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Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours

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Abstract: The present study focussed on the use of Foxtail millet (*Setaria italica*) along with other flour for production of ready-to-eat snack products using extrusion cooking. The ultimate objective is to add value to millet and other subtropical crops to enable their commercialisation and thereby provide additional livelihood opportunities to the farmers in semi-arid regions. Composite flours were prepared using whole Foxtail millet flour and other flours namely; rice flour, chick pea, Amaranth seed flour and cow pea. Nutritional properties of the blends were analyzed and extrusion cooking was carried out using a twin screw extruder at optimised extrusion parameters namely temperature: 115˚C and 90°C for two different heating zones, die diameter: 3 mm and screw speed: 400 rpm. The extrudate physical properties namely bulk density, piece density, expansion ratio and moisture retention were also analysed. The organoleptic qualities of extruded samples were analysed by panellists on a 9 point hedonic scale. The results indicated that composite flour (Foxtail millet; Amaranth; Rice; Bengal gram; Cow pea in the ratios of 60:05:05:20:10) could be used to produce quality extrudates with acceptable sensory properties.

Keywords: Extrusion, composite flour, pre-conditioning, physical properties, sensory evaluation

Introduction

The extrusion cooking process is high temperature short time process in which moist, soft grain is fed into the extruder where the desired temperature and pressure are obtained over the required period of residence time. For cooking of the product generally external heat is not supplied, heat for cooking is achieved through shear and friction in the extruder. Extrusion cooking is used worldwide for the production of expanded snack foods, modified starches ready-to- eat cereals, baby foods, pasta and pet foods. (Toft, 1979). This technology has many distinct advantages like versatility, low cost, better product quality and no process effluents (Abbott 1987; Camire *et al*., 1990). Snacks contribute an important part of daily nutrient and calorie intake for many consumers. Cereals have been popular raw materials for extrusion for food uses mainly because of functional properties, low cost and ready availability. Owing to high protein content, pulses and oil seeds can be effectively utilized for nutritional improvement of cereal based extruded snack foods.

Foxtail millet (*Setaria italica*) ranks second in the total world production of millets. Millet contains 9–14% protein, 70–80% carbohydrates and is a rich source of dietary fiber (Hadimani and Malleshi, 1993). It contains maximum amount of chromium among all the millets with an account of 0.030 mg per 100 g. Polymers of hexose's, pentoses, cellulose and pectinacious material constitute the major portion of its dietary fiber (Malleshi, 1986). Millet is a starchy food with a 25:75 amylose to amylopectin ratio and is a fairly good source of lipids (3–6%), having about 50% of the lipids in the form of polyunsaturated fatty acids (Sridhar and Lakshminarayana, 1994). Although millet is known to contain amylase inhibitors, the carbohydrate digestibility of millet foods is not affected because of heat-labile nature of the inhibitors (Chandrasekher *et al*., 1981). Even though the nutritional qualities of millet have been well recorded (Hulse *et al*., 1980), its utilization for food is confined to the traditional consumers in tribal populations, mainly due to non-availability of consumer friendly, ready-to-use or ready-to-eat products as are found for rice and wheat. In recent years, millets have received attention, mainly because of their high fiber content and efforts are under way to provide it to consumers in convenient forms.

Amaranth (*Amaranthus cruentus* L.) is the third most important staple crop for pre-colombian people. Snack foods with good acceptance and high nutritive value can be developed from the amaranth grain flour by using extrusion technology (cha'vez-Jauregui, 2000). Over the last few years Amaranth has become popular among patients with celiac disease because

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it does not cause allergic reactions in the intestinal mucosa (Thompson, 2001). It contains high protein (14.7%), low fat (1.9%) and high available carbohydrates (60.7%), crude fiber (9.6%) and good amount of Calcium (510 mg) and phosphorus (397 mg).

Rice (*Oryza sativa*) is a staple food crop for a large part of the world's human population, making it the second most consumed cereal grain. Rice provides more than one fifth of the calories consumed worldwide by humans. Rice contains approximately 7.37% protein, 2.2% fat, 64.3% available carbohydrate, 0.8% fiber and 1.4% ash content (Zhoul *et al*., 2002). In recent decades, health benefits and physiological effects of leguminous seeds and spices have been highlighted in a number of studies based on experimental animals as well as on clinical trials (Srinivasan, 2005).

Chickpea (*Cicer arietinum* L.) is another legume, grown in tropical and subtropical areas, that presents high potential as a functional ingredient for the food industry. The chickpeas contain moderately high protein (17–22%), low fat (6.48%), high available carbohydrate (50%) and crude fiber contents of 3.82% on dry basis (Saleh and Tarek, 2006). The available carbohydrate is mainly starch which is reported to be slow digestible, thus eliciting low glycemic responses in human nutrition. Hence chickpea seeds can play an important role as a low-glycemic functional ingredient in a healthy diet. The Kabuli Channa contains maximum amount of chromium than any other legumes with an account of 0.032 mg per 100 g of sample. (Gopalan *et al*., 2004). Cowpea (*Vigna unguiculata*) is an important food legume of many tropical countries. It contains appreciable amount of protein (24.1%), low fat (1.0%), moderately available carbohydrates (55%), crude fiber (3.8%) and it is rich in zinc (4.6%) and chromium (0.029%).

The objective of the present study was to develop novel extruded products with composite flour (Foxtail millet, Amaranth, Rice: Bengal gram and Cow pea) and to study the effect of composite flour on the physical properties (Mass flow rate, density, moisture retention, expansion ratio, water absorption index, water solubility index, water holding capacity, oil absorption capacity.) of extrudates and sensory acceptability of the product.

Materials and Methods

Raw materials

Foxtail millet, amaranth seeds, rice, chick pea and cow pea were purchased from local commercial suppliers, grounded separately in cyclotec mill (Foss Finland) and passed through a 2.5 mm screen. Hot-air oven (VT 43810, Mack Equipments, India), Ultra centrifuge (Remi, India), weighing balances (Mettler AE 163 and Sartorius CP225D) were used during the project.

Extruder

Clextral BC 21 (Firminy Cedex, France) twin-screw co-rotating, self wiping extruder with length/diameter ratio of 25, screw speed up to 600 rpm and outer screw diameter of 25 mm was used. The screw configuration (from feed section to die) used to process the extrudates consisted of three sections with forward elements. First section had four elements each 50 mm length having three screw flights and 13 mm pitch. The second zone consisted of five elements each 50 mm in length having four screw flights and 10 mm pitch. Third zone again consisted of five elements each 50 mm in length having six screw flights with 7 mm pitch. The total length of the screw was 700 mm with 14 elements in three zones. The extruder was equipped with a bulk solids metering feeder (KTRON T20, Switzerland). A die with a single circular opening (2.5 mm diameter), equipped with a rotary die face cutter (speed of 130 rpm) was used.

Composite flour preparation

Blends were prepared by mixing Foxtail millet flour, Rice flour, Amaranth seed flour, Kabuli Channa flour and Cow Pea flour in the different ratios on a dry-to-dry weight basis shown in the Table 1. These blends were chosen according to preliminary tests without jamming of extruder and for acceptable product's physical characteristics as well as better nutritive value in the final product. The blended samples were conditioned to 21–22% (w.b) moisture by spraying with a calculated amount of water and mixing continuously at medium speed in a blender. The samples were put in buckets and stored at 4^0C overnight. The feed material was then allowed to stay for 3hrs to equilibrate at room temperature prior to extrusion. This preconditioning procedure was employed to ensure uniform mixing and hydration and to minimize variability in the state of feed material. Moisture content of samples was determined by hot air oven method AOAC 1990).

Table. 1 Standardization of formulation of composite flours

Sr No	Flours	Proportion of Composite Flour Samples		
		A	B	C
1	Foxtail millet	70	60	50
2	Rice	07	05	10
3	Amaranth	05	05	05
4	Kabuli Channa (Bengal gram)	10	20	30
5	Cow pea	08	10	05

Extrusion cooking

Feeding of the pre conditioned composite flour to a twin screw extruder was accomplished by using a twin screw volumetric gravity feeder. Based on the most stable product expansion and stability of the extruder conditions, the extrusion conditions were used. The temperature of the two barrel zones of extruder from feeder end were set at 90^0C and 110^0C respectively. Samples were collected at the most stable die temperature which was around 80^0C. Screw speed was set up at 130 rpm and equipped with 3-mm restriction die or nozzle to extruder. Constant feeding rate was kept throughout the experiments. Three replicate samples were extruded and dried to about 5% moisture level. The dried samples were mixed with spices and edible oil.

Product analysis

Mass flow rate (MFR)

Mass flow rate was measured by collecting the extrudates in polyethylene bags for a specific period of time, as soon as it comes out of the die its weight taken instantly after its cooling to ambient temperature (Singh *et al*., 1996).

$$\text{MFR (gm/sec)} = \frac{\text{Weight of sample collected (grams)}}{\text{Time taken to collect sample (seconds)}}$$

Density of extrudates

This indicates the overall expansion and the changes in cell structure, pores and voids developed in the extrudates as effect of processing as well as raw material parameters.

Tap density (T.D.)

The Extrudates after grinding was filled in measuring cylinder of capacity 50 ml up to 20 ml and tapped 5-10 times. Weight of this 20ml of extrudates sample was taken.

$$\text{Tap Density (gm/cc)} = \frac{\text{Weight of 20 ml sample}}{\text{Volume of the sample (20 ml)}}$$

True density

True Density was calculated by filling the approximate 1gm of ground sample of extrudates in a burette containing toluene. Then raised in toluene level was measured and an average of two readings of true density was calculated as

$$\text{True Density} = \frac{\text{Weight of ground sample of extrudates}}{\text{Rise in toluene level}}$$

Bulk density (B.D.)

As an average diameter and average length of 25 readings of extrudates sample were known, its volume as computed as

$$\text{Vol. (cm}^3) = \pi d^2 L/4$$

Where d= Average diameter of extrudates
L= average specific length of extrudates in cm.

After calculating the volume of extrudates its bulk density is obtained as

$$\text{B.D. (Kg/cm}^3) = \frac{\text{Mass of extrudates (kg)}}{\text{Volume of extrudates (cm}^3)}$$

Moisture retention

The moisture content (w.b) of the feed and extruded samples was determined by AOAC method 925.10 (AOAC, 2005). Moisture retention (%) was calculated as

$$\text{Moisture Retention (\%)} = \frac{\text{Product Moisture} \times 100}{\text{Feed Moisture}}$$

Expansion ratio

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate (Fan *et al*., 1996). The diameter of extrudate was determined as the mean of 10 random measurements made with a Vernier caliper. The extrudate expansion ratio was calculated as

$$\text{Expansion ratio} = \frac{\text{Extrudate Diameter}}{\text{Die Diameter}}$$

Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI were determined by the method of Anderson (1982a).The extruded puffs were milled to a mean particle size of 200–250 µm. A 2.5 g sample was dispersed in 25 g distilled water, using a glass rod to break up any lumps and then stirred for 30 min. The dispersions were rinsed into tarred centrifuge tubes, made up to 32.5 g and then centrifuged at 4000 rpm for 15 min. The supernatant was decanted for determination of its solid content and sediment was weighed. WAI and WSI were calculated as

$$\text{WAI} = \frac{\text{Weight of Sediment}}{\text{Weight of Dry Solids}}$$

$$\text{WSI} = \frac{\text{Weight of Dissolved Solids in Supernatant} \times 100}{\text{Weight of Dry Solids}}$$

Water holding capacity

Approximately 5 grams of fine ground sample was weighed and allowed to rehydration over night in excess water (7:1) after draining, it was reweighed and WHC calculated as

$$\text{WHC} = \frac{\text{Weight of wet extrudate powder} - \text{weight of dry extrudate powder} \times 100}{\text{Weight of Dry Extrudate Powder}}$$

Oil absorption capacity

It denotes how much oil is bound to matrices in particular food system which could be used as the index of hydro-phobicity of the food.

Oil absorption capacity is expressed as the grams of oil bound per gram of the extrudate on dry basis.

Sensory evaluation

The sensory assessments were conducted in a Food science and Technology laboratory. The panel of 25members consisted of staff and post graduate students of the College of Food Technology, MAU, Parbhani. The panelists were naive to project objectives. Commercial control, samples (A, B and C) flavored with Mango amchur powder plus other spices were used in the evaluation. Samples were coded using random three-digit numbers and served with the order of presentation counter-balanced. Panelists were provided with a glass of water and, instructed to rinse and swallow water between samples. They were given written instructions and asked to evaluate the products for acceptability based on its flavour, texture, taste, color and overall acceptability using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely; Meilgaard *et al.*, 1999).

Table 2. Physical properties of extrudates*

Properties	Samples		
	A	B	C
Mass flow rate (g/s)	3.28±0.02	3.30±0.04	3.27±0.07
Tap density (g/cc)	0.37±0.05	0.34±0.06	0.36±0.03
True density	0.6±0.03	0.4±0.08	0.5±0.02
Bulk density (Kg/cm³)	0.12±0.06	0.10±0.02	0.10±0.05
Water Solubility Index (%)	0.24±0.01	0.32±0.06	0.33±0.09
Water Holding Capacity (WHC)	440±0.03	420±0.08	400±0.01
Moisture Retention	22.72±0.07	25.0±0.02	27.7±0.04
Expansion Ratio	2.17±0.02	2.32±0.03	2.0±0.05
Water Absorption Index (%)	5.0±0.03	5.2±0.04	5.4±0.04
Oil Absorption Capacity (%)	7.00±0.05	5.00±0.07	6.00±0.02

Results and Discussion

Physical characteristics

The flour particle size, moisture level, feed rate, temperature, screw speed and die speed were kept constant throughout the experiments. The effects of composite flour on physical properties of Extrudates are presented in Table 2 and Figures 1,2,3 and 4.

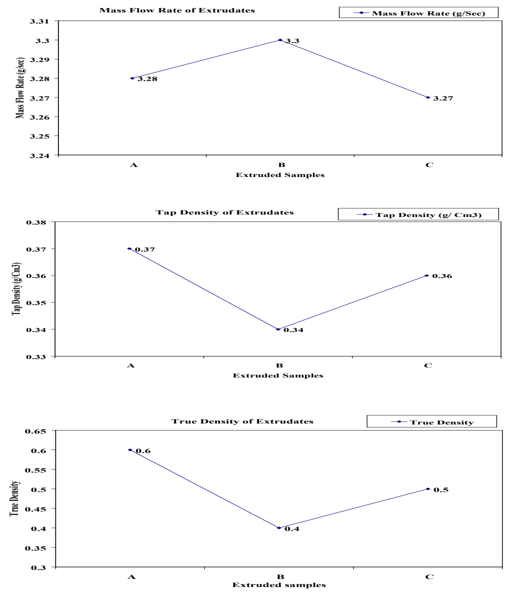

Figure 1. Mass flow rate, tap density and true density of extrudates

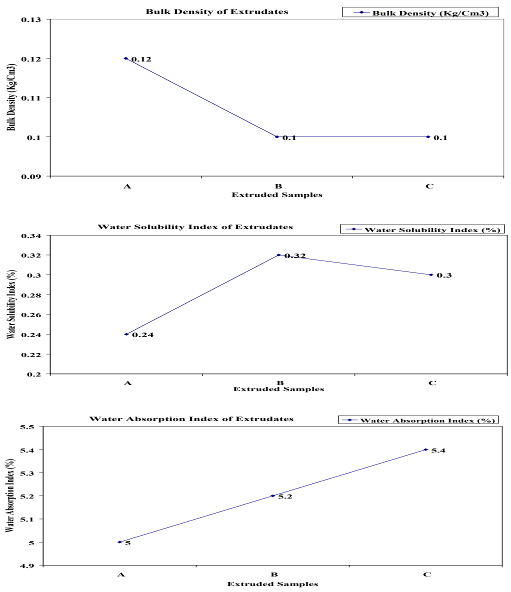

Figure 2. Bulk density, water solubility index and water absorption index of extrudates

Mass flow rate (MFR) was minimum for extruded sample-C (3.27±0.07) followed by sample-A (3.28±0.02) and sample –B (3.30±0.04). The variations in the mass flow rate of extrudate samples were very less, due to constant maintenance of barrel temperature as well as moisture content in the feed mixtures. The tap density decreased with optimum level of pulses in the composite flour. The Tap density was less for sample-B (0.34±0.06) than sample –C (0.36±0.02) and sample-A (0.37±0.05). The true density was less in case of extrudates produced from composite flour sample-B (0.4±0.08) followed by sample –C (0.5±0.02) and sample –A (0.6±0.03). The true density increased with cereals starch in extrudates. Similar findings were quoted by Quing *et al*., (2005) in scientific literature. The bulk density of extrudates samples B and C were same (0.1±0.02) but in case of sample- A (0.12±0.06), the higher bulk density may be due to the presence of more crude fiber in the composite flour sample. Similar types of results were observed by Singh *et al*. (1996).

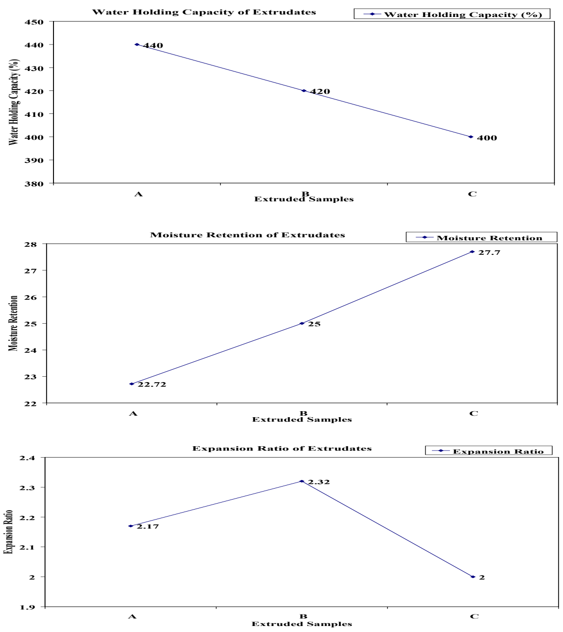

Figure 3. Water holding capacity, moisture retention and expansion ratios of extrudates

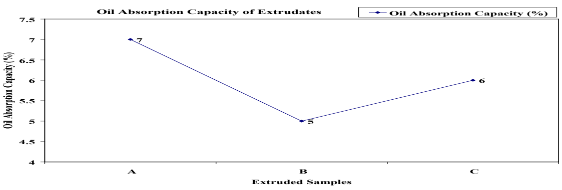

Figure 4. Oil absorption capacity of extrudates

The water solubility index was more for the extrudates made from composite flour sample –C (0.33±0.09) followed by extruded sample –B (0.32±0.06) and WSI was less for the extrudates prepared from composite flour sample-A (0.24±0.01). The water solubility index of the extrudates increased when Bengal gram flour incorporation increased from 10 to 30% in the composite flour samples. The water absorption index of the extrudates increased with increase of chick pea and Cow pea flours in the composite flour. The water absorption index was found to be more for extruded sample –C (5.4±0.04) followed by extruded sample –B (5.2±0.04) and sample –A (5.0±0.03). These results are in conformity with the observations made by Shirani and Ganeshranee (2009).

The water holding capacity was maximum for extruded sample-A (440±0.03) than sample –B (420±0.08) and sample-C (400±0.01). This could be due to higher level of cereal starch and crude fiber in the composite flour sample-A. Similar results were observed by Shirani and Ganeshranee (2009). The highest moisture retention was found in the extruded product prepared using composite flour sample –C (27.7±0.04) which may be due to the increase in protein content which was the result of maximum utilization of pulses (30 percent Bengal gram flour) in the composite flour sample.

The result of expansion ratio of extrudates indicates that expansion ratio decreased with increased level of cereals starch and decreased amount of proteins in the composite flour –A (2.17±0.02). This decrease in expansion ratio could be because of high level of Foxtail millet flour, which is rich in dietary fiber. Protein affects expansion through their ability to effect water distribution in the matrix and through their macro molecular structure and confirmation. The extruded sample –B (2.32±0.03) has more expansion ratio than extruded sample –C (2.0±0.05) and extruded sample-A. Similar findings were reported by Singh *et al.* (1996).

Oil absorption was found to be more for extruded sample-A (7±0.05%) than sample-B (6±0.07%) and C (5±0.02%). However, higher absorption of oil may be attributed to presence of less fat and more crude fiber in case of extrudate sample prepared from composite flour-A..

Sensory characteristics

The panels of semi- trained judges consisting of 25 members were given the extruded snack food samples for evaluation of organoleptic characteristics viz. appearance, colour, taste, flavour, texture and overall acceptability. It was served to judges on the day of preparation. The average score recorded by judges was considered, presented and discussed (Table 3 and Fig 5). The mean scores of sensory evaluation showed that all the extruded products prepared from composite flours were within the acceptable range, while the extruded product prepared from composite flour sample-B had significantly better appearance (7.8±0.04), color (7.9±0.07), flavour (7.8±0.07), texture (8.9±0.01), taste (8.2±0.06) and overall acceptability (8.5±0.06) when all the prepared extruded samples were compared with the commercial control. It was revealed from the scores of the overall acceptability that the coarse millet grains and pulses can be successfully mixed to the level of 70:30 respectively to produce a better acceptable product.

Table 3. Mean sensory score values for the extruded snack food

Extruded samples	Sensory attributes					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
control	8.3 ±0.01	8.6 ±0.02	8.4 ±0.03	8.8 ±0.05	8.6 ±0.01	8.9 ±0.03
A	7.5 ±0.03	7.0 ±0.05	7.0 ±0.04	7.9 ±0.06	7.0 ±0.04	7.7 ±0.02
B	7.8 ±0.04	7.9 ±0.07	7.8 ±0.07	8.9 ±0.01	8.2 ±0.06	8.5 ±0.06
C	7.2 ±0.07	7.4 ±0.01	7.2 ±0.09	8.0 ±0.02	8.0 ±0.03	7.7 ±0.01

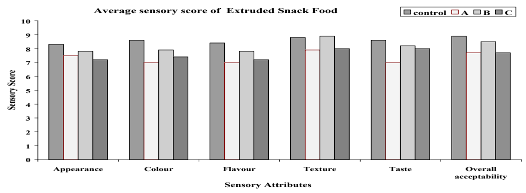

Figure 5. Mean sensory score of extruded snack foods

Conclusion

The present study revealed that, composite flour (Foxtail millet; Amaranth; Rice; Bengal gram; Cow pea in the ratios of 60:05:05:20:10) could be used to produce quality extrudates with acceptable sensory properties.

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