

NUTRITIONAL AND PROCESSING QUALITIES OF POP SORGHUM CULTIVARS AND VALUE ADDITION

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I. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) popularly called as *jowar*, is the “king of millets” and is the fifth in importance among the world’s cereals, after wheat, rice, maize and barley. It is a staple food grain in many Indian states. It is grown especially in the arid and semi-arid regions. The major sorghum production areas today include the great plains of north America, sub-Saharan Africa, north eastern China and the Deccan plateau of central India, Argentina, Nigeria, Egypt and Mexico. India has the largest share (32.3%) of the world’s area under sorghum and ranks second in production after the US. The wild world production of sorghum is 58.60 million tonnes from an area of 42.02 million hectares with a mean yield of 1394 kg per hectare. In India and Karnataka sorghum cultivation production amounts to 9.0 million tonnes and 1.85 million tonnes from an area of 10.3 million hectare and 2.3 million hectare with productivity of 874 kg per hectare and 1122 kg per hectare, respectively (Vikas, 2003).

The nutrient composition of sorghum grain indicates that it is a good source of energy, protein, vitamins, minerals including trace elements. Sorghum has 11.9 per cent of moisture and about 10.4 per cent of protein and a lower fat content of 1.9 per cent. The fibre and mineral content of grain sorghum is essentially similar, and is 1.6 per cent. It is a good source of energy and provides about 349 K cal and gives 72.6 per cent of carbohydrates (Gopalan *et al.*, 1996). Starch is the major carbohydrate of the grain. The other carbohydrates present are simple sugars, cellulose and hemicellulose. The amylose content of starch varies from 21.28 per cent. Sorghum is also rich in dietary fibre (14.3%). Calcium, phosphorous and iron content of sorghum is 25 mg, 222 mg and 4.1 mg (per 100 g of edible portion), respectively (Hosmani and Chittapur, 1997).

Sorghum grains are consumed in different forms, namely unleavened bread, dumpling (*mudde*) and boiled rice (*annam/bana*) like products (Thorat *et al.*, 1988). *Chapati* or *Roti* prepared from a blend of sorghum-greengram are also consumed (Sankarapandian, 2000). The use of malted sorghum flour in supplemented foods for children has been well established (Gopaldas, 1992). Popped sorghum is a very popular, traditional snack food in central India. Popped grains mixed with oil and spice or sweetened are popular snack foods. It can also be used in weaning food formulations and also used as ready-to-eat products (Thorat *et al.*, 1988). Popped sorghum had been well utilized during festival times, like *Nagarpanchami*, usually *laddu* will be prepared out of popped sorghum grains and pops can also be used after seasoning.

Though sorghum is the third most important cereal in the country after rice and wheat, these days cultivation of sorghum is considered as not profitable. Hence, sorghum production is relegated to marginal lands and less fertile soils. Sorghum, besides its known adaptability to harsh environments and yielding potential, possesses sustainable and commercial significance in semi arid tropic areas. One such type is popsorghum.

The goal of grain sorghum research in the past has been concentrated on physico-chemical properties of sorghum and on the development of varieties with desirable agronomic characteristics but with limited regard for utilization, processing and value addition to the grain. There is a need for information concerning measurable characteristics which are closely related to the utilization of grain sorghum. The most efficient utilization of grain sorghum as a human food can be accomplished by objectively establishing attributes and matching these with appropriate food formulas. However, application of suitable processing technologies may add value to the crop (Miller and Burns, 1970).

Popping is a simplest, inexpensive and quickest traditional method of dry heat application, wherein grains will be exposed to high temperature for short time (HTST). Super heated vapour will be produced inside the grains by instantaneous heating, which cooks the grain and expand the endosperm while escaping with great force through the micropores of the grain structure. During popping the material practically gets sterilized and most of the seed microflora are destroyed and some of the factors are also denatured (Hadimani, 1994). There are different methods of popping used *viz.*, conventional method of dry heat, sand and salt treated, hot air popping, gun puffing, popping in hot oil and microwave popping throughout the world (Yenagi *et al.*, 2005a).

Popcorn is a type of maize which is used specially for popping. Popcorn, the original snack food is undoubtedly the oldest one and has been consumed from centuries. The recent surge in popcorn sales is due to the proliferation of microwavable popcorn products to

consumers who demand improved convenience. Also, there has been a proliferation in recent years of flavoured ready popped popcorns in addition to the usual salted, buttered and caramel coated popcorns. Besides home consumption, popcorn is widely consumed at theaters, amusement parks and sporting events. Americans consume 54 quarts per man, woman and child each year. Humans consume popcorn as a versatile and nutritious snack. It is enjoyed both as sweet and savory by fans around the world. One factor, which makes it so popular, is its nutritional value. One cup of air-popped popcorn contains 31 calories, 1 g of protein, 6 g of carbohydrate and 1 g of fibre and just a trace of fat and it is favourite snack of consumers of all ages.

A few reports available on popping of sorghum revealed that, sorghum expands very well when subjected to high temperature and short time (HTST) treatment. Popping imparts acceptable taste and desirable aroma to pop sorghum. Popping being a dry heat process may inactivate the lipase and improve the shelf life of popped products. Popped sorghum being a pre-cooked ready to eat material, can be used in snack foods, speciality foods as a base for development of supplementary foods. However, detailed investigations are needed to determine the quality of popped sorghum and its suitability for different food uses. Hence, the study was undertaken with the following objectives.

1. Evaluation of nutritional and processing qualities of pop sorghum cultivars grown in different season.
2. Evaluation of nutritional and processing qualities of pop sorghum cultivars processed by conventional and modern method, and
3. Development of pop sorghum snacks.

II. REVIEW OF LITERATURE

The cereals are a group of variable, small-seeded, annual grasses that are native to many parts of the world. They supply the bulk of the food consumed by the human race. They are the cheapest source of food energy and constitute a high percentage of calorie and protein intake of man. Cereal grains have been used for centuries for food because of the ease of growing them and their storage stability. Processing of grains to produce products results in improved nutritional profile through inactivation of undesirable microorganisms and certain antinutrients.

Popping is one such processing technique which not only improves the shelf-life but also improves nutritional quality of the grains, it also improves the grain quality and adds flavour to the grains and hence the acceptability also gets improved.

2.1 POPPING OF CEREALS

Popping of cereals has been practiced since hundreds of years. Popping is a type of starch cookery, where grains are exposed to high temperature for short time. Though a wide range of cereals are used for popping, only few of them pop well. The reason for this may be the factors which influence popping qualities of cereals, such as season, varietal difference, grain characters *i.e.* bran content, bran thickness, moisture content, type of endosperm, physical characters of grains and also the method of popping. Available scientific information regarding these qualities and the nutritional quality and also value added products of popped cereals are reviewed in this chapter.

The properties of gun puffed wheat with variation in grain moisture (10-25%) and firing pressure (100-180 p.s.i) were studied by Ferrel and Shepaerd (1966) who observed that the degree of expansion of wheat depended primarily on firing pressure. Wheat samples with 10-16 per cent moisture gave more tender products for comparable degree of expansion than samples with 19 to 25 per cent.

Mottern *et al.* (1967) studied the differences in popping characteristics of rice varieties. Optimum conditions of air steam temperature (230°C in air) and moisture content (13.19%) of a long grain paddy rice were determined for obtaining highest yields on popping. The yield of popped cereal from long-grain rice (Blue bonnet) was three fourth that of (Machi-game) a short grain waxy rice accepted for popping. Popped rice flour is cold water soluble and is suggested in combination with oilseed flour as an ingredient in an instant food for infant feeding in rice eating countries.

Srinivas *et al.* (1973) studied the varietal differences in puffing quality of 30 paddy varieties. Wide varietal variation has been found in the puffing quality of paddy. There was no consistent relation between puffing quality and amylose content, although some waxy types were the best puffers. There existed no relation between protein content and puffing quality.

Srinivas and Desikachar (1973) studied the various factors affecting the puffing quality of five paddy varieties. In good puffing varieties of paddy the aleuronic layer was thin and weak at the specific points of bursting while the clearance between the husk and kernel was large and the grain was easily shelled. In the poor puffing varieties, the aleurone layer was uniformly thicker along the peripheral section while clearance between husk and grain was smaller and the grains were relatively more difficult to shell. Optimum maturity of grains at an average grain moisture of 20 to 40 per cent was essential for getting maximum puffing. Delayed harvesting caused sun checks and reduced overall puffing expansion. Sun checks caused by severe drying in the sun produced a similar effect. High grain density was associated with better puffing.

Betschart *et al.* (1981) studied the effects of temperature on nutritional quality of *A. cruentus* seeds. Drying at 60°C and hot air popping at 220±50°C for 10-15 seconds had no significant effect on PER apparent nitrogen digestibility. Exposing whole seeds at 60°C had

no effect on amino acid composition, but hot air popping resulted in approximately 15 per cent decrease in lysine.

Malleshi and Desikachar (1981) studied the effect of various processing conditions to determine the optimum conditions. Optimal conditions for puffing of ragi were moistening to 19 per cent moisture and equilibration for 4 hr, followed by puffing in sand medium to 270°C. Wide varietal variation has been found in the puffing quality, among the fourteen varieties studied. No consistent relationship was observed between the grain in amylose, protein content or thickness of bran with puffing quality. 'Purna', 'Annapurna', 'Shakti', 'P.R.202' and 'Indaf-3' possessed good puffing quality.

Gupta *et al.* (1985) evaluated the effect of popping of maize kernels on the *in vitro* digestibility of protein and on lysine and tryptophan. Popping slightly decreased lysine and tryptophan contents. *In vitro* protein digestibility improved in sweet kernels after popping.

Pant (1985) studied the effect of popping on nutritional quality of grain amaranth. Popping did not affect the proximate composition, but there was significant loss in total lysine which was more in home popped grain (36%) than in commercially popped grains (25%). The NPR of commercially popped grains was similar to that of raw grains whereas home popping resulted in decreased NPR value, suggesting that well popped grains do not suffer deterioration in protein quality.

Malleshi and Desikachar (1985) analysed fourteen varieties of foxtail, two varieties each of proso and barnyard, one variety each of little millet and kodo millet for their popping characteristics. Wide variation in yield as well as volume expansion of popped grains was observed. The yield of popped grains varied from 47 and 94 per cent whereas expansion volume ranged between 4.8 to 11.6 ml/g. Slurries of flours of 9 well popped samples exhibited higher cold paste and lower hot paste viscosity.

Murugesan and Bhattacharya (1986) studied the effect of various processing conditions on puffing, using a small laboratory coffee roaster, and a small hot air puffing system using 25 g paddy in each experiment. The optimum conditions were; grain moisture of 14 per cent (wet basis) in either system and sand puffing at about 200°C and air puffing at 225°C at an air-flow rate of 1.5 m³ min⁻¹. Immature kernels did not puff well, but cracked grains showed slightly increased puffed volume. Parboiling reduced puffing. Addition of salt increased puffed volume, appreciably and also shifted the optimum moisture content to 17 per cent.

Shukla *et al.* (1986) tested eight new ragi varieties for their puffing yield, chemical composition and organoleptic quality. Brown seeded varieties were more suitable for puffing. Significant variation in composition was observed among the samples of puff prepared from different varieties. Protein, non-protein nitrogen and total carbohydrates of ragi puffs ranged from 5.61 to 8.83 per cent, 0.15 to 0.32 per cent and 75.00 to 85.30 per cent, respectively. Whereas soluble, reducing and non-reducing sugars and fat and phytic acid ranged from 2.05 to 3.70 mg, 1.28 to 2.16 mg, 0.62 to 2.27 mg, 1.08 to 1.44 per cent and 65.0 to 133.3 mg, respectively. However, mineral content of ragi puffs varied significantly. Calcium, phosphorus and sulphur content ranged from 316.0 to 442.4 mg and 289.6 to 359.2 mg and 96.4 to 149.5 mg. Sodium, potassium and magnesium contents of ragi puffs ranged from 12.93 to 22.66 mg 138.7 to 184.0 mg and 113.4 to 189.6 mg. White seeded varieties yielded organoleptically superior quality puffs.

Lin and Anantheswaran (1988) determined the optimum processing conditions, and characteristics of five popcorn varieties for better popping performance in a microwave oven. In every variety, the range of optimum moisture content resulting in maximum expansion volume was found to be different from that for the minimum number of unpopped kernels. Under the optimum moisture contents M-045 yielded the highest expansion volume and IOPOP12 had the lowest unpopped kernel ratio. Large kernels within the variety M-045 yielded the highest expansion volume and IOPOP12 had the lowest unpopped kernel ratio. Surface damage to kernels reduced the expansion volume drastically. Long term frozen

storage increased the popped volume in comparison with storage at room temperature. The effect of salt and oil on the popping performance of popcorn was complex.

Pordesimo *et al.* (1990) evaluated kernel dimensions/sphericity, kernel size and specific gravity of popcorn as indicators of popping characteristics of microwave popcorn. Expansion volume correlated positively with sphericity whereas there was poor correlation between sphericity and unpopped kernel ratio. Smaller, shorter and broader kernels had a higher sphericity and such kernels had higher expansion volume. Unpopped kernel ratio decreased with increasing kernel size when popped in a microwave oven. Specific gravity of kernels had a significant effect on expansion volume and flake size, but not on unpopped kernel ratio. Expansion volume increased with increasing specific gravity. Flake size increased upto specific gravity of 1.350 to 1.370 and then leveled off.

Kulkarni (1990) studied the popping quality of five high yielding and local varieties of minor millets, viz., *Bargu*, *Haraka*, *Navane*, *Savi* and *Udalu*. Considering the completely popped percentage and expansion ratio. *Harak* was the best among the millets studied followed by *Savi*. However, millets *Baragu*, *Navane* and *Udalu* were least poppers. Variety CO-2 of *Baragu* was found to be best popper with highest completely popped per cent and expansion ratio (1.67 and 1.38 per cent, respectively). However, in *Haraka*, the local variety was found to be the best popper with completely popped percentage of 34.17 and an expansion ratio of 3.17. Similarly, local varieties of *Navane* and *Savi* exhibited highest completely popped percentage (2.83 and 20.83 respectively) and also highest expansion ratio (1.33 and 2.10 respectively). However, the other varieties of *Navane* and *Savi* and *udalu* were found to be poor poppers.

Singhal and Kulkarni (1991) studied the puffing effects on functional properties of *A. paniculatus* (Rajgeera) seed flour. Water and fat holding capacities were higher for puffed grain flour. Gelatin was not affected, while foaming was adversely affected by puffing. A decrease in viscosity of flour pastes also resulted due to puffing.

Delost *et al.* (1992) studied eight experimental varieties of proso millet to determine varietal differences in puffing quality. Significant differences in puffing quality were observed on the basis of puffed yields and expansion volumes. Variety 2027, which demonstrated good puffing quality, was selected for further study of nutritional properties of products processed under various puffing conditions. Puffing quality was significantly improved when grains were tempered to 15 or 18 per cent moisture and gun puffed at 140 or 160 psi. The puffed products were more highly expanded, less dense and higher in protein content, but lower in ash and total dietary fibre. *In vitro* nitrogen digestibility of the puffed products was adversely affected by low moisture and the intense heat treatments. The puffed products demonstrated a much greater rate of *in vitro* starch digestibility than unprocessed millet.

Mohamed *et al.* (1993) studied the popping performance of 18 popcorn hybrids. Differences in popping quality indices between the two microwave treatments, indicated a negative effect of salt on popping. Pericarp thickness gave highest correlation with expansion volume in microwave and conventional popping while, sphericity correlated slightly better in unsalted microwave popping.

Bhuvaneshwari (1995) studied two varieties of grain amaranthus for their popping qualities. The expansion ratio and popping number was higher in variety IC-42258-1 (4.6 and 61.66 per cent, respectively) whereas the variety R-104-1-1 showed lower expansion ratio and popping number (4.2 and 52.33 per cent, respectively).

Hadimani *et al.* (1995) evaluated 38 pearl millet cultivars, comprising local varieties, popular and new hybrid lines for physico-chemical composition and popping characteristics, and their correlation. Wide variations were observed in 1000-kernel weight (3.2-17.6 g) and volume (2.2-12.9 ml) and hardness (49.3-98.5 Bu) of native seeds of the varieties, in addition to considerable variations in protein, starch, fat and ash contents. The yield and expansion ratio of popped grains ranged from 8.3 to 77.1 per cent, and 2.3 to 11.3 per cent, respectively. The grain hardness correlated positively with protein content. Protein content showed a significant positive correlation with popping yield.

Srivastava and Batra (1998) studied relationship between physical properties and popping qualities of various genotypes of foxtail millet, finger millet, barnyard millet and prosomillet. Significant differences in puffing yield of various genotypes of above mentioned millets was observed. Of all the millets, the highest popping yield (92.77%) and expansion volume (6.51) were observed for proso millet followed by finger millet, foxtail millet and barnyard millet. Foxtail millet revealed significant positive correlations between 1000-kernel weight and popping per cent; 1000 kernel weight and expansion volume; 1000-kernel volume and expansion volume. Finger millet showed significant positive correlations between hydration capacity and popping per cent and between per cent floaters and expansion volume.

Bhuvaneshwari (1999) studied the effect of bulgarisation on popping quality of ten different wheat varieties. The expansion ratio of bulgarized popped wheat of different varieties varied significantly, the highest expansion ratio was in DDK1-3 and lowest in DWR-185. On bulgurization the expansion ratio increased when compared to raw popped wheat varieties. Whereas, bulk density of raw popped wheat was significantly higher in all the varieties when compared to bulgurized popped wheat.

Hadimani *et al.* (2001) examined three cultivars of pearl millet, microscopically for their kernel texture and analysed for carbohydrate and protein composition. Good popping varieties of pearl millet [CO6 and traditional variety (TV)] possessed thin, single layered compact aleurone cells with corneous endosperm and also contained a higher proportion of non-starch polysaccharide and prolamin protein fraction. The poor popping variety (MBH 157) contained thick, multilayered and loosely arranged aleurone cells with larger proportion of floury endosperm. However, significant differences in the physico-chemical characteristics of the isolated starches of the millet varieties was not noticed.

Madhuri (2002) studied physical and chemical characteristics of fifteen rice varieties and were evaluated for popping and puffing qualities. The rice varieties showed a wide significant variation for physico-chemical and processing qualities. Grain dimensions, L:B ratio, thousand kernel weight, volume and bulk density were strongly related to processing quality of rice varieties. The optimum total amylose content 27.60 per cent and 13.40 per cent (df) hot water insoluble amylose of rice variety were found to be the best combination for better expansion of puffed and popped rice. Intan, a commercial cultivar showed superior puffing and popping qualities over the newly developed rice varieties (Prasanna, MTU-1001, Mugad basumati, Pusa-basumati) as well as earlier varieties (Dodiga, Udarsali, Navali *etc.*).

Yenagi and Bhuvaneshwari (2004) studied the effect of bulgarisation on popping quality of wheat varieties. The process of bulgarisation increased the expansion of popped wheat grains preferable in dicocum wheats than durum and bread wheat. Significant difference in expansion ratio of raw and bulgarised wheat varieties was observed.

2.2 POPPING OF SORGHUM

Grain sorghum, the most important cereal after rice and wheat is considered as less economical. However, application of suitable processing technologies may add value to the crop. Popping is one such technique which improves the quality of the grain. The factors responsible for popping qualities of grain sorghum includes season, grain structure/physical characteristics of the grain, chemical composition and also the method of popping.

Devadas *et al.* (1966) studied the popping quality of four sorghum hybrids (MS x IS 84; MS x IS 2930; MS x IS 3687 and MS x IS 3691) and a local strain (CO-18) by counting the number of grains which were fully popped, partially popped and unpopped. The percentage of fully popped grain was highest in the case of local strain CO-18 (21%) and the hybrids MS x IS 84 stood next (17%). The unpopped percentage was highest in MS x IS 3687 (26%) and least in MS x IS 2930. Thus, significant varietal difference in the popping quality was seen.

Puffing quality of fourteen improved sorghum strains showed that the puffing yield varied from 21 per cent for K- jowar to 74.6 per cent for H-I Bellary. The specific volume

ranged from 7.0 ml/g (M35-1) to 11.4 ml/g (H-I Bellary). Only five out of fourteen varieties gave a moderate yield of puffed grains. No correlation was found with the specific volume and yield (Viraktamath, 1972).

Structural changes took place in sorghum starch when popped (Harbers, 1975). The process of popping changed the starch granules into thin lattices of inter-connecting sheets. Whereas, protein bodies remained intact but protein surrounding individual starch granule disrupted.

Popping quality of five sorghum varieties was studied by Hosamani and Shankare Goud (1978). Variety A-1 was the best for popping among the tested varieties. Popping quality of Muguthi was found to be moderate but those of SPV-86, CSH-8R and M35-1 was poor.

Thirty six pop sorghum germplasm accessions maintained at the ICRISAT center were screened for superior pop sorghum (Murty *et al.*, 1982). Most suitable pop sorghums for popping exhibited small grain size, white colour, medium thick pericarp, breaking strength of about 7 kg, hard endosperm and a very low germ/endosperm size ratio.

Murty *et al.* (1983) studied the association of some physical grain characters with popping quality of thirty sorghum cultivars. A wide range of variation was observed for all the characters studied. Per cent corneousness of the 30 cultivars varied from 4 to 88. Diameter of starch granules varied from 17 to 26 μ . The range of pop volume for varieties showing similar per cent popping was significantly higher. Popping quality was negatively associated with the quantity of flour passing through the 75 μ sieve showing that hard endosperm is associated with popping quality. A significant correlation between small starch granules and popping quality was observed.

Savithri and Meera Rao (1985) evaluated two varieties ('SB-1066' and 'SB-1079') and two hybrids ('CSH-1' and 'CSH-5') of jowar grown in *kharif* and *rabi* seasons for popping qualities. The popping quality of normal varieties were superior to that of hybrids grown in *kharif* and *rabi* seasons. Popped grains were maximum in normal varieties than in hybrids grown in either season, with 'SB-1079' yielding the maximum and 'CSH-1' the least. Expansion ratio of popped grain followed the same trend as the popping number; higher ratio indicated a higher yield of popped grains.

Thorat *et al.* (1988) assessed nineteen cultivars of grain sorghum of *kharif* (July-October) harvest for their physical characteristics and their relationship with popping quality. The results indicated that there were significant genotypic differences in kernel weight, kernel volume, bulk density, true density, seed hardness, seed moisture, volume of pop, expansion ratio and popping percentage. Expansion ratio had significant positive effect due to seed hardness and bulk density, whereas, seed hardness had strong positive correlation with pop yield. Pop volume did not show any relationship with any of the physical parameters tests.

Grain properties of nineteen sorghum cultivars harvested in *kharif* season were evaluated by Thorat *et al.* (1990). Thousand kernel weight and grain volume of selected sorghum cultivars ranged from 14 to 32 g and 18 to 46 cc, respectively. The highest kernel weight was observed in cultivar HFS-12 followed by HFS-7 and HFS-9, while the lowest was in HFS-5. There was little variation in bulk density among the cultivars.

Four cultivars of sorghum were artificially inoculated with *Fusarium moniliforme* conidia at flowering and bagged (Satish *et al.*, 1991). These samples along with their untreated controls were harvested at physiological maturity and 2 weeks after physiological maturity. The grains obtained from both the treatments were studied for their popping characteristics. Late harvested grains exhibited better popping characteristics. The seed mycoflora was reduced by popping.

Singh and Srivastava (1993) studied ten sorghum genotypes for their popping quality, which were tempered to 12-20 per cent grain moisture level and evaluated for popping %, popping volume, expansion volume and flake size. The popping % of the genotypes differed

significantly at different levels of grain moisture. SPV-881 had the highest popping volume of 23.22 ml at 12 per cent grain moisture while genotypes 'SPV-462', 'SPV-881' and 'CSH-6' exhibited highest expansion volume at same grain moisture. 'SPV-881', 'SPH-504' and 'CSH-10' had the highest flake size at the same level of grain moisture.

Kasturiba *et al.* (1994) studied the popping quality of six new sorghum hybrids and one variety. The percentage of completely popped was highest in hybrid SB-101A x SPV-462 followed by the variety SPV-86 and the least was observed in SB323A x SB905. The expansion ratio of the hybrid SB101A x SPV-462 was the highest (6.66), and least was seen in the hybrid SB 323 A x SB 7001 (3.5).

Gupta *et al.* (1995) studied the sorghum grain variety Gwalior white, which was stored at 50 - 80 ± 3 per cent Relative Humidity (RH) and at 248°C for 6-12 months. Sorghum stored at 80±3 per cent RH showed the highest popping, popping volume, expansion volume, flake size and organoleptic qualities. Grain hardness had significantly negative correlation with flake size, expansion volume, popping per cent and grain moisture.

Kasturiba *et al.* (1997) studied popping quality of nine *rabi* genotypes. The genotype 9-13 was most suitable for popping, as it showed highest percentage of completely popped grains followed by CSH-13R and least was observed in SB-401 x SPV 570 (Pusa basmati) as well as earlier varieties (Dodiga, Udarsali, Navali *etc.*).

Twenty three samples of jowar comprising released varieties, hybrids (18 varieties and 5 hybrid) improved cultivars of grain types were studied for popping characteristics. Observations on 500 popped grain weight, diameter of the popped grain, density of the popped grain were recorded. The jowar varieties 'K4' and the local cultivar 'TWC 120' registered significantly higher 500 popped grain weight. The samples 'MMK', 'Co19', 'K-tall' and 'IS 3541' recorded higher diameters for the popped grains, having lower densities of popped grains. Swelling capacity showed significantly positive correlation with swelling index and diameter of popped grain (Sankarpandian, 2000).

Ten pop sorghum cultivars grown in *kharif* and *rabi* seasons and their popped grains were analysed for chemical composition (Anon., 2002). Significant variation was observed in proximate composition of sorghum cultivars. Protein content (7.42 to 14.84%) showed significant variation among the cultivars. Similarly moisture (9.63-11.83%), fat (1.87-2.66%), ash (1.67-2.97%), crude fibre (1.32-1.97%) and total carbohydrates (79.23-86.25%) differed significantly. The mean moisture, fat and ash contents of *kharif* cultivars were lower than *rabi* grown cultivars. Whereas, the total carbohydrate contents was higher in *kharif* cultivars than *rabi* cultivars. However, popping did not affect the protein (7.99-9.04%) or fat (2.09-2.76) and total carbohydrates (79.59-84.24%) contents but a slight reduction in total ash (1.09-2.16%) was observed.

Mallinath (2002) studied the popping quality of pop sorghum cultivars and evaluated popping yield, flake size and expansion ratio. Flake size had highest correlation followed by expansion ratio with popping yield. Whereas popping yield was significantly but negatively associated with 1000 kernel weight.

Yenagi *et al.* (2005a) studied different processing methods *viz.*, dry heat application, moist heat application, sand/salt/oil as heating media and microwave popping for assessing the suitable method for popping of pop sorghum cultivars. Popping quality of sorghum processed by different methods differed significantly. Popping by dry heat, moist grain and dry heat and oil as heating media showed the highest popping yield, whereas it was only 60 per cent in microwave oven. Expansion ratio of popped grain was significantly high in dry heat popping and low in microwave method. Flake size of popped grain was the highest in moist grain and lowest in microwave.

Yenagi *et al.* (2005b) screened the native pop sorghum cultivars (N=101) for popping quality and nutrient composition (N=10). The popping yield ranged from 43.33-90.00 per cent. About 10 per cent of the cultivars showed a better popping yield of above 80 per cent. Maximum number of cultivars (60%), showed popping yield of above 70 per cent. The

expansion volume and flake size ranged from 4.14 to 11.96 and 0.16-0.53 ml/popped grains respectively. Among the cultivars 14 per cent showed a better expansion volume of above ten and 24.75 per cent cultivars had above eight. Maximum number of cultivars (59%) showed a flake size of 0.20-0.3 ml. Significant variation was observed in proximate composition of raw and popped pop sorghum cultivars. The popped samples were highest in protein and fat but lower in ash and crude fibre contents than those of the raw pop sorghum samples.

2.3 VALUE ADDED PRODUCTS OF POPPED CEREALS

Popping not only improves the shelf-life but also improves the nutritional quality with respect to bioavailability of nutrients. It inactivates enzymes and also reduces microbial contamination. This simple processing technique helps in developing value added ready-to-eat snacks and health foods for different segments of the population as supplementary food. Several commercial weaning mixes are being marketed in India, but they are too expensive for the population of low socio-economic status, especially those in rural area. It is therefore imperative to formulate inexpensive weaning mixes from locally available resources, that can be easily prepared at home.

Tovar and Carpentar (1982) reported that supplementation of boiled maize and tortillas with grain amaranth roasted to the point of popping increased the PER from 1.55 to 2.22, with tryptophan as limiting amino acid.

Malleshi (1987) studied the food uses of malted sorghum and also evaluated the quality of sorghum malt based weaning foods versus popped sorghum based and roller dried weaning foods. Sorghum malt can be well utilized for preparation of malt extract, malt sugars and supplementary and weaning foods. The cooked past viscosity of the malted weaning food was significantly lower than popped and roller dried foods. The protein efficiency ratio of weaning foods at 10 per cent level of protein intake were 2.3, 1.5 and 1.9 for malted, popped and roller dried weaning foods, respectively. Thus, the malted sorghum has a promise in its use for weaning food formulation.

Pederson *et al.* (1987) observed that supplementation of wheat, corn and low tannin sorghum with 10, 25 and 50 per cent popped amaranth flour resulted in considerable improvement of amino acid scores, though lysine remained the first limiting amino acid. Addition of amaranth alleviated the tryptophan deficiency of corn protein.

Reddy *et al.* (1990) found that the puffed "amaranth flour" with puffed jowar and bajra flour increased the protein (12.5 g/100 g), total iron (12 mg/100 g) and gives 357 k cal of energy in the preparation of weaning mixes for infants.

Snehalatha *et al.* (1990) formulated four weaning mixes using local foods and traditional processing techniques *viz.* JRGP-jowar, rice, greengram, potatoes (roasting), GW-wheat, greengram moth beans (malting), JR – jowar, rajkeera, bajra (puffing) and JIBS-jowar, Italian millet, Bengal gram and spinach (fermentation). They were evaluated for acceptability by a sample target population of mothers and infants, and for protein, iron and energy content using established laboratory methods. All the mixes were inexpensive and nutritious, and remained acceptable even after being stored for one month. Crude protein content was highest in GW whereas iron content and energy value was highest in JR.

Rathod and Udipi (1991) studied the nutritional quality and acceptability of weaning foods incorporating amaranth. Substitution of milk powder for puffed amaranth increased the contents of calories, protein and calcium. The acceptability trials revealed that, 76 per cent to 85 per cent of the mothers reported that the mixes were acceptable to their children.

Ashturkar *et al.* (1992) formulated four weaning foods namely, RGB-Rajkeera: green gram: Bengal gram dhal, BRB-bajra: rice flakes: Bengal gram dhal, JSB-Jowar: Soybean: Bengalgram dhal, JPG-Jowar: puffed: Bengalgram: greengram and analysed energy, protein, calcium and iron contents and who evaluated for protein and carbohydrate digestibility. The weaning foods supplied 349 and 362 k cal and 12.6 to 17.29 of protein per 100 g. Among the

four weaning foods RGB had the highest calcium and iron contents and the maximum per cent digestibility of protein followed by JSB. Whereas the maximum per cent digestibility of carbohydrate was observed in RGB followed by BRB.

Annie *et al.* (1993) studied the effect of processing, on wheat and chickpea, development of weaning food formulations and their nutritional quality. There was no significant difference in the biological values among the diets. The fairly high NPU values for all the diets indicate the good growth promoting quality irrespective of the treatments the ingredients received. The food formulations met the standards of codex alimentarius, that the protein quality of cereal based foods for infants and children should not be less than 70 per cent of that of casein. The higher dietary bulk of popped or roller dried weaning foods could be lowered by addition of a small quantity of malt flour.

Hadimani (1994) studied the nutritional quality of supplementary foods prepared from popped and roller dried chickpea. *In vitro* protein digestibility content of popped supplementary food (PSF) (78%) and roller dried supplementary food (RDSF) (75%) was higher than the raw blend (70%). Carbohydrate digestibility of cooked slurry of PSF was significantly higher than RDSF at all comparable incubation times.

Srivastava (1996) compared and studied the nutritional quality as well as acceptability of supplementary foods which were prepared by combining popped or malted sorghum flour, roasted legume flour and sugar (popped sorghum + groundnut, popped sorghum + chickpea, malted sorghum + groundnut, malted sorghum + chickpea). The protein contents of various mixes ranged from 10.6 to 12.5 g and their energy contents from 280 and 425 k cal per 100 g. Supplementary foods based on popped or malted sorghum flour did not differ significantly ($p=0.05$). The overall acceptability of all the supplementary foods was above average indicating that popped sorghum flour could be used instead of malted sorghum flour in the routine preparation of supplementary foods for children.

In a study nutritive quality of popped cereal based health mixes were monitored for blood haemoglobin level of 16 adolescent girls (Yenagi *et al.*, 2002). Health mix fulfilled the protein and energy requirement of adolescent girls by providing 12 per cent protein energy ratio. It provided 16 per cent RDA of iron and also provided $\frac{1}{4}$ RDA of important blood forming nutrients.

III. MATERIAL AND METHODS

The present study was carried out to investigate the quality of pop sorghum cultivars grown in *kharif* and *rabi* seasons for popping and nutritional qualities and to develop value added products from popped grains. The study was carried out in the Department of Food Science and Nutrition, College of Rural Home Science, University of Agricultural Sciences, Dharwad, Karnataka. The details of the materials collected and different methods used to assess the quality of pop sorghum cultivars and to develop different types of snack products are presented in this chapter.

3.1 SELECTION OF POP SORGHUM CULTIVARS

Pop sorghum cultivars grown during *kharif* and *rabi* seasons in the year 2004-2005 were procured from different growing areas of Karnataka (Table 1). All the samples were collected at one lot, cleaned and used for the entire study.

3.2 PHYSICAL CHARACTERISTICS OF POP SORGHUM CULTIVARS

3.2.1 Visual observation

Colour and shape of the whole grains were observed visually and recorded.

3.2.2 Thousand-kernel weight, volume and density

One thousand kernels were counted and their weight was noted and the volume was measured using in a measuring cylinder. Density of grains was calculated from thousand kernel weight and volume.

3.3 NUTRITIONAL QUALITY OF POP SORGHUM CULTIVARS

Pop sorghum cultivars selected for the study were pulverized in a laboratory model Willey mill and the whole meal was used for analysis of proximate composition and to study carbohydrate profile.

3.3.1 Proximate composition

Proximate composition *viz.*, moisture, crude protein, ash, fat and crude fibre contents were determined according to standard procedure of AOAC (Anon., 1990).

Moisture

Moisture content was determined by the difference between the accurately weighed samples before and after drying in a hot oven at 105°C.

Protein

Total nitrogen was estimated by using micro-kjeldhal method. Crude protein was obtained by multiplying the total nitrogen by factor 5.7.

$$\text{Nitrogen (\%)} = \frac{(\text{STV}-\text{BTV}) \times V_1 \times \text{N of HCl for distillation} \times 14 \times 100}{\text{Weight of the sample taken} \times V_2}$$

Where,

STV = Sample titer value
BTV = Blank titer value
V₁ = Volume made up

Table 1. Pop sorghum cultivars selected for the study

Sl. No.	Season	Cultivars	Locality
1.	<i>Kharif</i>	a. Mugad local	Mugad
		b. Uppinbetgeri local	Uppinbetgeri
		c. Bogoore local	Bogoore
2.	<i>Rabi</i>	a. Bijapur local	Bijapur
		b. Marole local	Marole
		c. Hulginal local	Hulginal

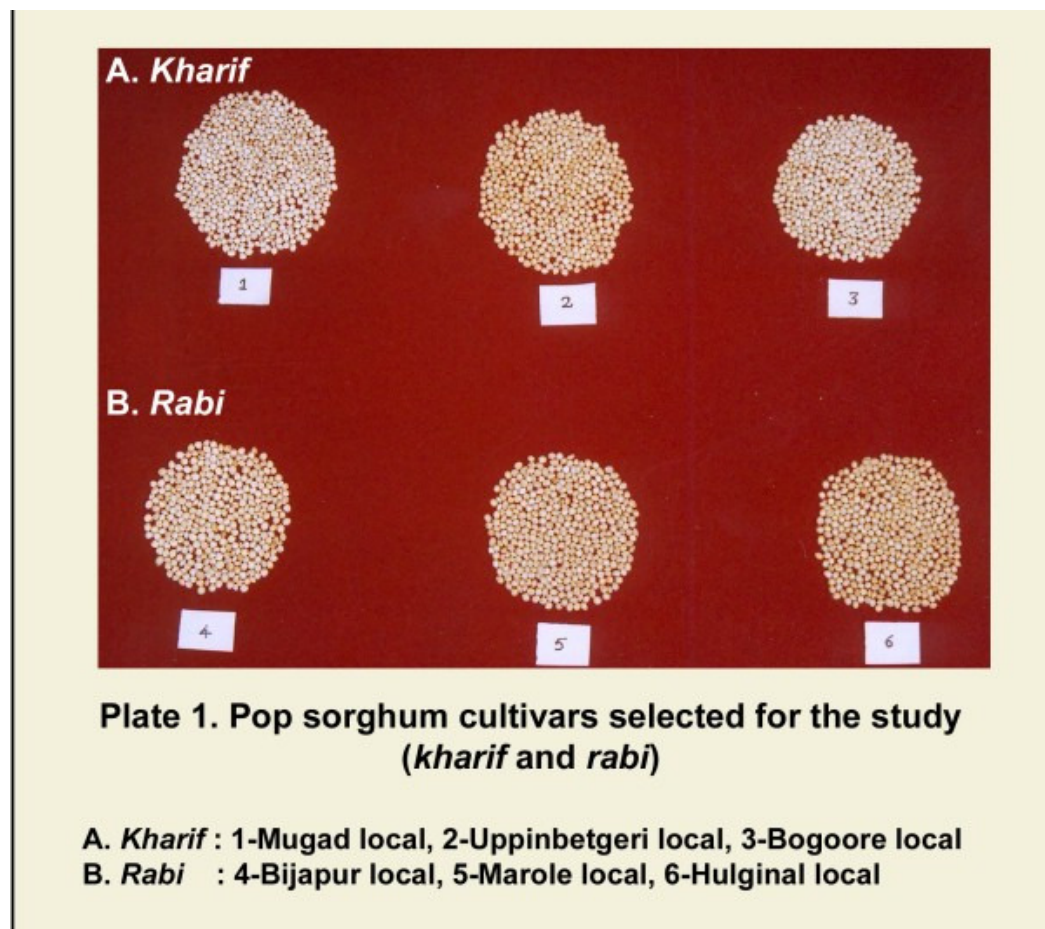


Plate 1. Pop sorghum cultivars selected for the study (Kharif and rabi)

V_2 = Volume taken for distillation

Fat

The total fat content was estimated by solvent extraction method by refluxing with petroleum ether (60°C) in soxhlet apparatus for 12 hours.

$$\text{Fat content (\%)} = \frac{\text{Weight of ether extract}}{\text{Weight of sample (equivalent to fresh sample taken)}} \times 100$$

Ash

Five gram sample weighed in a dry crucible and ignited in a muffle furnace for three hours at 600°C, cooled and weighed. The difference in weight was taken as the weight of ash.

$$\text{Total ash (\%)} = \frac{\text{Weight of the ash}}{\text{Weight of the sample}} \times 100$$

Crude fibre

Crude fibre was estimated by the acid alkali digestion method. The residue obtained after digestion was dried in a crucible and its weight was recorded (W_e). The acid residue was then ashed in a muffle furnace at 600°C for three hours and its weight (W_a) was recorded. The difference between these two weights ($W_e - W_a$) was taken as the weight of the crude fibre.

$$\text{Crude fibre} = \frac{W_e - W_a}{\text{Weight of the sample}} \times 100$$

Total carbohydrates

The contents of total carbohydrates was calculated by subtracting the sum of moisture, protein, fat, ash and crude fibre from 100.

3.3.2 Carbohydrate profile

Estimation of total, reducing and non-reducing sugars

The sugars were extracted from the dried sample by alcohol extraction. Dried 500 mg sample was placed in a conical flask. Ethyl alcohol (80%) was added to it and boiled for 5 minutes on a hot water bath. After the contents settled down the supernatant was transferred to a volumetric flask. The extraction was carried out thrice and the final volume was made upto 2.5 ml. Total sugars was estimated after acid hydrolyzing the alcoholic extraction followed by neutralizing with alkali using Nelson-Somogyi's method (Hawk *et al.*, 1965).

Neutralized 1 ml extract was taken and one ml of alkaline copper reagent was added to it. It was kept in boiling water bath for 20 minutes and cooled. One ml of arsenomolybdate reagent was added to it. After shaking well, the volume was made upto 20 ml, optical density was measured at 510 nm in spectrophotometer.

Reducing sugar was estimated from alcoholic extract directly after evaporation of alcohol by Nelson Somogyi's method (Hawk *et al.*, 1965).

Estimation of starch

Starch content was analysed according to the method of Basarkar and Srinivasan (1997) by hydrolyzing the dried defatted pop sorghum flour in perchloric acid.

Hundred milligram of dried homogenous sample was taken in centrifuge tube, 5-10 ml of 80 per cent alcohol was added and placed the tube in a water bath at 80-85°C for 5-10 min. Then it was centrifuged for 10 min 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 contents were stirred for 5 min continuously and then occasionally for the next 15 min. Little water was added and again centrifuged at 2000

rpm for 5 min. 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 min. The pooled supernatant was diluted with distilled water neutralized with 4 N NaOH, made further dilution to 100 ml and glucose content of the hydrolysate was estimated for reducing sugars according to the method of Nelson-Somogyi' (Hawk *et al.*, 1965).

Estimation of total and soluble amylase

Total and soluble amylose contents of isolated starch samples were determined according to the method of Sowbhagya and Bhattacharya (1979).

Total amylose

One hundred milligram of sample was dispersed in 1 ml ethanol and add 10 ml 1 N NaOH, left overnight and the contents were diluted to 100 ml volumetric flask, 3 drops of 0.1 per cent phenolphthalein and about 50 ml boiled and cooled distilled water were added and the slurry was neutralized with 0.1 N HCl. To that 2 ml of 0.2 per cent iodine solution was added and the volume made upto 100 ml. The blue colour developed was measured at 630 nm. Pure amylose (from potato type III Sigma) was used as standard.

$$\text{Amylose content (\% dry basis)} = \frac{R}{A} \times \frac{a}{r} \times \frac{1 \text{ ml}}{5 \text{ ml}} \times 100$$

Where,

- R = Reading of sample flour dispersion
- A = Reading of standard amylose solution
- a = Amount of standard amylose weighed (mg)
- r = Amount of sample taken (mg)

Soluble amylose

One hundred milligram sample, dispersed in 50 ml water was heated in a water bath for 20 min and filtered. The filtrate was estimated similar to total amylose.

$$\text{Soluble amylose content (\% dry basis)} = \frac{R}{A} \times \frac{a}{r} \times \frac{1 \text{ ml}}{5 \text{ ml}} \times 100$$

$$= \frac{R}{A} \times \frac{a}{r} \times 20$$

Where,

- R = Reading of pop sorghum flour extract
- A = Reading of standard amylose solution
- r = Amount of pop sorghum powder weighed (mg)
- a = Amount of standard amylose weighted (mg)

Insoluble amylase

Subtracting the water soluble amylose value from the total amylose content gives the insoluble amylose content.

$$\text{Insoluble amylose (\% dry basis)} = \text{Total amylose} - \text{Soluble amylose}$$

Amylopectin

The content of amylopectin was calculated by subtracting the total amylose from 100.

$$\text{Amylopectin (\% dry basis)} = 100 - \text{Total amylose content}$$

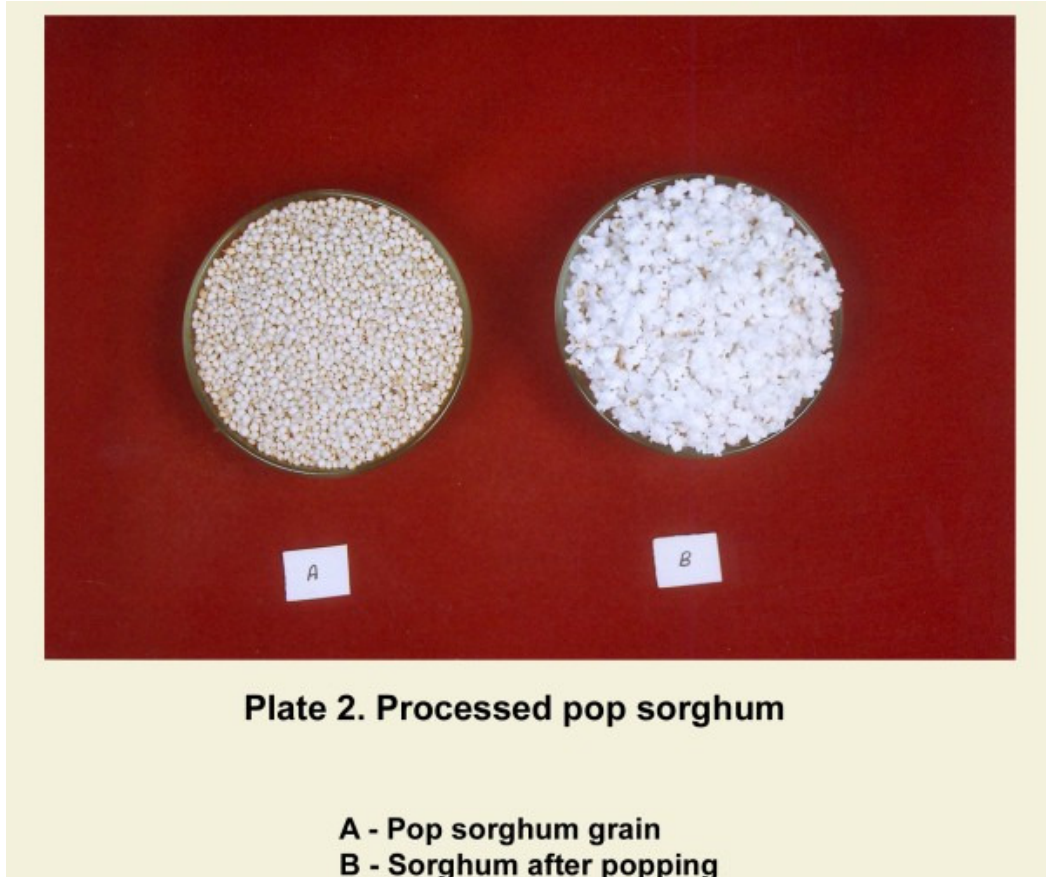


Plate 2. Processed pop sorghum

3.4 POPPING QUALITY OF POP SORGHUM CULTIVARS

Popping is a traditional method of heat processing technique applied to cereals and legumes. Popping can be done by different methods viz., conventional method of dry heat popping, moist grain and dry heat popping, moist grain and dry heat, sand and salt treated, hot air popping, gun puffing, popping in hot oil and microwave popping. In present study, both conventional (moist grain and dry heat) and microwave oven method of popping were used to assess the popping and nutritional qualities.

Conventional method of popping

In conventional method of popping known quantity of cleaned grains were poured in boiling water and boiled for one minute. The grains were strained and tempered for 3 hours. Tempered grains were put in a hot pan of temperature 220°C and covered with a cloth and stirred continuously and continued popping till the popping sound of grains stopped. Popped grains were then removed from the hot pan and after cooling weight of popped and unpopped grains were noted and the following quality parameters were used to assess the popping quality (Yenagi *et al.*, 2004).

Popping quality

a. Popping yield (%)

$$\text{Popping yield (\%)} = \frac{\text{Total weight of popped grains}}{\text{Total weight of popped grains + unpopped grains}} \times 100$$

b. Expansion ratio (ml)

Expansion ratio is the ratio of total popped volume (ml) to that of volume of raw kernels (ml) and expressed as ml.

$$\text{Expansion ratio} = \frac{\text{Total popped volume (ml)}}{\text{Volume of raw kernels (ml)}}$$

c. Flake size (ml/grain)

The flake size determined by the ratio of volume of the popped sorghum to that of number of popped kernels.

$$\text{Flake size (ml/grain)} = \frac{\text{Volume of popped sorghum}}{\text{Number of popped kernels}}$$

Microwave oven method of popping

Microwave oven was used as a modern method of popping. In the present study the KENSTAR microwave oven model no. M09706, voltage: 230 V, 50 Hz AC, input power : 1200 ± 5 per cent watts, microwave output: 800 watts and frequency: 2450 MHz was used. Known quantity of tempered pop sorghum grains were put in glass bowl and covered with lid. Container was kept inside and popped for 3 minutes at high power level, 100 per cent (Yenagi

et al., 2004). Popped grains were then assessed for popping quality by the different method given earlier (section 3.4a to 3.4c).

3.4.1 Nutritional quality of popped cultivars

Pop sorghum cultivars popped by conventional and microwave oven method were assessed for proximate composition and carbohydrate profile as per the procedures mentioned earlier (section 3.3.1-3.3.2).

3.5 DEVELOPMENT OF POPPED SNACKS

3.5.1 Selection of pop sorghum cultivar

Commercially available pop sorghum was collected at one lot from the local market, cleaned and used for the study.

3.5.2 Spice flavoured popped snacks

Two spice flavoured popped sorghum snacks were selected for consumer acceptability by conducting preliminary trials using 11 different spices in the Department of Food Science and Nutrition Laboratory, University of Agricultural Sciences, Dharwad. The evaluation was done by ten semi-trained pannelists for sensory quality characters for overall acceptability (Appendix IV). Based on these results two spice flavoured snacks were selected for consumer preference. A consumer panel of 30 members evaluated this products for organoleptic characters using five point hedonic scale (Swaminathan, 1995).

3.5.3 Sweet coated popped snacks

Two sweet coated products (popped jaggery laddu and sugar coated coloured snack) were preliminarily standardized for ingredients and method of preparation (Appendix XXI-XXII). Further the samples were evaluated for organoleptic characters by 30 consumers using five point hedonic scale (Swaminathan, 1995) for scoring.

3.5.4 Nutrient composition of developed snacks

Two spice flavoured and sugar coated and popped jaggery coated laddu were evaluated for nutrient composition by calculating the nutrients (Gopalan *et al.*, 1996).

3.6 STORAGE QUALITY OF POPPED SORGHUM

Sorghum pop is one of the products commonly used as ready-to-eat snack. Popped flour can be used as a base in the preparation of value added health products like supplementary or weaning food formulations.

Hence a study was carried out to know the changes in quality of popped sorghum and popped flour when stored for one month in different packaging materials.

3.6.1 Packaging materials used for storage

Storage quality of popped grains was assessed by using suitable packaging material for popped grains like paper covers and polythene bags whereas aluminium pouches and low density polythene covers were used to study the storage quality of popped flour.



Plate 3. Popped sorghum snacks

Table 2. Packaging materials used for storage of popped sorghum grains and flour

Sl. No.	Popped sorghum grains	Packaging materials
1.	Popped sorghum grains	a. Polythene cover b. Paper bag
2.	Popped sorghum flour	a. Aluminium pouch b. Low density polythene cover



Plate 4. Different packaging materials used for storage of popped sorghum grains

**A-Polythene cover
B-Paper bag**

Plate 4. Different packaging materials used for storage of popped sorghum grains



Plate 5. Different packaging materials used for storage of popped sorghum flour

**A-Low density polythene cover
B-Aluminium pouch**

Plate 5. Different packing materials used for storage of popped sorghum flour for storage fo popped sorghum flour

3.6.2 Storage of popped sorghum grains and its flour

Commercially available sorghum cultivar was popped by conventional method. Known quantity (100 g) of popped grains were packed in paper covers and polythene bags and were tightly covered/heat sealed and stored at ambient conditions (92% RH and 26.48°C). Conventionally popped grains were milled into fine powder in local flour mill and similarly packed in aluminium pouches (25 microns) and low density polythene covers (180 gauge) and stored at ambient conditions (92% RH and 26.48°C). During storage care was taken to keep samples free from insect attack.

3.6.3 Analysis of stored samples

Stored popped grain samples were withdrawn at weekly intervals and analysed for moisture content and were organoleptically evaluated for storage quality. Similarly popped flour was withdrawn at weekly intervals and evaluated for moisture content, sensory qualities and for free fatty acid content.

3.6.4 Organoleptic evaluation of popped grains and its flour

Organoleptic evaluation of popped sorghum grains and popped flour stored in different packaging materials were evaluated for appearance, colour, texture, flavour and overall acceptability by scoring method (Swaminathan, 1995) using five point hedonic scale (Appendix VI and VII). Code numbers were given to different packaging samples and evaluated by 10 semi trained judges. The mean score was obtained for all the characters and the data was statistically analysed.

3.6.5 Moisture

Moisture content of stored samples was analysed as per the procedure mentioned earlier (section 3.3.1).

3.6.6 Free fatty acid

The amount of free fatty acid present gives an indication of age and quality of fat in foods. The FFA content is expressed as oleic acid equivalents. It was estimated by titrating the sample against potassium hydroxide in presence of phenolphthalein indicator. The detailed procedure is as follows (Anon., 1983).

Reagents

1. Neutral alcohol
2. N/100 potassium hydroxide (KOH) solution
3. 1 per cent phenolphthalein indicator

Procedure

A known quantity of sample (25 g) was used for extraction of fat in chloroform at the ratio of 1:4. Samples was kept for extraction overnight and filtered. Fat extract of 25 ml in a conical flask was added with 50 ml of hot neutral alcohol and 2-4 drops of phenolphthalein indicator. The content was titrated against N/100 KOH solution, until a pink colour which persisted for 15 seconds or more. The same procedure was followed for blank also.

FFA content of sample was obtained as,

$$\text{FFA (\% oleic acid)} = \frac{S \times N \times 28.2}{\text{Weight of fat (g)}}$$

Where,

S = ml of KOH

N = Normality of KOH solution

3.7 STATISTICAL ANALYSIS

The data collected on physical properties, chemical composition and popping qualities of pop sorghum cultivars grown in different seasons were statistically analysed. Completely Randomized Design (CRD) was applied to test the significant differences in quality parameters. Whereas developed popped snacks and storage quality was analysed by using factorial CRD. 'F' test was used to test the significance difference in quality parameters within the cultivars. The limit of probability fixed for the test of significance was $P=0.05$, wherever, the significant result was obtained, the critical test was used for comparing treatments (Steel and Jorrie, 1960). The correlation coefficient, among physical characters, chemical composition and processing qualities was also determined (Snedecor and Cochran, 1962).

IV. EXPERIMENTAL RESULTS

The grain quality of different pop sorghum cultivars grown in *kharif* and *rabi* seasons were studied for physical characteristics, chemical composition and popping qualities. Popped sorghum was also assessed for the development of value added products. The results of the same are presented in this chapter.

4.1 PHYSICAL CHARACTERISTICS OF POP SORGHUM CULTIVARS

Physical characteristics *viz.*, thousand-kernel weight, volume and density and colour and shape of pop sorghum cultivars grown in *kharif* and *rabi* are presented in Table 3.

4.1.1 Visual observation

Pop sorghum cultivars grown in *kharif* season were creamy white or brownish white in colour and oval or oblong in shape. Mugad local and Boroore local cultivars were creamy white in colour and oval in shape. Whereas, Uppinbetgeri local was brownish white in colour and oblong in shape. Among *rabi* cultivars Bijapur local was dull white and oblong in colour and shape respectively. Whereas, Marole local and Hulginal local were oval and oblong in shape and brownish white in colour.

4.1.2 Thousand-kernel weight volume and density

Pop sorghum cultivars grown in *kharif* and *rabi* seasons showed significant ($P<0.05$) variation in thousand-kernel weight with range of 15.60 to 20.30 g (Table 3). Among *kharif* grown cultivars significant ($P<0.05$) variation was observed. Uppinbetgeri local (18.52 g) had higher kernel weight when compared with Bogoore local (16.32 g) and Mugad local (15.60 g). Whereas kernel weight of *rabi* cultivars did not differ significantly. The observed mean of *rabi* cultivars was 20.10 g. All the *rabi* cultivars had kernel weight of 20.10 g which was higher than all the *kharif* cultivars.

The thousand kernel volume of pop sorghum cultivars varied significantly ($P<0.05$). It ranged from 18.67-25.33 ml. Among *kharif* cultivars significant ($P<0.05$) variation was observed. Uppinbetgeri local (24.00 ml) showed higher kernel volume followed by Bogoore local (23.00 ml) and Mugad local (18.67 ml), whereas observed kernel volume of *rabi* cultivars was not significant. The mean kernel volume of *rabi* cultivars observed was 25.00 ml. However, all the *rabi* cultivars showed higher kernel volume than all the *kharif* cultivars (Table 3).

The thousand-kernel density of different pop sorghum cultivars ranged from 0.77 to 0.83 g/ml with significant variation ($P<0.05$). Among *kharif* grown cultivars the kernel density observed was 0.83, 0.82 and 0.77 g/ml for Mugad local, Bogoore local and Uppinbetgeri local, respectively. *Rabi* grown cultivars showed significant ($P<0.05$) variation in kernel density. Bijapur local showed higher bulk density (0.81 g/ml) when compared with Hulginal local (0.80 g/ml) and Marole local (0.78 g/ml). Significant variation was observed between *kharif* and *rabi* cultivars. All the *kharif* cultivars showed higher kernel density (0.81 g/ml) than *rabi* cultivars (0.80 g/ml).

Table 3. Physical characteristics of pop sorghum cultivars grown in different seasons

Cultivars	Visual observation		1000-kernel		
	Colour	Shape	Weight (g)	Volume (ml)	Density (g/ml)
<i>Kharif</i>					
Mugad local	Creamy white	Oval	15.60	18.67	0.83
Uppinbetgeri local	Brownish white	Oblong	18.52	24.00	0.77
Bogoore local	Creamy white	Oval	16.32	23.00	0.82
<i>Rabi</i>					
Bijapur local	Dull white	Oblong	20.30	25.00	0.81
Marole local	Brownish white	Oval	20.00	25.33	0.78
Hulginal local	Brownish white	Oblong	20.01	24.67	0.80
F-value	-	-	198.23*	3.962*	4.367*
S.Em±	-	-	0.456	0.70	0.006
CD at 5%	-	-	1.26	1.93	0.01

* The values are significantly different at 5% point of distribution of F.

4.2 NUTRIENT COMPOSITION OF POP SORGHUM CULTIVARS

4.2.1 Proximate composition

Proximate composition *viz.*, moisture, protein fat, ash, crude fibre and total carbohydrate of *kharif* and *rabi* grown cultivars is given in Table 4.

Moisture content of pop sorghum cultivars showed significant ($P<0.05$) variation. It ranged from 9.50 to 12.55 per cent with a total mean of 10.98 per cent. Mugad local a *kharif* cultivar had higher (10.30%) moisture content with the mean of 9.91 per cent, *kharif* cultivars did not revealed significant difference. Whereas *rabi* cultivars showed significant ($P<0.05$) variation in moisture content. It ranged from 11.30 to 12.55 per cent with mean of 12.02 per cent. Hulginal local (12.55%) had higher moisture content among *rabi* cultivars followed by Bijapur local (12.22%) and Marole local (11.30%). Higher (12.02%) moisture content was observed in *rabi* cultivars than *kharif* cultivars.

The protein content of different pop sorghum cultivars indicated significant ($P<0.05$) difference. The range observed was from 7.77 to 12.78 per cent with the mean of 10.36 per cent. *Kharif* cultivars did not show significant difference. The mean of *kharif* cultivars observed was 8.63 per cent Uppinbeteri had higher (9.17%) protein content. Whereas significant difference was found in protein content in *rabi* cultivars. Hulginal local (12.78%) showed higher protein content followed by Bijapur local (12.73%) and Morole local (10.77%). However, significant ($P<0.05$) variation was observed among *kharif* and *rabi* cultivars. Protein content was higher (12.09%) in *rabi* grown cultivars than in *kharif* (8.63%) grown cultivars.

Pop sorghum cultivars grown in *kharif* and *rabi* showed significant ($p<0.05$) variation in fat content, which ranged from 2.71 to 3.31 per cent (Table 4). Mugad local (3.06%) possessed higher fat content among *kharif* grown cultivars followed by Bogoore local (2.85%) and Uppinbetgeri local (2.71%). The variation among *kharif* grown cultivars was significant ($P<0.05$). Significant ($P<0.05$) difference was found in fat content among all the *rabi* cultivars with higher fat content in Hulginal local (3.31%). However, significant ($P<0.05$) variation was observed between *kharif* and *rabi* grown cultivars. All the *rabi* cultivars showed higher fat content than *kharif* grown cultivars.

Observations from Table 4 showed significant ($P<0.05$) variation in ash content with of 1.92 and 2.37 per cent. Uppinbetgeri local (2.24%) had higher ash content among *kharif* grown cultivars followed by Mugad local (2.10%) and Bogoore local (1.92%). The difference in ash content among *kharif* cultivars was found to be significant ($P<0.05$). Whereas *rabi* cultivar did not differ significantly. The mean of ash content in *rabi* cultivars was 2.32 per cent. However, a significant ($P<0.05$) variation was observed among *kharif* and *rabi* grown cultivars. Ash content was found to be higher (2.32%) in all the *rabi* cultivars than in the *kharif* cultivars.

Crude fibre content of pop sorghum cultivars ranged between 1.07 to 1.44 per cent with a significant ($P<0.05$) variation. All the *kharif* cultivars showed significant ($P<0.05$) variation in crude fibre content. Mugad local, Uppinbetgeri local and Bogoore local had 1.30, 1.22 and 1.07 per cent of crude fibre content, respectively. Whereas among *rabi* cultivars crude fibre content did not differ significantly. The mean of *rabi* cultivars was 1.40 per cent. However with a significant ($P<0.05$) variation all the *rabi* cultivars showed higher crude fibre (1.40%) content than *kharif* cultivars (1.19%).

Observations of Table 4 revealed a significant ($P<0.05$) variation of total carbohydrates among different pop sorghum cultivars. It ranged from 67.55 to 76.44 per cent. The data revealed no significant difference in total carbohydrate content among *kharif* grown cultivars. The mean of *kharif* cultivars was 75.29 per cent. Whereas total carbohydrate content varied significantly ($P<0.05$) among the *rabi* cultivars. Marole local (71.00%) had higher total carbohydrate content when compared with Bijapur local (68.48%) and Hulginal local (67.55%). However *kharif* cultivars showed higher (75.29%) total carbohydrate content than *rabi* cultivars. The variation observed was significant ($P<0.05$).

Table 4. Proximate composition (g/100 g) of pop sorghum cultivars grown in different seasons

Cultivars	Moisture	Protein	Fat	Ash	Crude fibre	Total carbohydrate
<i>Kharif</i>						
Mugad local	10.30	8.96	3.06	2.10	1.30	74.28
Uppinbetgeri local	9.50	9.17	2.71	2.24	1.22	75.16
Bogoore local	9.95	7.77	2.85	1.92	1.07	76.44
<i>Rabi</i>						
Bijapur local	12.22	12.73	2.93	2.29	1.35	68.48
Marole local	11.30	10.77	3.21	2.31	1.41	71.00
Hulginal local	12.55	12.78	3.31	2.37	1.44	67.55
F-value	58.204*	104.488*	26.101*	7.721*	10.020*	244.508*
S.Em±	0.355	0.576	0.063	0.050	0.040	1.020
CD at 5%	0.98	1.59	0.17	0.13	0.11	2.81

* The values are significantly different at 5% point of distribution of F.

Table 5. Sugar content (%) of pop sorghum cultivars grown in different seasons

Cultivars	Sugars (%)		
	Total sugar	Reducing sugar	Non-reducing sugar
<i>Kharif</i>			
Mugad local	2.05	0.12	1.93
Uppinbetgeri local	1.89	0.12	1.77
Bogoore local	1.56	0.14	1.42
<i>Rabi</i>			
Bijapur local	1.52	0.13	1.39
Marole local	1.79	0.14	1.65
Hulginal local	1.65	0.15	1.50
F-value	90.892*	4.600	156.258*
S.Em±	0.050	0.003	0.058
CD at 5%	0.13	NS	0.16

* The values are significantly different at 5% point of distribution of F. NS-Not significant

4.2.2 Carbohydrate profile

The results of the sugar content of different pop sorghum cultivars is given in Table 5. The data revealed significant ($P < 0.05$) variation in total sugar content among different pop sorghum cultivars grown in *kharif* and *rabi* seasons. It ranged from 1.52 to 2.05 per cent. Among *kharif* cultivars Mugad local (2.05%) had higher total sugar content followed by Uppinbetgeri local (1.89%) and then Bogoore local (1.56%). Among *rabi* cultivars, Marole local (1.79%) had higher total sugar content. However, data revealed significant difference among *kharif* and *rabi* cultivars. Total sugar content (1.83%) was higher in *kharif* grown cultivars than *rabi* cultivars (1.65%).

Reducing sugar content of different pop sorghum cultivars did not vary significantly. The mean of reducing sugars in *kharif* cultivars was 0.12 per cent with higher values in Bogoore local (0.14%). *Rabi* cultivars showed the mean of 0.14 per cent with the higher values of 0.15 per cent in Hulginal local a *rabi* cultivar.

Pop sorghum cultivars showed significant ($P < 0.05$) variation in non-reducing sugar contents (Table 5). It ranged from 1.39 to 1.93 per cent, with the mean of 1.80. The higher non-reducing sugar content among *kharif* cultivars was observed in Mugad local (1.93%) followed by Uppinbetgeri local (1.77%) and Bogoore local (1.42%). The mean of *kharif* cultivars observed was 1.70 per cent. Non-reducing sugar content of *rabi* cultivars ranged between 1.39 to 1.65 per cent with the mean of 1.51 per cent. Marole local (1.65%) a *rabi* cultivar showed higher non-reducing sugar content followed by Hulginal local (1.50%) and Bijapur local (1.39%). All the *kharif* cultivars showed higher non-reducing sugar content (0.70%) than *rabi* cultivars (1.51%).

Starch, total amylose, soluble amylose and insoluble amylose and amylopectin contents of different pop sorghum cultivars grown in *kharif* and *rabi* cultivars are presented in Table 6.

Starch content of different pop sorghum cultivars did not differ significantly. The mean of *kharif* cultivars was 68.10 per cent with higher values of Uppinbetgeri local (69.75%). In case of *rabi* grown cultivars Marole local (71.31%) showed higher values of starch with total mean of *rabi* cultivars (70.95%).

Observations of Table 6 revealed significant ($P < 0.05$) difference in total amylose content of different pop sorghum cultivars. It ranged from 21.06 to 25.65 per cent with the total mean of 23.86 per cent. Among *kharif* cultivars the higher total amylose content was observed in Mugad local 22.08 per cent when compared with other two cultivars with the mean of cultivars 21.61 per cent. Total amylose content showed higher values of 25.65 per cent in Hulginal local among *rabi* cultivars. Higher mean of total amylose content of 24.33 per cent was observed in *rabi* cultivars than *kharif* cultivars (21.61%).

Soluble amylose content of different pop sorghum cultivars showed significant ($P < 0.05$) difference. The range was between 12.67 to 16.39 per cent with the overall mean of 14.57 per cent. Uppinbetgeri local (14.01%), a *kharif* cultivar showed higher values of soluble amylose content followed by Bogoore and Mugad local (12.67%). The mean of *kharif* cultivars was 13.36 per cent which was found to be lower than the total mean content (14.67%) of *rabi* cultivars. Hulginal local (16.39) showed higher soluble amylose content among *kharif* cultivars followed by Marole local (14.72%) and Bijapur local (12.92%).

Insoluble amylose content of different pop sorghum cultivars varied significantly ($P < 0.05$). The range observed between 7.05 to 10.33 per cent with the overall mean of 9.30 per cent. The higher insoluble amylose content was observed in Mugad local (9.41%) when compared with other two *kharif* grown cultivars, Bogoore local (8.29%) and Uppinbetgeri local (7.05%). Among *rabi* grown cultivars the higher insoluble amylose content was found in Bijapur local (10.33%) followed by Marole local (9.37%) and Hulginal local (9.26%). Insoluble amylose content showed higher mean values in *rabi* cultivars (9.65%) than *kharif* cultivars (8.25%).

Table 6. Starch, amylose and amylopectin (%) content of pop sorghum cultivars grown in different seasons

Cultivars	Starch (%)	Amylose (%)			Amylopectin (%)
		Total	Soluble	Insoluble	
<i>Kharif</i>					
Mugad local	67.45	22.08	12.67	9.41	77.92
Uppinbetgeri local	69.76	21.06	14.01	7.05	78.94
Bogoore local	67.11	21.71	13.42	8.29	78.29
<i>Rabi</i>					
Bijapur local	70.45	23.25	12.92	10.33	76.75
Marole local	71.31	24.09	14.72	9.37	75.91
Hulginal local	71.09	25.65	16.39	9.26	74.35
F-value	1.283	9.015*	13.066*	11.445*	10.585*
S.Em±	0.4697	0.4993	0.3966	0.330	0.54
CD at 5%	NS	1.35	1.07	0.91	1.49

* The values are significantly different at 5% point of distribution of F.
NS-Not significant

Data presented in Table 6 indicates a significant ($P < 0.05$) variation in amylopectin content among the different pop sorghum cultivars. The amylopectin content varied from 74.35 to 78.94 per cent in different pop sorghum cultivars. The mean amylopectin content was higher in pop sorghum cultivars grown in *kharif* season (78.38%) than grown in *rabi* (75.67%). Among *kharif* cultivars, Uppinbetgeri local (78.94) showed higher amylopectin content followed by Bogoore local (78.29%) and Mugad local (77.92%). Amylopectin values were higher in Bijapur local (76.75%), among *rabi* cultivars followed by Marole local (75.91%) and Hulginal local (74.35%).

4.3 POPPING QUALITY OF POP SORGHUM CULTIVARS

Popping qualities were evaluated for popping yield, expansion ratio and flake size and the data is presented in Table 7.

Conventional method of popping

The popping yield of conventionally popped sorghum cultivars grown in *kharif* and *rabi* season varied significantly ($P < 0.05$), in conventional popping method. It ranged from 79.43 to 93.17 per cent, among *kharif* grown cultivars, Mugad local showed higher popping yield (93.17%) followed by Bogoore local (89.02%) and Uppinbetgeri local (84.12%). Popping yield of *kharif* grown cultivars varied significantly ($P < 0.05$). Among *rabi* grown cultivars the popping yield ranged from 79.43 to 88.98 per cent. The difference among *rabi* cultivars varied significantly ($P < 0.05$). The higher popping yield was observed in Marole local (88.98%) followed by Hulginal local (80.28%) and then Bijapur local (79.43%). However, the data revealed that in conventionally popped grains, *kharif* cultivars showed highest mean of popping yield (88.77%) than *rabi* grown cultivars (82.89%).

Expansion ratio of conventionally popped pop sorghum cultivars did not show significant difference. The mean expansion ratio of *kharif* cultivars was 13.75 ml. Higher expansion ratio was observed in Mugad local (15.07 ml) among *kharif* cultivars. *Rabi* cultivars did not show significant difference in expansion ratio. The mean of *rabi* cultivars was 14.17 ml. Marole local a *rabi* cultivar showed 16.33 ml of expansion ratio. No significant variation was observed among *kharif* and *rabi* cultivars when popped by conventional method.

Significant ($P < 0.05$) variation was found in flake size, among different popped sorghum cultivars when processed by conventional popping method. It ranged from 0.31 to 0.55 ml/grain. Flake size of popped grains of *kharif* cultivars did not differ significantly. The total mean of *kharif* cultivars was 0.32 ml/grain. Among *rabi* cultivars significant ($P < 0.05$) variation was observed in flake size when popped conventionally. The higher flake size was found in Marole local (0.55 ml/grain), when compared with Bijapur local (0.46 ml/popped sorghum) and Hulginal local (0.35 ml/grain). *Rabi* cultivars showed higher flake size than *kharif* cultivars.

Microwave method of popping

In microwave popping, popping yield ranged between 57.78 to 78.64 per cent among *kharif* and *rabi* grown cultivars with significant ($P < 0.05$) variation. Among *kharif* cultivars popping yield ranged from 57.78 to 78.35 per cent with the mean of 67.85 per cent Mugad local (78.35), a *kharif* cultivar showed higher popping when compared with Bogoore local (67.43%) and Uppinbetgeri local (57.78%). In case of *rabi* cultivars popping yield ranged from 57.93-78.64 per cent. The higher popping yield was found in Marole local (78.64%) among *rabi* cultivars followed by Hulginal local (80.28%). However, *rabi* cultivars showed higher (69.82%) popping yield than *kharif* (67.85%) cultivars (Table 7).

The interaction effect of processing of pop sorghum, showed significant ($P < 0.05$) variation with respect to popping yield and expansion volume (Appendix I). The sorghum cultivars processed by conventional method of popping had the highest popping yield 85.83 per cent than the pop sorghum cultivars processed by microwave popping 68.84 per cent.

Table 7. Popping quality of pop sorghum cultivars grown in different seasons

Cultivars	Popping yield (%)		Expansion volume (ml/g)		Flake size (ml/grain)	
	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping
<i>Kharif</i>						
Mugad local	93.17	78.35	15.07	13.73	0.34	0.36
Uppinbetgeri local	84.12	57.78	12.33	10.53	0.31	0.31
Bogoore local	89.02	67.43	13.87	12.73	0.33	0.33
<i>Rabi</i>						
Bijapur local	79.43	57.93	13.33	11.60	0.46	0.48
Marole local	88.98	78.64	16.33	15.40	0.55	0.55
Hulginal local	80.28	72.91	14.07	12.67	0.35	0.37
Mean	85.83	68.84	14.17	12.78	0.39	0.40
F-value	5.75*	8.09*	2.00	4.86*	5.37*	73.28*
S.Em±	1.43	2.3816	0.46	0.46	0.0256	0.0212
CD at 5%	3.95	6.58	NS	1.27	0.07	0.05

NS-Not significant

* The values are significantly different at 5 per cent, point of distribution of F.

In case of microwave popping, expansion ratio of popped grains varied significantly ($P < 0.05$). It ranged from 10.53 to 15.40 ml with the overall mean of 12.78 ml. *Kharif* grown popped sorghum cultivars ranged from 10.53 to 13.73 ml, with the mean of 12.33 ml. In *rabi* cultivars expansion ratio ranged from 11.60 to 15.40 ml. The higher value was observed in Marole local (15.40 ml). However, no significant difference was found between *kharif* and *rabi* cultivars.

The interaction effect of expansion ratio showed significant ($P < 0.05$) variation when processed by different popping methods (Appendix II). Pop sorghum cultivars showed the highest expansion ratio of 14.17 ml when popped by conventional method than processed by microwave method (12.78 ml).

When pop sorghum cultivars were popped in microwave oven, significant ($P < 0.05$) difference was observed in flake size. *Kharif* grown cultivars ranged between 0.31 to 0.36 ml/grain with the mean of 0.33 ml/popped. In *rabi* cultivars higher flake size was observed in Marole local (0.55 ml/grain). The difference was significant ($P < 0.05$) among *rabi* cultivars. All the *rabi* cultivars showed higher flake size (0.46 ml/grain) than *kharif* cultivars when they were popped in microwave oven (0.33 ml/grain).

However, interaction effect of flake size did not revealed any significant variation when processed by different popping method (Appendix III).

4.3.1 Nutritional quality of sorghum cultivars after popping

The proximate composition of pop sorghum cultivars after popping were analysed and the results are presented as follows.

Conventional method of popping

Observations of Table 8 revealed that there was a significant ($P < 0.05$) variation in moisture content of conventionally popped sorghum cultivars grown in *kharif* and *rabi* season. It ranged from 6.42 to 10.67 per cent. The higher moisture content among *kharif* cultivars was in Bogoore local (8.20%) followed by Mugad local (7.82%) and Uppinbetgeri local (6.42%). Moisture content of *rabi* cultivars was higher in Hulginal local (10.67%), when compared with other two cultivars. *Rabi* cultivars with the mean of 9.83 per cent showed higher moisture content than *kharif* cultivars (7.48%).

Microwave method of popping

The protein content of conventionally popped cultivars ranged from 8.16 to 14.15 per cent with the overall mean of 11.29 per cent. *Kharif* cultivars, when popped by conventional method showed higher protein content in Uppinbetgeri local (10.56%) followed by Mugad local (9.96%) with the mean of 9.56 per cent. Among *rabi* cultivars, popped grains showed higher protein content in Hulginal local (14.15%) followed by Bijapur local (13.16%) and Marole local (11.16%) with the mean of 12.82 per cent in *rabi* grown popped grains which was higher than mean of 9.56 per cent in *kharif* grown popped grains. All the cultivars showed significant ($P < 0.05$) difference when popped conventionally.

Data presented in Table 8 showed that fat content in pop sorghum cultivars when popped by conventional method varied significantly ($P < 0.05$). The range observed was from 2.85 to 3.46 per cent with the overall mean of 3.15 per cent. *Kharif* cultivars, when popped conventionally showed higher fat content in Mugad local (3.13%) followed by Bogoore local (2.91%) and Uppinbetgeri local (2.85%) with the mean of 2.96 per cent. Fat content of *rabi*, popped grains showed higher fat content in Marole local (3.46%) followed by Hulginal local (3.38%) and Bijapur local (3.18) with the mean of 3.34 per cent which was higher than the mean of all the *kharif* cultivars (2.96%).

Observations of Table 8 showed that ash content of pop sorghum cultivars, when popped by conventional method did not show significant variation. The observed range of ash content was from 1.03 to 1.31 per cent with the overall mean of 1.16 per cent. The higher ash

Table 8. Proximate composition (g/100 g) of pop sorghum cultivars (*kharif* and *rabi*) after popping

Cultivars	Moisture		Protein		Fat		Ash		Crude fibre		Total carbohydrate	
	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping
<i>Kharif</i>												
Mugad local	7.82	8.00	9.96	10.15	3.13	3.18	1.18	1.82	1.18	1.16	76.73	75.68
Uppinbetgeri local	6.42	6.32	10.56	11.35	2.85	2.78	1.31	2.10	1.09	1.06	77.77	76.38
Bogoore local	8.20	8.00	8.16	8.56	2.91	2.95	1.03	1.43	1.03	1.05	78.67	78.00
<i>Rabi</i>												
Bijapur local	9.80	9.62	13.16	13.34	3.18	3.29	1.13	1.74	1.22	1.23	71.51	70.07
Marole local	9.02	8.78	11.16	11.75	3.46	3.43	1.18	1.44	1.27	1.27	73.91	73.32
Hulginal local	10.67	10.45	14.15	13.94	3.38	3.40	1.20	1.89	1.37	1.35	69.23	68.96
Mean	8.65	8.53	11.29	11.52	3.15	3.17	1.16	1.74	1.19	1.18	74.63	73.73
F-value	16.330*	34.392*	41.902*	36.049*	12.455*	17.131*	2.343	7.572*	14.487*	8.247	48.483*	87.522*
S.Em±	0.43	0.40	0.63	0.55	0.07	0.07	0.03	0.07	0.03	0.3	1.07	1.00
CD at 5%	1.18	1.10	1.74	1.38	0.19	0.19	NS	0.19	0.08	NS	2.95	2.76

NS-Not significant

*The values are significantly different at 5% point of distribution of F

content was observed among *kharif* cultivars in Uppinbetgeri local (1.31%). Ash content of *rabi* cultivars was higher in Hulginal local 1.20 per cent.

Crude fibre content of conventionally popped pop sorghum cultivars varied significantly ($P < 0.05$). The range observed was from 1.03 to 1.37 per cent with the overall mean of 1.19 per cent. Crude fibre content of *kharif* cultivars was higher in Mugad local (1.18%), when compared with other two cultivars. Among *rabi* cultivars 1.37 per cent in Hulginal local, was higher crude fibre content followed by Marole local (1.27%) and Bijapur local (1.22%). The mean of popped *rabi* cultivars (1.28%) was higher than popped *kharif* cultivars (1.10%).

Total carbohydrate content of conventionally popped pop sorghum cultivars grown in *kharif* and *rabi* season differed significantly ($P < 0.05$). It ranged from 69.23 to 78.67 per cent with the total mean of 74.63 per cent. Among *kharif* cultivars Bogoore local (78.67%) had higher total carbohydrate content followed by Uppinbetgeri local (77.77%) and Mugad local (76.73%). Among *rabi* cultivars, Marole local (73.91%) showed higher values of total carbohydrate, when compared with Bijapur local (71.51%) and Hulginal local (69.23%). The mean of popped *kharif* cultivars showed higher total carbohydrate content (77.72%) than popped *rabi* cultivars (71.55%).

In microwave popped grains, moisture content showed significant ($P < 0.05$) difference among pop sorghum cultivars grown in *kharif* and *rabi* seasons (Table 8). The range observed was between 8.00 to 10.45 per cent. The mean of *kharif* cultivars was 7.44 per cent, when popped in microwave oven with higher moisture content in Mugad local and Bogoore local (8.00%). *Rabi* cultivars when popped in microwave oven showed mean of 9.61 per cent which was higher than *kharif* cultivars. Hulginal local had higher moisture content (10.45%) among *rabi* cultivars when compared with other two cultivars.

Pop sorghum cultivars grown in *kharif* and *rabi* seasons when popped in microwave oven showed a significant ($P < 0.05$) variation in protein content. It ranged from 8.56 to 13.94 per cent with the overall mean of 11.52 per cent. In case of *kharif* grown popped grains, Uppinbetgeri showed higher protein content of 11.35 per cent followed by Mugad local (10.15%) and Bogoore local (8.56%). The mean of *rabi* cultivars was 13.01 per cent which was higher than *kharif* cultivars when popped in microwave oven. The higher protein content among *rabi* cultivars was in Hulginal local (13.94%) followed by Bijapur local (13.34%) and Marole local (11.75%).

Pop sorghum cultivars, when popped in microwave oven, the fat content ranged between 2.78 to 3.43 per cent with the overall mean of 3.17 per cent. It showed significant ($P < 0.05$) variation. Among *kharif* cultivars Mugad local (3.18%) had higher fat content, when compared with other two cultivars with the mean of 2.97 per cent. Fat content was higher in Marole local (3.43%), among *rabi* cultivar followed by Hulginal local (3.40%) and Bijapur local (3.29%). The mean of *rabi* cultivars (3.37%) was higher than *kharif* cultivars (2.97%), when popped in microwave oven.

In microwave popped grains, ash content varied significantly ($P < 0.05$). The range observed was between 1.43 to 2.10 per cent with the overall mean of 1.74 per cent. Between *kharif* cultivars the ash content observed 2.10, 1.82 and 1.43 per cent for Uppinbetgeri local, Mugad local and Bogoore local respectively. Among *rabi* cultivars higher ash content was found in Hulginal local (1.89%) followed by Bijapur local (1.74%) and Marole local (1.44%). The mean ash content (1.78%) was higher in *kharif* cultivars than *rabi* cultivars (1.69%).

Microwave popped sorghum cultivars did not differ significantly in crude fibre content. The overall mean of crude fibre was 1.18 per cent. The observed mean of *kharif* cultivars was 1.09 per cent, Mugad local (1.16%) a *kharif* cultivar had higher crude fibre content. Among *rabi* cultivars the mean was 1.28 per cent and Hulginal local (1.35%) had higher crude fibre content.

Microwave popped pop sorghum grains showed significant ($P < 0.05$) variation in total carbohydrate content. The range observed from 68.6 to 78.00 per cent with the overall mean of 73.73 per cent. Bogoore local (78.00%), a *kharif* cultivar showed higher values when

Table 9. Sugar content (%) of pop sorghum cultivars grown in different seasons after popping

Cultivars	Sugars (%)					
	Total sugar		Reducing sugar		Non-reducing sugar	
	Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping
<i>Kharif</i>						
Mugad local	1.93	1.85	0.16	0.14	1.77	1.71
Uppinbetgeri local	1.35	1.24	0.11	0.06	1.27	1.18
Bogoore local	1.38	1.30	0.10	0.08	1.29	1.22
<i>Rabi</i>						
Bijapur local	1.45	1.35	0.12	0.09	1.35	1.25
Marole local	1.72	1.67	0.13	0.09	1.60	1.57
Hulginal local	1.43	1.37	0.14	0.07	1.30	1.29
Mean	1.54	1.46	0.12	0.08	1.43	1.37
F-value	2546.120*	2807.24*	12.829*	5.400	852.00*	5660.00*
S.Em±	0.06	0.06	0.005	0.002	0.05	0.05
CD at 5%	0.16	0.16	0.01	NS	0.13	0.13

NS-Not significant

* The values are significantly different at 5 per cent, point of distribution of F.

compared with other two cultivars. Among *rabi* cultivars Marole local (73.32%) showed higher total carbohydrate content, when compared with other two cultivars. The mean of popped *kharif* cultivars (76.68%) was found to be higher than that of popped *rabi* cultivars (78.78%).

Total, reducing and non-reducing sugar content of popped sorghum cultivars was analyzed and the results are presented in Table 9.

Conventionally popped sorghum grains showed significant variation ($P < 0.05$) in total sugar content. The range observed between all the grains were 1.35 to 1.93 per cent with the overall mean of 1.54 per cent. The higher total sugar content was found in Mugad local (1.93%) a *kharif* cultivar followed by Bogooore local (1.38%) and Uppinbetgeri local (1.35%). The higher total sugar content of popped grains among *rabi* cultivars was found in Marole local (1.72%) then followed by Bijapur local (1.45%) and Hulginal local (1.43%). All the *kharif* popped grains showed higher mean of ash content (1.55%) than *rabi* popped grains.

Observations of Table 9 showed that significant ($P < 0.05$) variation existed in reducing sugar content among all the conventionally popped sorghum cultivars. The range observed was from 0.10 to 0.16 per cent with the overall mean of 0.12 per cent. Mugad local showed higher reducing sugar content among *kharif* cultivars followed by Uppinbetgeri local (0.11%) and Bogooore local (0.10%). Hulginal local (0.14%) showed higher reducing sugar content among *rabi* cultivars, followed by Marole local (0.13%) and Bijapur local (0.12%). The mean of reducing sugars of *rabi* cultivars was found to be higher than *kharif* cultivars.

Non-reducing content of conventionally popped grains varied significantly ($P < 0.05$). The observed range was from 1.27 to 1.77 per cent with the overall mean of 1.43 per cent. Mugad local a *kharif* popped grains (1.77%) showed higher non-reducing sugar content followed by Bogooore local (1.29%) and Uppinbetgeri local (1.27%). Among *rabi* cultivars, Marole popped grain showed higher non-reducing sugar content followed Bijapur local (1.35%) and Hulginal local (1.30%). The mean of *kharif* popped grains was higher (1.44%) than *rabi* popped grains.

Pop sorghum cultivars popped in microwave oven showed significant difference ($P < 0.05$) in total sugar content (Table 9). It ranged from 1.24 to 1.85 per cent with the overall mean of 1.46 per cent. Mugad local (1.85%), a *kharif* popped cultivar showed higher total sugar content followed by Bogooore local (1.30%) and Uppinbetgeri local (1.24%). Among *rabi* popped grains, Marole local (1.67%) had higher total sugar content when compared with other two cultivars, Hulginal local and (1.37%) and Bijapur local (1.35%). The mean of both *kharif* and *rabi* was found same in total sugar content (1.46%).

Reducing sugar content of microwave popped grains did not show significant difference. The overall mean of sorghum cultivars was 0.08 per cent. *Kharif* grain popped cultivars showed mean of 0.09 per cent with higher reducing sugar content in Bogooore local and *rabi* popped cultivars showed mean of 0.08 per cent with higher reducing sugar content in Bijapur local and Marole local (0.09%).

Sorghum grains popped by microwave method showed significant variation ($P < 0.05$) in non-reducing sugar. The range of non-reducing sugar observed was from 1.22 to 1.71 per cent. Mugad local, a *kharif* popped grain showed higher (1.71%) non-reducing sugar content followed by Bogooore local and Uppinbetgeri local (1.22 and 1.18% respectively). Among *rabi* cultivars, the higher non-reducing sugar content was found in Marole local (1.57%) followed by Hulginal local (1.29%) and Bijapur local (1.25%). The mean content of non-reducing sugars was same (1.37%) in both *kharif* and *rabi* popped cultivars.

Starch, total amylose, soluble amylose, insoluble amylose and amylopectin contents were analysed and the results are presented in Table 10.

Pop sorghum cultivars, when popped conventionally did not show significant difference in starch content. The overall mean of starch was 70.80 per cent in *kharif* cultivars and 70.23 per cent was the mean of starch content among *rabi* cultivars, when popped conventionally.

Table 10. Starch, amylose and amylopectin (%) content of pop sorghum cultivars grown in different seasons after popping

Cultivars	Starch (%)		Amylose (%)						Amylopectin (%)	
	Conventio nal popping	Microwave popping	Total		Soluble		Insoluble		Conventio nal popping	Microwave popping
			Conventio nal popping	Microwave popping	Conventio nal popping	Microwave popping	Conventio nal popping	Microwave popping		
<i>Kharif</i>										
Mugad local	69.68	69.71	24.01	24.56	13.87	13.91	10.14	10.65	75.99	75.68
Uppinbetgeri local	71.06	71.91	21.96	23.75	14.48	14.28	7.47	8.97	78.04	76.72
Bogoore local	71.67	73.04	22.67	23.75	14.54	14.45	8.12	9.30	77.33	76.25
<i>Rabi</i>										
Bijapur local	70.71	71.00	23.61	24.84	13.84	13.36	10.63	11.48	76.38	75.15
Marole local	69.99	70.01	25.14	24.81	15.57	15.75	9.57	9.06	74.85	75.18
Hulginal local	69.99	69.62	26.42	26.25	17.35	16.73	9.06	9.00	73.58	73.75
Mean	70.38	70.88	23.94	24.66	14.94	14.74	9.16	9.74	76.03	75.45
F-value	0.277	0.671	6.603*	12.360*	27.21*	10.593*	5.009*	5.275*	7.781*	14.853*
S.Em±	0.59	0.63	0.48	0.26	0.37	0.36	0.36	0.32	0.48	0.29
CD at 5%	NS	NS	1.32	0.71	1.02	0.99	0.99	NS	1.32	0.80

NS-Not significant

*The values are significantly different at 5% point of distribution of F

Observations of Table 10, revealed significant ($P < 0.05$) difference in total amylose content of different pop sorghum cultivars when popped conventionally. The total amylose content ranged from 21.96 per cent to 26.42 per cent. The higher total amylose content was found in Mugad local (24.01%) among *kharif* cultivars. The mean observed was 23.94 per cent among *rabi* popped cultivars. Hulginal local (26.42%) had higher total amylose content with the mean of 25.05 per cent which was higher than *kharif* popped grains (22.88%).

Soluble amylose content of conventionally popped grains varied significantly ($P < 0.05$). It ranged between 13.84 to 17.35 per cent with the mean of 14.94 per cent. Among *kharif* grown popped grains Bogoore local (14.54%) showed higher soluble amylose contents than Uppinbetgeri local and Mugar local (14.48% and 13.87% respectively). Hulginal local (17.35%) had higher soluble amylose content among *rabi* popped grains followed by Marole local (15.57%) and Bijapur local (13.84%). All the *rabi* popped grains showed higher mean of 14.94 per cent than *kharif* popped grains.

Conventionally popped sorghum grains showed significant ($P < 0.05$) variation for insoluble amylose content. The range observed was from 7.47 per cent to 10.63 per cent with the overall mean of 9.16 per cent. Insoluble amylose contents observed were 10.14, 8.12 and 7.47 per cent respectively for Mugad local, Bogoore local and Uppinbetgeri local grains. Among *rabi* cultivars higher insoluble amylose content was observed in Bijapur local (10.63%) followed by Marole local (9.57%) and Hulginal local (9.06%). The mean insoluble amylose content of *kharif* cultivars was lower (8.57%) than mean (9.75%) of *rabi* cultivars.

Pop sorghum cultivars, popped by conventional method showed significant ($P < 0.05$) variation in amylopectin content. It ranged from 73.58 to 78.04 per cent, with the overall mean of 76.03 per cent. Among *kharif* popped grains Uppinbetgeri local (78.04%) showed higher amylopectin content followed by Bogoore local (77.33%) and Mugad local (75.99%). Bijapur local (76.38%) a *rabi* popped cultivar showed higher amylopectin content followed by Marole local (74.85%) and Hulginal local (73.58%). All the *kharif* popped cultivars showed higher mean of amylopectin (77.12%) than *rabi* cultivars.

Starch content of pop sorghum cultivars when popped in microwave oven did not show significant difference. The overall mean popped *kharif* cultivars was 71.55 per cent with the higher value in Bogoore local (73.04%). Among *rabi* popped grains, total mean observed was 70.21 per cent with the higher starch content in Bijapur local (71.0%).

In microwave popped grains, total amylose content showed significant ($P < 0.05$) variation. The range observed was 23.75 to 26.25 per cent with total mean of 25.30 per cent. The higher total amylose content was found in Mugad local (24.56%) followed by Uppinbetgeri local and Bogoore local (23.75%). Among *rabi* popped grains, Hulginal local (26.25%) and higher total amylose content followed by Bijapur local (24.84%) and Marole local (24.81%). The mean of popped *rabi* grains (25.30%) was higher than popped *kharif* grains (24.02%).

In microwave popped grains the soluble amylose content showed significant ($P < 0.05$) variation. It ranged between 13.36 to 16.73 per cent with the overall mean 14.74. Among *kharif* popped grains Bogoore local (14.45%) had higher soluble amylose content followed by Uppinbetgeri local (14.28%) and Mugad local (13.91%). Hulginal local (16.73%) a *rabi* cultivar show higher soluble amylose content followed by Marole local (15.75%) and Bijapur local (13.36%). The mean of *rabi* popped grains 15.28 per cent was higher than *kharif* popped grains.

Insoluble amylose content of microwave popped grains did not show significant difference. The overall mean observed among all the cultivars irrespective of season was 9.74 per cent. *Kharif* popped grains showed mean of 9.64 per cent with higher values in Mugad local (10.65%). Among *rabi* popped grains the mean observed was 9.84 per cent with the higher insoluble amylose content in Bijapur local (11.48%).

Microwave popped sorghum cultivars also showed the same trend of amylopectin content as in conventionally popped grains, i.e. among *kharif* popped grains Uppinbetgeri

local (76.72%) had higher values followed by Bogoore local (76.25%) and Mugad local (75.68%). Among *rabi* cultivars, Marole local had higher (75.18%) amylopectin content. Higher mean of amylopectin (76.21%) content was observed in *kharif* popped grains than *rabi* popped grains (74.69%).

4.3.2 Relationship between physico-chemical and processing qualities of pop sorghum cultivars

Correlation coefficients among physico-chemical and processing qualities of different pop sorghum cultivars was statistically analysed and is presented in Table 11.

Table 11 presents correlation between popping quality characteristics of sorghum cultivars with physico-chemical characteristics. It was observed from the table that among the two methods of popping the type of relation for different grain characteristics with processing quality is different.

The relation of popping quality with physical characters is of same trend in both the methods.

A negative significant correlation was observed between thousand-kernel weight ($r=-0.635$), volume ($r=-0.622$) and popping yield in conventional methods of popping. Whereas positive significant correlation was observed between thousand-kernel weight ($r=0.680$), volume ($r=0.760$) with flake size when popped by both the methods. The kernel density did not show any significant relationship with any of the popping qualities of the cultivars. Only few nutrients were significantly correlated with popping quality characteristics. Protein content of sorghum did not show any significant relationship with processing qualities. Fat content showed positive significant correlation with popping yield ($r=0.674$) and in microwave popping method and with expansion ratio ($r=0.672$) in conventional method of popping. A significant negative correlation was observed between ash ($r=0.678$), crude fibre ($r=-0.690$), soluble amylose ($r=-0.606$) with popping yield in conventional method of processing. Starch content of sorghum cultivars showed significant negative correlation ($r=-0.577$) with expansion ratio of conventional popped grains. A significant negative correlation was observed between starch ($r=-0.623$) and flake size of popped grains in conventional method of popping. Total amylose and insoluble amylose content of sorghum did not show any significant correlation with any of the processing qualities assessed.

4.4 DEVELOPMENT OF POPPED SNACKS

4.4.1 Nutrient composition of developed popped snacks

The nutrient composition of developed popped snacks is presented in the table 12 revealed that cinnamon flavoured popped snack contributed 21.64 per cent of total carbohydrate, 3.10 per cent protein, 0.90 per cent fat and 104.86 kcal of energy. Whereas garlic flavoured popped snacks provided 23.83 per cent of total carbohydrate, 4.55 per cent of protein, 2.90 per cent of fat and 133.21 kcal of energy. Among sweet coated popped snacks, popped jaggery laddu contributed 96.85 per cent of total carbohydrate, 7.75 per cent of protein, 1.47 per cent of fat and 425.36 kcal of energy. Whereas sugar coated coloured popped snack provided 81.28 per cent of total carbohydrate, 3.16 per cent protein, 0.90 per cent of fat and 338.66 kcal of energy.

4.4.2 Organoleptic evaluation of popped snacks

Organoleptic evaluation of spice flavoured popped snacks of pop sorghum are presented in Table 13.

The mean score for appearance of popped snacks was higher in cinnamon flavoured (4.47) than garlic flavoured snack (4.20). However, the products did not show significant

Table 11. Correlation between physico-chemical and processing qualities of pop sorghum cultivars

Sl. No.	Characteristics	Popping yield (%)		Expansion ratio (ml/g)		Flake size (ml/grain)	
		Conventional popping	Microwave popping	Conventional popping	Microwave popping	Conventional popping	Microwave popping
1.	Thousand-kernel weight	-0.635*	-0.150	0.216	-0.490	0.680*	0.760**
2.	Volume	-0.622*	-0.221	0.138	-0.148	0.631*	0.765**
3.	Density	0.348	0.362	0.081	0.369	-0.304	-0.516
4.	Protein	-0.391	-0.111	0.233	-0.055	0.508	0.522
5.	Fat	-0.414	0.674*	0.672*	0.564	0.338	0.290
6.	Ash	-0.678*	0.151	0.172	0.113	0.459	0.556
7.	Crude fibre	-0.690*	0.370	0.235	0.110	0.279	0.327
8.	Starch	0.380	-0.273	-0.577*	-0.255	-0.623*	-0.329
9.	Total amylose	-0.435	0.331	0.539	0.297	0.349	0.398
10.	Soluble amylose	-0.606*	0.181	0.231	-0.290	0.155	0.112
11.	Insoluble amylose	0.074	0.172	0.459	0.367	0.378	0.456

* Significant at 5% level (P<0.05)

** Significant at 1% level (P<0.01)

Table 12. Nutrient composition of developed popped snacks

	Cinnamon flavoured popped snack	Garlic flavoured popped snack	Popped jaggery laddu	Sugar coated coloured popped snack
Total carbohydrate	21.64	23.83	86.6	81.28
Protein	3.10	4.55	7.75	3.16
Fat	0.90	2.90	1.47	0.90
Energy	105	133	389	339

Table 13. Organoleptic evaluation of spice flavoured popped snacks

Products	Appearance	Colour	Texture	Taste	Flavour	Overall acceptability
Cinnamon flavoured	4.37	4.40	4.03	4.40	4.30	4.40
Garlic flavoured	4.27	4.23	3.33	3.97	3.43	3.57
F-value	2.785	0.424	0.164*	0.003*	6.790*	8.414*
S.Em±	0.12	0.13	0.16	0.15	0.17	0.15
CD at 5%	NS	NS	0.44	0.41	0.46	0.41

NS – Not significant

* The values are significantly different at 5%, point of distribution of F.

difference. The mean score for colour was also higher in cinnamon flavoured (4.60) than in garlic flavoured snack (4.03). The mean score varied significantly ($P < 0.05$) between the products. The mean score for texture was higher in cinnamon flavoured (4.30) than garlic flavoured snack (3.77). However, they did not show significant difference. Similarly, the mean score for taste and flavour of cinnamon flavoured was higher (4.63 and 4.50) than garlic flavoured snack (3.67 and 3.53) respectively. However, the products showed significant difference ($P < 0.05$). It was also observed from the overall acceptability that, cinnamon flavoured showed higher (4.53) mean score than garlic flavoured snack (3.80).

4.4.3 Organoleptic evaluation of sweet coated popped snacks

Organoleptic evaluation of sweet coated popped snacks of pop sorghum are presented in Table 14.

The mean score for colour and appearance for popped jaggery laddu and sugar coated coloured snack were 4.37, 4.27 and 4.40, 4.23 respectively. Popped jaggery laddu had higher scores than sugar coated coloured snack.

The mean score for texture and taste for popped jaggery laddu was higher (4.03 and 4.40) than sugar coated coloured snack (3.33 and 3.97, respectively). Similarly, it was observed that flavour and overall acceptability scores were higher for popped jaggery laddu (4.30 and 4.40, respectively) than sugar coated coloured snack (3.43 and 3.57, respectively). Statistical analysis of the data revealed that the sweet coated popped snacks differed significantly, only for texture, taste, flavour and overall acceptability at 5 per cent level. There was no significant difference for other characters.

4.5 STORAGE QUALITY OF POPPED SORGHUM GRAINS AND ITS FLOUR

4.5.1 Changes in organoleptic characters of popped grains and its flour during storage

Popped grains stored in polythene cover and paper bag were analyzed for changes in organoleptic characters at weekly intervals and the results presented in Table 15 reveals that, the popped grains scored less organoleptic scores for all parameters as the duration of storage increased. Among the packages, popped grains stored in paper bags showed very less scores for all the parameters. And on 28th day of storage the popped grains developed fungal growth and some off flavour also, it also lost its appearance quality. As a result it was not used for the organoleptic evaluation on 28th day of storage. Whereas, in polythene cover, popped grains were in acceptable state even on 28th day of storage. It shows that deterioration was at faster rate in popped grains of paper bag compared to the polythene cover.

Appearance

Appearance scores of popped grains stored in polythene cover and paper bag during storage study are presented in Table 15.

Initially pop looked very bold and white in colour with a mean score of 4.90 on 1st day to 3.7, 3.3 and 2.55 at 7th, 14th and 21st days of storage, irrespective of packages used to store. It changed to compressed in size and greenish in colour (Table 15) after storage. The popped grains stored in different packaging material showed significant ($P < 0.05$) difference with respect to appearance during storage. Popped grains stored in polythene cover showed higher score (4.00) for appearance than stored in paper bag (2.27) irrespective of duration of storage.

The results of interaction effect of packages and duration of storage differed significantly ($P < 0.05$). The popped grains stored in polythene cover had higher appearance

Table 14. Organoleptic evaluation of popped sweet snack

Products	Appearance	Colour	Texture	Taste	Flavour	Overall acceptability
Jaggery coated laddu	4.47	4.60	4.30	4.63	4.50	4.53
Sugar coated	4.20	4.03	3.77	3.67	3.53	3.80
F-value	2.176	4.561*	2.553	7.611*	8.386*	3.533*
S.Em±	0.16	0.17	0.21	0.17	0.18	0.17
CD at 5%	NS	0.46	NS	0.46	0.49	0.46

NS – Not significant

* The values are significantly different at 5%, point of distribution of F.

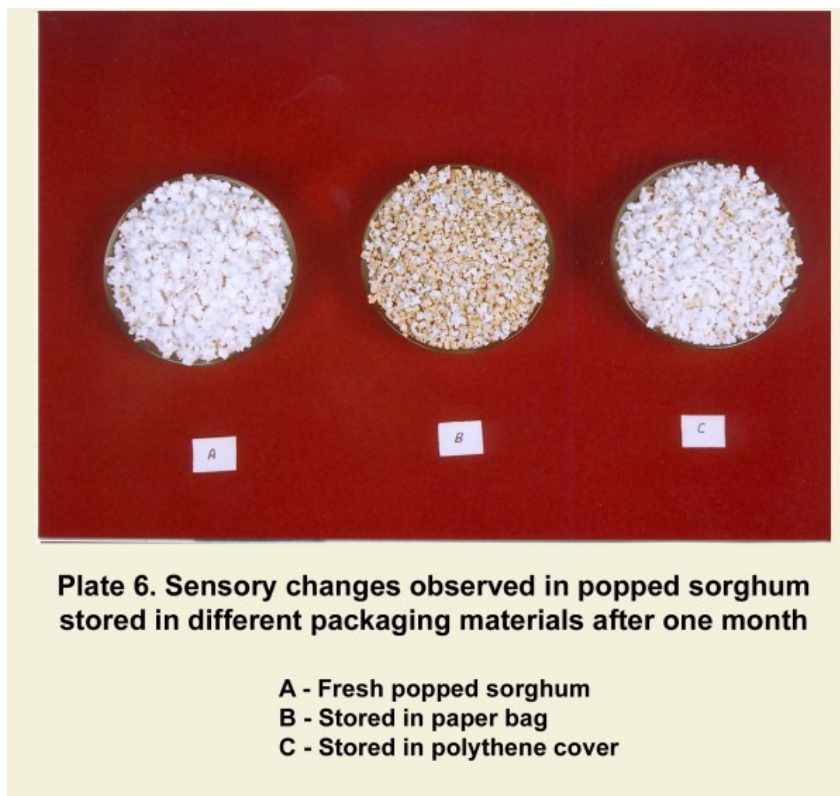


Plate 6. Sensory changes observed in popped sorghum stored in different packaging materials after one month

Table 15. Changes in organoleptic qualities during storage of popped sorghum grains at ambient conditions (92% RH, 26-28 °C)

Packaging material	Storage period (days)				
	1	7	14	21	28
Appearance					
Polythene cover	4.90	4.40	4.10	3.80	3.40
Paper bag	4.90	3.00	2.50	1.30	ND
Colour					
Polythene cover	4.87	4.30	4.20	3.90	3.20
Paper bag	4.87	2.90	2.60	1.30	ND
Texture					
Polythene cover	4.95	4.30	3.70	3.60	2.50
Paper bag	4.95	2.30	2.00	1.20	ND
Flavour					
Polythene cover	4.87	4.00	3.90	3.90	2.90
Paper bag	4.87	2.50	2.20	1.40	ND
Overall acceptability					
Polythene cover	4.80	4.00	3.90	3.60	3.20
Paper bag	4.80	2.30	1.90	1.20	ND

ND – Not determined

Organoleptic characteristics	F-value	S.Em±	CD at 5%
Appearance	145.188	0.12	0.33
Colour	109.206	0.12	0.33
Texture	152.357	0.14	0.38
Flavour	173.938	0.13	0.35
Overall acceptability	245.127	0.13	0.35

scores of 4.90, 4.40, 4.10 and 3.80 than the popped grains stored in paper bag which had the appearance scores of 4.90, 3.00, 2.50 and 1.30 on 1st, 7th, 14th and 21st days of storage period, respectively. The interaction effect of packages and duration of storage differed significantly at $P < 0.05$ (Appendix VIII).

Colour

The initial colour of popped grains was white with a mean of 4.87 on 1st day to 3.60, 3.40, 2.60 at 7th, 14th and 21st day of storage, respectively, irrespective of package material used for storage (Table 15). The colour of popped grains stored in different packaging material varied significantly ($P < 0.05$). The popped grains, which were stored in polythene cover had higher score (3.95) for colour than the popped grains stored in paper bag (2.27) irrespective of duration of storage period.

The interaction effect of packages used to store and duration of storage showed that, the popped grains stored in polythene cover had scores of colour as 4.87, 2.90, 2.60 and 1.30 which were slightly higher than the cores of popped grains packed in paper bag, 4.87, 4.30, 4.20 and 3.90 on 1st, 8th, 14th and 21st days of storage period, respectively (Appendix IX).

Texture

The texture of popped grains stored in different packages showed significant ($P < 0.05$) difference. The texture of popped grains decreased from 4.95 on 1st day to 3.30, 2.85 and 2.40 at 7th, 14th and 21st days of storage period respectively, irrespective of packages used for storage. The mean score of texture of stored grains is 2.82 irrespective of the package material used. This shows the deterioration of the product during storage and the texture changed from crispy to soggy. Popped grains stored in polythene cover showed higher score (3.77) than pops stored in paper bag.

The interaction effect of packages used to store and duration of storage showed significant results, where popped grains packed in polythene cover had textural scores as 4.95, 4.30, 3.70 and 3.60 and the samples in paper bag had 4.95, 2.30, 2.00 and 1.20 at 0, 7th, 14th and 21st day of storage period, respectively (Appendix X).

Flavour

Flavour of popped grains initially *i.e.* on first day storage had higher scores (4.9). Flavour of popped grains stored in different packages varied significantly ($P < 0.05$) from 4.87 at zero day to 3.25, 3.05 and 2.65 at 7th, 14th and 21st day of storage period, respectively, irrespective of packages used to store. The popped grains, stored in polythene cover had higher score of 3.51 for flavour than popped grains stored in paper bag 1.9, irrespective of duration of storage period (Table 15).

The high scores of flavour were found in the popped grains stored in polythene cover which was 4.87, 4.00, 3.90 and 3.90 at 0, 7th, 14th and 21st days of storage respectively whereas, the low score value was in popped grains stored in paper bag which had the mean scores of flavour was 4.87, 2.50, 2.20 and 1.40 at 0, 7th, 14th and 21st days of storage respectively. The interaction effect of packages and duration of storage differed significantly at $P < 0.05$ (Appendix XI).

Overall acceptability

Overall acceptability scores of popped grains stored in polythene cover and paper bag showed significant ($P < 0.05$) difference. The initial score for overall acceptability of popped grains was 4.80 on 1st day which started decreasing from 3.15, 2.9 and 2.4 at 7th, 14th and 21st day of storage, irrespective of packages used for storage (Table 15). The popped grains stored in polythene cover showed higher score (3.72) than stored in paper bag (1.83), irrespective of duration of storage.

Table 16. Changes in organoleptic qualities during storage of popped sorghum flour at ambient conditions (92% RH, 26-28°C)

Packaging material	Storage period (days)				
	1	7	14	21	28
Appearance					
Low density polythene covers	4.8	4.50	4.00	3.80	3.30
Aluminium pouch	4.8	4.70	4.60	4.00	3.50
Texture					
Low density polythene covers	4.85	4.20	3.70	3.50	3.40
Aluminium pouch	4.85	4.20	3.90	3.60	3.40
Flavour					
Low density polythene covers	4.65	3.80	3.80	3.40	3.30
Aluminium pouch	4.65	4.10	4.10	3.60	3.60

Organoleptic characteristics	F-value	S.Em±	CD at 5%
Appearance	29.137	0.06	0.16
Texture	42.444	0.07	0.19
Flavour	28.463	0.07	0.19

The popped grains stored in polythene cover had the higher overall acceptability scores of 4.80, 4.00, 3.90 and 3.60 on 1st, 7th, 14th and 21st days of storage period, respectively. This was followed by the same product in paper bag (4.80, 2.30, 1.90 and 1.20 on 1st, 7th, 14th and 21st days of storage period, respectively). There was significant difference in results of interaction effect of popped grains of different storage period and packages used, with respect to scores of overall acceptability (Appendix XII).

4.5.2 Changes in organoleptic qualities of popped sorghum during storage

The data on changes in appearance, texture and flavour of popped flour of pop sorghum stored in aluminium pouch and low density polythene cover at ambient storage conditions is presented in Table 16.

Appearance

The initial appearance of flour was creamish white. The mean score of 4.80 on first day decreased to 4.75, 4.30, 3.90 and 3.40 at 7th, 14th, 21st and 28th days of storage, respectively and it changed to dull white (Table 16) irrespective of packages used for storage.

The popped flour stored in different packaging materials showed significant ($P < 0.05$) difference with respect to appearance during storage. Among the different packages the popped sorghum flour stored in low density polythene cover had lower scores for colour 3.85 while, aluminium pouch had the higher score of 4.36, irrespective of duration of storage. The popped sorghum flour stored in aluminium pouch had higher appearance scores of 4.80, 4.70, 4.60, 4.00 and 3.50 than popped sorghum flour stored in low density polythene cover which had scores for appearance was 4.80, 4.50, 4.00, 3.80 and 3.30 on 1st, 7th, 14th, 21st and 28th days of storage period respectively (Appendix XIII).

Texture

The texture of popped sorghum flour showed significant ($P < 0.05$) difference during storage. The mean score of popped flour for texture was 4.85 on 1st day and decreased to 4.20, 3.80, 3.55 and 3.40 at 7th, 14th, 21st and 28th days of storage respectively, irrespective of packages used for storage. The popped flour, which was stored in aluminium pouch had higher score (3.77) for texture than the popped flour stored in low density polythene cover (3.72) irrespective of duration of storage period (Table 16).

Popped sorghum flour stored in aluminium pouch had the higher texture of 4.85, 4.20, 3.70, 3.50 and 3.40 than the popped sorghum flour stored in low density polythene cover which had the texture score of 4.85, 4.20, 3.90, 3.60 and 3.40 on 1st, 7th, 14th, 21st and 28th days of storage period respectively (Appendix XIV).

Flavour

The flavour of popped sorghum flour decreased from 4.65 on 1st day to 3.95, 3.95, 3.5 and 3.45 at 7th, 14th, 21st and 28th days of storage period, respectively, irrespective of packages used for storage. The mean score of popped flour was equal for 7th and 14th days of storage (3.95). The popped pop sorghum flour, which was stored in aluminium pouch showed higher score (3.82) than popped flour stored in low density polythene cover, irrespective of duration of storage period.

The higher flavour scores was found in popped sorghum flour packed in aluminium pouch (4.65, 4.10, 4.10, 3.0 and 3.60 on 1st, 7th, 14th, 21st and 28th days of storage respectively), followed by the same popped flour stored in low density polythene cover which had the flavour scores of 4.65, 3.80, 3.80, 3.40 and 3.30 on 1st, 7th, 14th, 21st and 28th days of storage period, respectively (Appendix XV).

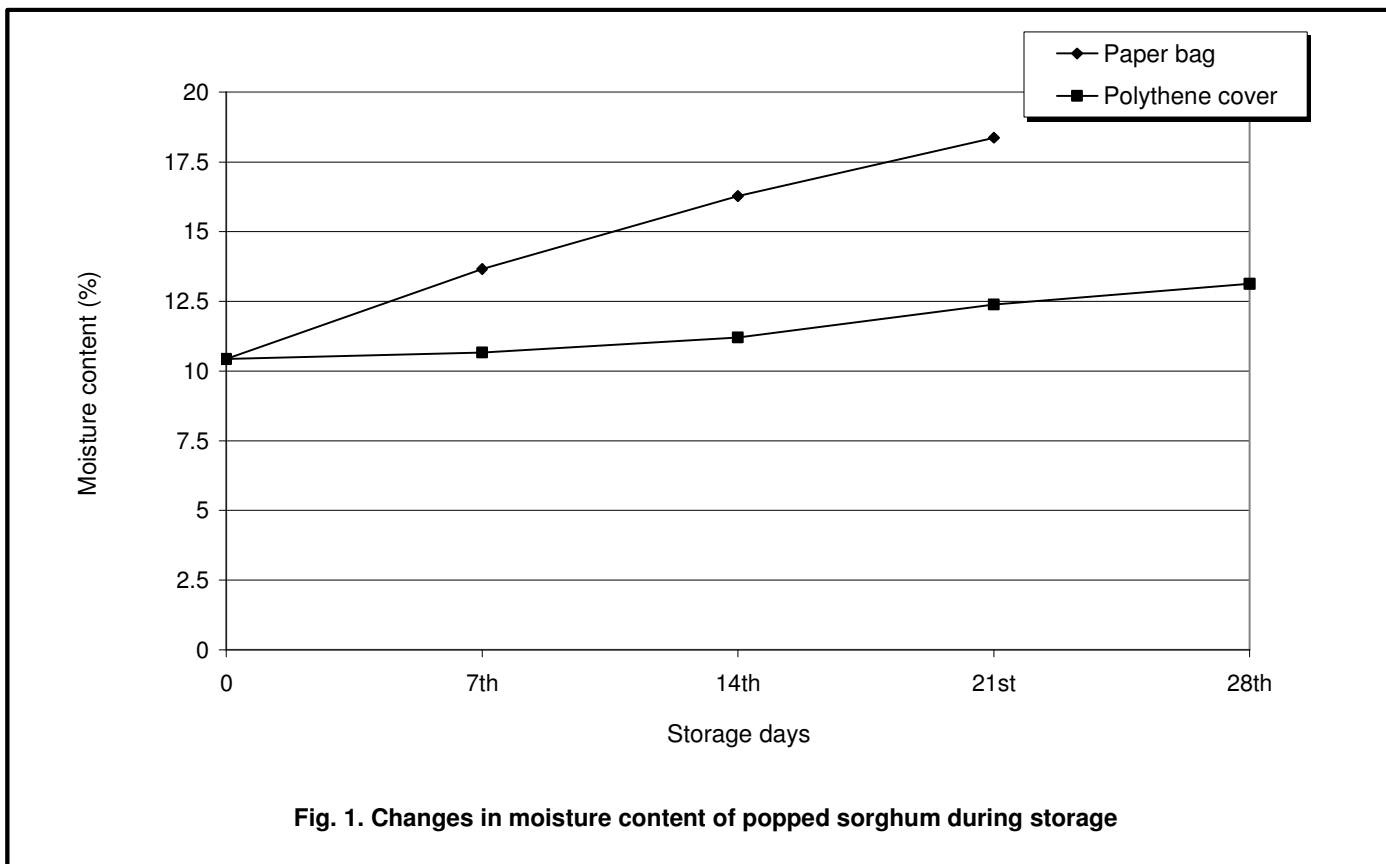


Fig. 1. Changes in moisture content of popped sorghum during storage

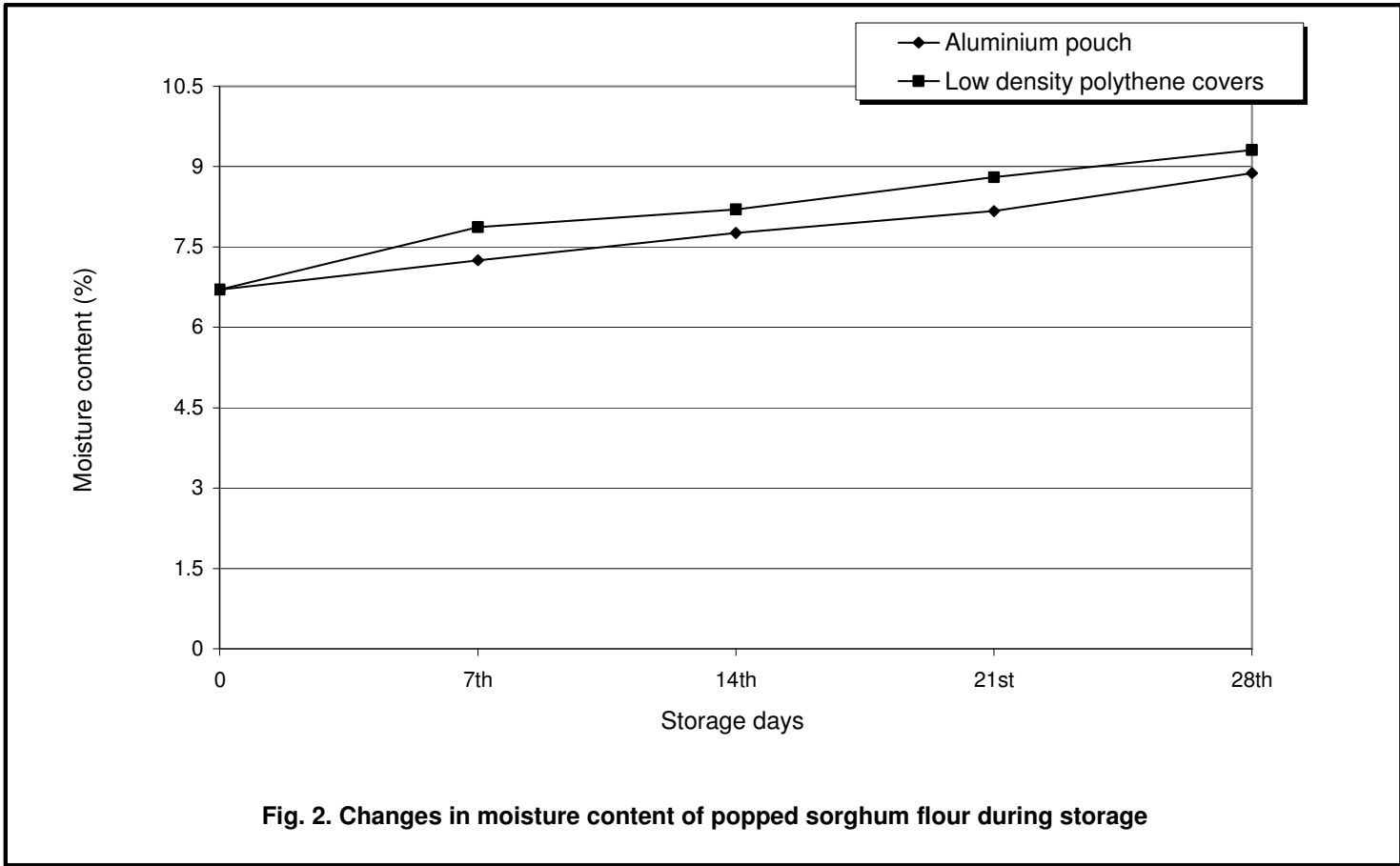


Fig. 2. Changes in moisture content of popped sorghum flour during storage

4.5.3 Changes in moisture content of popped sorghum grains and its flour during storage

The data on changes in moisture content of popped sorghum grains stored in paper bag and polythene cover at ambient storage conditions (92% RH, 26.48°C) is presented in Fig. 1.

The moisture content of popped sorghum grains, irrespective of type of packages used for storage, increased from 10.43 per cent on 1st day to 12.13, 13.73, 15.37 at 7th, 14th, 21st days of storage period, respectively. The mean moisture content of popped grains, irrespective of type of packages used for storage, increased significantly from 10.43 to 15.37 per cent on 1st to 21st days of storage period, respectively. The effect of packaging on moisture content of popped grains was significant ($P < 0.05$) during storage. Higher moisture content was observed in popped grains packed in paper bag (14.68%) than the ones stored in polythene cover (11.54%) during storage.

The interaction effects of packages and duration of storage of popped grains, showed significant variation in moisture content. The popped grains packed in paper bag had higher moisture content of 10.43, 13.66, 16.27 and 18.37 per cent than the popped grains stored in polythene cover which had moisture content of 10.43, 10.60, 11.20 and 12.38 per cent on 1st, 7th, 14th and 21st days of storage period, respectively (Appendix XVI).

The data on changes in moisture content of popped sorghum flour stored in low density polythene cover and aluminium pouch at ambient conditions (92% RH, 26.48°C) is represented in Fig. 2.

The moisture content of popped sorghum flour, irrespective of type of packages used for storage, increased significantly ($P < 0.05$). The mean moisture content of popped sorghum flour irrespective of type of packages used for storage, increased from 6.70 to 9.10 per cent on 1st to 28th days of storage, respectively. Popped sorghum flour stored in low density polythene cover had higher moisture content of 8.17 per cent while aluminium pouch had lower 7.75 per cent moisture content. The moisture content of popped sorghum flour increased from 6.70 per cent on 1st day to 7.56, 7.98, 8.48 and 9.10 per cent at 7th, 14th, 21st and 28th day of storage, respectively, irrespective of type of packages used for storage.

The interaction effects of packages and duration of storage of popped sorghum flour showed significant variation in moisture content. The popped sorghum flour packed in low density polythene cover had higher moisture content of 6.70, 7.87, 8.20, 8.80 and 9.31 per cent than the popped flour stored in aluminium pouch which had moisture content of 6.70, 7.25, 7.76, 8.17 and 8.88 and on 1st, 7th, 14th, 21st and 24th days of storage period, respectively (Appendix XVII).

4.5.4 Changes in free fatty acid content of popped sorghum flour during storage

The data on changes in free fatty acid content of popped sorghum flour stored in low density polythene cover and aluminium pouch at ambient storage conditions are represented in Fig. 3.

The free fatty acid content of popped sorghum flour stored in different packaging materials showed significant ($P < 0.05$) difference. Free fatty acid content increased from 0.13 per cent on 1st day to 0.14, 0.15, 0.16 and 0.16 per cent at 7th, 14th, 21st and 28th days of storage period, respectively irrespective of types of packages used to store. The free fatty acid content was higher in popped sorghum grains stored in low density polythene cover (0.148%) than stored in aluminium pouch (0.14%). However the effect of packaging on free fatty acid content of popped pop sorghum flour did not show significant difference.

The Appendix XVIII, showed the interaction effect of packages and duration of storage, which differed significantly ($P < 0.05$). The higher free fatty acid content was found in

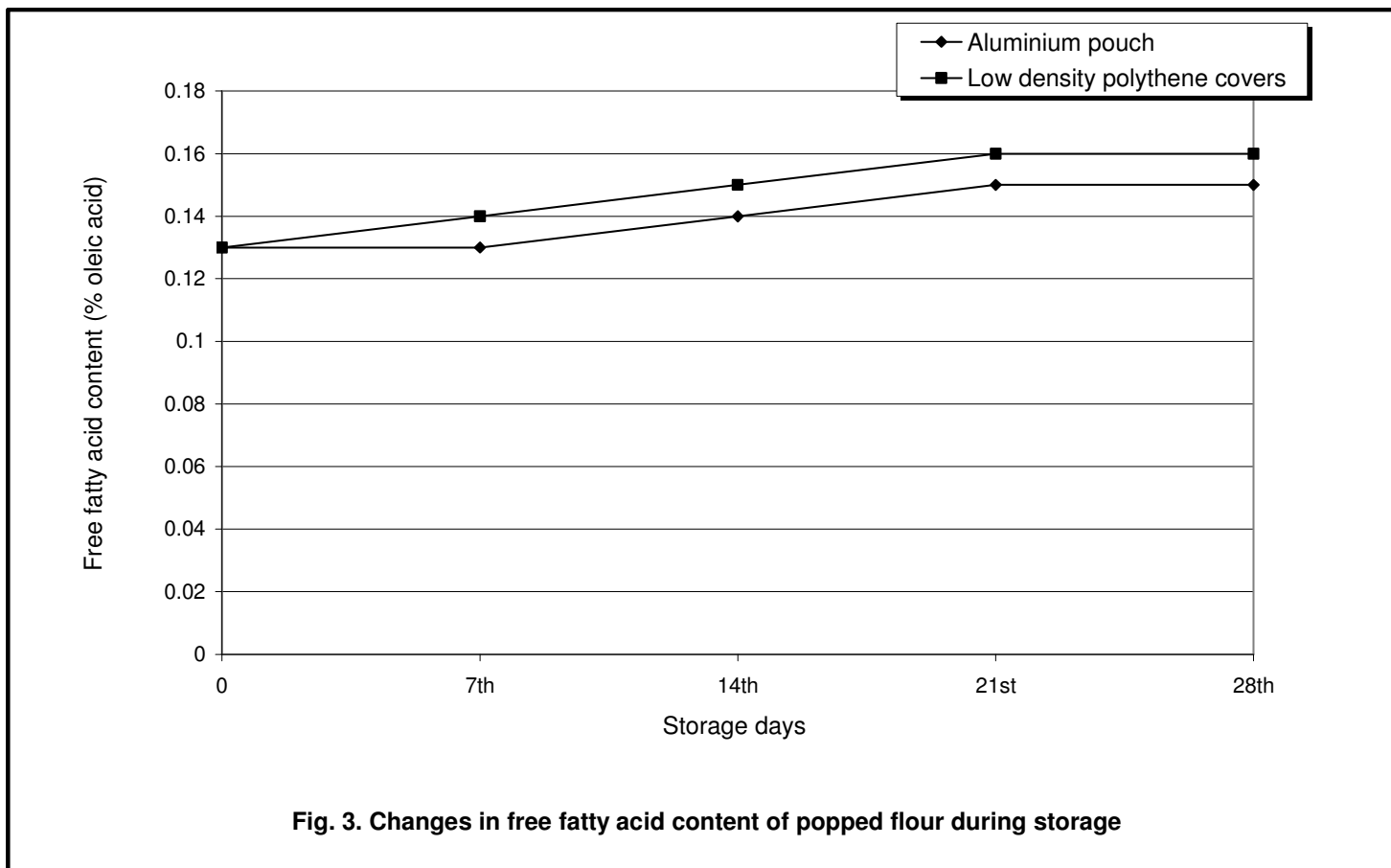


Fig. 3. Changes in free fatty acid content of popped flour during storage

popped sorghum flour packed low density polythene cover (0.13, 0.14, 0.15, 0.16 and 0.16 per cent on 1st, 7th, 14th, 21st and 28th days of storage, respectively) and the lower free fatty acid content was found in popped sorghum flour packed in aluminium pouch of 0.13, 0.13, 0.14, 0.15 and 0.14 per cent on 1st, 7th, 14th, 21st and 28th days of storage period, respectively. The popped sorghum flour stored in aluminium pouch and low density polythene cover showed equal free fatty acid content of 0.15 and 0.16 on 21st and 28th days of storage period, respectively.

V. DISCUSSION

The results of quality characteristics of pop sorghum cultivars grown in different seasons and subjected for conventional and modern methods of processing, value addition and storage are discussed here.

5.1 PHYSICO-CHEMICAL CHARACTERISTICS OF POP SORGHUM CULTIVARS GROWN IN *KHARIF* AND *RABI* SEASONS

Visual observation of the morphological features of the traditionally grown pop sorghum cultivars revealed variation in colour and shape. Most of the cultivars were creamy white or brownish white. Madhavi (2000) and Anupama (2002) also observed variations in grain colour. In the present study the thousand-kernel weight, volume and density of the cultivars varied significantly ($P < 0.05$) among the cultivars grown in *kharif* and *rabi* seasons. Similarly, Thorat *et al.* (1988) also reported significant variation in physical characteristics among pop sorghum cultivars. Significant variation for physical characteristics among different pop sorghum cultivars grown in different seasons was also observed by Madhavi (2000) and Anupama (2002). In the present study, the thousand-kernel weight, volume and density of pop sorghum cultivars ranged from 15.60 to 20.30 g, 18.67 to 25.33 and 0.77 to 0.83 g/ml, respectively (Table 3). All the *rabi* cultivars had higher kernel weight (20.01 g) and volume (25.00 ml) than *kharif* cultivars (16.81 g and 21.89 ml, respectively). Mugad local grown in *kharif* had the lowest kernel weight (15.60 g) followed by Bogoore local (16.32 g). Wide variation in 1000-kernel weight, volume and density among different pop sorghum cultivars was also reported by Yenagi *et al.* (2005). These variations may be due to the influence of genetic and environmental factors.

5.2 NUTRIENT COMPOSITION OF POP SORGHUM CULTIVARS

5.2.1 Proximate composition

The proximate composition of pop sorghum cultivars was influenced by the season (Anon., 2002). In the present study, the protein content of pop sorghum cultivars showed significant ($P < 0.05$) difference and the values varied from 7.77 to 9.17 per cent in *kharif* cultivars and from 10.77 to 12.78 per cent in *rabi* cultivars (Table 4). The mean protein content was the highest in pop sorghum cultivars grown in *rabi* (12.09%) than in *kharif* (8.63%) cultivars. Similar results were also observed by Yenagi *et al.* (2005).

Difference in fat content among the cultivars grown in *kharif* and *rabi* seasons was also significant ($P < 0.05$). The fat content varied from 2.71 to 3.06 per cent with the mean value of 2.08 per cent in the sorghum cultivars grown during *kharif* season (Table 4). The pop sorghum cultivars grown in *rabi* season ranged from 2.93 to 3.31 per cent with the mean value of 3.15 per cent respectively. Similar results were also observed by Anon. (2002). It was also observed that the highest fat content was found in *rabi* grown cultivars than in the *kharif* cultivars. Madhavi (2000) also made similar observations.

The *rabi* grown pop sorghum cultivars produced higher mean ash (2.32%) content than *kharif* (2.08%) cultivars, the difference for observed was significant ($P < 0.05$) and it ranged from 1.92 to 2.37 per cent. Among *kharif* cultivars, ash content ranged between 1.92 to 2.24 per cent whereas in *rabi* cultivars it ranged from 2.29 to 2.37 per cent. Thakare (1981) also observed higher ash content in *rabi* cultivars than in *kharif* cultivars. Similarly, the crude fibre content also varied significantly ($P < 0.05$) with the range of 1.07 to 1.44 per cent. It was found that *rabi* grown cultivars had the higher crude fibre content than the *kharif* grown cultivars.

Similar observations were also reported by Anon. (2002). In the present investigation, the *kharif* cultivars showed higher total carbohydrates contents compared to *rabi* cultivars. The mean total carbohydrate content was lower (72.15%) in *rabi* cultivars than in *kharif* cultivars (75.29%).

The higher protein, fat, ash and crude fibre contents were found in *rabi* grown cultivars than in *kharif* grown cultivars. While, the mean of total carbohydrate contents were higher in *kharif* cultivars.

5.2.2 Carbohydrate profile

The sugar content of the different pop sorghum cultivars differed significantly ($P < 0.05$). The *kharif* cultivars showed higher per cent (1.83%) sugars than *rabi* (1.65%) grown cultivars (Table 6). This could be due to the fact that *kharif* crop often received rains during grain formation and grain development which might have favoured the accumulation of higher sugars in grains. The reducing and non-reducing sugar content ranged from 0.12 to 0.15 and 1.39 to 1.93 per cent respectively. Significant increases were observed ($P < 0.05$) non-reducing sugar content was found in both the seasons than reducing sugars. Similar results were also observed in the Ethiopian sorghum varieties (Anon., 1993).

In an independent study, starch content of the grain of 10 pop sorghum cultivars varied from 73.50 to 78.32 (Chavan and Nagarkar, 1988). Starch is the major constituent of sorghum grains. In the present study it was observed that, starch content ranged between 67.11 to 71.31 per cent with the overall mean of 70.34 per cent. The *kharif* cultivars showed mean value of starch of 68.10 per cent whereas *rabi* cultivars showed mean value of starch of 70.34 per cent (Table 6). Madhavi (2000) reported that the soluble amylose content of *kharif* and *rabi* cultivars ranged from 12.70 to 13.21 per cent and the insoluble amylose content was ranged from 6.44 to 10.85 per cent. The total amylose content of the pop sorghum cultivars grown in *kharif* and *rabi* ranged from 21.06 to 25.65 per cent. The mean of total amylose content was higher in pop sorghum cultivars grown in *rabi* season (24.33%) than in *kharif* season (21.61%). The soluble and insoluble amylose content of different pop sorghum cultivars ranged between 12.67 to 16.39 per cent and 7.05 to 10.33 per cent respectively. The mean soluble and insoluble contents were higher in *rabi* cultivars (14.57 and 9.3% respectively) than *kharif* cultivars.

5.3 POPPING QUALITY OF POP SORGHUM CULTIVARS GROWN IN KHARIF AND RABI SEASONS

In the present study, pop sorghum cultivars were processed by conventional and modern, microwave method and were evaluated for popping quality. The results of popping quality showed significant ($P < 0.05$) variation among the cultivars of different seasons. The popping yield in conventionally popped cultivars ranged from 79.43 to 93.17 per cent (Table 7). Maximum popping yield was in Mugad (93.17%) followed by Bagoore local (89.02%) *kharif* grown cultivars and Marole local (88.98%), a *rabi* cultivar was next in the order. The lowest popping yield was in Bijapur local (79.43%). The mean popping yield (88.17%) of *kharif* cultivars was higher than the *rabi* cultivars (82.89%). In case of microwave popping the popping yield ranged between 57.78 to 78.64 per cent. The *kharif* cultivars showed lower popping yield when compared with *rabi* cultivars. The higher popping yield was observed in Marole local (78.64%) a *rabi* cultivar followed by Mugad local (78.35%). Among *rabi* cultivars Marole local has highest popping yield when processed by both conventional and microwave method of popping. Among *kharif* cultivars Mugad had the highest popping yield when processed by conventional and microwave method of popping. Grain characteristics could be responsible for variation in popping quality of cultivars grown in different seasons. Low percentage of popping yield in microwave oven may be due to power absorption by the kernel which in turn is determined by the material's dielectric properties and thermo physical properties (Lin and Anantheswarn, 1988). Pordesimo *et al.* (1990) evaluated kernel dimensions using sphericity, kernel size and specific gravity of popcorn as indicators of popping characteristics of popcorn.

Table 17. Proximate composition (g/100 g) of raw and popped sorghum cultivars grown in different seasons

Cultivars	Moisture			Protein			Fat			Ash			Crude fibre			Total carbohydrate		
	R	C	M	R	C	M	R	C	M	R	C	M	R	C	M	R	C	M
<i>Kharif</i>																		
Mugad local	10.30	7.82	8.00	8.96	9.96	10.15	3.06	3.13	3.18	2.10	1.18	1.82	1.30	1.18	1.16	74.28	76.73	75.68
Uppinbetgeri local	9.50	6.42	6.32	9.17	10.56	11.35	2.71	2.85	2.78	2.24	1.31	2.10	1.22	1.09	1.06	75.16	77.77	76.38
Bogoore local	9.95	8.20	8.00	7.77	8.16	8.56	2.85	2.91	2.95	1.92	1.03	1.43	1.07	1.03	1.05	76.44	78.67	78.00
<i>Rabi</i>																		
Bijapur local	12.22	9.80	9.62	12.73	13.16	13.34	2.93	3.18	3.29	2.29	1.13	1.74	1.35	1.22	1.23	68.48	71.51	70.07
Marole local	11.30	9.02	8.78	10.77	11.16	11.75	3.21	3.46	3.43	2.31	1.18	1.44	1.41	1.27	1.27	71.00	73.91	73.32
Hulginal local	12.55	10.67	10.45	12.78	14.15	13.94	3.31	3.38	3.40	2.37	1.20	1.89	1.44	1.37	1.35	67.55	69.23	68.96
Mean	10.98	8.65	8.53	10.36	11.29	11.52	3.01	3.15	3.17	2.21	1.16	1.74	1.29	1.19	1.18	72.15	74.63	73.73
F-value	58.20 4*	16.33 0*	34.392 *	104.4 8*	41.90 2*	36.04 9*	26.10 1*	12.45 5*	17.13 1*	7.721*	2.343	7.572*	10.02 0*	14.48 7*	8.247	244.5 *	48.48 3*	87.52 2*
S.Em±	0.355	0.43	0.40	0.576	0.63	0.55	0.063	0.07	0.07	0.050	0.03	0.07	0.040	0.03	0.3	1.020	1.07	1.00
CD at 5%	0.98	1.18	1.10	1.59	1.74	1.38	0.17	0.19	0.19	0.13	NS	0.19	0.11	0.08	NS	2.81	2.95	2.76

R – Raw, C-Conventional popping, M-Microwave popping

NS – Not significant

* The values are significantly different at 5% point of distribution of F

Table 18. Sugar content (%) of raw and popped sorghum cultivars grown in different seasons

Cultivars	Total sugar			Reducing sugar			Non-reducing sugar		
	R	C	M	R	C	M	R	C	M
<i>Kharif</i>									
Mugad local	2.05	1.93	1.85	0.12	0.16	0.14	1.93	1.77	1.71
Uppinbetgeri local	1.89	1.35	1.24	0.12	0.11	0.06	1.77	1.27	1.18
Bogoore local	1.56	1.38	1.30	0.14	0.10	0.08	1.42	1.29	1.22
<i>Rabi</i>									
Bijapur local	1.52	1.45	1.35	0.13	0.12	0.09	1.39	1.35	1.25
Marole local	1.79	1.72	1.67	0.14	0.13	0.09	1.65	1.60	1.57
Hulginal local	1.65	1.43	1.37	0.15	0.14	0.07	1.50	1.30	1.29
Mean	1.94	1.54	1.46	0.12	0.12	0.08	1.80	1.43	1.37
F-value	90.892*	2546.120*	2807.24*	4.600	12.829*	5.400	156.258*	852.00*	5660.00*
S.Em±	0.050	0.06	0.06	0.003	0.005	0.002	0.058	0.05	0.05
CD at 5%	0.13	0.16	0.16	NS	0.01	NS	0.16		

R – Raw, C-Conventional popping, M-Microwave popping

NS – Not significant

* The values are significantly different at 5% point of distribution of F

Table 19. Starch, amylose and amylopectin content (%) of raw and popped sorghum cultivars growing in different seasons

Cultivars	Starch			Total amylose			Soluble amylose			Insoluble amylose			Amylopectin		
	R	C	M	R	C	M	R	C	M	R	C	M	R	C	M
<i>Kharif</i>															
Mugad local	67.45	69.68	69.71	22.08	24.01	24.56	12.67	13.87	13.91	9.41	10.14	10.65	77.92	75.99	75.68
Uppinbetgeri local	69.76	71.06	71.91	21.06	21.96	23.75	14.01	14.48	14.28	7.05	7.47	8.97	78.94	78.04	76.72
Bogoore local	67.11	71.67	73.04	21.71	22.67	23.75	13.42	14.54	14.45	8.29	8.12	9.30	78.29	77.33	76.25
<i>Rabi</i>															
Bijapur local	70.45	70.71	71.00	23.25	23.61	24.84	12.92	13.84	13.36	10.33	10.63	11.48	76.75	76.38	75.15
Marole local	71.31	69.99	70.01	24.09	25.14	24.81	14.72	15.57	15.75	9.37	9.57	9.06	75.91	74.85	75.18
Hulginal local	71.09	69.99	69.62	25.65	26.42	26.25	16.39	17.35	16.73	9.26	9.06	9.00	74.35	73.58	73.75
Mean	70.34	70.38	70.88	23.86	23.94	24.66	14.57	14.94	14.74	9.30	9.16	9.74	76.14	76.03	75.45
F-value	1.283	0.277	0.671	9.015*	6.603*	12.360*	13.066*	27.21*	10.593*	11.445*	5.009*	5.275*	10.585*	7.781*	14.853*
S.Em±	0.4697	0.59	0.63	0.4993	0.48	0.26	0.3966	0.37	0.36	0.330	0.36	0.32	0.54	0.48	0.29
CD at 5%	NS	NS	NS	1.35	1.32	0.71	1.07	1.02	0.99	0.91	0.99	NS	1.49	1.32	0.80

R – Raw, C-Conventional popping, M-Microwave popping

NS – Not significant

* The values are significantly different at 5% point of distribution of F

Expansion ratio and flake size of conventionally popped sorghum cultivars ranged from 12.33 to 16.33 ml and 0.31 to 0.55 ml/grain. The mean higher expansion ratio and flake size was observed in *rabi* cultivars (14.57 ml and 0.45 ml/grain) than in *kharif* cultivars (13.75 ml and 0.32 ml/grain) respectively. The higher expansion ratio and flake size was in Marole local (16.33 ml and 0.55 ml/grain), a *rabi* grown cultivar. The lowest expansion ratio and flake size was observed in Uppinbetgeri local (12.33 ml and 0.31 ml/grain). In case of microwave popping expansion ratio and flake size ranged between 10.53 to 15.40 ml and 0.31 to 0.55 ml/grain respectively. Marole local, a *rabi* grown cultivar showed higher expansion ratio (15.40 ml) and flake size (0.55 ml/grain). A *kharif* grown cultivar, Uppinbetgeri local showed lowest expansion ratio (10.53 ml) and flake size (0.31 ml/grain).

5.4 NUTRITIONAL QUALITY OF SORGHUM CULTIVARS AFTER POPPING

Nutritional quality of pop sorghum cultivars grown in two seasons was assessed for proximate composition (Table 17) and carbohydrate profile (Table 18 and 19) after popping. Similarly, the nutritional quality of sorghum cultivars was also evaluated after processing by conventional and modern microwave method of popping.

5.4.1 Proximate composition of sorghum cultivars

The proximate composition of processed sorghum by conventional and microwave method of popping exhibited significant ($P < 0.05$) difference among the cultivars of *kharif* and *rabi* seasons (table 17). The protein content ranged from 8.16 and 14.50 per cent and 8.56 and 13.94 per cent is conventional and microwave method respectively. *Rabi* cultivars showed higher protein content than *kharif* cultivars when processed by both the methods. The fat content varied from 2.85 to 3.46 per cent with the mean value of 3.15 per cent in conventional method. Whereas it ranged from 2.78 to 3.43 per cent with mean value of 3.17 per cent in microwave method. It was also observed that higher fat content was observed in microwave popped sorghum. Similar results were also observed by Yenagi *et al.* (2005). Ash content of conventionally popped grains ranged from 1.03 to 1.31 per cent, which was not found significant. Whereas, there was a significant ($P < 0.05$) difference in microwave method. The mean ash content was higher in microwave popped grains than in conventional popped grains.

The crude fibre content ranged from 1.03 to 1.37 per cent in conventional method of popping. Whereas it was 1.05 to 1.35 per cent in microwave method of popping. The higher crude fibre content was found in conventionally popped grains than in microwave method. The total carbohydrate content ranged from 68.96 to 78.67 per cent. When popped by both the methods. These values are slightly lower than the other study reported by Anon. (2002). The total carbohydrate content was higher in conventional popped grains (74.63%) than microwave popped grains (73.73%).

Proximate composition of popped sorghum was compared with raw grain of different seasons (Table 17). From the table it was found that the mean moisture content of raw grain was 10.98 per cent whereas it 8.65 per cent and 8.53 per cent in popped grains of conventional and microwave method. The lower moisture content of processed grains was due to the application of heat during popping. It was also observed from the table that there was no significant difference between the raw and popped grains of conventional and microwave method for protein, fat, crude fibre and total carbohydrate. It shows that processing of rain at high temperature for short time (HTST) retain nutrients more efficiently than long duration of processing.

5.4.2 Carbohydrate profile of sorghum cultivars after popping

Carbohydrate profile of popped sorghum differed significantly from raw sorghum for total sugar, reducing (Table 12) sugar and total amylose. There is a significant decrease in total carbohydrate content of sorghum after popping. Application of heat treatment may be the

reason for the change. From this result it can be said that there is not much change in the nutrient composition of the popped grains when compared to raw sorghum.

5.4.3 Relationship between physico-chemical and processing qualities of pop sorghum cultivars

Popping yield showed a negative relationship with thousand-kernel weight and volume. Similar result was also reported by throat *et al.* (1988) in nineteen sorghum varieties. Whereas flake size was positively related with kernel weight and volume. This indicates that the size of grain is one of the important factor to improve the expansion of individual grain. Proximate composition though they have shown significant positive or negative relationship for processing quality characteristics, it is very difficult to draw any conclusion. Similar trend was also observed with starch and its components. So it is very difficult to draw any conclusion for relationship of chemical composition with popping qualities of sorghum cultivars. Studies have reported that many factors are responsible for popping qualities. Murty *et al.* (1982) reported that small grain size, white colour, medium thick pericarp, hard endosperm, low germ/endosperm ratio of sorghum cultivars (N=36). Thorat *et al.* (1988) observed that thousand-kernel weight, volume, bulk and true density and seed hardness were the good indicators of popping quality of sorghum cultivars. Murty *et al.* (1983) reported that small starch granules of sorghum cultivars exhibited good popping quality. Malleshi and Desikachar (1985) observed that amylose content was negatively correlated ($r=-0.512$) with expansion volume of popped sorghum grains. Lin and Anantheswaron (1988) in a study on microwave popping reported that popping yield of pop corn was related to the power absorption by the kernel, which in turn was determined by the material's dielectric properties and thermophysical properties. Yenagi *et al.* (2005a) reported that suitable method of popping is an important factor in determining the popping quality of sorghum cultivars.

More number of cultivars needs to be evaluated to confirm the strong relationship between popping quality characters with physico-chemical properties of the sorghum cultivars.

5.5 DEVELOPMENT OF POPPED SNACKS

5.5.1 Nutrient composition

The total carbohydrate, protein, fat and total calories of four developed snacks ranged from 21.64 to 86.6 per cent, 3.10 to 7.75 per cent, 0.90 to 2.90 per cent and 104.86 to 425.36 kcal respectively (Table 12). It also revealed that, among the four developed popped snacks, popped jaggery laddu contributed higher nutrient contents followed by sugar coated coloured snack and by garlic flavoured snack.

5.5.2 Organoleptic qualities of popped snacks

Two spice flavoured and two sweet coated popped snacks were standardised (Appendix XVI, XVII, XVIII and XIX) and studied for consumer acceptability for better market potential. Among spice flavoured popped snacks the scores for overall acceptability was highest for cinnamon flavoured snack product than the garlic flavoured product. It was also observed that texture, taste and flavour scores were significantly ($P<0.05\%$) higher for the cinnamon flavoured snacks whereas for appearance and colour the scores did not show significant difference (Table 13). The less acceptability of garlic flavoured product may be due to its high pungent flavour which was not as acceptable as cinnamon flavour by the consumers. Among sweet coated popped snacks, the scores for overall acceptability was highest for popped jaggery laddu than the sugar coated popped snack (Table 14). It was also observed that the appearance, colour, texture, taste and flavour scores were the highest for the popped jaggery laddu. This may be because of texture and taste of the jaggery which was liked much by the consumers.

5.6 STORAGE QUALITY OF POPPED SORGHUM AND ITS FLOUR

The popped sorghum grains and popped flour is popularly used as traditional snack food in India. As the current generation is the biggest consumer of convenience food, these popped grains and popped flour can be utilized in the development of popped snacks. The present study was undertaken to study the popped grains and flour stored in different packaging materials for their chemical and organoleptic changes during storage.

The changes in organoleptic characters viz., appearance, colour, texture, flavour and overall acceptability of popped grains stored in different packaging materials during storage presented in Table 15 revealed that, the scores for all the characters in different packages lowered, as the storage period extended. The popped grains had scores for appearance, colour, texture, flavour and overall acceptability respectively on 1st day 4.90, 4.87, 4.95, 4.87 and 4.80 then lowered to 2.55, 2.60, 2.40, 2.65 and 2.40 on 21st day of storage. The popped grains packed in paper bag became unacceptable by the end of 21st day, while the grains packed in polythene cover accepted upto 28th days of storage period. The grains packed in paper bag developed intense off odour, soft texture and with fungal growth on 21st day. Whereas the organoleptic changes in popped grains stored in polythene cover were not so prominent and can be reheated and used further for the consumption.

The changes in organoleptic qualities of popped sorghum flour stored in different packaging materials during storage presented in Table 16, revealed that, the scores for all the characters in different packaging lowered, as the storage period increased. The flour had scores for appearance, texture and flavour on 1st day 4.80, 4.85 and 4.65 then lowered to 3.40, 3.40 and 3.45 on 28th day of storage. Organoleptic changes are more closely related to the secondary and tertiary oxidation of products including free fatty acid content (Deman, 1990). The popped sorghum flour packed in low density polythene cover developed slight off flavour by the end of 28th day, while the flour packed in aluminium pouch was acceptable upto 28th day of storage period.

The changes in moisture content of popped grains, presented in Fig.1, revealed that, there was an increase in mean moisture content in the popped grains of different packaging materials from 10.43 per cent on 1st day to 15.37 per cent on 21st day of storage period. The popped grains had tendency to absorb moisture during storage and the grains that are packed in paper bag (14.68%) had higher moisture pickup than the samples in polythene cover (11.54%). This may be the cause for popped grains to absorb moisture rapidly from the atmosphere unless adequately protected because of the large surface, area and because of the gelatinized starch that is more hygroscopic than the native starch and also due to the hygroscopic nature of paper bags (Klaus, 1991). The changes in moisture content of stored flour, presented in Fig. 2, revealed that, there was an increase in mean moisture content in the flour of different packaging materials from 6.70 per cent on 1st day to 9.10 per cent on 28th day of storage period. The flour had tendency to absorb moisture during storage and the flour that is packed in low density polythene cover (8.17%) had higher moisture pickup than the samples in aluminium pouch (7.75%). This may be due to hygroscopic nature of low density polythene cover. Sood (1998) reported that cereal based processed products and weaning foods are highly sensitive to change in moisture and have tendency to form cake. The rate of moisture pickup in flours during storage can be reduced by adding preservatives, thereby increase the shelf-life.

Similarly, the free fatty acid content of flours increased from 0.13 per cent on 1st day to 0.16 per cent on 28th day of storage. Free fatty acid might be formed as a result of secondary degradation of flours of hydroperoxides or due to hydrolysis of triglycerides during storage (Thakur and Arya, 1990). The flour which was packed in low density polythene cover, had higher free fatty acid (0.148%) than the flour packed in aluminium pouch (0.140%). This could be due to higher transmission rate (OTR) of low density polythene cover, thereby increased production of degradation compounds and also due to exposure of foods in pouches. Singh *et al.* (1978) also observed increased free fatty acid content of wheat flour significantly by four months of storage period.

The present study concludes that the pop sorghum cultivars grown in *kharif* and *rabi* seasons exhibited wide variation for physico-chemical characters and also for processing qualities. Grain characters, nutrient composition and popping qualities of *rabi* cultivars were superior than *kharif* grown cultivars. Mugad local of *kharif* and Marole local of *rabi* cultivars exhibited good popping qualities when popped by conventional as well as modern microwave popping method. Popping yield and expansion ratio were better in conventional popping methods than microwave method. Among developed products jaggery coated laddu was highly acceptable followed by cinnamon flavoured and by sugar coated popped snacks. Processed fresh pop sorghum can be stored without affecting the organoleptic characters for 21 days in polythene cover. Further storage requires reheating of sorghum pops to regain its textural quality. Popped sorghum flour stored for one month still exhibited acceptable sensory scores when stored both in aluminium and low density polythene covers. However, the changes observed with respect to moisture and organoleptic qualities were more prominent in low density polythene covers.

Popping is a simple and less expensive processing method which improves textural and sensory qualities of sorghum and also there are minimum changes with respect to nutrient composition in the processed product. Traditionally popped sorghum products are prepared only during few specific occasions. This type of home processed ready-to-eat snacks has a great market potential as value added health products, convenient food, as consumer needs are changing towards more convenient foods as well as less refined or polished grains. Pop sorghum products can be popularised more among children and adolescents and thus value addition definitely enhances the economic value of sorghum.

FUTURE LINE OF WORK

1. There is a need to optimise processing methods for popping of sorghum in microwave method
2. Pop sorghum is a ready-to-eat whole cereal food. Hence further needs to be assessed for micronutrients availability, dietary fibre content and *in vitro* protein and carbohydrate digestibility, to develop value added health foods to meet the community nutritional problems

VI. SUMMARY

Sorghum is a major staple food in semi-arid tropics. However the demand for sorghum as a staple food is declining day by day as there are no alternative uses and value added products similar to rice and wheat. Popped sorghum is one of the ready-to-eat snack which is popularly consumed only by local growers. It has got potential to develop value added products as a convenient ready-to-use food. There is a need to study the grain quality characteristics of sorghum cultivars grown for popping to develop value added products to meet the needs of present day consumers. Hence, the study was undertaken to study nutritional and processing qualities of pop sorghum cultivars grown in different seasons and value addition.

In the present study six pop sorghum cultivars grown in *kharif* and *rabi* seasons were selected. Visual observation of pop sorghum cultivars grown in *kharif* and *rabi* season revealed that cultivars grown in *kharif* season were creamy white colour with oval or oblong in shape. Whereas *rabi* cultivars were brownish white in colour and oblong or oval in shape.

The thousand-kernel weight, volume and density of pop sorghum cultivars grown in *kharif* and *rabi* season differed significantly ($P < 0.05$) and ranged from 15.60- to 20.30 g. The mean 1000-kernel weight and volume of *rabi* cultivars was higher than *kharif* cultivars.

Proximate composition like moisture, protein, fat, ash, crude fibre and total carbohydrates of *kharif* and *rabi* grown cultivars differed significantly ($P < 0.05$) and ranged from 9.50 to 12.55, 7.77 to 12.78, 2.71 to 3.31, 1.92 to 2.37, 1.07 to 1.44 and 67.55 to 76.44 per cent, respectively. The mean moisture, protein fat, ash, crude fibre contents of *kharif* cultivars were lower than *rabi* grown cultivars. Whereas, the total carbohydrate content was higher in *kharif* cultivars than in *rabi* cultivars.

The results of the sugar content of different pop sorghum cultivars differed significantly ($P < 0.05$). The mean values of the total sugars of pop sorghum cultivars ranged from 1.52 to 2.05 per cent. The *rabi* grown cultivars had higher per cent of total sugars (1.65%) than *kharif* cultivars (1.83%). The reducing sugar and non-reducing sugar contents ranged from 0.12 to 0.15 and 1.39 to 1.93 per cent, respectively. Significantly, higher mean of non-reducing sugar content (1.70%) was found in *kharif* grown cultivars than in *rabi* grown cultivars (1.51%).

The starch and amylose contents of different pop sorghum cultivars ranged from 67.11 to 71.31 per cent respectively, total amylose from 21.06 to 25.65 per cent respectively, soluble amylose from 12.67 to 16.39 per cent respectively, insoluble amylose from 7.05 to 10.33 per cent respectively and amylopectin from 74.35 to 78.94 per cent respectively. The starch content of different pop sorghum cultivars did not show significant difference. Whereas amylose content of different pop sorghum cultivars varied significantly ($P < 0.05$). The mean amylose contents were higher in pop sorghum cultivars grown in *rabi* than the *kharif*. Whereas amylopectin content was higher in *kharif* cultivars than in *rabi* cultivars.

Popping quality like popping yield, expansion ratio and flake size of conventional and microwave popped grains varied significantly ($P < 0.05$). Popping yield of conventionally popped sorghum cultivars ranged from 79.43 to 93.17 per cent. The mean popping yield of *kharif* cultivars was higher (88.77%) than those of *rabi* cultivars (82.89%). Whereas, popping yield of microwave popped sorghum cultivars ranged from 57.78 to 78.64 per cent. The mean popping yield of *rabi* cultivars was higher (69.82%) than those of *kharif* cultivars (67.85%). Microwave popping decreased the popping yield from 85.33 to 68.84. Expansion ratio of conventionally popped pop sorghum cultivars ranged from 12.33 to 16.33 ml. The mean expansion ratio of *rabi* cultivars was higher (14.59 ml) than *kharif* cultivars (13.75 ml). Whereas, expansion ratio of microwave popped sorghum cultivars ranged from 10.53 to 15.40 ml. The mean expansion ratio of *rabi* cultivars was 12.33 ml. Microwave popping decreased the expansion ratio from 14.17 to 12.78 ml.

Flake size of conventionally popped sorghum cultivars ranged from 0.31 to 0.55. The mean flake size of *rabi* cultivars was higher (0.45 ml/grain) than those of *kharif* cultivars (0.32 ml/grain). Flake size of microwave popped sorghum cultivars also ranged from 0.31 to 0.55 ml/grain. The mean flake size of *rabi* cultivars was higher (0.46 ml/grain) than those of *kharif* cultivars (0.32 ml/grain). Microwave popping increased the flake size from 0.39 to 0.40 ml/grain.

Proximate composition like moisture, protein, fat, ash, crude fibre and total carbohydrate of *kharif* and *rabi*, popped conventionally and microwave differed significantly

($P < 0.05$). Proximate composition (mentioned above) of conventionally popped pop sorghum cultivars ranged from 6.42 to 10.67, 8.16 to 14.15, 2.85 to 3.46, 1.03 to 1.20, 1.03 to 1.37 and 69.23 to 78.67 per cent, respectively. Proximate composition mentioned above of microwave popped sorghum cultivars ranged from 6.32 to 10.45, 8.56 to 13.94, 2.78 to 3.43, 1.43 to 2.10, 1.05 to 1.35 and 68.96 to 78.00 per cent, respectively. However, ash content of conventionally popped pop sorghum cultivars and crude fibre content of microwave popped pop sorghum cultivars did not show significant difference.

The results of sugar content of different pop sorghum cultivars, popped by conventional and microwave method differed significantly ($P < 0.05$). However, reducing content of microwave popped grains did not show significant difference. The mean values of the total sugars of conventionally popped pop sorghum cultivars ranged from 1.35 to 1.93 per cent. The *kharif* popped cultivars showed higher total sugar content (1.55%) than the *rabi* cultivars (1.53%). Whereas total sugar content of microwave popped pop sorghum cultivars showed equal values of 1.46 per cent for both *kharif* and *rabi* cultivars. The reducing sugar and non-reducing sugar content of conventionally popped cultivars ranged from 0.10 to 0.16 and 1.27 to 1.77 per cent respectively. The mean of reducing sugar content of *rabi* cultivars (0.13%) was higher than *kharif* (0.12%). The mean values of non-reducing sugar content was higher in *kharif* (1.44%) cultivars than in *rabi* cultivars (1.41%). In microwave popped grains, reducing and non-reducing sugar content ranged from 0.06 to 0.14 and 1.22 to 1.57 per cent, respectively. The mean value of reducing sugars was higher in *kharif* (0.09%) than in *rabi* cultivars (0.08%). Whereas, the mean values of non-reducing sugar content was comparable (1.37%) in *kharif* and *rabi* cultivars.

Starch and amylose contents of different pop sorghum cultivars popped by conventional and microwave method oven ranged from 69.68 to 71.67 per cent, 21.96 to 26.42 per cent total amylose, 13.84 to 17.35 per cent (soluble amylose), 7.47 to 10.63 per cent (insoluble amylose) and 73.58 to 78.04 per cent amylopectin. The starch content of different popped pop sorghum cultivars did not differ significantly. Whereas, total amylose content of different popped sorghum cultivars varied significantly ($P < 0.05$).

The mean of total amylose content was higher in *rabi* cultivars than in *kharif* cultivars when popped by conventional method. The same trend was observed in microwave popped grains. The soluble amylose content was higher (15.58%) in all the *rabi* cultivars than the *kharif* (14.29%) cultivars, when popped by conventional method. The same trend was observed in soluble amylose content, when popped by microwave method. In soluble amylose content was found to be higher in *rabi* cultivars than in *kharif* cultivars when popped by conventional method. However, insoluble amylose content did not show significant difference in microwave popped grains. While all the *kharif* cultivars showed higher (77.12% and 76.21%) amylopectin content than the *rabi* cultivars (74.93% and 74.69%) when popped by conventional and microwave method respectively.

Acceptability of spice flavoured and sugar coated popped sorghum snacks were evaluated subjectively to identify the best product. The total mean scores for cinnamon flavoured among spice flavoured and popped jaggery laddu among sweet coated popped snacks were higher for appearance, colour, texture, taste, flavour and overall acceptability than garlic flavoured and sugar coated products. Among spice flavoured popped snacks cinnamon flavoured showed better organoleptic scores than garlic flavoured product. Among sweet coated snacks, popped jaggery laddu showed better organoleptic qualities than sugar coated.

Changes in organoleptic qualities of popped pop sorghum grains and flour stored in different packaging materials during storage period showed significant variation ($P < 0.05$). The popped grains and flour which were stored in polythene cover and aluminium pouch had higher scores for all the quality parameters compared to the popped grains and popped flour stored in paper bag and low density polythene cover respectively, irrespective of duration of storage period.

Quality of popped pop sorghum grains stored in paper bag and polythene cover was observed weekly for changes in moisture. The mean moisture content, irrespective of type of packages used for storage, increased significantly, from 10.43 to 15.37 per cent at zero day to 21st days of storage. The popped pop sorghum grains stored in different packaging materials showed significant ($P < 0.05$) difference with respect to moisture content. Among the different packages, popped grains stored in polythene cover had lower moisture content.

Quality of popped sorghum flour, stored in aluminium pouch and low density polythene cover was observed weekly for changes in moisture and free fatty acid content.

The mean moisture and free fatty acid content of popped flour, irrespective of type of packages used for storage, increased significantly ($P < 0.05$) from 6.70 and 0.13 per cent at zero day to 9.10 and 0.15 per cent at 28th days of storage period, respectively. The popped flour stored in different packaging materials showed significant ($P < 0.05$) difference with respect to moisture and free fatty acid contents during storage. Among different packages, popped flour stored in low-density polythene cover had the higher moisture content and free fatty acid content.

The pop sorghum cultivars grown in *rabi* season are superior for grain characters, nutrient composition and also popping qualities. Conventional popping is superior over microwave popping. Among the cultivars studied Mugad local, a *khariif* cultivar and Marole local and *rabi* cultivar were the best pop sorghum cultivars for popping. Among developed products popped jaggery laddu was highly acceptable followed by cinnamon flavoured and sugar coated coloured popped snacks. Popped sorghum stored in polythene cover and popped flour stored in aluminium pouch had better storage quality of 21 and 28 days with excellent organoleptic qualities respectively. Thus, market potential of pop sorghum cultivars can be enhanced by popularising more convenient value added processed products of pop sorghum as spice flavoured, sweet coated snacks and also varieties of health foods.

VII. REFERENCES

- ANNIE, S., LIVINGSTONE, JAIN, J.F. AND NAGAPPA, G.M., 1993, Development and nutritional quality evaluation of weaning foods based on malted, popped and roller dried wheat and chickpea. *International Journal of Food Science and Technology*, **28**: 35-43.
- ANONYMOUS, 1983, *Approved Methods of American Association of Cereal Chemists*. 8th Edition, AACC, The Association : St. Paul, M.N.
- ANONYMOUS, 1990, *Official Methods of Analysis of the Association of Official Analytical Chemist*, 20th Edition, AOAC, Washington D.C.
- ANONYMOUS, 1993, Studies on sorghum. Nutritive value of foods, *NIN Annual Report*, p.5-7.
- ANONYMOUS, 1996, Production, *FAO Year Book*, **50**: 68.
- ANONYMOUS, 2002, Identification and conservation of pop sorghum. *ICAR Ad-hoc Project Report*, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad.
- ANUPAMA, G., 2002, Grain quality characteristics and product evaluation of sorghum cultivars grown for conventional use. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.
- ASHTURKAR, P.B., VIJAYPANDE AND SNEHALATHA REDDY, 1992, Development and evaluation of weaning food formulation. *Journal of Food Science and Technology*, **29**(3): 197-198.
- BASARKAR, P.W. AND SRINIVASAN, C.N., 1997, *Basic Biochemistry. Laboratory Manual*, University of Agricultural Sciences, Dharwad, pp.11-12.
- BETSCHART, A.A., IRVING, D.W., SHEPARD, A.D., AND SAUNDERS, R.M., 1981, *Amaranthus cruentus*, milling characteristics, distribution of nutrients within seed components and the effect of temperature and nutritional quality. *Journal of Food Science*, **46**(4): 1181-1187.
- BHUVANESHWARI, G., 1995, Composition, cooking quality and utilization of grain amaranth in foods. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.
- BHUVANESHWARI, G., 1999, Nutritional and processing qualities of dicocum (*Triticum dicocum* Schrank Suhulb) wheat varieties. *Ph.D. Thesis*, University of Agricultural Sciences, Dharwad.
- CHAVAN, J.K. AND NAGARKAR, V.D., 1988, Nutrition and *bhakri* making qualities of some improved cultivars of grain sorghum. *Journal of Maharashtra Agricultural Universities*, **13**(2): 198-201.
- DELOST, L.K., LORENZ, K. AND TRIBELHORM, R., 1992, Puffing quality of experimental varieties of proso millets (*Panicum miliaceum*). *Cereal Chemistry*, **69**(4): 359-365.
- DEMAN, M.J., 1990, *Principle of Food Chemistry – ZED, AVI, Van Nostrand Reinhold*, New York, pp.1-56.
- DEVADAS, P.R., JALAJA, R. AND RADHA RUKMANI, A. 1966, Comparison of the nutritive value of sorghum. *Indian Journal of Nutrition and Dietetics*, **3**: 47-49.
- FERREL, R.E. AND SHEPAERD, A.D., 1966, Gun-puffing wheat and bulgur. *Cereal Chemistry*, **43**(4): 529-537.
- GOPALAN, C., RAMASASTRI, B.V. AND BALASUBRAMANIAN, 1989, *Nutritive Value of Indian Foods*, revised and updated by Narasingh Rao, B.S., Deosthale, Y.G. and Pant, K.C., National Institute of Nutrition, Indian Council of Medical Research, Hyderabad.
- GOPALAN, C., RAMASASTRI, B.V. AND BALASUBRAMANIAN, S.C., 1996, *Nutritive Value of Indian Foods*. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India.
- GOPALDAS, T., 1992, Amylose reactive foods in the improvement of young child diet. *Proceedings of Nutrition Society of India*, **39**: 87-100.
- GUPTA, A., RATNA AND SRIVASTAVA, S., 1995, Effect of storage conditions on popping quality of sorghum. *Journal of Food Science and Technology*, **32**(3): 211-213.
- GUPTA, H.O., CHATTERJEE, S.R. AND JOGINDER SINGH, 1985, Effect of popping and boiling on protein quality of maize (*Zea mays* L.) kernels. *Journal of Food Science and Technology*, **23**: 59-60.

- HADIMANI, N.A., 1994, Pearl millet (*Pennisetum americanum*) grain quality with special emphasis on milling and popping of millet. *Ph.D. Thesis*, CFTRI, Mysore, India.
- HADIMANI, N.A. AND MALLESHI, N.G., 1995, Popping of pearl millet and development of supplementary food based on popped millet. *Abstracts of Seminar Papers of Post harvest Tech for Rural Develt*, p.36.
- HADIMANI, N.A., MURALIKRISHNA, G., THARANATHAN, R.N. AND MALLESHI, N.G., 2001, Nature of carbohydrates and proteins in three pearl millet varieties varying in processing characteristics and kernel texture. *Journal of Cereal Science*, **33**: 17-25.
- HARBERS, L.H., 1975, Starch granules, structural changes and amylopectin patterns in processed sorghum grains. *Journal of Animal Science*, **41**: 1496-1501.
- HAWK, B.P., O'SER, B.L. AND SUMMERSON, H.W., 1965, *Practical Physiological Chemistry*. McGraw Hill Co. Inc., New York.
- HOSMANI, M.M. AND CHITTAPUR, B.M., 1997, *Sorghum Production Technology*, published by Sarasijakshi M.H., Dharwad, India and 5910, Wood Ridge Hill, San Antonio, Texas 78249, USA.
- HOSMANI, S.A. AND SHANKARE GOUD, B.T., 1978, 'Roti' (bread) making qualities of elite sorghum cultivars. Unpubl. A paper presented in All India Sorghum Workshop, held at Dharwad camp., 17-19, April, 1978.
- KASTURIBA, B., MEERA RAO AND JOSHI, M.S., 1994, Cooking qualities of different sorghum hybrids. *Maharashtra Journal of Extension Education*, **13**: 59-61.
- KASTURIBA, B., MEERA RAO AND KAMTAR, M.Y., 1997, Cooking qualities of different rabi sorghum genotypes. *Maharashtra Journal of Extension Education*, **16**: 366-368.
- KLAUS, J., 1991, *Handbook of Cereal Science and Technology*. Ed: Klaus, J., Lorenz, and Karel Kulp, 1991, Marcel Dekker, In C. New York.
- LATA, R.K., 1990, Chemical composition and quality evaluation of minor millets. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.
- LIN, Y.E. AND ANANTHESWARAN, R.C., 1988, Studies on popping of popcorn in a microwave oven. *Journal of Food Science*, **53**(6): 1746-1749.
- MADHAVI, R., 2000, Influence of process variables and flour characteristics of sorghum genotypes on rheological properties of dough and roti. *Ph.D. Thesis*, University of Agricultural Sciences, Dharwad.
- MADHURI, S.K., 2002, Varietal suitability of rice (*Oryza sativa* L.) for conventional processing. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.
- MALLESHI, N.G. AND DESIKACHAR, H.S.R., 1981, Varietal differences in puffing quality of ragi (*Elusine coracana*). *Journal of Food Science and Technology*, **26**: 26-28.
- MALLESHI, N.G. AND DESIKARHAR, H.S.R., 1985, Milling, popping and malting characteristics of some minor millets. *Journal of Food Science and Technology*, **22**: 400-403.
- MALLESHI, N.G., 1987, Malting of sorghum for food uses. *Proceeding of the National Seminar on technology and Application for Alternative Uses of Sorghum*, Parbhani, pp.144-152.
- MALLINATH, 2002, Genetic studies in pop sorghum. *M.Sc.(Agri.) Thesis*, University of Agricultural Sciences, Dharwad.
- MILLER, O.H. AND BURNS, E.E., 1970, Starch characteristics of selected grain sorghum as related to human foods. *Journal of Food Science and Technology*, **35**(5): 666-668.
- MOHAMED, A.A., ASHMAN, R.B. AND KIRLEIS, A.W., 1993, Pericarps thickness and other kernel physical characteristics related to microwave popping quality of popcorn. *Journal of Food Science*, **58**: 342-346.
- MOTTERN, H.H., VIX, H.L.E. AND SPADARA, J.J., 1967, Popping characteristics of rice. *Rice Journal*, **70**: 24-31.
- MURTY, D.S., NICODEMUS, K.D., PATIL, H.D., MUKUR, S.Z. AND HOUSE, L.R., 1983, Studies on popping quality in sorghum. *Sorghum Newsletter*, **20**: 97-99.
- MURTY, D.S., PATIL, H.D., PRASAD RAO, K.E. AND HOUSE, L.R., 1982, A note on screening the India sorghum collection for popping quality. *Journal of Food Science and Nutrition*, **19**: 79-80.
- MURUGESAN, G. AND BHATTACHARYA, K.R., 1986, Studies on puffed rice, effect of processing conditions. *Journal of Food science and Technology*, **23**: 197-202.
- PANT, K.C., 1985, Effect of heat processing (popping) on protein nutritional quality of grain amaranth. *Nutrition Reports International*, **32**(5): 1089-1098.

- PEDERSON, B., KALINOCOSKI, L.S.S. AND EGGUM, B.P., 1987, The nutritive value of amaranth grain (*Amaranthus caudatus*) qualities plantatum plant foods. *Human Nutrition*, **36**(4): 309-324.
- PORDESIMO, L.O., ANANTHESWARAN, R.C., FLEISCHMANN, A.M., LIN, Y.E. AND HANNA, M.A., 1990, Physical properties as indicators of popping characteristics of microwave pop corn. *Journal of Food Science*, **55**(5): 1352-1355.
- RATHOD, P. AND UDIPI, S.A., 1991, The nutritional quality and acceptability of weaning foods incorporating amaranth. *Food and Nutrition Bulletin*, **13**(1): 58-64.
- REDDY, S.N., WAGHMARE, S.Y. AND PANDE, V., 1990, Formulation of home made weaning mixes based on local foods. *Food and Nutrition Bulletin*, **12**(2): 138-140.
- SANKARAPANDIAN, R., 2000, Physical-physiological cooking and popping characteristics of some jowar varieties and this inter-correlation and regression analysis. *Journal of Food Science and Technology*, **37**(3): 327-329.
- SATISH KUMAR, L., PRAKASH, H.S., SHETTY, H.S. AND MALLESHI, N.G., 1991, Influence of seed mycoflora and harvesting conditions of milling, popping and malting qualities of sorghum (*Sorghum bicolor*). *Journal of Science of Food and Agriculture*, **55**: 617-625.
- SAVITHRI, A. AND MEERA RAO, 1985, Influence of season on roti making and popping qualities of high yielding sorghum varieties. *Journal of Food Science Technology*, **22**(1): 64-65.
- SHUKLA, S.S., GUPTA, O.P. AND SHARMA, Y.K., 1986, Puffing quality of characteristics of some ragi (*Elusine coracana*) cultivars. *Journal of Food Science and Technology*, **23**:329-330.
- SINGH, M. AND SRIVASTAVA, S., 1993, Sorghum grain. Moisture: Its effect on popping quality. *Journal of Food Science and Nutrition*, **30**(4): 296-297.
- SINGH, V., SHARMA, S.S. AND THAPUR, V.K., 1978, Suitability of packaging material for storing wheat flours. *Bulletin of Grain Technology*, **17**(1): 119-123.
- SINGHAL, R.S. AND KULKARNI, P.R., 1991, Puffing effects and functional properties of *A. Paniculatus* (Rajgeera) seed flour. *Journal of Food Science*, **56**(94): 1121-1122.
- SNEHALATHA REDDY, N., WAGHMARE, S.Y. AND VIJAY PANDE, 1990, Formulation and evaluation of home made weaning mixes based on local foods. *Food and Nutrition Bulletin*, **12**(2): 138-140.
- SOOD, V.K., 1998, Modern food packaging. Indian Institute of Packaging, New Radharaman Printing Press, Mumbai, pp.462.
- SOWBHAGYA, C.M. AND BHATTACHARYA, K.R., 1979, Simplified determination of amylose in milled rice starch. *Stärke*, **31**: 159-163.
- SRINIVAS, T. AND DESIKACHAR, H.S.R., 1973, Factors affecting the puffing quality of paddy. *Journal of science of Food and Agriculture*, **24**: 883-891.
- SRINIVAS, T., LAKSHMI, T.K. AND DESIKACHAR, H.S.R., 1973, Varietal differences in puffing quality of paddy. *Journal of Food Science and Technology*, **11**: 134-135.
- SRIVASTAVA, S. AND BATRA, A., 1998, Popping qualities of minor millets and their relationship with grain physical properties. *Journal of Food Science and Technology*, **35**(3): 265-267.
- SRIVASTAVA, S., 1996, Use of popped versus malted sorghum flour in supplementary foods for children. *Sorghum News Letter*, **37**: 71-72.
- STEEL, G.D. AND JORRIE, J.H., 1960, *Principles and Procedures of Statistics*. McGraw-Hill Book Company, Inc., New York, p.134.
- SWAMINATHAN, M., 1995, *Food Science, Chemistry and Experimental Foods*. The Bangalore Printing and Publishing Co. Ltd., India, pp.286-300.
- THAKRE, S.K., 1981b, Nutritive values of grain of some sorghum cultivars. *Journal of Maharashtra Agricultural Universities*, **6**(1): 60-61.
- THAKUR, B.R. AND ARYA, S.S., 1990, Packaging requirement and stability of fried wheat snacks (Trisnacks). *Journal of Food Science and Technology*, **27**(2): 76-81.
- THORAT, S.S., SATWADHAR, P.N., KULKARNI, D.N., CHOUDHARI, S.D. AND INGLE, U.M., 1988, Effect of various grain parameters on popping quality of sorghum. *Journal of Food Science and Technology*, **25**(8): 361-363.
- THORAT, S.S., SATWADHAR, P.N., KULKARNI, D.N., CHOUDHARI, S.D. AND INGLE, U.M., 1990, Varietal differences in popping quality of sorghum grains. *Journal of Maharashtra Agricultural Universities*, **15**(2): 173-175.

- TOVAR, L.R. AND CARPENTER, K.J., 1982, The effects of alkali cooking of corn and supplementation with amaranth seed in its deficiencies in lysine and tryptophan. *Arch. Latinomer Nutr*, **32**(4): 961-972.
- VIKAS, S., 2003, *Indian Economic Data Research Centre*, p.166.
- VIRAKTAMATH, C.S., RAGHAVENDRA RAO, G. AND DESIKACHAR, H.S.R., 1972, Varietal differences in chemical composition, physical properties and culinary qualities of some recently developed sorghum strains. *Journal of Food Science and Technology*, **2**: 73-79.
- YENAGI, N.B. AND BHUVANESWARI, G., 2004, Cooking and popping qualities of raw and bulgurised wheat varieties. *Research Highlights*, JADU, **14**: 82-186.
- YENAGI, N.B., CHITTAPUR, B.M., KACHAPUR, M.D. AND NADAGOUD, V.V., 2005a, Suitable process for popping of sorghum cultivars for value addition. *Maharashtra Journal of Agricultural Extension Education*, (in press).
- YENAGI, N.B., CHITTAPUR, B.M., NADAGOUDA, V., AND KULKARNI, S.S., 2002, Value added ready-to-eat products of pop sorghum cultures to stimulate economic growth of rural community, presented at 2nd International Agronomy Congress November, 26th-30th, New Delhi, India p.1915.
- YENAGI, N.B., KACHAPUR, M.D. AND BHUVANESHWARI, G., 2005b, Popping quality and proximate composition of pop sorghum cultivars. *Research Highlights*, JADU, **15**: 119-124.
- YENAGI, N.B., RAGHAVAN, G.S.V., SOSLE, V., OSATAND, V. AND SHASHIDHAR, K.C., 2004, Assessment of popping quality of sorghum for market potential. *Presented at ASAE/CSAE Annual International Meeting*, 1-4 August, 2004, At Ottawa, Canada.

APPENDIX I

Popping yield of pop sorghum cultivars grown in different seasons

Cultivars	Popping yield (%)		Processing mean
	Conventional popping	Microwave popping	
<i>Kharif</i>			
Mugad local	93.17	78.35	85.76
Uppinbetgeri local	84.12	57.78	70.95
Bogoore local	89.02	67.43	78.22
<i>Rabi</i>			
Bijapur local	79.43	57.93	68.68
Marole local	88.98	78.64	83.81
Hulginal local	80.28	72.91	76.59
Cultivars mean	85.83	68.84	

	F-Value	S.Em±	CD at 5%
Cultivars (C)	6.472881	0.821	2.396
Processing (P)	107.0223	0.273	0.798
Interaction (CxP)	8.222266	1.642	4.793

APPENDIX II

Expansion ratio of pop sorghum cultivars grown in different seasons

Cultivars	Expansion ratio (ml)		Processing mean
	Conventional popping	Microwave popping	
<i>Kharif</i>			
Mugad local	15.07	13.73	14.40
Uppinbetgeri local	12.33	10.53	11.43
Bogoore local	13.87	12.73	13.30
<i>Rabi</i>			
Bijapur local	13.33	11.60	12.46
Marole local	16.33	15.40	15.86
Hulginal local	14.07	12.67	13.37
Cultivars mean	14.17	12.78	

	F-Value	S.Em±	CD at 5%
Cultivars (C)	6.102154	0.25392	0.741028
Processing (P)	7.479655	0.08464	0.247009
Interaction (CxP)	0.072858	0.50784	1.482055

APPENDIX III

Flake size of pop sorghum cultivars grown in different seasons

Cultivars	Flake size (ml/grain)		Processing mean
	Conventional popping	Microwave popping	
<i>Kharif</i>			
Mugad local	0.34	0.36	0.35
Uppinbetgeri local	0.31	0.31	0.31
Bogoore local	0.33	0.33	0.33
<i>Rabi</i>			
Bijapur local	0.46	0.48	0.47
Marole local	0.55	0.55	0.55
Hulginal local	0.35	0.37	0.36
Cultivars mean	0.39	0.40	

	F-Value	S.Em±	CD at 5%
Cultivars (C)	6.102154	0.253	0.741
Processing (P)	7.479655	0.084	0.247
Interaction (CxP)	0.072858	0.507	1.482

APPENDIX IV

Scorecard for the evaluation of popped snacks

Name of the consume : _____

Product: Cinnamon flavoured/Garlic flavoured

Age : _____ Place : _____ Date: _____

Please tick (✓) mark against the score that you think is the most appropriate

Characters	Cinnamon flavoured					Garlic flavoured				
	5	4	3	2	1	5	4	3	2	1
Appearance										
Colour										
Texture										
Taste										
Flavour										
Overall										

Note: 5-Excellent, 4-Very good, 3-Good, 2-Fair, 1-Poor

Any remarks:

Signature

APPENDIX V

Scorecard for the evaluation of popped snacks

Name of the consume : _____

Product: Popped jaggery laddu/Sugar coated coloured popped snack

Age : _____ Place : _____ Date: _____

Please tick (✓) mark against the score that you think is the most appropriate

Characters	Popped jaggery laddu					Sugar coated coloured popped snack				
	5	4	3	2	1	5	4	3	2	1
Appearance										
Colour										
Texture										
Taste										
Flavour										
Overall										

Note: 5-Excellent, 4-Very good, 3-Good, 2-Fair, 1-Poor

Any remarks:

Signature

APPENDIX VI

Scorecard for evaluation of popped sorghum during storage

Name of Judge: _____

Date: _____

Kindly observe the changes in all the parameters of products during storage and put tick mark whichever you feel appropriate.

Texture : Observe for crispiness
 Flavour : Observe for development of off flavour

Sl. No.	Quality parameters	Score	Product		
			A	B	C
1.	Appearance				
	Highly acceptable	5			
	Moderately acceptable	4			
	Acceptable	3			
	Fairly acceptable	2			
2.	Poorly acceptable	1			
	Colour				
	Highly acceptable	5			
	Moderately acceptable	4			
	Acceptable	3			
3.	Fairly acceptable	2			
	Poorly acceptable	1			
	Texture	5			
	Highly acceptable	4			
	Moderately acceptable	3			
4.	Acceptable	2			
	Fairly acceptable	1			
	Poorly acceptable				
	Flavour	5			
	Highly acceptable	4			
5.	Moderately acceptable	3			
	Acceptable	2			
	Fairly acceptable	1			
	Poorly acceptable				
	Overall acceptability	5			
6.	Highly acceptable	4			
	Moderately acceptable	3			
	Acceptable	2			
	Fairly acceptable	1			
	Not acceptable				
	Any remarks				

Signature of the Judge

APPENDIX VII

Quality changes of physical properties of popped sorghum flour during storage

Name of Judge: _____

Date: _____

Please observe the changes in all the parameters of products during storage and put tick () mark whichever you feel most appropriate

Texture : Observe for lumps and cake formation

Flavour : Observe for development of off flavour

Sl. No.	Quality parameters	Score	Product		
			A	B	C
1.	Appearance				
	Highly acceptable	5			
	Moderately acceptable	4			
	Acceptable	3			
	Poorly acceptable	2			
	Not acceptable	1			
2.	Texture				
	Dry	5			
	Slightly soft	4			
	Soft	3			
	Too soft	2			
	Lumpy	1			
3.	Flavour	5			
	Highly acceptable	4			
	Moderately acceptable	3			
	Acceptable	2			
	Poorly acceptable	1			
	Not acceptable				

Signature of the Judge

APPENDIX VIII

Appearance of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.90	4.40	4.10	3.80	3.40	4.12

Paper bag	4.90	3.00	2.50	1.30	ND	2.92
Duration mean	4.90	3.70	3.30	2.55	3.40	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	466.5904	0.012	0.033
Duration (D)	34.44578	1.600	4.485
Interaction (PxD)	23.16867	0.048	0.134

APPENDIX IX

Colour of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.87	4.30	4.20	3.90	3.2	4.09
Paper bag	4.87	2.90	2.60	1.30	ND	2.91
Duration mean	4.87	3.60	3.40	2.6	3.2	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	321.2542	0.014	0.040
Duration (D)	32.13559	0.019	0.305
Interaction (PxD)	13.42373	0.057	0.160

APPENDIX X

Texture of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.95	4.30	3.70	3.60	2.50	3.81
Paper bag	4.95	2.30	2.00	1.20	ND	2.61
Duration mean	4.95	3.30	2.85	2.4	2.50	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	302.4922	0.016	0.045
Duration (D)	14.77283	0.021	0.602
Interaction (PxD)	7.276169	0.064	0.180

APPENDIX XI

Flavour of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.87	4.0	3.90	3.90	2.90	3.91
Paper bag	4.87	2.50	2.20	1.40	ND	2.74
Duration mean	4.87	3.25	3.05	2.65	2.90	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	371.9915	0.014	0.040

Duration (D)	20.9831	0.019	0.053
Interaction (PxD)	8.712676	0.573	0.160

APPENDIX XII

Overall acceptability of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.80	4.00	3.90	3.60	3.20	3.90
Paper bag	4.80	2.30	1.90	1.20	ND	2.55
Duration mean	4.80	3.15	2.90	2.40	3.2	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	522.3808	0.012	0.034
Duration (D)	2.07692	1.635	4.583
Interaction (PxD)	12.42692	0.049	0.137

APPENDIX XIII

Appearance of popped sorghum flour stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.80	4.50	4.00	3.80	3.30	4.08
Paper bag	4.80	4.70	4.60	4.00	3.50	4.32
Duration mean	4.80	4.60	4.30	3.90	3.40	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	30.78477	0.013	0.037
Duration (D)	2.622517	0.017	0.049
Interaction (PxD)	1.817881	0.052	0.148

APPENDIX XIV

Texture of popped sorghum flour stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.85	4.20	3.70	3.50	3.40	3.93
Paper bag	4.85	4.20	3.90	3.60	3.40	3.99
Duration mean	4.85	4.20	3.8	3.55	3.40	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	31.57792	0.016	0.045
Duration (D)	3.142857	0.021	0.061
Interaction (PxD)	1.058442	0.065	0.183

APPENDIX XV

Flavour of popped sorghum grains stored in different packaging materials

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	4.65	3.80	3.80	3.40	3.30	3.79

Paper bag	4.65	4.10	4.10	3.60	3.60	4.10
Duration mean	4.65	3.95	3.95	3.50	3.45	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	49.75522	0.013	0.039
Duration (D)	3.823881	0.018	0.052
Interaction (PxD)	1.970149	0.055	0.156

APPENDIX XVI

Moisture content (%) popped sorghum grains during storage

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Polythene cover	10.43	13.66	16.27	18.37	ND	14.68
Paper bag	10.43	10.66	11.20	12.38	13.12	11.54
Duration mean	10.43	12.13	13.73	15.37	13.12	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	336.795	0.013	0.040
Duration (D)	2108.894	0.018	0.054
Interaction (PxD)	2707.356	0.055	0.162

APPENDIX XVII

Moisture content (%) popped sorghum flour during storage

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Aluminium pouch	6.70	7.25	7.76	8.17	8.88	7.75
Low density polythene cover	6.70	7.87	8.20	8.80	9.31	8.17
Duration mean	6.70	7.56	7.98	8.48	9.10	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	89.774	0.028	0.084
Duration (D)	14.604	0.038	0.112

Interaction (PxD)	3.731	0.115	0.337
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APPENDIX XVIII

Free fatty acid (% oleic acid) of popped flour during storage

Packages	Storage period (days)					Package mean
	1	7	14	21	28	
Aluminium pouch	0.13	0.13	0.14	0.15	0.15	0.140
Low density polythene cover	0.13	0.14	0.15	0.16	0.16	0.148
Duration mean	0.13	0.14	0.15	0.16	0.16	

ND – Not determined

Mean are average of 10 judges

	F-Value	S.Em±	CD at 5%
Packages (P)	4.40E+13	1.700	5.239
Duration (D)	1.06E+13	2.404	7.409
Interaction (PxD)	2.64211E+12	3.400	1.047

APPENDIX XIX

Preparation of cinnamon flavoured popped snack

Ingredients	Quantity
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Popped sorghum	30 g
Oil	5 ml
Turmeric	One pinch
Salt	To taste
Cinnamon powder	3 g

Method: Take 30 g of popped sorghum and season with oil, turmeric, salt and with cinnamon powder and mix well.

APPENDIX XX

Preparation of garlic flavoured popped snack

Ingredients	Quantity
Popped sorghum	30 g
Oil	5 ml
Turmeric	One pinch
Salt	To taste
Garlic powder	3 g

Groundnuts	5 g
Curry leaves	5-6 leaves

Method: Take 30 g of popped grains and season with oil, curry leaves, groundnuts, turmeric, salt and garlic powder and mix it well.

APPENDIX XXI

Preparation of sugar coated coloured popped snack

Ingredients	Quantity
Popped sorghum	30 g
Sugar	60 g
Water	15 ml
Vanilla extract	2 drops
Food colour (orange)	Little

Method: Take 30 g of popped sorghum and keep a side. Take 60 g of sugar and add 15 ml of water and boil, till it attains single thread stage, then add 2 drops of vanilla extract and food colour to it. Then pour popped sorghum into it and mix well.

APPENDIX XXII

Preparation of popped jaggery laddu

Ingredients	Quantity
Popped sorghum	30 g
Jaggery	60 g
Water	30 ml
Cardamom powder	To taste
Popped rajgeera	30 g

Method: Take 30 g of popped sorghum and popped rajgeera and keep a side. Take 60 g of jaggery and put 30 ml of water, boil it, till it attains single thread stage, then add little cardamom powder and pour popped sorghum and popped rajgeera into it, mix well. Prepare laddu out of this.

NUTRITIONAL AND PROCESSING QUALITIES OF POP SORGHUM CULTIVARS AND VALUE ADDITION

ZEENATH A. GUNDBOUDI 2006

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ABSTRACT

The demand for sorghum as a staple food is declining day by day, as there are no alternative uses and value added products. Popped sorghum is one of the ready to eat snacks which is popularly consumed by local growers. It has got potential to develop value added products as a convenient ready-to-use food. Hence, the study was undertaken to evaluate nutritional and processing qualities of pop sorghum cultivars, grown in different seasons and value addition. Physico-chemical characteristics of three *kharif* and three *rabi* cultivars were analyzed by standard procedures. Cultivars were also evaluated for conventional and modern microwave method of popping and nutritional quality. Two spice flavoured and two sweet coated popped snacks were standardized and studied for consumer acceptability by using 5 point scale. Storage quality of popped grains and flour were assessed for changes in moisture, free fatty acid content and organoleptic characters, stored in suitable packaging materials at ambient temperature. Sorghum cultivars grown in *rabi* season possess superior physico-chemical and popping qualities than *kharif*. Popping qualities were better in conventional than microwave method. Mugad local a *kharif* and Marole local a *rabi* cultivars exhibited good popping qualities in both the methods. Popping yield showed a negative relationship with 1000-kernel weight and volume, and flake size was positively related with kernel weight and volume. Among the developed products of sweet coated and spice flavoured snacks, popped jaggery laddu and cinnamon flavoured snacks had better organoleptic scores than other snacks respectively. Popped sorghum stored in polythene cover and flour stored in aluminium pouch had better storage quality of 21 and 28 days with excellent organoleptic scores respectively. Thus market potential of pop sorghum can be enhanced by developing varieties of popped snacks of different flavouring substances as value addition.