Formulation and nutritional evaluation of multigrain ready-to-eat snack mix from minor cereals

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Abstract A ready-to-eat nutritious snack mix was developed by blending the flour from popped millets and legumes with sugar and other ingredients in the optimized proportion of 30:20:27:23. The nutrient composition, functional properties, sensory qualities and storage characteristics of the product were analysed. The product contained protein 14.0 ± 0.07 g, fat 14.5 ± 0.72 g, carbohydrates 59.0 ± 1.20 g and dietary fiber 6.3 ± 0.04 g per 100 g of mix. The sensory evaluation of the product revealed that color, taste, texture, aroma, appearance and overall quality were in acceptable range with mean score of 6.8. Shelf life of the product was about 90 days under normal conditions when stored in low density polypropylene pouches. The work indicates the potential of using coarse cereals and legumes for preparation of nutritious food for societal program.

Keywords Popping · High temperature short time treatment · Physicochemical characteristics · Functional properties · Sensory qualities · Shelf life studies

Introduction

Compared to the availability of ready-to-eat products from rice, wheat and corn, the products based on minor cereals

such as sorghum and millets are still scanty. Sorghum and millets possess unique nutritional characteristics, specifically, they are gluten-free, represent good source of carbohydrates, rich in dietary fibre, phenolic compounds and also minerals (Saturni et al. 2010). These grains, apart from the macro nutrients, also form a good source of micronutrients and phytochemicals and complement well with lysine-rich vegetable (leguminous) and animal proteins to prepare nutritionally balanced composites of high biological value (Gorinstein et al. 2002). Sorghum and millets are used in many traditional foods namely roti, dumpling and porridges and some of the novel food uses include preparation of bakery products (Taylor et al. 2006). No special processing or treatment is generally given to them during milling or subsequent preparation of products. However, the nutrient composition and technological properties of minor cereals offer a number of opportunities for processing and value addition. Among the minor cereals, sorghum and pearl millet are important nutritionally as well as their agriculture produce is concerned. Grain amaranthus stands unique because of its superior nutritional characteristics. These grains serve as a good source of protein, micronutrients and phytochemicals. Sorghum contains about 10 % protein and about 3.5 % lipids, pearl millet contain 12–16 % protein and about 5 % lipids and amaranthus contain 13–16 % protein and 6–7 % lipids. Pearl millet and amaranthus contain a better amino acid profile compared to the other cereals. Niacin content is comparatively higher in pearl millet, while lysine content is 2–3 times higher in amaranthus. Research & Development work carried out at CFTRI on processing and value addition to sorghum and millets has indicated the possibility of preparation of a number of new generation products (Meera et al. 2008; Meera 2009). Among them, popped products find a potential role in preparation of ready-to-eat products.

Popping is one of the easy and economic processing methods to prepare ready-to-eat products. Popping

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essentially creates a crisp, aerated product with desirable sensory qualities. Since, the process involves a high temperature short time treatment (HTST), popped products contain a low moisture level and generally be microbially safe. Popping not only improves the shelf-life but also improves the nutritional quality with respect to the bioavailability of nutrients. But, during popping, the surface bran is normally retained in the product and hence palatability of popped products largely depends on the thickness and softness of the bran layers. The popped grains are consumed in small quantities as a crunchy snack item either after sweetening or after mild flavouring with spices. However, quantity of consumption in this form is limited because of the presence of coarse bran layers. If the popped material is slightly refined by grinding to a coarse or fine flour and seed coat or bran is partially removed by sieving, special foods can be formulated. A few popular Indian products in this category are *sattu* and *hurihittu*. Blending of one or more popped grains generally improves the taste as well as the nutritional quality of the product. Reddy et al. (1990) reported that, popped amaranth flour with popped sorghum and pearl millet flour increased protein and total iron contents of the weaning foods. Reports are available on use of popped wheat, sorghum, corn, soybeans and bengal gram in Nepal (Krantz et al. 1983) and popped rice, sorghum, corn, wheat, soybeans and mung beans in Korea (Patterson and Bray 1985). However, preparation of a snack mix exclusively from popped sorghum, pearl millet and grain amaranthus along with expanded legumes will be unique of its kind. Hence, the main objectives of this study were to prepare a ready-to-eat snack mix from popped minor cereals and legumes, to evaluate the suitability of the mix to prepare snacks of multiple choices and, to determine the physicochemical, sensory and shelf-life characteristics of the product.

Materials and methods

Materials

Sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum americanum*), grain amaranthus (*Amaranthus gangeticus*), bengal gram (*Cicer arietinum*), green gram (*Phasleolus aureus*) and soya bean (*Glycine max*) and other ingredients such as sugar, honey, sunflower oil, skimmed milk powder and groundnut seeds were procured from local market. The grains were cleaned to remove dust and other extraneous materials and stored at room temperature in plastic containers. All other minor ingredients like guar gum, pectin and glycerol (food grade) were procured from M/s. Indra Agencies (Bangalore, India).

Processing

About 5 kg each of sorghum and pearl millet were equilibrated to a moisture content of 18 % by adding water and tempered for 6 h in a closed container. The tempered grains were popped by high temperature and short time (HTST) treatment in a domestic grain popper (Nova popcorn maker NPC-1212) at 230 ± 5 °C (Malleshi et al. 1986). Amaranthus was popped by subjecting the grains to direct heat contact in an open pan. For popping the legume components, about 5 kg of each of split green gram and soya were steeped in required quantity of water at ambient temperature for 2 h, followed by steaming at atmospheric pressure for 20 min. The steamed grains were dried in a mechanical drier HTST treatment as described above.

Groundnut seeds were toasted at a temperature of about 70 °C until the seeds turned to light brown color. Popped sorghum, pearl millet, grain amaranthus, green gram, soya and bengal gram were pulverized individually to prepare a flour of particle size less than 355 µm. The toasted groundnut seeds were disintegrated to smaller grits (less than 1204 µm).

A good number of trials were undertaken to optimise the ingredient composition of the ready mix. Based on the preliminary trials, the ingredient composition was optimised by considering both nutritional requirement and sensory characteristics of the product. Accordingly, the ready-to-eat snack mix was prepared by blending 10 g popped sorghum, 10 g popped bajra, 10 g popped amaranthus, 8 g popped green gram dhal, 8 g popped bengal gram dhal, 4 g popped soy dhal, 6 g skimmed milk powder, 3 g roasted groundnut seeds, 27 g sugar, 9 g oil, 2 g honey, 1 g each of pectin, edible gum and glycerol in a ribbon mixer/blender. The various operations involved in the preparation of the ready-to-eat popped product are detailed in Fig. 1. The product was mixed with desired quantity of water and shaped into different forms (*laddu*, *burfi* etc.) or with milk to prepare *porridge*.

Physicochemical characteristics

The product was pulverized to prepare a flour of particle size less than 250 µm and analyzed for its physicochemical characteristics.

Color The color of the product was measured in accordance with CIE L*, a*, b* color space system (Lab Scan XE Hunter Lab Instruments, Virginia, USA) based on the tristimulus value. The L*, a*, b* values were recorded and ΔE values [difference of reflection value between the standard white (Barium sulphate) and the sample] were calculated (Kimura et al. 1993).

Fig. 1 Flow chart for preparation of ready-to-eat snack mix

Bulk density The volume of 100 g of the product using a measuring cylinder was determined after tapping the measuring cylinder (250 ml) on a wooden plank until no visible decrease in volume was noticed. Based on the weight and volume, the apparent (bulk) density was calculated (Jones et al. 2000).

Swelling power and solubility index One gram of the pulverized sample, taken in a graduated centrifuge tube, was mixed with 10 ml of water and the tube was kept in a shaking water bath maintained at 30 °C for 30 min, followed by centrifugation. The supernatant was transferred to a weighed Petri-plate and evaporated to dryness on a water bath followed by drying in a hot air oven maintained at 105 °C for 3 h. The residue in the centrifuge tube and the dried Petri-plates were weighed to calculate swelling power and solubility index. The experiment was repeated at 97 °C (Bello-Perez et al. 2000).

Dispersibility About 5 g of product was dispersed uniformly in 100 ml of water. An aliquot (10 ml) of the dispersion was taken and was filtered through a pre-weighed filter paper. The filtrate was dried and weighed separately. Solids remaining on the filter paper accounted for the

percent dispersed solids and the dried filtrates gave percent soluble solids (Kulkarni et al. 1991).

Viscosity A 10 % (w/v) slurry of the sample, prepared by dispersing 20 g of material in 180 ml of distilled water was measured for its viscosity in a Brookfield viscometer (model RV; Brookfield Engineering Inc., Stoughton, USA) using appropriate spindles. Subsequently, the samples were heated to boiling in a water bath, cooled to 30 °C and the cooked paste viscosity was measured (Brandtzaeg et al. 1981).

Pasting profile Pasting profile of the product was recorded in a Brabender Viscoamylograph (Model No. 803202, Brabender, Duisburg, Germany). For the purpose, 12 % (w/v) slurry of the flour was taken in a measuring bowl and heated progressively to raise the temperature from 30 °C to 92 °C at the rate of 7.5 °C/min, maintained at 92 °C for 5 min and cooled to 50 °C at the same rate and changes in the viscosity were noted.

Nutrient composition The product was analyzed for ether extractives, protein and ash as per standard AACC (2000) methods and the total carbohydrate content was determined by the method of difference. Total and soluble amylose

contents were determined as per the method of Sowbhagya and Bhattacharya (1971). The free sugar content was estimated by extracting 5 g of sample in 15 ml of 70 % ethanol thrice, and analyzing the sugars by phenol sulphuric acid method (Ford 1981). The total calcium, iron, zinc and magnesium were estimated by Atomic Absorption Spectrophotometry (AOAC 2000). The total polyphenols were extracted using HCl-methanol and assayed by Folin-Ciocalteu method with Gallic acid (Sigma, 205-749-9) as a standard (Singleton et al. 1995).

Carbohydrate digestibility

The defatted sample (100 mg) was mixed with 10 ml of water containing 0.5 ml of termamyl (Sigma, 9000-85-5) and heated in a boiling water bath for 15 min. To the contents, 15 ml of phosphate buffer (pH6.8) containing 15 mg of pancreatin (Sigma, 8049-47-6) was added and incubated at 37 °C for 2 h. The pH of the reactants was then lowered to 4.5 using dilute acetic acid, and 15 ml of 0.05 M acetate buffer (pH4.5) containing 15 mg of amyloglucosidase (Sigma, 9032-08-0) was added and incubated for 2 h at 55 °C. The glucose released was estimated by using dini-trosalicylic acid reagent (Ngo Som et al. 1992).

Protein digestibility

In vitro protein digestibility was determined according to the method of Prajwala et al. (1993). Accordingly, sample containing 100 mg protein was treated with 12.5 mg of pepsin (Sigma, 232-629-3) in 50 ml of 0.1 N HCl at 37 °C for 3 h. After neutralization with 0.5 N NaOH, 6 mg of pancreatin (Sigma, 8049-47-6) dissolved in 25 ml of phosphate buffer (pH8.0) was added and the digestion continued for 24 h at 37 °C. The volume was then made up to 100 ml and centrifuged at 1650 x g for 20 min. An aliquot of the supernatant was analyzed for its protein content following Lowry's method (Schacterle and Pollack 1973).

Fatty acid profile

Fatty acid methyl esters (FAME) of the ether extractives were prepared by trans-esterification, according to AOCS (1997) method. FAMES were analyzed by Fisons 8000 series gas chromatograph (Fisons Co., Italy) equipped with a hydrogen flame ionization detector (FID) and a Varian, Factor four capillary column, VF-1 ms (30 m×0.25 mm ID, DF-0.25 µm film thickness coated) stationary phase. The oven temperature was programmed from 140 to 240 °C at 4 °C/ min with an initial hold at 140 °C for 5 min. The injector and FID were maintained at 260 °C. A reference standard FAME mix was analyzed under the same operating

conditions to identify the peaks. The FAMES were expressed as relative area percentage.

Free fatty acid (FFA)

To determine the free fatty acid content, the sample (20 g) was refluxed with petroleum ether in a water bath for 14 h to extract fat. To 5 g of fat, 10 ml of warm neutral alcohol and 10 ml of petroleum ether were added along with few drops of phenolphthalein indicator and titrated against 0.1 N NaOH and the results were expressed in terms of oleic acid equivalents (AOAC 2000).

Sensory analysis

'Quantitative Descriptive Analysis' method (Stone et al. 1974) was used to assess the quality of the product. Panelists were trained to evaluate the product for different attributes in order to ensure that subtle differences were detected and scaled appropriately. The product was reconstituted in milk diluted with water (1:1) at ratio of 1:2.5 (w/v) and served to the panelists. The temperature of the product was maintained between 40 and 45 °C at the time of serving. The panelists were asked to evaluate the product with different descriptive parameters such as buff, smooth, pasty, sticky, gritty particle, mouth coating, roasted flavor, stale, sweet, bitter and off-note on an intensity scale of 0–10 cm indicating 0 as 'very poor', 5 as 'fair' and 10 as 'very good' rankings. For evaluating the overall quality of the product, the panelists were asked to mark on intensity scale. Sensory scores for each attribute were tabulated and mean scores were calculated. These mean scores represented the panel's judgment about the sensory quality of the samples. Subsequently, the blend was mixed with required quantity of water, shaped into *laddu* and *burfi* and subjected to consumer acceptance study. Consumer acceptance study was carried out among 50 trained and untrained panelists as target groups for the three products viz, *porridge*, *laddu* and *burfi*. Seven point hedonic scale was used to assess the degree of liking that ranged from 'Like very much' to 'Dislike very much' with 'Neither like Nor Dislike' (NLND) as midpoint. The data were analyzed and expressed the number of responses, as percentage.

Sorption studies

Sorption studies of the product were carried out by exposing weighed quantity of sample in Petri dishes to relative humidities (RH) ranging from 11 % to 92 % built inside the desiccators by using appropriate salt solutions (Rockland 1960). The samples were periodically weighed till they attained practically concordant weight or showed visible mould growth. After equilibration, the samples were

assessed for changes in visible microbial spoilage. The equilibrium moisture content (EMC) of the product at different RH was calculated by subtracting or adding the percentage loss or gain in moisture content from or to the initial value.

Shelf life studies

The product was packed in low density polypropylene (LDPE) pouches of 350 gauge (87.5 μm) into 0.5 kg unit packs and stored at 27 °C, 65 % RH (ambient) and 38 °C, 92 % RH (accelerated) storage conditions. The control sample was kept under refrigerated condition. The samples were withdrawn periodically at an interval of 15 days up to 3 months from accelerated storage conditions and 30 days up to 6 months from normal storage conditions. The stored samples were analyzed for the changes in moisture and free fatty acid contents and also for sensory attributes.

Statistical methods

The values were calculated per 100 g of dry matter. The experiments were performed with three independent trials, and data are presented as mean $\pm$ standard deviation (SD). Duncan's Multiple Range Test was applied to differentiate among the means of different samples ($p \leq 0.05$).

Results and discussion

Physicochemical properties

The ready-to-eat snack mix was a homogeneous powder with light cream color and desirable aroma. The moisture content (5.1 g/100 g) of the mix was low as most of the ingredients used for its preparation were popped, which in turn favored its shelf life. The product formed a good source of protein (14 g/100 g), ether extractives (14.5 g/100 g) and minerals such as calcium (219.3 mg/100 g), magnesium (49 mg/100 g), iron (6.6 mg/100 g) and zinc (4.13 mg/100 g) (Table 1). In spite of high free sugar content (30 g/100 g), the product formed fairly good source of dietary fiber. The *in vitro* protein and carbohydrates digestibility were 87 and 64.4 % respectively, indicating that it is easily digestible. This may be due to the HTST treatment and presence of very low (0.89 g/100 g) polyphenols. It has been reported that, popping increases the digestibility of carbohydrates and protein (Prajwala et al. 1993).

The functional properties of the product presented in Table 2, indicate that, the product was cream colored with lightness (L^*) value of 72.06 and ΔE value of 24.89.

Table 1 Nutrient composition of ready-to-eat snack mix (g/100 g)

Moisture	5.1 $\pm$ 0.02
Ether extractives	14.5 $\pm$ 0.72
Protein	14.0 $\pm$ 0.07
Ash	1.63 $\pm$ 0.01
Dietary fibre	
Soluble	2.7 $\pm$ 0.02
Insoluble	3.6 $\pm$ 0.03
Total	6.3 $\pm$ 0.04
Carbohydrates (Diff)	58.4 $\pm$ 0.71
Carbohydrates digestibility	64.4 $\pm$ 0.04
Protein digestibility	87.0 $\pm$ 1.8
Free sugars	30.6 $\pm$ 0.4
Polyphenols	0.8 $\pm$ 0.20
Free fatty acids	1.6 $\pm$ 0.01
Calcium (mg/100 g)	219.3 $\pm$ 1.0
Iron (mg/100 g)	6.6 $\pm$ 0.18
Zinc (mg/100 g)	4.1 $\pm$ 0.15
Magnesium (mg/100 g)	49.0 $\pm$ 0.16

$n=3$ for all parameters except fatty acids

Redness (a^*) and yellowness (b^*) values of the product were 0.74 and 17.05 respectively. Bulk density of the product was 0.66 g/ml indicating its fluffy nature. Swelling power of the product at 30 °C was 178 %, which increased by 1.8 fold on cooking. The solubility index values of the product did not differ significantly at 30 and 97 °C. The

Table 2 Functional properties of ready-to-eat snack mix (g/100 g)

Parameters	
Color	
L^*	72.1 $\pm$ 0.14
a^*	0.74 $\pm$ 0.06
b^*	17.1 $\pm$ 0.13
ΔE	24.9 $\pm$ 0.19
Bulk density (g/ml)	0.66 $\pm$ 0.01
Water absorption capacity (g/100 g)	
30 °C	178.0 $\pm$ 2.20
97 °C	315.0 $\pm$ 3.27
Water solubility index (g/100 g)	
30 °C	7.8 $\pm$ 0.18
97 °C	8.4 $\pm$ 0.33
Viscosity 10 % slurry (cP)	
Cold paste	38.5 $\pm$ 0.70
Cooked paste	92.5 $\pm$ 0.57
Dispersibility (g/100 g)	
Dispersed solids	69.3 $\pm$ 0.70
Soluble solids	19.0 $\pm$ 1.40

$n=3$ for all parameters

product exhibited a cold paste viscosity of 38.5 cP which increased to 92.5 cP on cooking. Increase in viscosity and swelling power of the product may be due to the presence of pectin and guar gum which swell to a significant level upon cooking resulting in comparatively high viscous slurry. The product exhibited about 69.3 % dispersible solids and 19 % soluble solids. Dispersibility is the ease with which the food powder becomes distributed as a particulate in the liquid phase. Higher the values, better is the dispersibility (Shittu and Olaitan 2011). It was observed that the product in powder form could be easily dispersed in milk without formation of any lumps.

The pasting profile of the product is presented in Fig. 2. Peak viscosity of the product was 49 BU, which slightly decreased during cooking phase (41 BU) and again increased marginally on cooling (49 BU). The initial viscosity of the product was 36 BU. Viscosity parameters indicate that, the product is completely gelatinized. Similar observations have been reported in the case of popped foxtail millet by Ushakumari et al. (2004).

Fig. 2 Pasting profile and sorption isotherm of ready-to-eat snack mix

Fatty acid profile

Table 3 shows fatty acid composition of the extracted fat from the product. It was observed that, oleic (58.4 %), linoleic (29 %) palmitic (8.8 %) and linolenic acid (3.6 %) were the major fatty acids present. Traces of saturated fatty acids, myristic acid and stearic acid were also observed. The presence of monounsaturated fatty acid such as oleic acid may be helpful to reduce hypercholesterolemia and LDL cholesterol (Kris-Etherton and Shaomei 1997).

Sensory studies

Sensory profile (Fig. 3) indicated that, the product was smooth and had homogenous texture (score=4.8) and contained roasted cereal/ legume aroma (5.9) which was a desirable property. Popping induces desirable aroma and snack products based on them are highly acceptable (Bunkar et al., 2012). The score for gritty particle was 5.0 which may be because of the presence of the roasted ground nut in grit form. The scores for stale, off-note and bitterness were marginally low. Even though, the product scored 5.0 for pastiness and 4.2 for stickiness, there were no adverse remarks by the panelists. The overall quality of the product was fairly high (6.8) which aptly reflected its acceptability. Further, the consumer acceptance study indicated that the product in the form of *porridge*, *laddu* and *burfi* was under “like category” by majority of the population (Fig. 4).

Sorption and Shelf-life studies

The product with initial moisture content of 4.7 % equilibrated to 30 % RH. There was no appreciable change in FFA of the equilibrated samples from 11 to 64 % RH above which sorption isotherm takes a steep raise which was considered as critical. The corresponding equilibrium moisture content of 8.3 % was critical to the product. As the moisture tolerance is 3.6 %, a moisture barrier packing material like 300–350 gauge low density poly ethylene

Table 3 Fatty acid profile of ether extractives from ready-to-eat snack mix (g/100 g)

Fatty acid	Concentration
Myristic acid (14:0)	0.1±0.02
Palmitic acid (16:0)	8.8±0.07
Stearic acid (18:0)	0.1±0.02
Oleic acid (18:1)	58.4±0.5
Linoleic acid (18:2)	29.0±0.2
Linolenic acid (18:3)	3.6±0.04

n=2

Fig. 3 Sensory profile of ready-to-eat snack mix

(LDPE) or poly propylene is suitable for the product. The sorption studies (Fig. 2) indicates that, the critical moisture content and critical relative humidity (RH) of the product were 8.3 and 60 %, respectively. A moisture content of 24.88 % was attained at 92 % RH and visible mould growth was noticed after 4 weeks. At 86 % RH, the product attained a moisture content of 19.54 % and showed mould growth after 5 weeks of exposure. The equilibrated product exhibited musty odour at 75 % RH and stored product odour at 64 % RH. However, no visible mould growth was noticed below 86 % RH.

The FFA content of the formulation in both the storage conditions (accelerated and normal) increased from 0.035 to 1.32 and 1.56 %, respectively (Fig. 5). This was also felt by the absence of off flavour in the product during the storage period, probably, due to inactivation of lipase during HTST treatment. The formation of FFA due to microbial lipase is

Fig. 4 Consumer acceptability of different forms of ready-to-eat snack mix. Mean values with different letters on each bar differ significantly ($p < 0.05$), $n = 50$

also ruled out, since the product at RH lower than 86 % did not show any mould growth.

The changes in the color of the product during storage period are shown in Fig. 5. No significant change was observed in the L^* values of the product, both at normal and accelerated conditions till 90 days. A slight increase in the lightness values was observed at normal conditions after 90 days. The ΔE values of the product also remained almost unchanged during the initial 60 days of storage period at both the storage conditions and started increasing at accelerated condition and decreased slightly at normal conditions.

The changes in the sensory attributes of the product during storage studies are presented in Table 4. It was

Fig. 5 Changes in free fatty acid profile and color values (L , ΔE) of ready-to-eat snack mix during storage. Mean values with different letters on each point of a particular series differ significantly ($p < 0.05$), $n = 3$

Table 4 Sensory mean scores of stored-ready-to eat snack mix

Storage days		0	15	30	45	60	75	90
Buff	Amb	4.9±0.24 ^{bc}	–	5.2±0.39 ^c	–	4.6±0.35 ^a	–	4.7±0.36 ^{ab}
	Acc	4.9±0.24 ^b	4.6±0.24 ^a	4.9±0.27 ^b	5.1±0.12 ^c	5.4±0.18 ^d	5.8±0.13 ^e	5.9±0.43 ^f
Smooth	Amb	4.8±0.29 ^b	–	4.8±0.36 ^b	–	4.9±0.35 ^b	–	4.6±0.24 ^a
	Acc	4.8±0.29 ^b	5.1±0.44 ^c	5.1±0.12 ^c	5.2±0.27 ^c	4.2±0.3 ^a	4.9±0.18 ^{bc}	4.3±0.32 ^a
Pasty	Amb	5.0±0.22 ^a	–	5.0±0.41 ^a	–	4.8±0.31 ^a	–	5.0±0.24 ^a
	Acc	5.0±0.22 ^a	5.4±0.44 ^c	5.2±0.36 ^b	5.3±0.29 ^{bc}	5.2±0.18 ^b	5.4±0.21 ^c	5.4±0.21 ^c
Sticky	Amb	4.2±0.39 ^b	–	3.8±0.38 ^a	–	3.7±0.25 ^a	–	3.6±0.30 ^a
	Acc	4.2±0.39 ^b	4.1±0.4 ^b	3.6±0.32 ^a	4.6±0.33 ^c	4.1±0.29 ^b	4.1±0.29 ^b	4.8±0.30 ^c
Gritty particle	Amb	5.0±0.38 ^c	–	4.9±0.40 ^{bc}	–	4.8±0.47 ^b	–	4.6±0.29 ^a
	Acc	5.0±0.38 ^b	4.9±0.38 ^b	4.8±0.31 ^b	4.9±0.18 ^b	4.2±0.33 ^a	5.0±0.28 ^b	4.3±0.23 ^a
Mouth coating	Amb	5.2±0.29 ^b	–	4.8±0.43 ^a	–	4.8±0.26 ^a	–	5.2±0.33 ^b
	Acc	5.2±0.29 ^d	5.2±0.33 ^d	4.3±0.43 ^a	4.7±0.3 ^b	4.9±0.39 ^c	4.6±0.40 ^b	5.4±0.21 ^c
Roasted cereal/legume	Amb	5.9±0.34 ^c	–	4.9±0.31 ^b	–	4.0±0.33 ^a	–	4.1±0.4 ^a
	Acc	5.9±0.34 ^e	5.7±0.43 ^d	4.2±0.35 ^c	4.0±0.29 ^b	3.8±0.24 ^b	3.5±0.24 ^a	3.7±0.33 ^b
Stale	Amb	–	–	0.2±0.03 ^a	–	0.6±0.10 ^b	–	1.4±0.27 ^c
	Acc	–	0.5±0.12 ^a	0.8±0.11 ^{ab}	1.1±0.11 ^{bc}	1.3±0.1 ^c	1.2±0.11 ^c	2.4±0.45 ^d
Sweet	Amb	5.3±0.37 ^c	–	5.2±0.31 ^c	–	4.7±0.36 ^b	–	3.7±0.25 ^a
	Acc	5.3±0.37 ^f	5.5±0.28 ^g	4.1±0.40 ^d	4.3±0.41 ^e	3.6±0.32 ^b	3.8±0.24 ^c	3.4±0.33 ^a
Bitter	Amb	–	–	1.0±0.31 ^a	–	1.2±0.2 ^a	–	1.2±0.36 ^a
	Acc	–	0.5±0.05 ^a	0.5±0.06 ^a	1.0±0.32 ^b	1.0±0.08 ^b	1.0±0.39 ^b	1.3±0.13 ^c
Off-note	Amb	–	–	1.0±0.31 ^a	–	2.3±0.25 ^b	–	2.1±0.38 ^c
	Acc	–	0.2±0.1 ^a	0.8±0.12 ^b	1.2±0.21 ^c	1.6±0.1 ^d	2.3±0.21 ^e	4.1±0.29 ^f
Overall quality	Amb	6.8±0.17 ^c	–	5.8±0.27 ^b	–	5.7±0.33 ^{ab}	–	5.3±0.41 ^a
	Acc	6.8±0.17 ^f	6.0±0.4 ^e	5.3±0.47 ^d	5.5±0.25 ^d	4.9±0.18 ^c	4.5±0.29 ^b	3.4±0.18 ^a

Mean values with different superscripts in the same row differ significantly at $p \leq 0.05$ by DMRT

$n=10$

Amb Ambient (27 °C, 65 % RH), Acc Accelerated (38 °C, 92 % RH)

observed that, the scores for smooth and pasty attributes did not change appreciably during 90 days of storage at ambient condition. Significant increase in the scores for buff was observed at the end of 90 days storage at accelerated conditions while, the scores for smoothness of the product did not follow any trend. The scores for pastiness of the product changed significantly at accelerated storage conditions. A slight decrease in the grittiness of the product was observed and the scores for mouth coating changed slightly during the storage period at both the conditions. However, a significant decrease in the roasted cereal aroma and sweetness perception was observed both at ambient and accelerated storage conditions. The sensory scores for staleness, bitterness and off-note flavour increased marginally for ambient storage condition. However, the scores for off-note increased significantly towards the end of storage studies at accelerated conditions. It was observed that, the overall quality of the product decreased by 31 % at ambient conditions and 50 % at accelerated storage conditions. The decrease in the overall quality of the product may be due to the loss in the roasted

cereal aroma which may be overcome by packing the product in a laminate of 50 gauge PET/150 gauge low density polyethylene pouches.

Conclusions

The study revealed that popped sorghum, pearl millet and grain amaranthus can be mixed with expanded legumes to prepare a ready-to-eat snack mix. The mix can be shaped into either *laddu* or *burfi* or can be consumed in porridge form also. The mix contained adequate amount of protein and minerals and was found suitable for feeding children and also people of all age groups. The production methodology is economical and can be easily adopted in home to industrial scale using locally available underutilized grains. Sensory analysis and storage studies revealed that the product prepared from popped minor cereals and legumes exhibited good overall acceptability with a shelf life period of 90 days.

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