzed for chemical components and it was reported that moisture content ranged from 8.21 to 8.85 per cent in all the varieties. Prakash and PAC 776 varieties showed the higher percentage of moisture (8.85 and 8.79%, respectively). It was also reported that varieties Paras and Prakash were rated superior for characters such as protein (10.23 and 9.80%), fat (4.45 and 5.00%) and tryptophan (0.72 and 0.70% of protein). Bio 9637 and Prabhat were promising for carbohydrate (77.33 and 77.74%), minerals (1.40% in both varieties) and energy values (358 and 356 Kcal).

Habtamu *et al*. (2003) compared nutrient composition of QPM with local maize and four high yielding hybrids. The total protein content among the cultivars ranged from 7 to 11.8 per cent. It was 9.8 per cent for QPM and 10.1 per cent for local maize cultivar. However, the QPM maize protein contained 30 to 82 per cent more lysine, higher levels of arginine, tryptophan, histidine, threonine, cysteine and valine.

Mosha and Vicent (2004) compared maize and sorghum based weaning mixtures supplemented with rojo bean flour, ground sardines and peanut paste. Ten different types of weaning mixtures were prepared and evaluated for proximate composition. It was reported that proximate composition of maize based weaning mixture varied with the sorghum based weaning mixture, with respect to increased amounts of carbohydrate, fat, energy and decreased amounts of protein, fibre and mineral contents.

A study on effect of extrusion on essential amino acid profile and colour of whole grain flours of QPM and normal maize cultivars was conducted by Paes *and* Maga (2004). It was observed that extrusion reduced the essential amino acids isoleucine, leucine, lysine, threonine and valine when compared to their original flours. But, the contents of histidine, methionine, phenylalanine and tryptophan were not affected. QPM samples, either raw or extruded, were significantly higher in lysine, methionine and tryptophan compared to samples of normal maize.

2.4 FUNCTIONAL PROPERTIES

The physicochemical properties of flour such as particle size, water and oil absorption capacities, swelling capacity and viscosity predict the functional properties of products. The grain constituents such as starch, fat and fibre influence the functional properties.

Mehta *et al.* (1989) studied on weaning gruels from maize/maize and green gram dhal and combined effect of fermentation and malting on bulk reduction and other physico-chemical properties. The process of fermentation was carried out on plain maize flour and maize + green gram dhal flour slurries at various temperatures (35, 40 and 45°C), time intervals (8, 12, 16 and 20 hours) and slurry concentrations (15, 20 and 25%). The results revealed a decrease in pH (from 6 to 3) with increase in titrable acidity (from 0.03 to 0.07) in all the maize based slurries as fermentation progressed, at all temperatures. Viscosity studies of cooked maize and maize green gram dhal slurries revealed reduction in viscosities at all time intervals and temperatures, in all the slurries. The best reduction in viscosity was observed in 15 per cent concentration slurries fermented for 8 hours at 35°C.

A study on water absorption capacity by Afoakwa (1996) reported that water absorption capacity influenced product cohesiveness. It was also reported that, proteins were mainly responsible for the water uptake and to lesser extent the starch and cellulose, at room temperature. Martinez *et al*. (1996) studied wet milling process of normal and QPM and reported that viscosity of QPM and normal maize hybrids were similar with 600-700 BU of viscosity.

Kikafunda *et al.* (1997) conducted an experiment to optimize viscosity of maize porridges. The study revealed that the viscosity of the maize porridges was significantly increased by increase in concentration (68.1 mPa.s to 233.8 mPa.s), cooking time from 128.1 mPa.s to 173.8 mPa.s and use of flour of fine particle size from 136.4 mPa.s to 165.5 mPa.s. Increased shear speed and addition of groundnut paste or pasteurized cow's milk significantly reduced the viscosity of the porridges from 156.9 mPa.s to 145 mPa.s, 214.5 mPa.s to 87.5 mPa.s and 176.1 mPa.s to 125.8 mPa.s.

Aminigo and Oguntunde (2000) studied on functional properties and nutritive composition of raw, blanched (pre treatment) and dry roasted maize. Nitrogen solubility and water absorption were reduced by roasting and this effect was more pronounced in blanched maize samples. Gelation capacity was reduced significantly by the heat treatments. Water and fat absorption were generally higher for samples blanched prior to roasting than for samples roasted without pre-treatment.

An investigation on functional properties *viz.*, viscosity of sorghum diastatic malt blends with maize flour was studied by Delgado and Serna (2000). It was reported that viscosity of the blends decreased as the concentration of sorghum diastatic malt increased. Addition of 6.7 per cent sorghum diastatic malt reduced viscosity by nearly 50 per cent.

A comparative study of the physicochemical properties of whole maize flour and dehulled-degermed maize flour was studied by Houssou and Ayernor (2002) to evaluate their functional behavior. It was observed that yield of flour was more in whole grain (92%) compared to dehulled-degermed flour (65%). However, dehulled-degermed flour showed higher water absorption capacity (197%) than whole milled grain flour (154%). Thus, the swelling capacity increased by one and a half times more in dehulled-degermed flour. The hot paste viscosity of dehulled-degermed flour was high compared to whole milled grain flour (505 and 370 BU, respectively).

Okezie *et al.* (2003) reported that water holding capacity of maize extract increased by addition of ripe bananas and ranged between 0.47 and 0.76 mg/g for 50 and 20 per cent levels of banana substitution, respectively. The values, however, initially increased from 0.72 to 0.76 mg/g for maize flour at 20 per cent level of substitution, it decreased progressively to 0.47 mg/g at 50 per cent level of banana substitution. It was also reported that water holding capacity increased from 2.82 ml/g for maize flour to 3.06 ml/g for 30 per cent banana substitution dropped again to 2.47 ml/g for 50 per cent banana substitution. The decrease in the water holding capacity of samples with high levels of banana substitution could be attributed to the coarse nature of the substituted samples.

An investigation on functional properties of three different flours/ meals and two blends of maize meal and soybean flour (ratios 9:1 and 8:2, maize: soybean) was conducted by Edema *et al*. (2005). The bulk density was lower in commercially sold soybean flours (0.38 g/ml) than in maize soybean blend flour (0.55 g/ml).

Wang *et al.* (2005) reported the effect of pericarp removal on properties of wet milled corn. The grains were steeped in 100 ml steeping solution (0.2% sulphur dioxide and 0.5% lactic acid). Pericarp was removed by sonication treatment in which the grains were filled with excess of water in a plastic bag. The bag was sealed with air squeezed out and placed in sonicator tank. The samples were sonicated for 3 min at room temperature and samples were blotted dried and manually pericarp was removed. It was reported that pericarp free samples with 6 hour steeping and 48 hour steeping exhibited lower peak breakdown (95 and 171 cp), final (1,333 and 1,358cp), than 1 hour steeping (426, 1646 and 585 cp, respectively). In case of pericarp intact maize 48 hour of steeping declined the peak breakdown final and set back viscosity from 445 to 301 cp, 1637 to 1463 cp and 563 to 428 cp. The authors reported that reduction in viscosity was higher in pericarp free maize than pericarp intact maize.

2.5 VALUE ADDITION

Consumer demands for convenient, inexpensive, nutritious and ready to eat products result in value addition. Utilization in diversified ways by converting them into a variety of products such as infant foods, health foods/mixes, convenience foods and specialty foods, make a significant impact on consumer acceptability.

Ortega *et al.* (1986) assessed the change in protein content of normal maize and QPM and reported that the protein content of *masa*, nixtamal and tortilla was higher than in native grains. However, lysine and tryptophan were higher in raw samples.

Bressani *et al.* (1990) reported that protein and ether extract of normal maize and QPM decreased when grain were either cooked or processed into tortilla. However, minerals like calcium, magnesium, potassium contents increased but sodium content decreased.

Mugula *et al.* (1992) developed maize-soybean tempe (70:30) as a potential nutritious weaning food and evaluated for acceptability and nutrient composition. The fermentation procedure involving a mixture of *Rhizopus oligosporus* and *R. oryzae* (1:1) was reported to increase the dietary fibre content, but decreased the phytates. Further, rest of proximate composition and mineral contents were not affected. It was also reported that the tempe weaning gruel was equally acceptable as maize gruel because of similarity in taste and flavor.

An investigation on consumer acceptability of tropical Ghanaian QPM was conducted by Ahenkora *et al*. (1999). Four QPM varieties and two normal maize varieties were processed into *Kenkey* and *Thozafi*. The products were evaluated using 7 point hedonic scale. *Ga kenkey* of QPM scored better for appearance (6.42) than the other attributes. The normal maize varieties produced better consistency (6.07) compared to QPM (5.76). However all the varieties produced acceptable *ga kenkey*.

Okezie *et al.* (2003) extracted maize by addition of ripe banana pulp at various proportions (0-50%). It was reported that addition of banana to all the mixes had significantly lower values of crude protein (5.37-5.93%). A similar trend was also noticed for the fat content and decreased from 4.25 per cent for maize flour to 2.87 per cent. The ash content, however, increased with increasing level of banana substitution from 0.03 to 2.42 per cent.

A study on soy-fortified maize *sattu* was conducted by Deshpande *et al.* (2004). Soybean, maize and Bengal gram were blended in different proportions to prepare nutritious and ready to eat snack chemical analysis of the products revealed that the protein (18 to 27%) fat (6.2 to 10.8%) and ash (2.74 to 3.32%) contents varied in the *sattu* samples with soy fortification, whereas carbohydrate content decreased with level of soya incorporation in maize *sattu* (62.6 to 48%).

Mosha and Vicent (2004) evaluated maize-sorghum based weaning mixtures organoleptically. It was reported that all mixtures (namely maize-rojo beans-peanut, maize-peanut-sardines, maize-peanut-sardine-rojo beans, maize-peanut-soaked rojo beans, sorghum-rojo-beans-peanut, sorghum-peanut-sardines, sorghum-peanut, sardine-rojo beans, sorghum-peanut-soaked rojo beans) except these containing germinated rojo beans were highly acceptable. Both maize and sorghum based composite gruels had a short shelf life under ambient conditions (26.4℃) ranging between 4 and 6 hour with gruels containing ground sardines showing a tendency to spoil faster.

A comparative study of wheat and QPM based biscuit was conducted by Gupta and Singh (2005). Biscuits were prepared with and without processed defatted maize germ cake (PDMGC) supplementation and compared with wheat flour based biscuits as standard. Four types of biscuits of wheat flour (10:0), wheat flour: PDMGC (8.5:1.5), wheat flour: QPM (6:4) and wheat flour: QPM: PDMGC (5.1:3.4:1.5) were prepared by common method used in bakeries. It was observed that wheat flour based biscuits were liked extremely whereas wheat flour: QPM based biscuits without supplementation of PDMGC were liked moderately. The biscuits of wheat flour and PDMGC were neither liked nor disliked whereas biscuits of wheat flour: QPM and with PDMGC were disliked moderately. The authors concluded that supplementation of PDMGC though increased the nutritional value, the sensory scores were discouraging. It was suggested that addition of flavoring agents like chocolate would enhance acceptability.

Valdez *et al*. (2005) conducted a study on infant food from QPM and chickpea. It was reported that nixtamalized maize flour and extruded chickpea flour in the ratio of 26.7 per cent and 73.3 per cent yielded best combination with a global desirability of 0.87. The global desirability was arrived at based on surface response methodology.

Naik *et al.* (2006) developed QPM based value added traditional foods (2 sweets, 2 savoury, 2 adjunts and 2 bakery items). It was reported that all the products were highly acceptable at varying levels and were nutritious. The result revealed that, the protein content of the product ranged from 5.47 – 17.10g, fat from0.6-36.66 g, carbohydrate from 28.32-100.66 g, calcium from 27.07-204.39 mg, iron from 2.29-10.73 mg and carotene from 55.85-7.04 µg per 100 g of cooked food.

Singh *et al.* (2006) developed and evaluated acceptability of QPM and normal maize based cakes. The cake were prepared by incorporating maize flour at 40, 60, 80 per cent level of refined flour. The results revealed that all types of cakes were acceptable and with increase in the level of incorporation of maize flour the acceptability scores were reduced. Proximate analysis indicated that moisture content of cakes ranged from 24.10 to 25.80 per cent cakes prepared with QPM varieties had significantly higher protein than those from normal varieties of maize. Fat, ash, crude fibre content of all the cakes ranged from 10.57 to 12.28, 1.05 to 1.17, 0.88 to 1.00 per cent respectively. Total carbohydrate content of cakes ranged from 71.21 to 75.03 g/100 g. The authors reported that the acceptability and nutritional composition data indicated that QPM can be successful utilized for preparation of cakes.

2.6 NUTRITIONAL QUALITY

Generally maize is poor in nutritional quality. But the breeding experiments resulting in improved quality protein maize has added inversely to its nutritional potential in alleviating both hunger and malnutrition. Several studies to evaluate the nutritional significance of QPM have been conducted in India and abroad.

A study was conducted by Graham *et al.* (1980) to evaluate the protein quality of endosperm and whole kernels meals of normal, opaque-2 and sugary-2 opaque-2. Eight convalescent malnourished children, 10-25months of age were fed iso-nitrogenous and iso-caloric diet. Each type of diet was fed for 9 days period (3 days adaptation period and 6 days of metabolic period), consecutively. Endosperm meals provided 83.2, 91.2 and 82.1 per cent of energy, while whole kernel meals provide 73.2, 68.6 and 67.2 per cent of energy in respective diets. Apparent nitrogen retention from endosperm meals was lower (15.1, 22.8 and 24.8%) than from whole kernel meals (26.8, 30.1 and 31.6%), both lower than from casein (39%). It was reported that there was strong correlation between lysine absorbed and nitrogen retention, in both endosperm and whole kernel meal, but higher in whole kernel. Further, it was also indicated that to match the nitrogen retention from casein presumably equal to requirement, 50 per cent of the children needed to consume about 125-200 per cent of energy requirement as normal, opaque-2 or sugary-2 opaque-2 and meals which was impossible. However, for whole kernel meals the children needed to consume 85-110 per cent of energy of the respective diets.

Ortega *et al.* (1986) assessed *in vitro* protein digestibility of nixtamal, *masa* and tortilla of normal maize and QPM. It was reported that, QPM and its products had lower *in vitro* protein digestibility (82, 73, 80 and 68%) compared to normal maize and its products (88, 82, 91 and 79%) for raw grain, nixtamal, *masa* and tortilla, respectively. The differences in distribution of protein fractions were attributed for the variation in digestibility.

Sproule *et al.* (1988) evaluated energy and apparent digestibility of food grade maize and QPM. Weanling rats were fed diets of raw grains, tortillas and defatted tortilla chips. Both the diets were supplemented with 1 per cent casein-HCl to improve rat growth and reduce experimental error and formulated to contain 10 per cent protein and 5 per cent ether extract. The diets were iso-nitrogenous and iso-caloric. It was reported that feed intake and average daily gain in weights of rats fed QPM products were significantly higher than rats fed on food grade maize but, lower feed/gain ratio. Processing raw grains into tortilla and tortilla chips significantly increase the protein digestibility. The energy digestibility of tortilla and tortilla chips products of both types of maize was higher than the raw grains. This has been attributed to the reduction of insoluble fibres and increment of starch availability.

Graham *et al*. (1989) conducted a study to know the digestibility and utilization of QPM. For the study, common maize and QPM were used. Both varieties were wet milled into whole kernel meals. These diets supplied 6.4 per cent of energy as protein, 10 per cent as fat and the balance as carbohydrate. Six recovering malnourished male infants (7.9 to 18.5 months of age) were divided in to two groups receiving normal and QPM diets separately. All the subjects received the casein control diet during the first 9 days followed by the maize diets for 7 days each. The metabolic study revealed that rats fed QPM had lower nitrogen retention (32%) than rats fed casein diet (41%). Similar observations were made with normal maize also. Further the same group of scientists (Graham *et al*. 1990) evaluated the efficacy of QPM as the sole source of dietary protein and fat on 10 recovering malnourished children aged 14 to 29 months. The experiment was conducted for 9-11 months. The children received 90 per cent of their diet energy and 100 per cent of protein and fat from QPM. It was reported that the linear growth children fed milk diet was slightly but not significantly greater than that of QPM fed children.

Bressani *et al.* (1990) investigated the changes in protein quality of common maize and QPM during traditional tortilla preparation. Three high land and low land maize types were compared with a QPM. A 5 kg sample of each maize sample was given to the same rural housewife to process the maize into *masa* and tortillas. The method involved cooking in lime water for 55-60 min allowed to stand over night, washing two to three times with water and grinding to *masa* of which 50 per cent converted to tortilla. Masa and tortilla samples were air-dried at 60°C, milled and subjected to protein quality evaluation in by rat feeding trials. Raw samples, their respective *masa* and tortilla were evaluated. The results revealed that rats fed the casein diet showed a weight gain food intake and protein efficiency (PER) ratio that was significantly higher than those for rats fed the different diets based on raw and processed maize. Rats fed QPM either raw or processed maize dough and tortilla showed a significantly higher weight gain, food intake and PER than animals fed common maize diets. With respect to processed maize, the animals consuming maize dough and tortilla showed significantly higher weight gain and PER. Further the authors reported that the change in protein quality was higher in normal maize than in QPM, attributing it to the changes in prolamine protein upon lime treatments.

Bhargava *et al.* (2003) assessed the nutritional quality of QPM and normal maize based *dalia* and *chapati* on 1-3 years of pre school children. The diet was isocaloric and contain one third of RDA of caloric and protein. Skimmed milk was used as standard. The result revealed that children fed with QPM based diet gained nearly 112, 43 and 117 per cent weight compared to those fed with normal milk based and standard diet, respectively. Also the height, head and mid arm circumferences of the children fed on QPM based diet were better than the group fed on skimmed milk diet.

Gupta (2003) studied the effect of removal of pericarp on protein quality in normal, hard endosperm opaque-2 and chalky opaque-2 maize types. Diets of ground whole kernels, kernels after removing pericarp with hand and by boiling in lime water (calcium oxide) of each varieties were administered to Wister weanling rats. It was reported that true digestibility of all the three varieties exceeded 87 per cent, whereas biological value, net protein utilization and utilizable protein were found to be higher in chalky and hard endosperm opaque-2 over the normal maize. The removal of pericarp improved all the protein quality indices of all the three varieties. However, in boiled kernels only the biological value of hard endosperm opaque-2 maize was improved over control and the true digestibility of chalky opaque variety decreased. This was attributed to increased non-digestible fiber due to boiling and other non-digestible products.

In another experiment (Gupta, 2004) these varieties of maize were roasted and supplemented with roasted non-defatted soybean and evaluated for protein quality. It was reported that biological value of all the maize types improved with 5 mg supplementation similar trend was evident with net protein utilization and utilizable protein of all the maize types.

Guerra *et al.* (2004) studied the protein quality of tortilla based diets produced from regular maize and QPM, with and without soybean fortification. The study was conducted in rats for two generation. Five different diets were prepared with fresh *masa* of a normal or QPM either enriched with micronutrients and/or soybean meal at 3 or 6 per cent level of supplementation were fed to rats and compared with casein group as control. The results revealed that the enrichment of normal and QPM *masa* diets with soybean increased the rat growth significantly in both the generation than the counterparts fed the enriched diets or fresh *masa* diets. Animals receiving QPM diets exhibited highest protein digestibility, but soybean supplemented animal showed highest biological value, net protein utilization and protein digestibility corrected essential amino acid scores. The difference among the treatments was more among second generation rats. The pregnancy rate, number of new borns/litter, litter weight and new born survival rate was reported to be higher in rats fed diets containing defatted soybean, QPM either enriched with soybean or micronutrients. Thus the study proved the superiority of QPM biologically.

A comparative study was conducted by Habtamu *et al*. (2003) on QPM, four high yielding maize hybrids and one local maize cultivar to assess the protein efficiency ratio in raw and traditional processed QPM products. It was reported that QPM was better than common maize for protein quality. The authors attributed this to higher proportion of lysine, arginine, tryptophane, histidine, threonine cystiene and valine. The corrected PER was reported to be high in QPM (2.2) as compared to hybrids (1.14to 1.67). It was also reported that the various traditional processes had no significant effect on the protein nutritional quality of the QPM.

Kumari and Singh (2004) evaluated the impact of supplementation of QPM based *ladoos* on the nutritional status of 60 (30 women in experimental and control groups) pregnant women of Pusa block of Samastipur, Bihar. Each woman of experimental group was fed two *ladoos* on alternate days in third trimester of pregnancy regularly. Nutritional status was assed by anthropometry, hemoglobin level, prevalence of anemia and mean birth weight of the new born babies. The results revealed significant increase in body weight and hemoglobin levels of pregnant women consuming the *ladoos*. A shift in severity of anemia was evident among the anemic pregnant women. Around 13 per cent of severe anemic and 80 per cent moderate anemic women shifted to mild anemic and normal. The newborn babies of supplemented group attained normal body weight.

Paula *et al.* (2004) evaluated a nutritional supplement prepared with QPM and other ingredients such as brown sugar, banana and oat meals. Fisher rats (21 days) were fed diets containing the supplement as a protein source, both with and without soybean flour. Casein diets with 10 or 7 per cent protein served as respective controls. The results of the biological study revealed that QPM supplement was a good protein source, especially when soybean flour was added.

An experiment was conducted by Rodriguez *et al.* (2004) to know the effect of solid state fermentation on protein quality of QPM tempe, in terms of *in vitro* protein digestibility. Results revealed that the digestibility was significantly higher in tempe 83.6 per cent than in raw flour (78.5%). The tempe flour had higher true protein (13%), available lysine (5.67 glycine/100 g protein) and lower lipid content (4.3%) and phytic acid (0.8 mg/g) than the raw sample (9.1%, 4.2 glycine/100 g protein, 6.1% and 10.1 mg/g, respectively).

Gupta and Singh (2005) evaluated *in vitro* protein digestibility (IVPD) of QPM based biscuits prepared with and without processed defatted maize germ cake (PDMGC) supplementation and compared with wheat flour biscuits as standard. It was indicated that IVPD of QPM grains (81%) was less than wheat flour (94%) and least (76%) was in PDMGC. But, supplementation of QPM or PDMGC to wheat slightly decreased the IVPD (about 91% in both). However, supplementation of both QPM and PDMGC further reduced the IVPD to 87 per cent with regard to the IVPD of biscuits supplementation of PDMGC or QPM reduced the IVPD to about 90 per cent as compared sole wheat biscuits (97%).

Valdez *et al.* (2005) formulated an optimized infant food made out of nixtamalized maize flour (NMF) (26.7%) and extruded chickpea flour (ECF) (73.3%). Response surface methodology was applied to determine the best combination of NMF/ECF, from experimental design of 11 assays. It was reported that optimized flour had a good global desirability of 0.87. It was found with better protein (19.72%), lipid (6.10%), carbohydrate (71.45%) and minerals (2.83%) contents. The *in vitro* protein digestibility (87.9%) and calculated protein efficiency ratio (1.86) was also good.

III. MATERIAL AND METHODS

Quality protein maize (QPM) is an important technology developed by agricultural scientists for the betterment of mankind of the developing countries where the diets are predominantly based on low input cereals, especially on maize. Utilization of such nutritious cereals in daily diet may improve nutritional status of the undernourished segments of society. The present investigation undertaken to assess physico-chemical and functional characteristics and explore utilization potentials of QPM. Materials used and methodology employed in carrying out the research are discussed in this chapter.

3.1 PROCUREMENT OF MAIZE SAMPLES

A total three samples of maize were studied. A white coloured QPM variety Shaktiman-1 was studied in comparison with white coloured variety maize S.A. Tall and a yellow variety maize DMH-2. QPM grains were obtained from Rajendra Agricultural University, Pusa, Samastipur, Bihar. The samples of DMH-2 and S.A. Tall were procured from University of Agricultural Sciences, Dharwad. Intact whole seeds were picked manually and stored at ambient condition for the further investigations.

3.2 PHYSICAL CHARACTERISTICS OF MAIZE VARIETIES

Physical characteristics such as colour, size and density were studied using standard procedures.

3.2.1 Grain colour

Randomly picked grains of each variety were matched for colour with the Exotica Horticultural colour guide (Graf, 1976).

3.2.2 Grain size

Length, breadth and thickness of grains of each variety were measured using electronic digital calipers. Thousand grains were manually counted and weight was recorded. Volume of thousand grains was assessed by water displacement method. Bulk density was determined using the formula given below.

$$\text{Bulk density (g/ml)} = \frac{\text{Thousand grain weight (g)}}{\text{Thousand grain volume (ml)}}$$

3.3 NUTRIENT COMPOSITION

Randomly selected intact grains were milled into a fine powder in a laboratory model Wiley mill and the whole meal was packed in polythene pouches and stored under refrigerated condition for further chemical analyses.

3.3.1 Moisture (g/100 g)

Sample meals of each variety was weighed into a previously weighed dry moisture cup and dried in an oven at 105℃ to a constant weight (Anon., 1990). Moisture content was calculated, as follows.

$$\text{Per cent moisture} = \frac{\left(\text{Weight of sample after drying (g)}\right) - \left(\text{Weight of sample before drying (g)}\right)}{\text{Sample weight (g)}} \times 100$$

3.3.2 Crude protein (g/100 g)

Paranas and Wagner apparatus was used to assess the nitrogen content of seeds by microkjeldahl method (Anon., 1990). Crude protein content was calculated by multiplying with factor 6.25

Plate 1. Different maize genotypes used for study

Plate 1. Different maize genotypes used for study

$$\text{Per cent protein} = \frac{\text{Titre value x Normality of } H_2SO_4 \text{ x } 14.007 \text{x} 6.25}{\text{Sample weight (g)}} \text{ X } 100$$

3.3.3 Crude fat (g/100 g)

Moisture free flour samples of each variety were weighed in moisture free thimbles and crude fat was extracted by refluxing with petroleum ether in a soxhlet apparatus. Per cent crude fat was calculated as follows (Anon., 1990).

$$\text{Per cent crude fat} = \frac{\left(\text{Weight of sample after extraction (g)}\right) - \left(\text{Weight of sample before extraction (g)}\right)}{\text{Weight of sample (g)}} \text{ X } 100$$

3.3.4 Total minerals (g/100 g)

Total mineral content (ash) was determined by igniting the samples in a muffle furnace, at 600°C, for 3-4 h (Anon., 1990).

$$\text{Per cent total minerals} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \text{ X } 100$$

3.3.5 Crude fibre

Crude fibre was estimated by acid alkali digestion method. The residue obtained after digestion was dried in a crucible and its weight was recorded. The dried residue was ignited in muffle furnace and its weight was recorded. The difference in the two weights was taken as the weight of the crude fibre (Jacobs, 1979).

3.3.6 Total carbohydrate

Total carbohydrates content was calculated by subtracting the sum of the values for moisture, crude protein, crude fat, crude fibre and ash from 100.

3.3.7 Calorific value (Kcal/100 g)

The calorific value was computed by summing up the values obtained by multiplying the values with Atwater constants for carbohydrates, crude fat and crude protein with the factors 4, 9 and 4, respectively.

3.3.8 Starch

Starch content was analyzed by hydrolyzing the moisture and fat free samples in perchloric acid. A dried homogenous sample of 100 mg was taken in a centrifuge tube, 5-10 ml of 80 per cent alcohol was added to it and the tube was placed in water bath at 80-85℃ for 5-10 min. It was centrifuged for 10 minutes at 3000 rpm. Alcoholic extraction was repeated thrice and supernatant was discarded. The residue left over was added with 3 ml distilled water followed by 6.5 ml of 52 per cent perchloric acid. The content was stirred for five minutes continuously and then occasionally for the next 15 minutes. About 10ml water was added and again centrifuged at 2000 rpm for five minutes. Then the supernatant was decanted into a 100 ml volumetric flask. The extraction was repeated thrice, increasing the time from 15 to 25 and finally to 30 minutes. The pooled supernatant was diluted with distilled water and neutralized with 4 N NaOH and further diluted to 100 ml and glucose content of the hydrolysate was estimated for reducing sugars according to the method of Nelson Somogyi's (Hawk *et al*., 1965) and sugar content was multiplied by a conversion factor 0.9 to calculate starch content.

3.3.9 Micronutrients

Micronutrients such as iron, copper, manganese and zinc were determined by atomic absorption spectrophotometer (SHI MADZO Model AA-6650). The samples were digested following the procedures of Jackson (1973) using diacid mixture of nitric acid and perchloric acid (HNO_3:$HClO_4$) in 9:4 ratio. To a known quantity of sample, 5 ml of nitric acid was added and left overnight for predigestion. It was then digested with 15-20 ml of diacid mixture till all the $HCLO_4$ evaporated and snow white residue was obtained. The solution was filtered through filter paper and the volume was made up to 100 ml with distilled water. The amount of iron, copper, manganese and zinc were determined by Atomic Absorption Spectrophotometer.

3.3.10 *In vitro* protein digestibility (%)

In vitro protein digestibility of sample was carried out using enzymatic method of Moulishwar *et al*. (1993). Samples containing 100 mg protein were treated with 12.5 mg of pepsin in 50 ml of 0.1 N HCl at 37℃ for 3 hours. After neutralization with 0.5 N NaOH, 6 mg of pancreatin dissolved in 25 ml of phosphate buffer (pH 8.0) was added and digestion continued for 24 hour at 37℃. The volume was made to 100 ml and 50 ml aliquot was treated with 10 per cent TCA, left overnight to precipitate the proteins. The suspensions were centrifuged at 4000 rpm. The undigested material was subjected to protein assay by microkjeldahl method. Protein digestibility was calculated by difference.

3.3.11 *In vitro* starch digestibility

In vitro starch digestibility was carried out using the method, described by Moulishwar *et al*. (1993). The slurry of sample (2%) was cooked on a boiling water bath for 15 minutes. To a slurry sample of 50 ml, 30 ml of 0.2 M glycine-HCl buffer (pH 2.0) containing 10 mg of pepsin was added. It was incubated at 37℃ for 2 hours and neutralized with 0.2 N NaOH and the volume was made to 100 ml. To an aliquot of 10 ml of this sample 5 ml of 0.5 M phosphate buffer containing 15 mg of pancreatin and 15 mg amyloglucosidase was added and incubated for 2 hours at 37°C. The reaction was stopped at desired intervals (3 hours) by heating the samples for 5 minutes in boiling water bath. Aliquots of 0.5 ml of these samples were mixed with 2 ml of *dinitrosalicylic* acid reagent for determining reducing sugars. Glucose was used as a standard, while starch equivalent was calculated using the conversion factor of 0.9.

3.4 FUNCTIONAL PROPERTIES

3.4.1 Hydration characteristics of maize grains

Hydration characteristics include hydration capacity, hydration index, swelling capacity and swelling index of the grains.

3.4.1.1 Hydration capacity (g 10^{-3} seeds)

Randomly selected thousand seeds were soaked in distilled water (1:10: *w/v)* under ambient conditions employing the methods of Williams *et al*. (1983). The hydration capacity per thousand seeds was calculated as follows.

$$\text{Hydration capacity (g/}10^{-3}\text{ seeds)} = \left(\begin{array}{c}\text{Weight of 1000 seeds}\\ \text{after soaking (g)}\end{array}\right) - \left(\begin{array}{c}\text{Weight of 1000 seeds}\\ \text{before soaking (g)}\end{array}\right)$$

3.4.1.2 Hydration index

Hydration index was calculated by using the formula given by Kantha *et al*. (1986).

$$\text{Hydration index} = \frac{\text{Hydration capacity per thousand seeds}}{\text{Original dry weight of thousand grain}} \times 100$$

3.4.1.3 Swelling capacity (g 10^{-3} seed)

The swelling capacity of grains was assessed by modifying the methods of Williams *et al*. (1983). The soaked seeds were blot dried, to remove the superfluous water and transferred to a measuring cylinder containing known volume of water. The change in volume was recorded and swelling capacity was calculated as given below.

$$\text{Swelling capacity (ml }10^{-3}\text{ seed)} = \begin{array}{c}\text{Volume of 1000 seeds}\\ \text{after soaking (ml)}\end{array} - \begin{array}{c}\text{Volume of 1000 seeds}\\ \text{before soaking (ml)}\end{array}$$

3.4.1.4 Swelling index

Swelling index of grains was calculated as described by Kantha *et al.* (1986) using the formula given below.

$$\text{Swelling index} = \frac{\text{Swelling capacity per thousand seeds}}{\text{Seed volume per thousand seeds}} \times 100$$

3.4.2 Cooking quality of grains

Soaked grains (50 g) were subjected to pressure cooking (15 lb /*psi*) for 30 min, in predetermined constant amount of water (3.5 times). The cooking quality was evaluated by expert panel in terms of doneness and taste of the cooked grains.

3.4.2.1 Cooked weight (g) and volume (ml)

The cooked seeds were drained and the superfluous water removed using an absorbent paper. The change in weight was recorded. The volume of the cooked seeds was measured by water displacement method. Increase in weight and volume of the seeds was calculated using the following formula.

$$\text{Per cent gain in weight after cooking} = \frac{\left(\text{Cooked seed weight (g)}\right) - \left(\text{Original dry seed weight (g)}\right)}{\text{Original dry seed weight (g)}} \times 100$$

$$\text{Per cent gain in volume after cooking} = \frac{\left(\text{Volume of cooked seeds (ml)}\right) - \left(\text{Original dry seed volume (ml)}\right)}{\text{Volume of dry seeds (ml)}} \times 100$$

3.4.3 Germination

Randomly selected thousand grains were soaked for 24 hours in 500ml distilled water. Soaked grains were drained and tied in a muslin cloth and placed in an incubator maintained at 33^0 C for 36 hours for germination. The sprouted grains were counted and classified as completely, partially or not germinated based on germination capacity. The values were expressed in percentage.

3.4.4 Popping

The trials for popping were carried out by conventional method and also in microwave oven. Hundred grains were treated either by blanching for 2 and 5 minutes or by application of oil and subjected to popping in heavy bottom pan and microwave oven separately. The popped grains were categorised as completely or partially popped and unpopped.

3.5.5 Functional properties of maize flours

3.5.5.1 Particle size

To determine the particle size a known quantity of sample was passed through sieves of different mesh sizes and the percentage of material retained on the sieve was measured.

3.5.5.2 Flour Dispersibility

Dispersibility was measured by placing 10 g of the sample in 100 ml stoppered measuring cylinder, distilled water added to the volume of 100 ml, stirred vigorously and allowed to settle for three hours. The volume of settled particles was subtracted from 100 and the difference was reported as percentage dispersibility.

3.5.5.3 Swelling power and solubility of flours

Swelling power and solubility of flours was assessed following the methods of Schoch (1964). A known amount of sample (W_1) was weighed in a centrifuge tube and weight recorded (W_2). To this 20 ml, of distilled water was added (V_E) and heated for 30 min in a water bath at 90℃ with occasional stirring. The cooled contents were centrifuged at 5000 rpm for 10 min. The supernatant was carefully decanted in a Petri plate (W_4), dried at 105℃ and weighed (W_5). The inner side of the centrifuge tube which was free from supernatant was wiped and weighed (W_3)). Values were expressed on per cent basis.

$$\text{Swelling power (g/g)} = \frac{W_3 - W_2}{W_1} \times 1$$

$W_5 - W_4 \times V_E$ 100

$$\text{Per cent solubility} = \frac{\quad}{V_E} \times \frac{\quad}{W_1}$$

3.5.5.4 Viscosity

Cooked paste viscosities of flour were tested at 10 per cent and 15 per cent slurry concentration by using line spread test (Griswold, 1962). Concentric circles measuring up to 6 cm were drawn on a sheet and placed under a glass plate. A hollow cylinder (2" diameter) was placed over glass plate at the centre of concentric circles.

Separately 10 and 15 per cent slurries were prepared and cooked in boiling water bath for 30 minutes. These cooked hot samples were poured to fill the cylinder individually. The cylinder was carefully lifted and flow of liquid was measured as viscosity. The spread of the slurry was measured at four different direction and average calculated viscosity.

3.5.5.5 Fat absorption

Fat absorption was measured by adding known amount of sample to measured amount of refined oil in a 15 ml centrifuge tube. The contents were stirred for 30 seconds every 5 min and after 30 min, the tubes were centrifuged at 4000 rpm for 25 min. The free oil was decanted and percentage of absorbed oil was determined by difference (Sosulski, 1962).

$$\text{\% fat absorption} = \frac{\text{Weight of sample after centrifugation} - \text{Weight of sample before centrifugation}}{\text{Weight of original sample taken}} \times 100$$

3.6 DEVELOPMENT OF VALUE ADDED PRODUCTS

3.6.1 Preparation of Malt

Maize grains were cleaned and soaked in double the amount of water for 24 hours. The soaked grains were drained and tied in a muslin cloth and allowed to germinate for 36 hours at 37°C in an incubator. The sprouted grains were dried and degerminated. These grains were roasted to desirable aroma. The grains were milled and sifted using a muslin cloth. The bran and fiber was discarded. This flour sample was used for preparation of beverage.

3.6.1.1 Malt recovery

Malt recovery of the maize samples was calculated by measuring the per cent of malt obtained using the following formula.

$$\text{Malt recovery} = \frac{\text{Malt obtained}}{\text{Weight of sample (g)}} \times 100$$

3.6.2 Preparation of Nixtamal

Grains were steeped in lime solution (1%Calcium oxide) for 5 minutes and boiled for 30 minutes in the same solution (Milan-Carrilo *et al.*, 2004). The boiled grains were left overnight in the same solution. The grains were then drained and washed under water for 3-4 times and dried at 60°C. The completely dried grains were roasted to a pleasant aroma and milled.

3.6.3 Malt Beverages

The malt flours obtained as indicated under 3.6.1 were used for the preparation of malt beverages. A smooth paste of malt flour was prepared with 15 ml of milk and kept aside. In another vessel 85 ml of milk was simmered and the paste was added slowly and cooked on a low flame for 15 minutes, stirring continuously. Sugar and garden cress seeds were added in different levels. Organoleptic evaluation of the malt beverages was carried out by a panel of semi trained panel of judges using a 9 point Hedonic scale (Appendix VI).

3.6.4 *Laddu*

Maize flour of each variety was substituted in the main ingredient (Bengal gram flour) at varying levels of 0, 25, 50, 75 and 100 per cent for preparation of *laddu* (Appendix V). The organoleptic evaluation of *laddus* evaluation was carried out by semi trained judges using a 9 point Hedonic scale (Appendix VI).

3.7 STATISTICAL ANALYSIS

The analyses of data pertaining to physical characteristics, proximate composition were done by Factorial Completely Randomized Designs. The results of functional qualities, nutritional properties and value addition were subjected to 2 factorial ANOVA and Duncan's Multiple Range Test. Paired t-Test was applied to find out the differences between the control and different levels of maize flour incorporation in *laddu* and ribbon *murukku*. The limit of probability fixed for the test of significance was $P \leq 0.05$. Whenever the significant result was obtained the critical difference test was used.

IV. EXPERIMENTAL RESULTS

Maize has acquired a well deserved reputation as a poor man's cereal. Presence of high amount of lysine and tryptophan has given Quality Protein Maize (QPM) a special and distinctive status among cereals. Replacement of common maize by QPM is the most effective and feasible measure to meet quality protein needs and raise the nutritional status. The nutritious products developed from QPM have a great potential in alleviating hunger and malnutrition among the maize dependent poorer sections of the society. The products can also replace fancied and highly priced industrial foods. The results of the present investigations on physical characteristics, chemical composition, functional properties and value addition to QPM are presented in this chapter.

4.1 PHYSICAL CHARACTERISTICS OF MAIZE VARIETIES

Majority of grains show variation in physical, chemical and functional properties according to their genetic endowment. These characteristics influence each other and could in turn affect the acceptability at field and domestic level.

The observations revealed variation in physical characteristics among the maize genotypes (Table 1). It was observed that QPM and SA Tall varieties possessed ivory cream colour, while DMH-2 was a mixture of grains ranging in colour from orange to burnt orange. The grains of SA Tall and DMH-2 were lustrous in appearance, whereas QPM was not lustrous. The measurement of dimensions of grains revealed variations in size. The grains of QPM were longer (10.08 mm) than DMH-2 (9.84 mm) and SA Tall (9.35 mm). It was found that QPM grains were broader and thicker (9.68 and 4.78 mm, respectively) than SA Tall (9.26 and 4.76 mm, respectively) and DMH-2 (8.76 and 4.74 mm, respectively). Thousand grains weight of QPM was significantly higher (288.37 g), than SA Tall (275.49 g) and DMH-2 (251.20 g) varieties. Likewise, thousand grain volume was significantly more in QPM (240.30 ml) than in SA Tall (230.40 ml) and DMH-2 (220.30 ml) grain samples. It was also observed that the grains of QPM and SA Tall were significantly denser (1.19 g/ml) than DMH-2 (1.14 g/ml).

4.2 NUTRIENT COMPOSITION

Maize has potentials for grain production even under low rainfall conditions. They sustain adverse agro-climatic conditions and form promising crop for the poor people depending on marginal lands. Hence, high yielding varieties of maize with better nutrient composition promote nutritional empowerment of people dependent on maize for food.

The chemical analysis of maize varieties for nutrient composition revealed varietal differences (Table 2). Moisture content was significantly higher in SA Tall and DMH-2 (8.27 and 8.03%, respectively) varieties than in QPM gains (6.92%). Protein being the body building nutrient was significantly higher in DMH-2 (10.29%), followed by QPM (10.15%) and SA Tall (8.90%).

Highest quality of crude fat content was exhibited by DMH-2 and QPM (5.53 and 5.29%, respectively) significantly low levels of crude fat were observed in SA Tall (2.92%). In case of crude fibre, QPM recorded significantly higher content (1.50%) followed by DMH-2 (1.34%) and SA Tall with (1.30%). Total minerals content was significantly higher in both QPM and DMH-2 (1.16% in each) than in SA Tall grains (1.13%).

It was observed that all the three varieties exhibited similar values for starch content which ranged from 65.42 per cent in DMH-2 to 66.88 per cent in QPM grains. The mean carbohydrate content was (75.32%) and was significantly highest in the case of SA Tall (77.46%) followed by QPM (74.91%) and DMH-2 (73.58%) computation of calorific value revealed a mean of 381 Kcal, QPM and DMH-2 varieties recorded significantly higher with calorific value of 385 Kcal than in SA Tall with 372 Kcal/100 g. Significant varietal differences were evident with regard to iron content. Mean iron content was 1.98 mg and significantly highest was in QPM followed by DMH-2 and least was in SA Tall (2.85, 1.92 and 1.18 mg/100 g, respectively). Copper content was significantly high in QPM (0.45 mg/100 g), followed by DMH-2 (0.33 mg/100) and SA Tall (0.13 mg/100 g) grains. Mean copper content was 0.30 mg/100 g.

Table 1. Physical characteristics of maize varieties

Characteristics	Varieties			Mean ± S.Em
	QPM	S.A. Tall	DMH-2	
Colour	Ivory cream	Ivory cream	Orange- burnt orange	-
Length (mm)	10.08	9.35	9.84	9.76± 0.18
Breadth (mm)	9.68	9.26	8.76	9.23± 0.37
Thickness (mm)	4.78	4.76	4.74	4.76± 0.32
Thousand grain weight (g)	288.37[a]	275.49[b]	251.20[c]	271.69± 1.43
Thousand grain volume (ml)	240.30[a]	230.40[b]	220.30[c]	230.33± 0.19
Density (g/ml)	1.19[a]	1.19[a]	1.14[b]	1.17± 0.005

In a row, means followed by the same letter are not significantly different ($P \leq 0.05$) by DMRT

Table 2. Nutrient composition of maize varieties (g/100 g)

Nutrient (g)	Varieties			Mean ± S.Em
	QPM	S.A. Tall	DMH-2	
Moisture	6.92^{b}	8.27^{a}	8.03^{a}	7.74±0.16
Crude protein	10.15^{b}	8.90^{c}	10.29^{a}	9.78±0.07
Crude fat	5.29^{a}	2.92^{b}	5.53^{a}	4.58±0.13
Crude fibre	1.50^{a}	1.30^{c}	1.34^{b}	1.38±0.11
Total minerals	1.16^{a}	1.13^{b}	1.16^{a}	1.15±0.01
Starch	66.88	66.03	65.42	66.94±0.94
Total carbohydrates	74.91^{b}	77.46^{a}	73.58^{c}	75.32±0.06
Calorific value (Kcal)	385^{a}	372^{b}	385^{a}	381±0.89
Iron (mg)	2.85^{a}	1.18^{c}	1.92^{b}	1.98± 0.004
Copper (mg)	0.45^{a}	0.13^{c}	0.33^{b}	0.30± 0.04
Manganese (mg)	0.17^{a}	0.13^{b}	0.18^{a}	0.16± 0.03
Zinc (mg)	1.22^{b}	0.82^{c}	1.65^{a}	1.23± 0.009

In a row, means followed by the same letter are not significantly different (P≤0.05) by DMRT

In case of manganese, DMH-2 and QPM recorded significantly high values (0.18 and 0.17 mg/100 g, respectively) than SA Tall (0.13 mg/100 g) followed by QPM (1.22 mg/100 g) and SA Tall grains (0.82 mg/100 g). However, former two were on par with each other. Zinc content was highest in DMH-2 (1.65 mg/100 g) followed by in QPM (1.22 mg/100 g) and SA Tall grains (0.82 mg/100 g). Thus, variation in chemical composition of the three varieties of maize was observed.

4.3 FUNCTIONAL PROPERTIES

4.3.1 Hydration and cooking characteristics

Hydration is an important determinant of cooking quality. The grains with good hydration and lower cooking time are generally preferred for cooking purposes.

Results of the experiment showed differences among the varieties in hydration and cooking characteristics (Table 3). The mean hydration capacity of QPM was significantly higher (184.70 g/1000 grain) than in DMH-2 (163.04 g/1000 grain) and SA Tall (140.94 g/1000 grain) varieties.

Hydration index was highest in DMH-2 (65.50) which however was on par with QPM (63.37). SA Tall recorded the lowest hydration index (49.55).

Although swelling capacity was higher in QPM (83 ml/1000 gains) than DMH-2 and SA Tall (77 and 75 ml/1000 grains), the values were statistically not significantly different. The swelling index was highest in DMH-2 (36.28) followed by QPM (35.14) and SA Tall (32.73), however, the indices were not significant statistically. The increase in weight after cooking was significantly highest in QPM (83.10%), followed by DMH-2 (56.10%) and least (50.25%) was observed in SA Tall. Likewise, increase in volume was found to be significantly highest in QPM (21.45%) followed by SA Tall (18.46%) and least was in DMH-2 (18.12%) grains. Thus, variation in hydration and cooking characteristics was observed.

4.3.2 Cooking quality

Cooking quality of the grains varied significantly among the varieties (Table 4). It was observed that the white colour of the grains of QPM and SA Tall varieties changed to yellow colour after cooking. However, only a slight colour change was observed in DMH-2 which changed from orange to dark orange. The pericarp of the grains were ruptured, but the grains were separate and not mashy even after pressure cooking for 30 minutes in all the varieties. The grains of QPM and DMH-2 were soft in texture and were completely cooked, while the grains of SA Tall were hard in texture and required much more time for complete cooking. With regard to taste of the cooked grains, QPM and DMH-2 were sweet, while SA Tall grains were bland to taste. Thus variation in cooking quality of the maize varieties was observed.

4.3.3 Germination

Germination is a common technique of grain processing where in complex carbohydrates and proteins are rendered easily digestible and several antinutrients are reduced. The process of germination enhances utilization potential of food grains by improving nutritional quality and acceptability. In the present investigation, it was observed that highest germination (53.87%) was observed in DMH-2 followed by grains of SA Tall variety (30.2%) (Table 5). QPM grains were slimy and not germinated even after 36 hours of incubation. Extended durations could not induce germination in QPM seeds.

Malt recovery is an important factor influencing its utilization in industry. It was observed that the malt obtained from QPM grains was highest (77.60%) among the three varieties. Higher malt recovery was observed in DMH-2 (66.40%) in which a majority of grains were completely germinated. The grains of SA Tall exhibited a low malt recovery of 55.40 per cent.

The malt of DMH-2 was light yellow in colour and exhibited a pleasant aroma, rest of the flours had creamish white appearance and had pleasant aroma.

4.3.4 Popping characteristics of selected maize varieties

The grains were subjected to open pan and microwave popping techniques. Results revealed unsuccessful popping characteristics in all the three maize varieties (Table 6).

Table 3. Hydration, cooking characteristics of maize varieties

Characteristics	QPM	S.A. Tall	DMH-2	Mean ± S.Em.
Hydration capacity (g/1000 grain)	184.70[a]	140.94[c]	163.04[b]	162.89± 3.47
Hydration index	63.37[a]	49.55[b]	65.50[a]	59.51±1.68
Swelling capacity (ml/1000 grain)	83.00 [a]	75.00[a]	77.00[a]	78.33±2.08
Swelling index	35.14[a]	32.73[a]	36.28[a]	34.72±0.80
Increase in weight after cooking (%)	83.10[a]	50.25[c]	56.10[b]	63.15± 0.49
Increase in volume after cooking (%)	21.45[a]	18.46[b]	18.12[b]	19.34±0.52

In a row, means followed by the same letter are not significantly different (P≤0.05) by DMRT

Table 4. Cooking quality* of maize varieties

Sl. No.	Varieties	Colour and appearance	Texture	Taste
1	QPM	White seeds changed to yellow, pericarp ruptured and separated grains	Soft, cooked	Slightly sweet
2	S. A. Tall	White seeds changed to yellow, pericarp ruptured separated grains	Hard, incomplete cooking	Bland
3	DMH-2	Orange coloured seeds slightly changed to dark orange, pericarp ruptured separated grains	Soft, cooked	Slightly sweet

*After pressure cooking for 30 minutes at 15 lbs/*psi*

Table 5. Germination, malt recovery (%) and quality characteristics

Sl. No.	Varieties	QPM	S.A. Tall	DMH-2
1	Completely germinated	-	30.20	53.87
2	Partially germinated	1.07	29.40	19.13
3	Not germinated	98.93	40.40	27
4	Malt recovery	77.60	55.40	66.40
5	Colour and aroma of maize malt	Creamish white and pleasant	Creamish white and pleasant	Light yellow and pleasant

Table 6. Popping trials of maize varieties

	Treatments	QPM	SA Tall	DMH-2
Hot pan popping				
1.	Native grains	Roasted, unpopped	Roasted, unpopped	Roasted, unpopped
2.	Blanched (2 min)	Slight expansion, but unpopped	Slight expansion, but unpopped	Slight expansion, but unpopped
3.	Blanched (5 min)	Slight expansion, unpopped with popped grain aroma	Slight expansion, unpopped with popped grain aroma	Slight expansion, unpopped with popped grain aroma
4.	Application of oil	Roasted unpopped	Roasted unpopped	Roasted unpopped cracked grains
Microwave popping				
1.	Native grains	Roasted unpopped	Roasted unpopped	Roasted unpopped, burnt
2.	Blanched (2 min)	Slight expansion unpopped	Slight expansion, roasted, unpopped	Roasted cracked grains
3.	Blanched (5 min)	Roasted, unpopped	Roasted, unpopped	Roasted, unpopped
4.	Application of oil	Roasted, popped aroma	Roasted, popped aroma	Roasted, cracked grains

Native grains and the grains treated either by blanching or oil application did not yield popped grains. The grains were rendered roasted and remained unpopped by traditional open pan and microwave popping process in all the three maize types. Similarly the grains subjected to blanching for 5 minutes exhibited slight expansion after heating in open pan or microwave oven. Further, when the grains were blanched for 2 minutes the grains became light expanded slightly accompanied by change in aroma, but the grains remained unpopped. Application of oil rendered the grains roasted but in DMH-2 the grains became light and cracked. Thus, none of the varieties exhibited good popping both by traditional and microwave popping techniques.

4.3.5 Functional properties of processed flours

Grains are generally processed to yield typical functional, organoleptic or nutritional characteristics in the resultant flours or products e.g. malting, nixtamalization etc. Particle size of flours as food ingredient influence food preparation and acceptability. In the present investigation the particle size of grains was revealed variations in distribution of particle size of flours of the three varieties processed by malting and nixtamalization.

4.3.5.1 Particle size

It was observed that particle size distribution of flours was influenced by processing treatments of malting and nixtamalization. Retention of coarse particles (500 μ) was highest in malted QPM (7.47%), native SA Tall (2.41%) and nixtamalized DMH-2 grains (2.65%). However, the nixtamalized DMH-2 grains also yielded highest quantity (72.59%) of fine particle flour (≤150 μ). Higher recovery of fine flour was also evident in native QPM (68.39%) followed by the native and malted samples of DMH-2 (64.99 and 64.49%, respectively). The performance of SA Tall in yielding fine particle flours was around 50 per cent in native, malted and nixtamalized grains. Relatively higher proportions of flours particle of size 150 μ and 180 μ were observed in native, malted and nixtamalized flours of QPM. The flours of SA Tall also exhibited similar trend but the proportion was high with 180 μ size particles, more than 25 per cent quantified both in malted and nixtamalized flours of SA Tall. Similar trend of coarseness of particles was also observed in DMH-2 flours, but was lower than in flours of SA Tall variety.

4.3.5.2 Dispersability, swelling power and solubility of processed flours

Results of the experiments to assess the dispersability, swelling power and solubility of processed flours is depicted in Table 8. Significantly highest flour dispersability was exhibited by nixtamal of SA Tall variety (72.33%) followed by different flours of QPM (69.33 to 71.00%). However, these values were not significant. Significantly dispersability was recorded in native flour of SA Tall (65.67%). Processing brought about an increased dispersability in all the varieties. However, swelling power of grains was neither affected by processing or variety. The solubility of flours was influenced by variety and also processing techniques of malting and nixtamalization. Significantly higher flour solubility was observed in SA Tall variety (8.91%) followed by DMH-2 and QPM (8.00 and 7.98%, respectively). However, the latter two were on par with each other. Further, it was also observed that native grains exhibit highest flour solubility (19.02%) as against malted and nixtamalized grains (3.20 and 2.67%, respectively). The trend was similar in all the varieties of maize employed in the present investigation.

Fat absorption was found to be highest in DMH-2 (82.40%) followed by SA Tall (76.20%) and least was observed in QPM (66.05)%.

4.3.5.3 Viscosity of processed flour

The viscosity is an important determinant of knowing pasting temperature at which the first detectable gelled starch is measured. This property helps in the food application of preparation of beverages, porridges and other products.

The cooked paste viscosity of processed maize flours is presented in Table 9. It was observed that viscosity of cooked slurries varied with concentration, varieties and also processing techniques. The cooked slurries of 10 per cent concentration were less viscous than those of 15 per cent slurries at all processing techniques and varieties. The cooked slurries of both malted and nixtamalized grains showed higher flow than the native grains of all varieties at both concentrations. Among the native samples cooked slurries (10%) of native

Table 7. Particle size of native and processed maize flours (%)

Variety	Type of flours	Particle size (μ)					
		500	**420**	**250**	**180**	**150**	**≤150**
QPM	Native	2.22	1.58	4.62	12.62	10.57	68.39
	Malted	7.47	1.77	4.04	13.24	14.74	58.70
	Nixtamalized	2.19	0.75	10.71	17.56	12.82	55.96
S.A. Tall	Native	2.41	1.99	18.85	13.24	16.46	47.05
	Malted	1.05	1.12	6.18	25.26	13.78	52.62
	Nixtamalized	1.12	1.68	5.17	25.67	15.20	51.16
DMH-2	Native	1.16	1.08	6.13	14.92	11.72	64.99
	Malted	1.17	0.97	7.75	13.26	12.35	64.49
	Nixtamalized	2.65	1.40	4.45	8.37	10.54	72.59

Table 8. Functional properties of maize flour

Parameter	Varieties	Native	Malted	Nixtamalized	Mean
Dispersibility (%)	QPM	71.00^{abc}	69.33^{cd}	69.67^{bcd}	70.00^{pq}
	SA Tall	65.67^{e}	69.00^{cd}	72.33^{a}	69.00^{q}
	DMH-2	68.70^{d}	71.67^{ab}	70.33^{abcd}	70.22^{p}
	Mean	68.44^{y}	70.00^{x}	70.78^{x}	69.74
Swelling power (%)	QPM	0.47^{ab}	0.44^{abc}	0.45^{abc}	0.45^{p}
	SA Tall	0.46^{ab}	0.49^{a}	0.41^{c}	0.45^{p}
	DMH-2	0.44^{abc}	0.43^{bc}	0.47^{ab}	0.44^{p}
	Mean	0.46^{x}	0.45^{x}	0.44^{x}	0.45
Solubility (%)	QPM	18.93^{b}	3.00^{de}	2.00^{e}	7.98^{q}
	SA Tall	20.93^{a}	3.40^{d}	2.40^{de}	8.91^{p}
	DMH-2	17.20^{c}	3.20^{de}	3.60^{d}	8.00^{q}
	Mean	19.02^{x}	3.20^{y}	2.67^{y}	8.30

Means followed by the same letter are not significantly different (P≤0.05) by DMRT
pqr – Variety means, abc – Interaction means, xyz – Processing means

Table 9. Viscosity of flour by line spread method

Varieties	10% slurry (cm)				15% slurry (cm)			
	Native	**Malted**	**Nixtamal**	**Mean**	**Native**	**Malted**	**Nixtamal**	**Mean**
QPM	4.97	5.03	5.20	5.07	4.10	4.53	4.40	4.34
SA Tall	4.87	5.50	5.46	5.28	4.20	4.57	4.60	4.46
DMH-2	4.63	5.30	4.67	4.87	4.17	4.93	4.47	4.52
Mean	4.83	5.28	5.10	5.07	4.16	4.68	4.49	4.44
Variable	S.Em±		CD (5%)		S.Em±		CD (5%)	
Variety (V)	0.21		NS		0.09		NS	
Processing (P)	0.22		NS		0.26		NS	
V x P	0.26		NS		0.14		NS	

QPM (4.97 cm) showed higher flow than SA Tall and DMH-2 (4.87 and 4.63 cm, respectively). Among the cooked slurries (10%) of the malted samples, flow was least in QPM (5.03 cm) as compared to SA Tall (5.50 cm) and DMH-2 (5.30 cm). Among the nixtamalized samples (10% slurries) highest flow was recorded in SA Tall (5.46 cm) followed by in QPM slurries (5.20 cm) and DMH-2 (4.67 cm) varieties. Similar trend was observed in 15 per cent paste slurries of all samples. Malted grains exhibited higher flow followed by nixtamalized samples and least in native flour slurries. However, these values were not significant statistically.

4.4 NUTRITIONAL QUALITY OF MAIZE

Several direct and indirect methods are employed in assessment of nutritional quality of food ingredients. In the present investigation the nutritional quality was assessed in terms of *in vitro* digestibility of starch and protein and indicated in Fig.1a and 1b (Appendix I and II). Starch digestibility was significantly influenced by variety and processing treatment. Significantly high starch digestibility was recorded in SA Tall grains (39.34%) followed by DMH-2 (37.79%) and QPM (36.35%). Highest starch digestibility was recorded in malted samples (38.60%) followed by the nixtamalized samples (37.86%) and lowest was observed in native grains (37.01%). Among the native samples SA Tall maize (38.33%) exhibited highest digestibility than DMH-2 (37.37%) and QPM (35.34%). Malting increased the starch digestibility of all the varieties significantly. Significantly high starch digestibility was observed in malted samples of SA Tall (40.48%) followed by malted DMH-2 (38.22%) and malted QPM (37.10%).

The process of nixtamalization influenced the starch digestibility. All the maize types showed significantly higher digestibility than the native counterparts except in DMH-2 samples where the values were not significant. Among the nixtamalized samples, SA Tall grains (39.21%) recorded highest digestibility followed by DMH-2 (37.76%) and lowest was in QPM

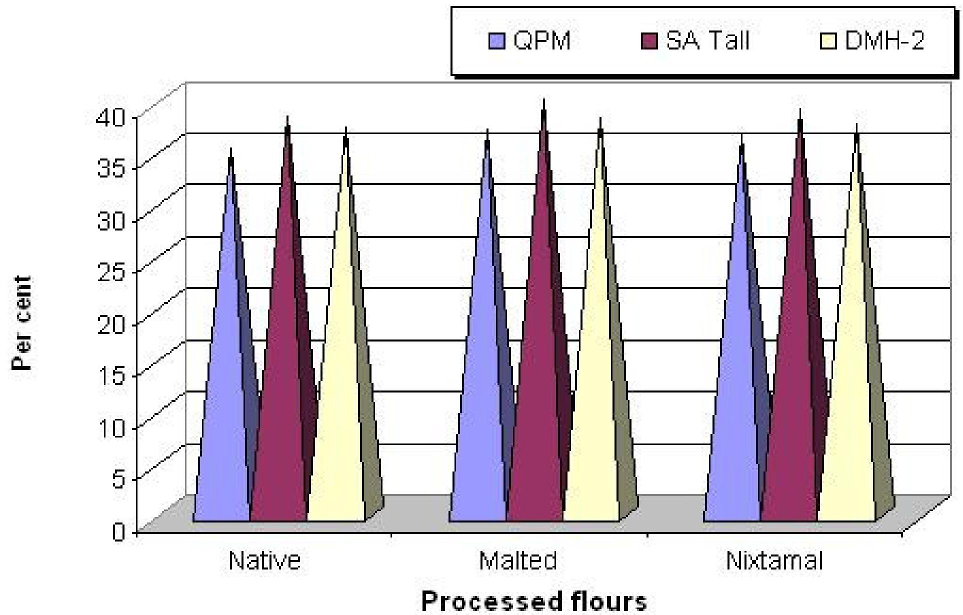

Fig. 1a. ***In vitro*** **starch digestibility (%) of maize flours**

Fig. 1a. In vitro starch digestibility (%) of maize flours

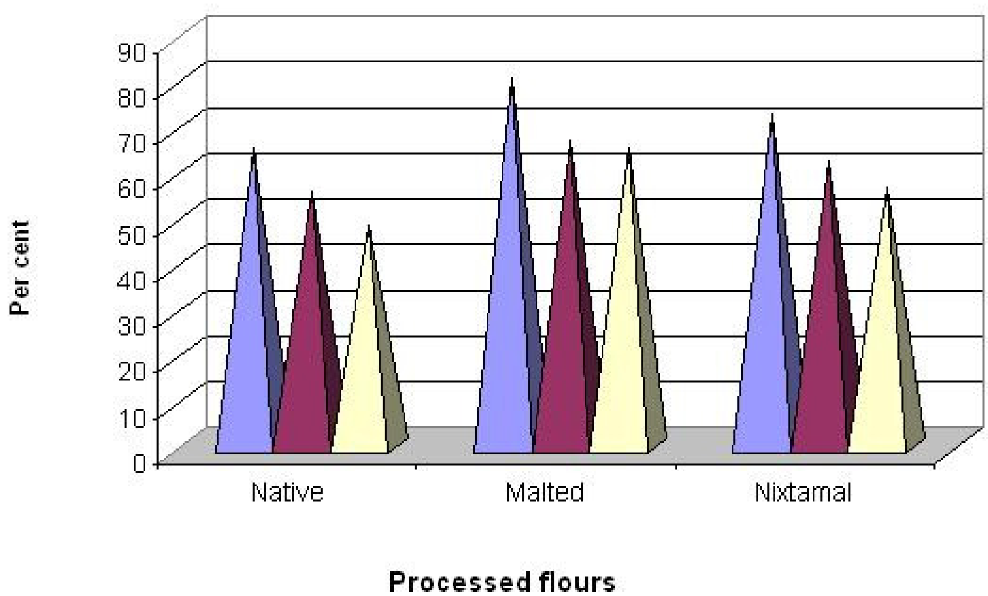

Fig. 1b. ***In vitro*** **protein digestibility (%) of maize flours**

Fig. 1b. In vitro protein digestibility (%) of maize flours

samples (36.60%). Thus, variation in starch digestibility among the varieties and treatments was observed.

In vitro protein digestibility of native, malted and nixtamalized maize is depicted in Fig. 1b (Appendix II). The results of the investigation revealed that *in vitro* protein digestibility was influenced by variety and processing treatments employed. It was observed that significantly high *in vitro* protein digestibility was recorded in QPM (72.83%) followed by SA Tall (61.61%) and DMH-2 (56.68%) samples. With regard to processing malting resulted in highest digestibility of protein (70.85%) followed by nixtamalization (63.83%). Lowest *in vitro* protein digestibility was recorded in native samples of maize, a mean of 56.44 per cent. Significantly high digestibility was recorded in QPM samples (65.29%) followed by SA Tall (55.81%) and least was in DMH-2 (48.23%). With regard to malted samples, QPM (72.64%) samples exhibited significantly high protein digestibility than SA Tall (62.34%) and DMH-2 (56.51%) samples. The process of nixtamalization also influenced the protein digestibility, positively. Nixtamalization increased the digestibility to 63.71 per cent from initial values of 56.44 per cent. The digestibility of nixtamalized samples of all the varieties was higher than respective native samples. Significantly high digestibility was recorded in QPM (72.83%) followed by SA Tall (61.61%) and lowest was in DMH-2 grains (63.71%).

Thus, nutritional quality of maize in terms of digestibility of starch and protein was influenced by variety and processing treatments.

4.5 VALUE ADDITION

A grain is said to be well exploited only when the grain potentials reach to the people in terms of either economic or nutritional benefits. Maize has good nutritional potentials to alleviate hunger and malnutrition of the people dependent on maize for food. The laboratory attempts to incorporate it in different products revealed encouraging results and are explained in the following paragraphs.

4.5.1 Malt beverage

Initial trials were conducted for the preparation of malt beverage (Appendix III) and evaluated organoleptically to standardize the product. Results of the initial experimentation are depicted in Table 10. Slurry concentration of 10 per cent was chosen as an ideal consistency for the malt beverage. Malt powder from bulk sample of seed was prepared and used for standardization of malt beverage. In the first attempt standardization trials were conducted for identifying quantities of sugar and garden cress seeds to be added. The organoleptic evaluation of the malt beverage by the semitrained judges indicated that the product needed improvement interms of appearance and consistency. The added garden cress seed sank to the bottom of the cooked gruel/malt beverage and the consistency was not approved. Hence, the garden cress seeds were powdered finely and incorporated in the malt beverage. However, cooked product was slimy and unacceptable. Hence, the panel suggested to incorporate the garden cress seeds in the form of coarse powder. Enhancement of sugar quantity was also taken case of and ultimately an acceptable malt beverage was developed with appropriate appeal, consistency, sweetness and overall acceptability.

4.5.2 Acceptability of maize malt beverages

Results of the organoleptic evaluation of maize malt beverages of each variety by semi-trained panel is depicted in Table 11. The malt beverages of QPM and SA Tall malts were creamy white and attractive, but the light yellow malt beverage of DMH-2 was highly appealing with highest scores for colour and appearance (7.50). Low scores of 6.70 and 6.90 were recorded by SA Tall and QPM malts, respectively. The consistency of DMH-2 (7.10) was highly acceptable. The consistency of QPM and SA Tall were moderately acceptable with scores of 6.50 and 6.60, respectively. The panel indicated high acceptability for taste, aroma and overall acceptability of DMH-2 malt beverage (7.3, 7.1 and 7.5, respectively). However, QPM malt beverage faired better (7.00 score for each attribute) than beverage of SA Tall (6.50, 6.70 and 6.70, respectively). However, the scores were not significant for any of the sensory quality parameters.

4.5.3 Nutrient composition of maize malt beverages

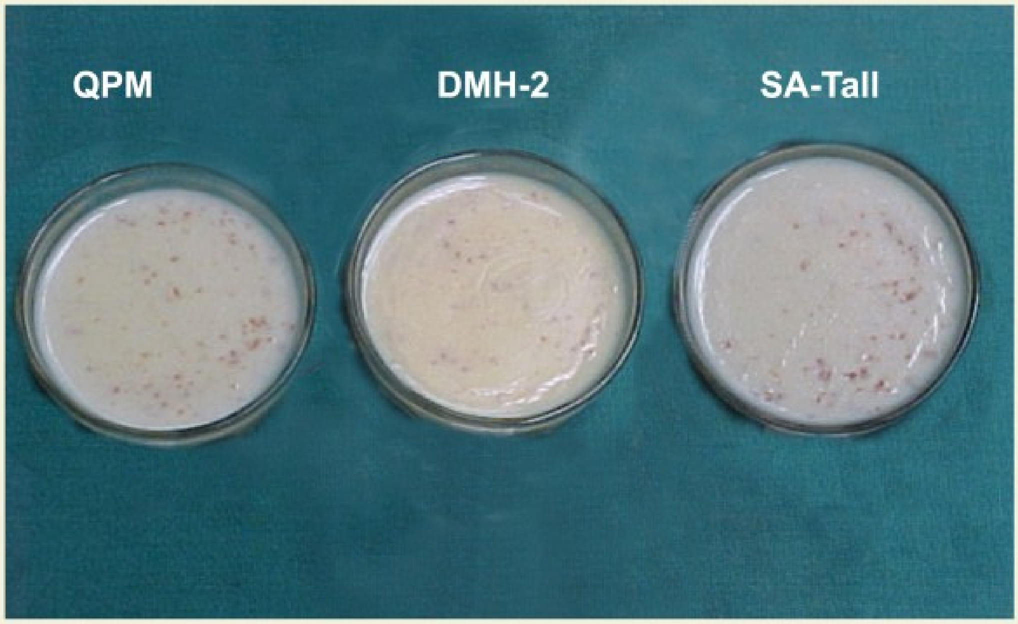

Plate 2. Malt beverage of three varieties

Plate 2. Malt beverage of three varieties

Computation of nutrients composition using analyzed values for maize varieties revealed variation in the different malts (Table 12). It was observed that protein and fat contents were higher in malt beverages of DMH-2 (7.13 and 7.72 g, respectively) followed by QPM and SA Tall malts (7.11 and 7.68 g and 6.93 and 7.33 g, respectively). Carbohydrate content was highest in malt beverage of SA Tall (49.03 g), followed by beverage of QPM (48.65 g) and DMH-2 (48.45 g). However, calorific value was found to be similar in malt beverage of QPM and DMH-2 (291 Kcal) and was higher than SA Tall malt beverage (289 Kcal). Similar trend was found in maize varieties with regard to total minerals content. It was observed that iron and copper content was highest in QPM based malt beverage (3.78 and 0.07 mg/100 g) followed by DMH-2 (3.74 and 0.05 mg/100 g) and SA Tall (3.53 and 0.02 mg/100 g) malt beverage. Similar values of manganese (0.023 mg/100 g) was observed in QPM and DMH-2 based malt beverage while, in malt beverage of SA Tall it was 0.02 mg/100 g. Zinc content was higher (0.25 mg/100 g) in DMH-2 based malt beverage than in malt beverage of QPM (0.18 mg/100 g) and least was observed in SA Tall based malt beverage (0.12 mg/100 g).

4.5.4 Acceptability of ribbon *murukku*

Results of the sensory evaluation of ribbon *murukku* of different varieties of maize incorporated at different levels (substituting for the total flour in the control sample) are depicted in Table 13. Scores for comparison of maize *murukku* with control samples is indicated in Table 14. It was observed that incorporation of maize influenced the sensory quality parameters in all the varieties.

It was observed that irrespective of levels of incorporation, DMH-2 *murukku* scored highest (7.13) for its colour and appearance. Moderately acceptable scores were recorded for *murukku* of QPM (6.06) and SA tall (5.16). Level wise, the ribbon *murukku* with 25 per cent maize incorporated showed significantly higher value (6.67) than 50 and per cent 75 per cent incorporation levels (6.34 and 5.87, respectively). Significantly low scores were recorded for *murukku* with complete substitution of flour with maize (100% maize *murukku*). While, at interaction levels, it was observed that DMH-2 scored significantly highest (7.63) in all varieties at all levels for colour and appearance. However, the least acceptability scores for colour and appearance were recorded in SA Tall *murukku* when the level of maize

Table 10. Sensory quality of maize based malt beverage in initial trials

Levels of incorporation(%)	Sensory quality
10:5:0.5 (Malt: Sugar: Garden cress seeds)	Creamy white beverage, but unequal distribution of garden cress seeds. Suggested to add the seed powder.
10:5:0.5 (Malt: Sugar: Fine powder of Garden cress seeds)	Light brown beverage, slimy, unacceptable consistency. Taste panel suggested powdering the garden cress seeds coarsely.
10:5:0.5 (Malt:: Sugar: Coarse powder of Garden cress seeds)	Light brown beverage, acceptable beverage consistency, suggested increasing the content of garden cress seed powder and sugar.
10:10:1 (Malt:: Sugar: Coarse powder of Garden cress seeds)	Light brown beverage, acceptable beverage consistency, suggested increasing the sugar and garden cress seed powder.
10:20:2 (Malt:: Sugar: Coarse powder of Garden cress seeds)	Light brown beverage, acceptable beverage consistency, sweet in taste, highly acceptable.

Table 11. Sensory quality scores for maize malt beverages of different varieties

Varieties	Colour and appearance	Consistency	Taste	Aroma	Overall acceptability
QPM	6.90	6.50	7.00	7.00	7.00
S.A.Tall	6.70	6.60	6.50	6.70	6.70
DMH-2	7.50	7.10	7.30	7.10	7.50
LSD	NS	NS	NS	NS	NS

Table 12. Computed nutrient composition of malt beverage per serving

Nutrient	QPM	S. A. Tall	DMH-2
Protein (g)	7.11	6.93	7.13
Fat (g)	7.68	7.33	7.72
Carbohydrate (g)	48.65	49.03	48.45
Calorific value (Kcal)	291	289	291
Total minerals (g)	1.60	1.60	1.60
Iron (mg)	3.78	3.53	3.64
Copper (mg)	0.07	0.02	0.05
Manganese (mg)	0.03	0.02	0.03
Zinc (mg)	0.18	0.12	0.25

One serving is equivalent to 150 ml
* Computed using analyzed values of maize

Table 13. Sensory quality scores for maize ribbon *murukku*

Parameter	Control	Incorporation levels (%)	QPM	SA Tall	DMH-2	Mean
Colour and appearance	7.75	25	6.88^{pq}	6.25^{pqr}	6.88^{pq}	6.67^{x}
		50	6.25^{pqr}	5.63^{qrs}	7.13^{pq}	6.34^{xy}
		75	6.13^{pqr}	4.63^{st}	6.88^{pq}	5.87^{xy}
		100	5.00^{rst}	4.13^{t}	7.63^{p}	5.58^{y}
		Mean	6.06^{b}	5.16^{c}	7.13^{a}	6.12
Texture	7.00	25	6.75^{p}	6.50^{p}	6.25^{p}	6.50^{x}
		50	6.00^{p}	5.88^{p}	6.50^{p}	6.13^{x}
		75	6.63^{p}	7.00^{p}	7.25^{p}	6.96^{x}
		100	6.00^{p}	6.88^{p}	7.13^{p}	6.67^{x}
		Mean	6.34^{a}	6.58^{a}	6.13^{a}	6.57
Taste	6.75	25	6.63^{p}	6.13^{p}	6.13^{p}	6.30^{x}
		50	6.50^{p}	6.13^{p}	6.38^{p}	6.34^{x}
		75	6.75^{p}	6.63^{p}	7.13^{p}	6.84^{x}
		100	6.25^{p}	6.50^{p}	6.88^{p}	6.54^{x}
		Mean	6.53^{a}	6.34^{a}	6.63^{a}	6.51
Aroma	6.63	25	6.50^{p}	6.38^{p}	6.75^{p}	6.54^{x}
		50	6.38^{p}	6.25^{p}	6.63^{p}	6.42^{x}
		75	6.54^{p}	6.00^{p}	6.63^{p}	6.37^{x}
		100	5.63^{p}	5.75^{p}	6.38^{p}	5.92^{x}
		Mean	6.25^{a}	6.10^{a}	6.68^{a}	6.34
Overall acceptability	7.25	25	6.75^{p}	6.25^{p}	6.75^{p}	6.58^{x}
		50	6.13^{p}	5.88^{p}	6.75^{p}	6.25^{x}
		75	6.75^{p}	6.38^{p}	7.38^{p}	6.84^{x}
		100	6.13^{p}	6.38^{p}	7.00^{p}	6.50^{x}
		Mean	6.43^{ab}	6.22^{b}	6.97^{a}	6.54

Means followed by the same letter are not significantly different ($P \leq 0.05$) by DMRT
abc- Variety means, pqr-Interaction means, xyz- Level means

C -Control   a - 25%
1 - QPM   b - 50%
2 - SA Tall   c - 75%
3 - DMH-2   d - 100%

Plate 3. Ribbon *murukku* of different varieties

Plate 3. Ribbon murukku of different varieties

Table 14. Paired t-test values for sensory quality of maize incorporated ribbon m*urukku* as compared to control

Parameter	Control means	Varieties	Levels of incorporation			
			25	50	75	100
Colour and appearance	7.75	QPM	2.49* (6.88)	3.97** (6.25)	6.17** (4.62)	11.00** (4.12)
		SA Tall	3.96** (6.25)	5.35** (5.87)	13.79** (4.62)	11.19** (4.12)
		DMH-2	NS (6.80)	NS (7.12)	7.00** (6.87)	NS (7.62)
Texture	7.00	QPM	NS (6.75)	2.64* (6.00)	NS (6.25)	NS (6.00)
		SA Tall	NS (6.50)	2.82 (5.87)	NS (7.00)	NS (6.80)
		DMH-2	NS (6.25)	NS (6.50)	NS (7.25)	NS (7.12)
Taste	6.75	QPM	NS (6.62)	NS (6.50)	NS (6.75)	NS (6.25)
		SA Tall	NS (6.00)	NS (6.12)	NS (6.62)	NS (6.50)
		DMH-2	NS (6.12)	NS (6.37)	NS (7.12)	NS (6.87)
Aroma	6.62	QPM	NS (6.50)	NS (6.37)	NS (6.50)	NS (5.62)
		SA Tall	NS (6.38)	NS (6.25)	NS (6.00)	NS (5.75)
		DMH-2	NS (6.75)	NS (6.62)	NS (6.62)	NS (6.37)
Overall acceptability	7.25	QPM	NS (6.75)	NS (6.12)	2.82* (6.42)	2.82* (6.12)
		SA Tall	3.74** (6.25)	4.24** (5.87)	NS (6.37)	NS (6.37)
		DMH-2	NS (6.75)	NS (6.75)	NS (7.37)	NS (7.00)

*Significant at 5%, ** Significant at 1%, NS Non-significant
Figures in parentheses indicate level means

incorporation exceeded 50 per cent. A comparison of maize incorporated *murukku* (at different levels) was made with control sample, it was evident that maize incorporation influenced the colour and appearance of *murukku* adversely in all the samples except in DMH-2 *murukkus* of 25, 50 and 100 per cent incorporation levels (Table 14). Both the white maize samples QPM and SA Tall were scored lower than control samples at all levels and was highly significant.

With regard textural properties, the maize *murukku* exhibited light and crisp characteristics which were acceptable by the taste panel (Table 13). It was observed that all the varieties were on par with each other and score ranged from 6.13 to 6.58. Regarding level of incorporation all the ribbon *murukku* scored similar values which ranged from 6.13 to 6.96. It was observed that 75 per cent incorporation had shown numerically higher values (6.96) than the other levels. At interaction levels, the varieties possessed similar scores but, with exception of 75 per cent incorporated DMH-2 *murukku* which recorded numerically higher value (7.25) than 50 per cent incorporated ribbon *murukku* (5.88).

Comparison of maize incorporated ribbon *murukku* with control samples revealed no significant differences in textural characteristics of all the varieties at all levels of maize incorporation except in 50 per cent maize incorporated QPM ribbon *murukku* (Table 14).

Ribbon *murukku* prepared with the three varieties were acceptable for taste with similar scores ranging from 6.34 to 6.63 (Table 13). Similar observations were also made for *murukku* prepared with maize at different incorporation levels, where in the scores were on par with each other with a mean of 6.51. Organoleptic evaluation revealed that *murukku* with 75 per cent maize incorporation showed higher value of 7.13 than 100 per cent incorporation level (6.88). It was noticed that ribbon *murukku* of SA Tall at 25 and 50 per cent levels of incorporation and DMH-2 at 25 per cent incorporation scored lowest scores of 6.13. Comparison of maize incorporated ribbon *murukku* with control samples indicated that the taste were not significantly different as revealed by paired t-test (Table 14). This was evident in all the varieties and at all levels of incorporation.

Regarding aroma of the maize ribbon *murukku* all the three varieties showed a similar score of 6.34 (Table 13). However, numerically, 25 per cent incorporation murukku scored higher (6.54) than by 50 per cent incorporated samples (6.42). Lowest score (5.92) was recorded in 100 per cent maize incorporated *murukku*. The *murukku* of DMH-2 at 25 per cent incorporation level scored highest (6.75) for aroma. Lowest score (5.75) was observed in *murukku* of SA Tall at 100 per cent level of incorporation, this was followed by QPM *murukku* at 100 per cent level of incorporation (5.63).

When maize incorporated ribbon *murukku* were compared with control sample it was indicated that aroma of *murukku* were as acceptable as control sample. Although the aroma scores decreased at 100 per cent of incorporation, the scores were not significantly different (Table 14).

The overall acceptability of ribbon *murukku* prepared by three varieties of maize revealed significant differences in overall acceptability. The taste panel rated DMH-2 (6.97) *murukku* to be better than QPM (6.43) and SA Tall *murukkus* (6.22). It was also observed that incorporation of maize at different levels did not influence the overall acceptability of *murukku* of all the varieties. Among the interaction levels, the ribbon *murukku* of DMH-2 were highly acceptable at 75 and 100 per cent levels of incorporation (7.38 and 7.00, respectively). Further, it was also noticed that the ribbon *murukku* prepared with SA Tall at 50 per cent incorporation level scored lowest for overall acceptability. Comparison of maize incorporated ribbon *murukku* with control samples influenced the overall acceptability of SA Tall and QPM based ribbon *murukku* at 25, 50 and 75, 100 per cent levels, respectively. However, rest of the incorporation levels were on par with control of all the three varieties.

4.5.5 Nutrient composition of maize ribbon *murukku*

Nutrient composition of maize incorporated ribbon *murukku* is depicted in table 15. The incorporation of maize substituting bengalgram and rice flour influenced the nutrient composition of ribbon *murukku* of all genotypes. It was observed that protein, total minerals, copper, manganese and zinc contents decreased as the level of maize incorporation increased from 25 to 100 per cent. Lowest reduction was observed in the *murukkus* containing relatively higher proportion of bengalgram and rice flour. However, carbohydrate

Table 15. Nutrient composition maize ribbon *murukku*/serving*

Nutrients		Protein (g)	Fat (g)	Carbo hydrate (g)	Total minerals (mg)	Iron (mg)	Copper (mg)	Manga nese (mg)	Zinc (mg)	Calorific value (Kcal)
Control		3.36	2.85	17.45	0.57	0.89	0.21	0.27	1.21	109
Varieties	Level of incor poration									
QPM	25%	3.19	2.97	17.87	0.52	0.88	0.19	0.17	0.71	111
	50%	3.03	3.08	18.15	0.46	0.85	0.17	0.13	0.60	113
	75%	2.86	3.21	18.52	0.41	0.84	0.16	0.10	0.50	114
	100%	2.70	3.34	18.94	0.34	0.82	0.13	0.06	0.40	116
SA Tall	25%	3.11	2.82	18.00	0.52	0.77	0.18	0.17	0.68	110
	50%	2.87	2.79	18.37	0.45	0.64	0.13	0.13	0.55	111
	75%	2.76	2.76	19.00	0.40	0.52	0.10	0.09	0.41	112
	100%	2.38	2.74	19.58	0.34	0.40	0.05	0.05	0.27	113
DMH-2	25%	3.20	2.98	17.79	0.52	0.82	0.19	0.17	1.47	111
	50%	3.05	3.12	18.13	0.46	0.74	0.16	0.14	1.29	113
	75%	2.88	3.25	18.27	0.41	0.66	0.13	0.10	1.13	114
	100%	2.73	3.40	18.61	0.34	0.58	0.10	0.06	0.96	116

* 1 serving ≈ 40 g
- Computed using analysed values of varieties

Table 16. Sensory quality scores for maize *laddu*

Parameter	Control	Incorporation levels (%)	QPM	SA Tall	DMH-2	Mean
Colour and appearance	6.63	25	7.63^{pq}	7.50^{pq}	6.13^{pq}	7.08^{x}
		50	7.88^{p}	7.00^{pq}	5.63^{q}	6.84^{x}
		75	6.38^{pq}	7.50^{pq}	6.88^{pq}	6.92^{x}
		100	5.88^{pq}	6.38^{pq}	6.88^{pq}	6.37^{x}
		Mean	6.94^{a}	7.09^{a}	6.37^{a}	6.80
Texture	6.63	25	7.38^{pq}	7.13^{pq}	4.87^{r}	6.45^{x}
		50	7.63^{p}	6.88^{pqr}	5.25^{qr}	6.58^{x}
		75	6.13^{pqr}	7.63^{p}	6.38^{pqr}	6.71^{x}
		100	5.50^{pqr}	7.00^{pqr}	6.25^{pqr}	6.25^{x}
		Mean	6.65^{a}	7.16^{a}	5.69^{b}	6.50
Taste	7.00	25	7.50^{p}	7.25^{p}	6.63^{p}	7.13^{x}
		50	7.38^{p}	7.13^{p}	6.38^{p}	6.96^{x}
		75	4.25^{q}	7.88^{p}	6.75^{p}	6.30^{x}
		100	4.38^{q}	7.13^{p}	6.75^{p}	6.08^{x}
		Mean	5.87^{b}	7.34^{a}	6.63^{ab}	6.62
Aroma	6.63	25	7.37^{p}	6.88^{pq}	6.50^{pq}	6.92^{x}
		50	7.25^{p}	6.88^{pq}	6.00^{pqr}	6.71^{x}
		75	4.25^{r}	7.38^{p}	6.50^{pq}	6.04^{x}
		100	4.75^{qr}	6.88^{pq}	6.63^{pq}	6.08^{x}
		Mean	5.91^{b}	7.00^{a}	6.41^{ab}	6.44
Overall acceptability	6.88	25	7.75^{p}	7.38^{p}	6.00^{pqr}	7.04^{x}
		50	7.50^{p}	7.00^{p}	6.00^{pqr}	6.84^{x}
		75	4.23^{r}	7.63^{p}	6.38^{qr}	6.08^{x}
		100	4.75^{qr}	7.00^{p}	6.38^{pq}	6.04^{x}
		Mean	6.06^{b}	7.25^{a}	6.19^{b}	6.50

Means followed by the same letter are not significantly different ($P \leq 0.05$) by DMRT
abc- Variety means, pqr-Interaction means, xyz- Level means

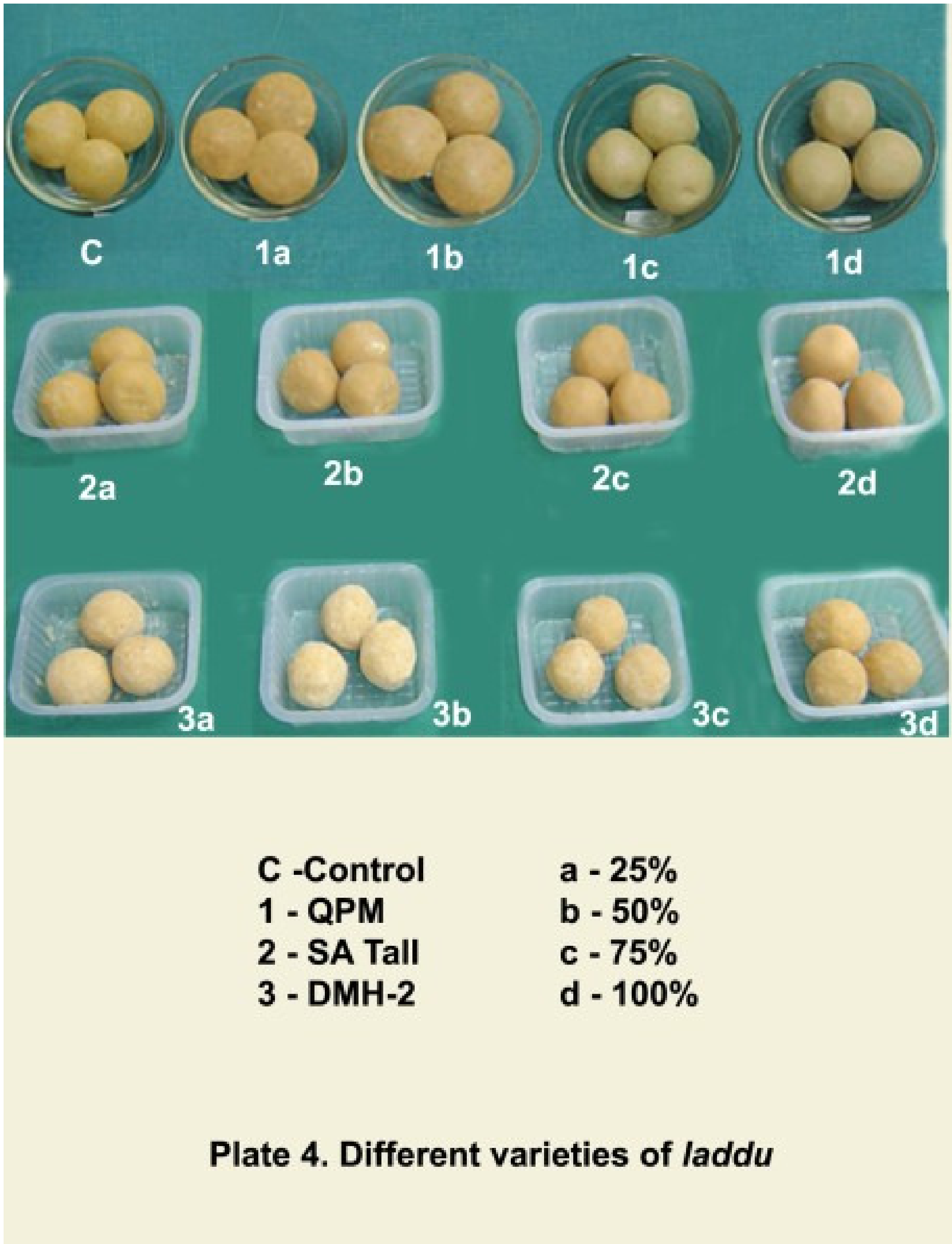

Plate 4. Different varieties of laddu

content of maize incorporated *murukkus* increased slightly with level of incorporation. Not much variation in calorific value and iron content was observed in all the maize *murukku* as compared to control samples. This trend was observed in all the genotypes and levels of incorporation.

4.5.6 Acceptability of maize *laddu*

Acceptability scores for different varieties of maize incorporated *laddus* at different levels are depicted in Table 16. The results indicated that the acceptability of maize incorporated *laddus* was as good as control *laddus* prepared with 100 per cent bengalgram dhal flour. It was observed that sensory quality parameters of *laddus* of all maize varieties was not much influenced by the incorporation of maize. With regard to colour and appearance, irrespective of levels of incorporation, the maize incorporated *laddus* scored similar range of values ranging between 6.37 to. 7.08. It was also observed that *laddu* of all the three varieties showed similar range of scores from 6.37 to 7.09, while, at interaction levels, it was observed that QPM scored significantly highest (7.88) in all varieties at 50 per cent incorporation levels. However, the least acceptability scores for colour and appearance were recorded in DMH-2 based *laddu* when the level of maize incorporation was 50 per cent. Comparison of maize incorporated *laddu* (at different levels) with control sample depicted that maize incorporation did not influence the colour and appearance of laddu except in SA Tall based *laddu* at 25 per cent incorporation levels (Table 16). All the maize varieties at all the incorporation levels were on par with control.

In case of texture, the maize *laddus* were soft and pliable and were acceptable by the taste panel (Table 16). It was observed that all the varieties except DMH-2 (5.69) were on par with each other and score ranged from 6.65 to 7.16. Regarding level of incorporation all the *laddus* scored similar values which ranged from 6.25 to 6.71. At interaction levels, the varieties QPM at 50 per cent and SA Tall at 75 per cent possessed significantly higher score (7.63) than the other interaction levels. It was observed that DMH-2, *laddu* incorporated at 25 per cent showed least score (4.87) and was fairly acceptable.

Comparison of maize incorporated laddu with control samples revealed no significant differences in textural characteristics of QPM variety at all levels of maize incorporation except in 25 per cent maize incorporated SA Tall and DMH-2 *laddu* (Table 17).

Taste is an important sensory quality influencing acceptability. In the present experimentation, it was observed that the incorporation maize flours in the bengalgram dhal based laddus, affected the taste adversely in QPM based *laddus* adversely (Table 16). It was observed that SA Tall incorporated *laddus* scored highest (7.34) for taste followed by DMH-2 *laddus* (6.63) and least was observed in QPM (5.87) incorporated *laddus*. However, levels of maize incorporation did not influence the taste parameters. The scores for *laddu* were on par with control *laddus* ranging from 6.08 to 7.13. At interaction levels, the *laddus* of all the varieties and at all level of incorporation levels showed similar taste scores but at 75 and 100 per cent incorporation levels, where in the scores were significantly low in QPM variety (Table 17).

Regarding aroma of the maize *laddu*, significant differences were observed among the varieties (Table 16). It was observed that SA Tall *laddus* scored higher for aroma (7.00) than DMH-2 (6.41) and least by QPM (5.91). However, level wise no significant difference was observed in all varieties of maize. At interaction level, QPM and SA Tall based *laddus* at 25, 50 and 75 per cent incorporation levels showed significantly higher scores (7.37, 7.25 and 7.38, respectively) and were on par with control. However, in contrast, *laddus* with QPM (75 and 100%) scored least (4.25 and 4.75) and were fairly acceptable.

When maize incorporated *laddu* were compared with control samples for aroma it was indicated that all *laddus* were as acceptable as control samples, except for QPM *laddus* of 75 and 100 per cent incorporation levels and the scores were significantly low (Table 17).

The overall acceptability of *laddu* prepared by three varieties of maize revealed significant differences (Table 16). The taste panel rated SA Tall (7.25) *laddu* to be better than DMH-2 and QPM (6.19 and 6.06, respectively). It was also observed that incorporation of maize at different levels did not influence the overall acceptability of *laddu* of all the varieties. Among the interaction levels, the *laddu* of SA Tall were highly acceptable at all the levels of incorporation. However, QPM *laddus* with 25 and 50 per cent incorporation were on par with

Table 17. Paired t-test values for sensory quality of maize incorporated *laddu* as compared to control

Parameter	Control means	Varieties	Levels of incorporation			
			25	50	75	100
Colour and appearance	6.63	QPM	NS (7.63)	NS (7.50)	NS (6.38)	NS (5.88)
		SA Tall	3.86** (7.50)	NS (6.88)	NS (7.50)	NS (6.38)
		DMH-2	NS (6.13)	NS (5.63)	NS (6.88)	NS (6.88)
Texture	6.63	QPM	NS (7.38)	NS (7.63)	NS (6.13)	NS (6.63)
		SA Tall	2.65* (7.13)	NS (6.88)	NS (7.63)	NS (7.00)
		DMH-2	3.86** (4.88)	NS (5.25)	NS (6.38)	NS (1.25)
Taste	7.00	QPM	NS (7.50)	NS (7.13)	4.44** (4.25)	3.19** (4.38)
		SA Tall	NS (7.25)	NS (7.13)	NS (7.87)	NS (7.12)
		DMH-2	NS (6.63)	NS (6.38)	NS (6.75)	NS (7.00)
Aroma	6.62	QPM	NS (7.37)	NS (7.25)	3.68** (4.25)	2.93* (4.75)
		SA Tall	NS (6.87)	NS (6.87)	NS (7.37)	NS (6.87)
		DMH-2	NS (6.50)	NS (6.00)	NS (6.50)	NS (6.62)
Overall acceptability	6.87	QPM	NS (7.75)	NS (7.50)	5.27** (4.25)	3.18** (4.75)
		SA Tall	NS (7.37)	NS (7.00)	NS (7.62)	NS (7.00)
		DMH-2	NS (6.00)	NS (6.00)	NS (6.37)	NS (6.37)

*Significant at 5%, ** Significant at 1%, NS Non-significant
Figures in parentheses indicate level means

Table 18. Nutrient composition maize *laddu*/serving*

Nutrients		Protein (g)	Fat (g)	Carbo hydrate (g)	Total minerals (mg)	Iron (mg)	Copper (mg)	Manga nese (mg)	Zinc (mg)	Calorific value (Kcal)
Control		3.44	17.73	35.37	0.62	0.96	0.24	0.24	1.22	315
Varieties	Level of incor poration									
QPM	25%	3.10	17.73	36.08	0.05	0.87	0.20	0.19	0.98	316
	50%	2.75	17.73	36.77	0.12	0.78	0.16	0.14	0.73	317
	75%	2.40	17.73	37.48	0.17	0.69	0.15	0.09	0.50	319
	100%	2.05	17.72	38.18	0.23	0.61	0.09	0.03	0.24	320
SA Tall	25%	3.04	17.61	36.20	0.53	0.79	0.18	0.19	0.96	315
	50%	2.62	17.49	37.03	0.44	0.61	0.13	0.13	0.69	316
	75%	2.22	17.37	37.86	0.34	0.44	0.08	0.08	0.43	317
	100%	1.51	17.25	38.69	0.25	0.27	0.03	0.03	0.17	317
DMH-2	25%	3.10	17.98	36.01	0.53	0.82	0.19	0.19	1.00	316
	50%	2.76	18.22	36.65	0.44	0.69	0.15	0.14	0.78	317
	75%	2.42	18.48	37.28	0.35	0.55	0.11	0.09	0.55	319
	100%	2.08	18.72	37.91	0.26	0.42	0.07	0.04	0.33	320

* 1 serving is 2 *laddus* (≈ 30 g each)
- Computed using analysed values of varieties

SA Tall *laddus*. It was also noticed that the *laddu* prepared with QPM at 75 per cent incorporation level scored lowest for overall acceptability. However, the incorporation of maize at various levels did not influence the overall acceptability of *laddus*, but of QPM incorporated *laddus* at 75 and 100 per cent levels, the overall acceptability was significantly low.

4.5.7 Nutrient composition of maize based *laddu*

Computation of nutrient composition of maize incorporated *laddu* is shown in Table 18. It was observed that incorporation of maize at different level influenced the nutrient composition of three varieties of maize *laddu*. Major changes were observed in protein, total minerals and micro-mineral contents, which decreased as the level of maize incorporation increased from 25 to 100 per cent. However, incorporation of maize flour at 25 per cent showed lower reduction than the other incorporation levels. Carbohydrate content increased with the increase in incorporation level of maize in all the varieties. There was not much variation in fat and carbohydrate content in all the varieties of *laddus* at all the levels as compared to control.

V. DISCUSSION

Maize is a large seeded cereal belonging to the family of poaceae. It is the staple food of millions of people inhabitating in the tropical region and is one of the important cereal grains nourishing the people. The protein quality of maize is poor because of the deficiency of essential amino acids lysine and tryptophan. Several attempts have been made by scientists engaged in maize research to improve the protein quality of maize and its nutrient availability. Quality protein maize (QPM) is one such maize resulted out of research endeavours, which fulfills the requirement of protein in terms of quantity and quality. The present investigation was undertaken to know the physical, functional and nutritional characteristics and utilization potentials of quality protein maize. The results of the study are discussed hereunder.

5.1 PHYSICAL AND FUNCTIONAL PROPERTIES OF MAIZE

Physical characteristics indicate relative excellence of a grain based on sensory estimates of colour, appearance, size, weight, volume and density. These attributes determine consumer acceptability and marketability. Preliminary acceptance or rejection of a food/grain usually is based on the physical characteristics such as colour, appearance, size *etc.* In the present investigation variation in physical parameters was observed. The grains of QPM and SA Tall were ivory cream in colour and can be a major criteria influencing acceptability in the form of foods. In India maize is used in various foods in many ways. The flour and semolina of maize find various food applications in cuisine of Karnataka also. White coloured maize of QPM and also local variety SA Tall could best fit in preparation of roties which are patted thin slightly thicker than *papads*. Sorghum is commonly used for roti preparation and white varieties find suitable substitutes for this. Further, the fine semolina of white grain varieties find suitable substitutes for this. Further, the fine semolina of white grain varieties find suitable applications in preparation of traditional gruels, porridges, *idli* etc. Further, the white coloured grain can also be used in other food preparations enhancing the colour with other food ingredients such as turmeric, chilli powder, etc.

Variation in size of the grain, weight, volume and density was evident among the selected varieties and QPM. These variations in physical characteristics may be due to genetic endowment. The QPM grains were big and denser than SA Tall and DMH-2. Large seed size of QPM grains was also reported by Szaniel *et al.* (1984), Sproule *et al.* (1988), Lopes and Larkins (1991), Martinez *et al.* (1996), Moro *et al.* (1996) and Gibbon *et al.* (2003).

5.1.1 Hydration and cooking characteristics

Good hydration usually indicates good cooking quality in terms of reduced cooking time and better cook ability. Although cooking of whole maize grains finds limited application in Indian cuisine, elsewhere whole grains are soaked, boiled/nixtamalized and/or fermented to prepare traditional foods (Ahenkora *et al*., 1999).

In the present investigation the QPM and local varieties exhibited variations in hydration and cooking characteristics. Significantly higher hydration capacity of 184.70 g/1000 grains was exhibited by QPM grains, which might be due to the structure of grain components or due to the relative thickness of pericarp. This higher hydration capacity may also due to the higher starch content of the seeds (Table 2). Accordingly, higher hydration index was recorded in QPM (63.37) than in SA Tall (49.55). However, the former was on par with DMH-2 (65.50).

QPM grains exhibited highest increase in weight after cooking (83.10%) which might be due to its highest hydration capacity. Similar trend was observed in the grains of DMH-2 also. Further, the increase in volume after cooking was highest in QPM seeds which could be due to the high hydration and swelling capacities. The variations in physical characteristics and hydration properties influenced the cooking characteristics also (Table 4). QPM exhibited good cooking quality with cooked seeds attaining complete doneness, accompanied by change in colour from white to yellow after cooking. Similar cooking quality was exhibited by DMH-2 grains. However, the cooking quality of SA Tall grains was poor even after pressure cooking at 15 lbs psi for 30 minutes. The pericarp of the grains though ruptured, the grains required even further cooking to attain doneness. Even though the grains of SA Tall were relatively smaller in size than QPM grains, the cooking time of 30 minutes was not sufficient enough to render the grains soft. This might due to the compactness of grain components and also thickness of pericarp.

5.1.2 Germination

Germination is a traditional food processing technique employed in India and abroad. Traditionally cereals and millets are germinated for the preparation of malt in breweries and also as a malt food for infants and others. Malting renders the carbohydrates and proteins more digestible apart from improving organoleptic characteristics. In the present investigation, it was observed that germination was very poor in all the varieties of maize. Only the grains of DMH-2 exhibited a germination capacity of more than 50 per cent, where in about 27 per cent grains did not germinate. About 20 per cent grains germinated only partially. Lowest germination was observed in QPM grains where in about 99 per cent of grains did not germinate in all the replication. Grains of another local variety SA Tall exhibited a moderate germination of 30 per cent, with an equal proportion grains partially germinated. However, 40 per cent grains remained ungerminated. Although the process of germination was carried out in controlled atmospheres, the grains of these two varieties (QPM and SA Tall) failed to germinate, which might be due to the inherent germination potential of grains.

With regard to recovery of malt highest recovery was observed in QPM (77.60%) followed by DMH-2 (66.40%) and SA Tall (55.40%). However, technically the flour obtained from the grains subjected to soaking, incubation for germination, dehydration, devegetation and roasting, milling and sifting of QPM seeds may not be termed as malt, because of germination failure of grain. However, the term malt is used keeping in mind the uniform treatment given to all the varieties studied. The malt obtained from DMH-2 was highest though loss due to devegetation is expected. Lower yield in SA Tall might be due to the thickness of pericarp of the seed which is removed by sifting. The malt flour thus, obtained from the three varieties exhibited inherent colour of the respective grains (creamy white in QPM and SA Tall and yellow in DMH-2) and emitted pleasant characteristic aroma of malted flours.

5.1.3 Popping

Snacks of popped maize are popular among all the strata of society. Several varieties specially meant for the preparation of popped snacks are released. An exploration of popping potentials of the three maize varieties was studied in the investigation, with an objective of development of value added foods based on popped grains. However, in the present investigation it was observed that both traditional and microwave popping techniques were not suitable to pop the grains (Table 6). The compactness of the endosperm components or the thickness of the pericarp or genetic endowment might have attributed to the failure of popping in all the three maize varieties. The blanching treatments brought about a slight expansion of the endosperm, but failed to burst the endosperm to yield pop corn.

5.1.4 Functional properties of flour

The properties such as particle size, dispersability, swelling power, solubility and viscosity play an important role in product development.

5.1.4.1 Particle size

Particle size of flours is an important determinant of product quality in terms of texture, viscosity and dough handling properties. It was observed that all the samples of native, malted and nixtamalized grain flours of the three varieties showed more than almost 98 per cent flour fractions smaller than 500 μ size, except the malted samples of QPM where in only about 83 per cent flour fraction were smaller than 500 μ size (Table 7). The proportion of flour particles of less than 150 μ size was highest in native grains (68.39%) among the QPM samples, malted (52.62%) among the SA Tall samples and highest in nixtamalized samples (72.59%) of DMH-2. These variations may be attributed to the grain components, grain structure, pericarp thickness, varietal differences or due to processing techniques employed (Kikafunda *et al.* 1997; Houssour and Ayernor, 2002; Wang *et al.*, 2005).

5.1.4.2 Dispersability, swelling power and solubility

The property of dispersability determines the tendency of flour to move apart from water molecule and shows its hydrophobic interaction. With regard to dispersability of processed flours, the flour samples of malted and nixtamalized grains of all the varieties showed significantly higher dispersability than the native grains, which might be due to the roasting, malting or nixtamalization treatments affecting the dispersability of flour particles in aqueous solution. In the present investigation the swelling power of flour particles was not influenced by variety and processing treatment. However, the solubility of native flours of all the varieties significantly higher than the processed counterparts. This might be due to changes in grain components during roasting treatment important to germinated (malted) and nxitamalized grain resulting in denutration of proteins dextrinization or conversion of starch granules due to retrogradation variety wise. SA Tall exhibited higher solubility than the other two varieties. However, the results were non-significant. Okaka and Potter (1979) reported that water absorption of maize is influenced by processing methods affecting starch gelatinization and swelling power. However, in the present investigation the same tendency was observed but it was not significant.

5.1.4.3 Viscosity

Viscosity is a property of flour to resist in their free flow. It was observed that viscosity of malted and nixtamalized flour was reduced and the slurry was free following (Table 9). This might be due to the enzyme activity which accelerate in the initial period of cooking and culminate into a higher hydrolysis of starch (Moulishwar *et al.*, 1993). Thus, it is beneficial process qualitatively and also quantitatively via increasing the concentration of flour and the porirdges/beverages.

5.2 NUTRIENT COMPOSITION AND NUTRITIONAL QUALITY OF MAIZE

A wide range of nutrients perform various functions in the body. Most foods contain almost all the nutrients in various proportions whereas some foods are rich either or deficient in specific nutrients. The grain components not only determine shelf-life and nutritional quality but also determine end uses in development of designer foods for specific target groups.

Grain moisture, is an important determinant of its shelf life. Low moisture content helps in enhancing the storage of food grains at ambient. In the present study, the moisture content of the maize varieties varied from 6.92 to 8.27 per cent (Table 2) which is similar to most of the cereals and millets.

Protein, being an essential growth promoting factor, is present in fairly high amount of 8.90 to 10.29 per cent. Several investigators have reported a similar range of protein in QPM (Sproule *et al.*, 1988; Bressani *et al.*, 1990; Graham *et al.*, 1990; Ahenkora *et al.*, 1995 and Martinez *et al.*, 1996).

The crude fat content ranged from 2.92 to 5.53 per cent in QPM and other varieties (Table 5). Similar values were also reported by (Sproule *et al.*, 1988; Bressani *et al.*, 1990; Graham *et al.*, 1990 and Ahenkora *et al.*, 1995). It is important to note that higher fat content may pose a problem in shelf life of milled grains resulting in auto-oxidation and rancid flavour. The crude fibre content ranged 1.30 to 1.50 per cent. Similar range of 1.93 to 2.14 was reported in the literature (Sproule *et al.*, 1988; Graham *et al.*, 1990; Ahenkora *et al.*, 1995 and Osei *et al.*, 1999).

Carbohydrates are a class of energy yielding substances which also influence utilization. About 73 to 77 per cent of total carbohydrate was recorded in maize with a similar range as reported by Sproule *et al.* (1988), Graham *et al.* (1990) and Ahenkora *et al.* (1995). Starch content of maize varieties ranged from 65 to 66 per cent.

The QPM was found to be a good source of minerals like iron and copper (2.85 and 0.33 mg/100 g, respectively) (Table 2). Thus, the high nutritional potential of QPM is further enhanced by higher amounts of the vital minerals which play significant role in human health. Iron helps in the formation of haemoglobin and plays an important role in the transport of oxygen. Hence, products made out of QPM could fulfill the requirement of iron with sufficient copper content which helps in iron absorption.

Manganese is established as an essential element as it participates in a number of reactions as a component of metalo enzyme. In the present investigation, manganese content was found to be high in DMH-2 followed by QPM, also the zinc content was higher in DMH-2 which acts as an cofactor for a number of metabolic reaction. Thus, QPM compares well with other two varieties.

5.2.1 Nutritional quality

Nutritional quality of food is one of the important factors determining the utilization potential of foods. Evaluation of nutritional quality helps in the development of designer foods for specific end uses. In the present investigation nutritional quality of maize samples was assessed in terms of digestibility of starch and protein. Results of the experimentation indicated variation in starch and protein digestibilities among the varieties and processing treatments (Fig. 1a and 1b; Appendix I and II).

The starch digestibility was highest in native grains of SA Tall (38.33%) and lowest in native samples of QPM (35.34%). However, higher *in vitro* starch digestibility values (63% after 2 hour digestion period) have been reported for market samples of maize by Moulishwar *et al.* (1993). In the present investigation malting increased the starch digestibility marginally to 38.60 per cent (from an initial average of 37.60%), however this was significant. The processes of germination and subsequent could have induced the increased starch digestibility. However, similar marginally increased values for toasted maize over raw (62%) have been documented by Moulishwar *et al.* (1993). Nixtamalization is a traditional processing technique, employed in South African countries where maize is a staple food. The process involves steeping the grains in lime solution (1% lime oxide) and subsequent boiling for further preparation and processing. In the present investigation, the process altered the starch digestibility very moderately from an initial of 37.01 per cent to 37.86 per cent in nixtamalized samples. Though the increase was meager, it was significant. These variations in the starch digestibility could be due to genetic endowment or processing treatments.

With regard to *in vitro* protein digestibility significant variation was observed among the varieties and processing treatments. It was observed that QPM grains in all forms *viz.*, native, malted or nixtamalized recorded high protein digestibility. These high values of QPM might be due to the inherent genetic qualities which was also documented by several investigators. Ortega *et al.* (1986) reported a higher range of 82 to 88 per cent digestibility in QPM samples. The process of nixtamalization increased the digestibility of protein, in the current study. However, contradictory results have been revealed by Ortega *et al.* (1986) where in the digestibility of nixtamal QPM samples decreased from an initial average of 86 per cent to 78 per cent. Gupta and Singh (2005) also indicated slightly higher digestibility of 81.16 per cent. This higher digestibility might be due to soaking and removal of pericarp, whereas in the present investigation, the digestibility of the whole meal was assessed. Thus, the present investigation indicated superiority of QPM over local varieties for protein digestibility. Similar superiority of protein quality was also demonstrated by Bressani *et al.* (1990), Ahenkora *et al.* (1999) in terms of protein efficiency.

5.3 VALUE ADDITION

The challenge of processing QPM for human consumption is to develop acceptable foods of high nutritional value and make them available among the nutritionally vulnerable groups. Utilization of QPM either by incorporation or substitution of main ingredient in popular traditional foods is likely to help in enhancing utilization.

In the present investigation experiments carried out to develop value added maize based products in the form of iron enriched malt beverage, ribbon *murukku* and *laddu* revealed encouraging results (Tables 11, 13 and 16). All the products prepared with the three different varieties of maize were acceptable. It is important to note that none of the products were scored as unacceptable. Similar results of acceptability of *Ga Kenkey* (Ghanaian traditional food) prepared from different maize varieties was reported by Ahenkora *et al.* (1999).

It was evident that maize could be incorporated or substituted in either cereal or pulse based foods without affecting the organoleptic appeal adversely. Maize flour could easily fit in the preparation of both sweet and savoury traditional foods. Although in some products prepared with white genotypes (QPM and SA Tall) recorded lower scores for colour and appearance (Table 11, 13 and 16) such short comings can easily be overcome by addition of natural food colourants like saffron, safflower petals (in malt beverage and *laddus*) and common spices like turmeric or chilly powder in savoury snack item (*murukku*) such addition of natural colourants would not only enhance the colour and appeal of the product but also would add value in terms of carotenoids and other neutraceuticals.

The scores for organoleptic characters of *laddu* for taste, aroma and overall acceptability decreased significantly beyond 75 per cent level of incorporation. However, none of the products were unacceptable. The investigation also revealed improved texture scores of maize *laddus* over the control samples (Table 17). This might be due to higher fat absorption of maize flour (66.05, 76.20 and 82.40%, respectively for QPM, SA Tall and DMH-2 varieties) as against 76 per cent for bengalgram flour. Further, it was also noticed that there was a scope for extra addition of fat to maize *laddus* to attain better textural properties thus, directly increasing energy density. Overall acceptability is influenced by colour and appeal of the product and once this attribute is taken care, the overall acceptability could also be improved. Both ribbon *murukku* and *laddu* were as acceptable as control samples at 25 per cent level of incorporation for QPM and thus the value addition improvements were successful. However, the experiments conducted to prepare pop corn based value added foods were unsuccessful. All the three varieties studied in the present investigation could not yield popped maize. This might be due to inherent non-suitability of the genotypes for popping.

Further, with regard to malting also, the results were not encouraging because of inadequate germination count (Table 5). The high malt yield of QPM samples may be misleading because grains did not germinate. Though the grains were subjected to soaking in water (24 hours) and incubated in controlled condition (37°C for 36 hours) the malt thus obtained would not have attained those nutritional benefits which a completely germinated seed malt would have obtained. This fact might explain the figures for digestibility of starch and proteins exhibited in the present investigation (Fig. 1a and 1b; Appendix I and II). However, addition of special ingredients like garden cress seeds in malt beverage enhanced the nutritional benefits in terms of increased levels of iron. The maize malt beverages provided iron ranging from 0.53 to 0.78 mg/serving but addition of garden cress seeds enhanced the levels of iron by 3 mg per each serving (150 ml). The traditional cereal porridges/beverages form an important part of diet of young and old alike, providing easily digestible nutritious food. The porridges are normally prepared by heating the cereal flour with water. In the present investigation milk was used for the preparation of beverage. For such foods viscosity is an important physico-chemical characteristics that influences not only the quantity of food but also the nutrient density (Kikafunda *et al.*, 1997). The addition of milk reduces the viscosity through formation of insoluble complexes with the linear starch granules and/or formation of a fatty layer around the starch granules (Collison, 1968).

Acceptable weaning food in the form of maize-soybean tempe was demonstrated by Mugula *et al.* (1992) and the products were reported to be as acceptable as traditional maize gruel. Similarity of taste and flavour were attributed for the acceptability. Similar reports were made by Mosha and Vicent (2004) where maize sorghum based meaning mixtures were developed with or without peanut, rojo beans or sardines. The value added products were highly acceptable.

At a consumption capacity of 150 ml/serving an adolescent or adult would derive 291 KCal of energy. More important is the contribution of iron (3.78 g/serving) through the malt beverage. It was observed that daily a person could easily consume 2-3 servings and thus enhancing the iron intake about 6.0 to 9.0 mg in a day contributing significantly to iron status.

Kumari and Singh (2004) demonstrated improvement of haemoglobin status and shift in anaemia status of pregnant women of Samastipur by intervention of 3 months administering QPM *laddus* on alternate days. Similar reports were made by Bhargava *et al.* (2003) indicating that QPM based *dalia* improved the growth of 1-3 years of preschool children.

Further, the contribution of nutrient in the form of *murukku* and *laddu* is significant. The products being highly acceptable and favourite items among the adolescent and adults, would contribute significantly because 2-3 servings could be easily consumed in a day, as revealed by opinion of expert taste panel.

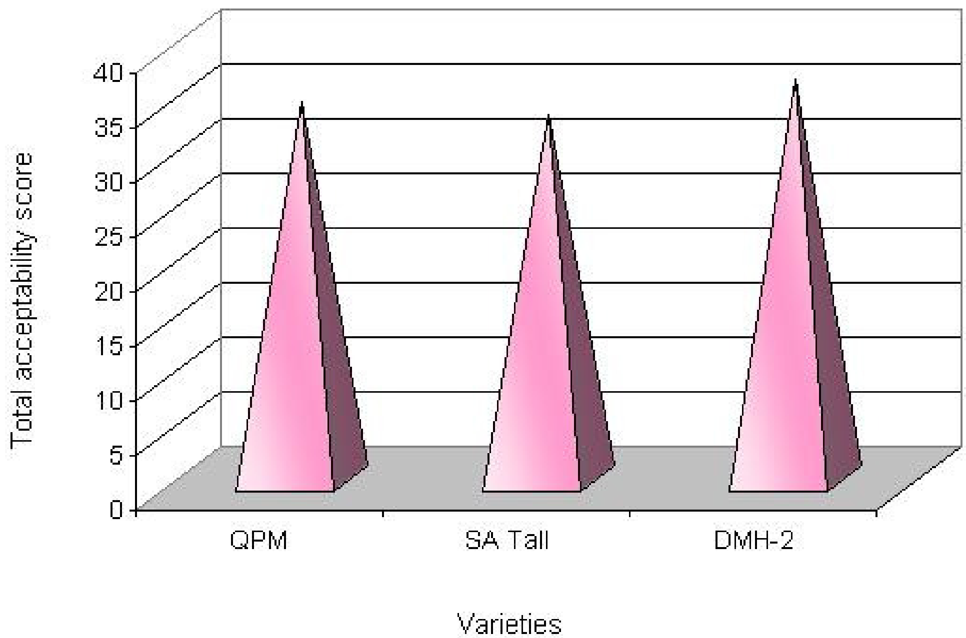

Fig. 2. Acceptability of malt beverage of different maize varieties

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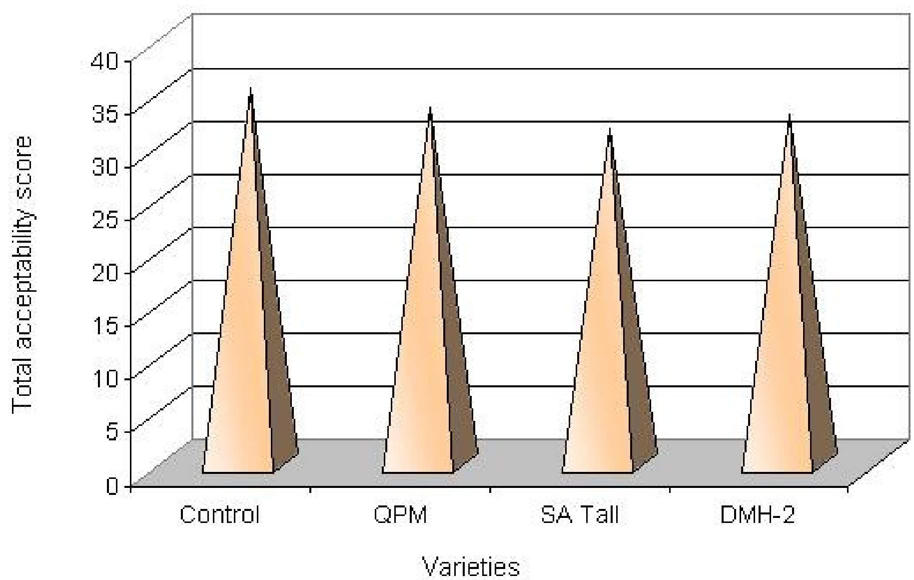

Fig. 3a. Acceptability of maize ribbon *murukku* in comparison with control

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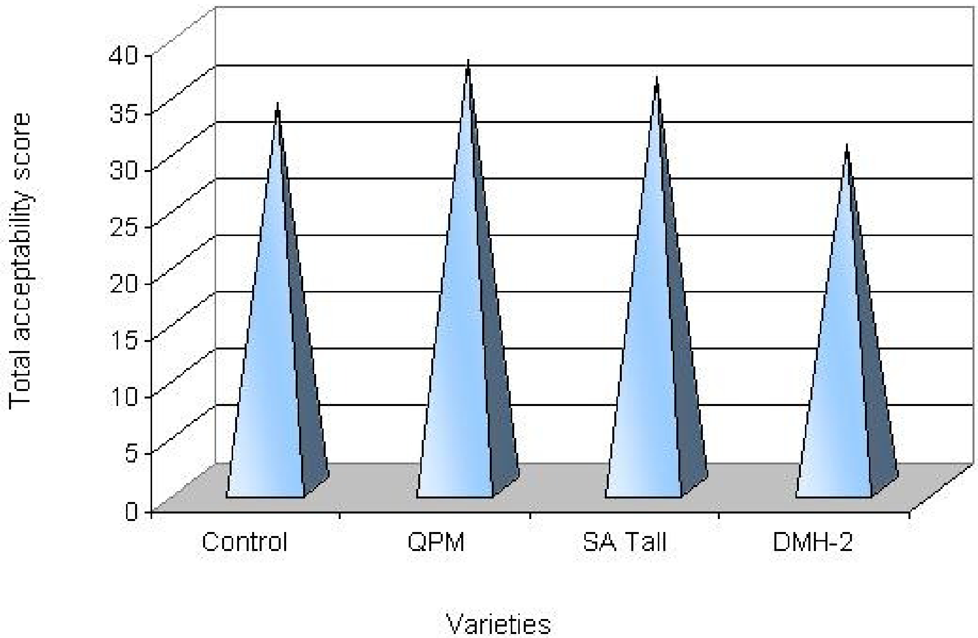

Fig. 3b. Acceptability of maize *laddu* in comparison with control

Fig. 3b. Acceptability of maize laddu in comparison with control

Another important revelation is that the QPM based *laddu* (25% incorporation levels) were better acceptable (37.63) than control sample (3.375) interms of total acceptability taking into consideration the colour, appearance, taste, texture, aroma and overall acceptability (Fig. 3b). However, the QPM faired better than the other two varieties for acceptability in the form of beverage, *laddu* or *murukku*. Similar higher acceptability of QPM based *Ga kenkey* over other traditional maize *Ga kenkey* was reported by Ahenkora *et al.* (1999). Further, QPM based value added traditional foods were also highly acceptable at varying levels as reported by Naik *et al.* (2006). Singh *et al.* (2006) developed QPM based cakes which were as acceptable as maize. Thus, QPM found better in present investigation and also these reported in literature. However, Gupta and Singh (2005) indicated moderate acceptability of QPM based biscuits incorporated with wheat flour and processed defatted maize germ cake.

VI. SUMMARY

Maize (*Zea mays* L.) is an important cereal with multiple uses as food, feed and an industrial raw material. Quality Protein Maize (QPM) is a high yielding high lysine maize released for alleviating hunger and malnutrition of the poorer sections of the maize dependent populations. The present investigation was undertaken to evaluate physico-chemical characteristics, analyze nutrient composition, assess nutritional quality and explore value addition potential of QPM in comparison with two local varieties SA Tall and DMH-2 in the Department of Food Science and Nutrition, College of Rural Home Science, Dharwad.

Samples of QPM were procured from Rajendra Agricultural University, Pusa, Samastipur, Bihar. The comparable maize varieties viz., SA Tall and DMH-2 were procured from University of Agricultural Sciences, Dharwad. Physical characteristics; functional properties; nutrient analyses, nutritional quality evaluation and value addition experiments were conducted by standard procedures. Iron, copper, zinc and manganese were analyzed in Atomic Absorption Spectrophotometer.

Flour recovery by *chakki* milling method was evaluated on a malted sample. Particle size of the native, malted and nixtamalized flour was determined by test sieves. Per cent dispersibility, swelling powder and solubility was also determined by standard procedure viscosity of the native and processed flour was analyzed using line spread test. The possibilities for incorporation of QPM at 25, 50, 75 and 100 per cent levels was assessed for products like ribbon murukku and *laddu*. Nutrient composition of products was calculated using analyzed values and standard tables. Salient findings of the investigations are given as under.

- The maize varieties QPM, SA Tall and DMH-2 showed variation in physical characteristics. The grains of QPM and SA Tall were ivory cream in colour while DMH-2 possessed orange colour. QPM grains were comparatively longer (10.08 mm), broader (9.68 mm) and thicker (4.78 mm) than other two varieties. Also the thousand grain weight (288.37 g), volume (240.30 ml) and density (1.19 g/ml) were higher in QPM than SA Tall and DMH-2.
- Variation in nutrient content was observed among the varieties. DMH-2 and QPM grain recorded higher protein content (10.29 and 10.15%, respectively) than SA Tall (8.90%) variety. Relatively higher carbohydrate (74.92 g) and calorific value (385 Kcal) were recorded in QPM than the other two varieties. QPM grains also recorded higher values for iron and copper contents (2.85 and 0.45 mg/100 g) than the DMH-2 and SA Tall (1.92 and 0.33, 1.18 and 0.13 mg/100 g, respectively). Better hydration and swelling characteristics were observed in QPM (184.70 g/1000 grain, 83 ml/1000 grain) and SA Tall varieties. Increase in weight and volume were better in QPM variety as compared to the rest of the varieties.
- It was observed that non of the three varieties were suitable for popping.
- Among the native grains, QPM yielded more (68.3%) fine particle flours ($\leq$150 μ) than other varieties. However, the nixtamalized grains of DMH-2 yielded highest quantity (72.5%) of fine flour.
- The dispersability of flour was highest with nixtamalized SA Tall (72.33%) flour followed by malted DMH-2 (71.67%) and native QPM (71.00%) flour. Swelling power was highest in malted flour of SA Tall (0.49%) followed by QPM native flours (0.47%). Highest solubility of flours was recorded in native form of flours (17-20%) than the malted (3.0 to 3.4%) and nixtamalized (2.0 to 3.6%) flours.
- Viscosity of cooked pastes of all the flours was higher at 15 per cent slurry concentration than 10 per cent. At both concentration, the native flours exhibited higher viscosity than the processed flour.
- *In vitro* digestibility of starch was highest in SA Tall (39.34%) followed by DMH-2 (37.79%) and QPM (36.35%). While *in vitro* protein digestibility was significantly higher in QPM (72.83%) than SA Tall (61.61%) and DMH-2 (56.68%) varieties.

- Value added products *viz.,* malt beverage, ribbon *murukku* and *laddu* prepared by incorporating maize flours of all the three varieties at 25, 50, 75 and 100 per cent levels were acceptable although at varying levels.
- Acceptability scores of malt beverage of DMH-2 variety were higher (7.50) than QPM (7.00) and SA Tall (6.70). Nutrient composition of malt beverage of QPM variety were higher with carbohydrate (48.65 g), calorific value (291 Kcal) and iron content (3.78 mg) than DMH-2 and SA Tall variety.
- The total acceptability score of ribbon *murukku* of QPM variety were higher (33.51) than DMH-2 (32.76) and SA Tall (31.51). protein and iron content was higher in QPM at 25 per cent of incorporation level than in other varieties.
- Maize based *laddus* were highly acceptable and total acceptability score of QPM *laddu* (37.63) was higher among the varieties followed by SA Tall (36.14) and DMH-2 (30.13). The *laddus* were as good as bengalgram *laddu*. Also the *laddus* were energy dense and QPM *laddu* could provide 120 Kcal energy per serving.

QPM is a superior grain and can find specific end uses in food product development and nutritional interventions. Future line of research can be undertaken in this regard to develop therapeutic foods, assess shelf life and market potential of such foods for nutritional empowerment of the communities dependent on maize for food.

VII. REFERENCES

AFOAKWA, E.O., 1996, Storage characteristics and quality evaluation of cowpea-fortified traditional foods. *B.Sc. Dissertation*, Department of Nutrition and Food Science, University of Ghana Legon-Accra, Ghana.

AHENKORA, K., TWUMASI, A.S., HAAG, W. AND DZAH, B.D., 1995, Ghanian Kenkey from normal and quality protein maize : comparative composition and rat growth trials. *Cereals Research Communication*, **23**(3): 229-304.

AHENKORA, K., TWUMASI, A.S., SALLAH, P.Y.K. AND OBENG-ANTWI, K., 1999, Protein nutritional quality and consumer acceptability of tropical Ghanaian quality protein maize. *Food and Nutrition Bulletin*, **20**(3): 354-359.

AMINIGO, E.R. AND OGUNTUNDE, A.O., 2000, Functional properties and nutritive composition of maize as affected by heat treatments. *Journal of Food Science and Technology*, **37**(1): 11-15.

ANGEL-DEL, ALMA, R. AND STOELO, A., 1982, Nutritive value of mixtures using chickpeas with wheat, triticale, normal and opaque-2 corns. *Journal of Nutrition*, **112**: 1474-1480.

ANONYMOUS, 1988, *Quality Protein Maize*, National Academic Press, Washington, DC, USA.

ANONYMOUS, 1990, *Official Methods of Analysis*. Association of Official Analytical Chemists, 20^{th} Edition, Washington, D.C.

ANONYMOUS, 2004, *FAO Statistical Year book*, Vol. II, pp.80-82.

ANONYMOUS, 2005, *Agriculture*, Centre for monitoring Indian Economy.

BHARGAVA, A., CHOPRA, N. AND GUPTA, H.O., 2003, Processing of quality protein maize (QPM) into *dalia* and processed flour and their synergistic effect on the growth of pre-school children. *IFCON*, Indian Agricultural Research Institute, New Delhi.

BRESSANI, R., BENAVIDES, V., ACEVEDO, E. AND ORTIZ, M.A., 1990, Changes in selected nutrient contents and in protein quality of common and quality protein maize during rural tortilla preparation. *Cereal Chemistry*, **67**(6): 515-518.

COLLISON, R., 1968, Swelling and gelation of starch. In *Starch and Its Derivatives*. Ed. J. A. Radley, 4^{th} edition, Chapman, London,

DELGADO, B.M.L. AND SERNA, S.S.O., 2000, Production and nutritional evaluation of liquefied weaning foods from malted sorghum, quality protein maize, and other cereals. *Cereal Chemistry*, **77**(5): 652-656.

DESHPANDE, S.S., JOSHI, K.C., BARGALE, P.C., JHA, K., SINGH, V. AND VARGHESI, S., 2004, Development, acceptability and shelf life studies of soy fortified maize sattu. *Journal of Food Science and Technology*, **41**(6): 674-678.

EDEMA, M.O., SANNI, L.O. AND SANNI, A., 2005, Evaluation of maize soybean flour blends for sour maize bread production in Nigeria.

GIBBON, B.C., WANG, X.L. AND LARKINS, B.A., 2003, Altered starch structure is associated with endosperm modification in quality protein maize. *Proceedings of the Academy of Sciences of the Untied States of America*, **100**(26): 15329-15334.

GOPALAN, C., SASTRI, R.B.V. AND BALASUBRAMANIAN, S.C., 1999, Nutritive value of Indian foods. *NIN*, ICMR, Hyderabad.

GRAF, A.B., 1976, *Exotica Horticultural Colour Guide*. Ed. E. Rutherford, N.J., Roehrs Company, Vol 2, p.1837.

GRAHAM, G.G., GLOVER, D.V., ROMANA, GUILLERMO, L.D., MORALES, E. AND MACLEAN, W.C., 1980, Nutritional value of normal, opaque-2 and sugary-2, opaque-2 maize hybrids for infants and children. *Digestibility and Utilization, Journal of Nutrition*, **110**: 1061-1069.

GRAHAM, G.G., LEMBCKE, J. AND MORALES, E., 1990, Quality protein maize as the sole source of dietary protein and fat for rapidly growing young children. *Pediatrics*, **85**(1): 85-91.

GRAHAM, G.G., LEMBCKE, J., LANCHO, E.B.S. AND MORALES, E., 1989, Quality protein maize digestibility and utilization by recovering malnourished infants. *Pediatrics*, **83**(3): 416-421.

GRISWOLD, M.R., 1962, *The Experimental Study of Foods*. Indiana University, Houghton, Miffin Company, Boston New York, Atlanta, Geneva, ILL, Dollas, Paloalto, p.540.

GUERRA, A., GUZMAN, A. AND SALDIVAR, 2004, Effects of soybean fortification on protein quality of tortilla based diets produced from regular and quality protein maize. *Plant Foods for Human Nutrition*, **59**(2): 45-50.

GUPTA, H.O., 2003, Effect of pericarp on protein quality in maize. *Journal of Food Science and Technology*, **40**(1): 80-83.

GUPTA, H.O., 2004, Improving the nutritional quality of maize after supplementation with processed soybean. *Journal of Food Science and Technology*, **41**(2): 167-170.

GUPTA, H.O. AND SINGH, N.N., 2005, Preparation of wheat and quality protein maize based biscuits and their storage, protein quality and sensory evaluation. *Journal of Food Science and Technology*, **42**(1): 43-46.

GUPTA, H.O., SACHDEV, A., JOHARI, R.P. AND SINGH, R.P., 2003, Storage protein and its impact on nutritional quality in quality protein maize. *Indian Journal of Agricultural Biochemistry*, **16**2): 67-71.

HABTAMU, F., GIRMA, A., ASRAT, W., TAFFESSE, S., TAKELE, G., SCHLOSSER, K., NOETZOLD, H. AND HENLE, T., 2003, Assessment of protein nutritional quality and effects of traditional processes : a comparison between Ethiopian quality protein maize and five Ethiopian adapted normal maize cultivars. *Nahrung*, **47**(4): 269-273.

HAWK, B.P., OSER, B.L. AND SUMMERSON, H.W., 1965, Practical physiological chemistry 12th Edition, McGraw Hill Book Co., Inc., New York.

HOUSSOU, P. AND AYERNOR, G.S., 2002, Appropriate processing and food functional properties of maize flour. *African Journal of Science and Technology*, **3**(1): 126-131.

JACKSON, M.L., 1973, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.

KANTHA, S.S., HETTIARACHCHY, N.S. ERDMAN, J.W., 1986, Nutrients antinutrient contents and solubility profiles of nitrogen, phytic acid and selected minerals in minged bean flour. *Cereal Chemistry*, **63**: 9-13.

KIKAFUNDA, J.K., WALKER, A.F. AND ABEYASEKERA, S., 1997, Optimising viscosity and energy density of maize porridges for child weaning in developing countries. *International Journal of Food Sciences and Nutrition*, **48**: 401-409.

KUMARI, P. AND SINGH, U., 2004, Impact of supplementation of quality protein maize based Ladoos on the nutritional status of pregnant women. *The Indian Journal of Nutritional and Dietetics*, **41**; 528.

LOPES, M.A. AND LARKINS, B.A., 1991, Cell biology an dmolecular genetics. *Crop Science*, **31**: 1655-1662.

MARTINEZ, B.F., FIGUEROA, J.D.G. AND LARIOS, S.A., 1996a, High lysine extruded products of quality protein maize. *Journal of Science Food and Agriculture*, **71**: 151-162.

MARTINEZ, B.F., SEVILLA, P.E. AND BJARNASON, M., 1996b, Wet milling comparison of quality protein maize and normal maize. *Journal of Science Food and Agriculture*, **71**: 156-162.

MEHTA, P., PATLE, P. AND PARIKH, N., 1989, Studies on weaning gruels maize, maize and green gram dhal : Part II effect of fermentation and malting on physico-chemical changes, bulk reduction property and suitability for children belonging to maize eating population. *The Indian Journal of Nutrition and Dietetics*, **26**: 354-364.

MILAN, C.J., GUTIERREZ, D.R., CUEVAR, R.E.O., GARZON, T.J.A. AND REYES, M.C., 2004, Nixtamalized flour from quality protein maize (*Zea mays* L.) optimization of alkaline processing. *Plant Food Human Nutrition*, **59**: 35-44.

MORO, G.L., HABBEN, J.E., HAMAKER, B.R. AND LARKINS, B.A., 1996, Characterization of the variability in lysine content for normal and opaque 2 maize endosperm. *Crop Science*, **36**: 1651-1659.

MOSHA, T.C.E. AND VINCENT, M.M., 2004, Nutritional value and acceptability of home made maize/sorghum based weaning mixtures supplemented with rojo bean flour, ground sardines and peanut paste. *International Journal of Food Science and Nutrition*, **55**(4): 301-315.

MOULISWAR, P., KURIEN, S., DANIEL, V.A., MALLESHI, N.G. AND VENKATARAO, S., 1993, *In vitro* digestibility of protein and starch as energy food and its bulk reduction. *Journal of Food Science and Technology*, **30**: 36-39.

MUGULA, J.K., 1992, Evaluation of the nutritive value of maize-soybean tempe as a potential weaning food in Tanzania. *International Journal of Food Sciences and Nutrition*, **43**: 113-119.

NAIK, R.K., KULKARNI, L.R. AND MASUR, S., 2006, Development of QPM based value added traditional and RTE products. *Proceedings of 38th Annual Meeting*, 2006, Nutrition Society of India held at Kolkata.

OKAKA, J.E., POTTER, N.N., 1979, Physico-chemical and functional properties of cowpea powders processed to reduce bean flavour. *Journal of Science*, **44**: 1235-1240.

OKEZIE, U., AKANBI, C.T. AND OTUNOLA, E.T. AND ADEYEMI, I.A., 2003, Effect of addition of ripe bananas on some physico-chemical properties of maize extract. *International Journal of Food Science and Nutrition*, **54**(6): 437-445.

OMUETI, O. AND MORTON, I.D., 1996, Development by extrusion of soyabari snack sticks : a nutritionally improved soya maize product base on the Nigerian snack (kokoro). *International Journal of Food Science and Nutrition*, **47**: 5-13.

ORTEGA, F.I., VILLGAS, EVAN G. AND VASAL, S.K., 1986, A comparative study of protein changes in normal and quality protein maize during tortilla making. *Cereal Chemistry*, **63**(5): 446-451.

OSEI, S.A., DEI, H.K. AND TUAH, A.K., 1999, Evaluation of quality protein maize as a feed ingredient for layer pullet. *Journal of Animal and Food Sciences*, **8**(2): 181-189.

PAES, M.C.D. AND MAGA, J., 2004, Effect of extrusion on essential amino acids profile and colour of whole grain flours of quality protein maize and normal maize cultivars. *Revista Brasileira e Mith e Sorgo*, **3**(1): 10-20.

PAULA, H.DE., SANTOS, R.C., SILVA, M.E., GLORIA,E.C.S., PEDROSA, M.L., ALMEIDA, N.A.V., COSTA, A.S.V. AND MALAQUIAS, L.C.C., 2004, Biological evaluation of a nutritional supplement prepared with QPM maize cultivar BR-473 and other traditional food items. *Brazialian Archines of Biology and Technology*, **47**(2): 247-251.

PRASANNA, B.M., VASAL, S.K., KASSAHUN, B. AND SINGH, N.N., 2001, Quality protein maize. *Current Science*, **81**(10): 1308-1318.

RODRIGUEZ, C.E.O., MILAN-CARRILLO,J., MORA-ESCOBEDO, R., CARDENAS-VALENZUELA, O.G. AND REYES, M.C., 2004, Quality protein maize (*Zea mays* L.) tempeh flour through solid state fermentation process. *Lebensmittel-Wissen Chaft Und Technologie*, **37**(1): 59-67.

SCHOCH, T.J., 1964, Swelling power and solubility of granular starches. In *Carbohydrate Chemistry*, Ed. Whistler, R.L., Smith, R.J., Miller, B.E.N.J. and Wolform, M.I., Academic Press, New York, pp.106-108.

SHARMA, S., SAXENA, A.K. AND SAXENA, V.K., 2002, Nutritional quality of evaluation of selected improved maize genotypes of Punjab. *The Indian Journal of Nutrition and Dietetics*, **39**: 194-196.

SINGH, V., KAWATRA, A. AND SEHGAL, S., 2006, Development, acceptability and proximate composition of cake prepared from quality protein maize. *Proceedings of 38th Annual Meeting*, 2006, Nutrition Society of India held at Kolkata.

SOSULSKI, F.W., 1962, The centrifuge method for determining flour absorption in hard red spring wheats. *Cereal Chemistry*, **39**: 344.

SPROULE, A.M., SALDIVAR, S.O., BOCKHOLT, A.J., ROONEY, W. AND KNABE, D.A., 1988, Nutritional evaluation of tortillas and tortilla chips from quality protein maize. *Cereals Foods World*, **33**(2): 234-236.

SZANIEL, J., SAGI, F. AND PALVOLGI, I., 1984, Hardness determination and quality prediction of maize kernels by a new instrument the monograph. *Maydica*, **29**: 9-20.

VALDEZ, C.A., CARILLO, J.M., VALENZUELA, O.G.C., ESCOBEDO, R.M., PEREZ, L.A. AND MORENO, C.R., 2005, Infant food from quality protein maize and chickpea : optimization for preparing and nutritional properties. *International Journal of Food Science and Nutrition*, **56**(4): 273-285.

WANG, Y.J., CHONG, S.W. AND YANG, W., 2005, Effect of pericarp removal on properties of wet milled corn starch. *Cereal Chemistry*, **83**(1): 25-27.

WILLIAMS, P.C., HANNIKAROUL AND SINGH, K.B., 1983, Relationship between cooking time and some physical characteristics in chickpea (*Cicer arietinum*). *Journal of the Science of Food and Agriculture*, **34**: 492-496.

ZARKADAS, C.G., HAMILTON, R.I., YU-ZI, RAN, CHOI, V.K., KHANIZADEM, S., ROSE, N.G.W. AND PATTISON, P.L., 2000, Assessment of the protein quality of 15 new northern adapted cultivars of quality protein maize using amino acid analysis. *Journal of Agricultural and Food Chemistry*, **48**(11): 5351-5361.

APPENDIX

APPENDIX I

In vitro starch digestibility (%) of native and processed maize varieties

Varieties	***In vitro* starch digestibility (3 hours)**			
	Native	**Malted**	**Nixtamal**	**Mean**
QPM	35.34	37.10	36.60	36.35
SA Tall	38.33	40.48	39.21	39.34
DMH-2	37.37	38.22	37.76	37.79
Mean	37.01	38.60	37.86	37.82
Variable	S.Em±		CD (5%)	
Variety (V)	1.50		4.45	
Processing (P)	0.80		2.36	
V x P	0.38		1.12	

APPENDIX II

In vitro protein digestibility (%) of native and processed maize varieties

Varieties	*In vitro* protein digestibility (%)			
	Native	**Malted**	**Nixtamal**	**Mean**
QPM	65.29	80.57	72.64	72.83
SA Tall	55.81	66.67	62.34	61.61
DMH-2	48.23	65.30	56.51	56.68
Mean	56.44	70.85	63.83	63.71
Variable	S.Em±		CD (5%)	
Variety (V)	8.28		7.20	
Processing (P)	24.60		21.40	
V x P	1.66		4.94	

APPENDIX III

Recipe for maize malt beverage

Ingredients

Maize malt flour	-	10 g
Milk	-	100 ml
Sugar	-	20 g
Coarsely powdered		
Garden cress seeds	-	2 g

Method

A smooth paste of malt flour was prepared with 15 ml of milk and kept a side. In another vessel 85 ml of milk was simmered and the paste was added slowly and cooked at a low flame for 15 minutes, stirring continuously. Sugar and coarsely powdered garden cress seeds were added for taste.

APPENDIX IV

Recipe for ribbon *murukku*

Ingredients

Bengalgram flour	-	30 g
Rice flour	-	20 g
Red chilli powder	-	1 tsp
Salt	-	1 tsp
Sesame, cumin seeds	-	2 tsps
Ghee or butter	-	6 tsps
Asafoetida	-	½ tsp

Method

Mix all the ingredients into thick paste. Place a large ball of this flour inside a "*murukku achu*" and squeeze the *achu* so that the *murukku* drops into boiling oil. Turn often until fully cooked.

APPENDIX V

Recipe for *laddu*

Ingredients

Bengalgram flour	-	60 g
Sugar powder	-	70 g
Ghee	-	50 g

Method

Roast Bengal gram flour in ghee for about 15-30 minutes till a sweet or roasted fragrance is obtained, taking care not to char the flour. Remove from heat, cool slightly, add sugar powder and mix thoroughly. Mix properly and mould manually into small balls.

APPENDIX VI

Score card for evaluation of value added products maize malt beverage/ribbon *murukku*/*laddu*

Name of the product : Date:

Name of the Judge :

1.	Colour and appearance	Scores			
	Excellent				
	Extremely good				
	Very good				
	Moderately good				
	Good				
	Fair				
	Very fair				
	Poor				
	Very poor				
2	Texture/consistency				
	Excellent				
	Extremely good				
	Very good				
	Moderately good				
	Good				
	Fair				
	Very fair				
	Poor				
	Very poor				
3	Taste				
	Excellent				
	Extremely good				
	Very good				
	Moderately good				
	Good				
	Fair				
	Very fair				
	Poor				
	Very poor				
4	Aroma				
	Excellent				
	Extremely good				
	Very good				
	Moderately good				
	Good				
	Fair				
	Very fair				
	Poor				
	Very poor				
5	Overall acceptability				
	Excellent				
	Extremely good				
	Very good				
	Moderately good				
	Good				
	Fair				
	Very fair				
	Poor				
	Very poor				

Remarks: Signature

PHYSICO-CHEMICAL PROPERTIES, NUTRITIONAL QUALITY AND VALUE ADDITION TO QUALITY PROTEIN MAIZE (*Zea mays* L.)

PUNITA GURIA 2006 Dr. BHARATI V. CHIMMAD
MAJOR ADVISOR

ABSTRACT

Quality Protein Maize (QPM) is a high yielding high lysine maize released for alleviating hunger and malnutrition among maize dependent populations. An investigation was undertaken in the Department of Food Science and Nutrition, University of Agricultural Sciences, Dharwad to evaluate the physico-chemical properties, nutritional quality and utilization potential of QPM in comparison with traditional varieties (SA-Tall and DMH-2).

Carbohydrate was calculated by difference and calorific values was computed using Atwater Constants. Trace minerals were estimated in Atomic absorption Spectrophotometer. *In vitro* starch and protein digestibility were estimated. Effects of malting, milling, nixtamalization on different functional properties were evaluated. Sensory qualities was assessed by incorporating the flours at 0, 25, 50, 75 and 100 per cent levels in malt beverage, ribbon *murukku* and *laddu*. The investigation revealed variations in physico-chemical and nutritional characteristics. QPM grains exhibited higher thousand grain weight (288.37 g), volume (240.30 ml) and density (1.19 g/ml) than SA Tall and DMH-2 grains (275.49 and 251.20 g, 230.40 and 220.30 ml, 1.14 g/ml, respectively). Protein content was high in DMH-2 (10.29%) and QPM (10.15%) and least in SA Tall (8.90%). QPM grain recorded higher values for iron and copper contents (2.85 and 0.45 mg/100 g) than DMH-2 and SA Tall (1.92 and 0.33, 1.18 and 0.13 mg/100 g, respectively). Variation in flour funcationality was observed. *In vitro* starch and protein digestibility varied (36-39 and 56-72%, respectively) among the varieties.

The DMH-2 maize malt beverage exhibited highest acceptability than QPM and SA Tall. However, the total acceptability score for ribbon *murukku* and *laddu* were highest in QPM (33.51 and 37.63, respectively) followed by DMH-2 (32.76 and 30.13, respectively) and SA Tall (31.51 and 36.14, respectively).