Physical and sensory characteristics of Ready-To-Eat food prepared from finger millet based composite mixer by extrusion

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Abstract: Extrusion cooking process is a high temperature and short time process in which moist, soft food material is fed to the extruder for desired temperature, pressure, and residence time. Finger millet being a "nutricereal" was used to develop Ready-To-Eat (RTE) snack food through extrusion cooking. Seven composite mixes were prepared using brown finger millet flour, maize flour, rice flour, full fat soy flour, bengal gram flour, and skimmed milk powder in varying proportions. Extrusion cooking was carried out using a Twin Screw Extruder at a temperature of $140\,°C$, screw speed of 300 r min^{-1} and die diameter of 3 mm. Physical properties of the extrudates namely bulk density, expansion ratio, Water Absorption Index (WAI), Water Solubility Index (WSI), colour and hardness were analyzed. Organoleptic qualities of the extruded products were also analyzed. The results indicated that the bulk density ranging from 0.1618 to 0.3946 g cm^{-3} while expansion ratio varied between 2.42 and 3.50. The water absorption index of the extrudates varied from 3.96% to 6.87%. The mix containing the least amount of finger millet flour (10%) had the lightest colour (highest L value) as indicated by Hunter Colour Flex Meter while the composite mix with the highest amount of brown finger millet flour (40%) had the least value for hardness as indicated by Food Texture Analyzer. The mean scores of organoleptic evaluation showed that all the extruded products prepared from the seven composite mixes were within the acceptable range. It is found that the composite mix comprising of brown finger millet flour, maize flour, rice flour, and full fat soy flour in the ratio of 20:50:20:10 produced the most acceptable RTE extrudates in terms of expansion ratio (3.5), hardness (23.37 N) and sensory characteristics (8.87).

Keywords: extrusion, water absorption index, hardness, expansion ratio

1   Introduction

Extrusion cooking process is a high temperature and short time process in which moist food material 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, but it is achieved through shear and friction in the extruder. Extrusion cooking is used worldwide for the production of expanded snack foods, starch modified ready-to-eat cereals, baby foods, pasta and pet foods   ((Malleshi, 1997; Deshpande *et al.,* 1999). This technology has many distinct advantages including versatility, low cost, better product quality, and no process effluents (Abbott 1987; Camire et al., 1990).

Finger millet or ragi, one of the important nutricereal widely grown in South Asia and African countries, is a staple food of millions of people, and it provides low cost protein, minerals, and vitamins to those people who entirely depend on it. It is considered as nourishing food for the people who put on manual labour because of

its long sustenance by providing energy for a long period after its consumption (Hulse et al., 1980).

Rice (*Oryza sativa*) is a staple food crop for a large part of the world's 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% carbohydrate available, 0.8% fiber, and 1.4% ash content (Zhoul et al., 2002).

Cereals have been popular raw materials for extrusion because of their functional properties, low cost, and ready availability. Owing to high protein content, pulses and oil seeds can be effectively utilized for enhancing the nutritional quality of cereal based extruded food. Soybean protein has been found to reduce the risk of coronary heart disease when consumed as part of a diet low in saturated fat and cholesterol (Tripathi and Misra, 2005). Bengal gram contains more chromium than any other legumes do with an account of 0.032 mg per 100g of sample (Gopalan et al., 2004).

The objective of the present study was to develop finger millet based extruded products with composite flour (Finger millet, maize, rice, soybean, bengal gram, and skimmed milk powder) and to study the effect of composite flour on the physical properties (bulk density, expansion ratio, water absorption index, water solubility index, colour, and hardness) of extrudates and sensory acceptability of the product.

2　Materials and methods

2.1　Raw materials

Brown finger millet, maize, rice, soybean, bengal gram flour, and skimmed milk powder were purchased from local market. Finger millet, maize, and rice were grounded separately in laboratory model hammer mill. Cleaned soybean will be dehulled and blanched for 30 min. Blanched soybean was dry and then converted into flour with hammer mill. In order to obtain homogenized flour sieve provided with hammer mill will be used.

2.2　Composite flour preparation

Blends were prepared by brown finger millet flour, maize flour, rice flour, full fat soy flour, bengal gram flour and skimmed milk powder 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 16% - 17% (w.b) moisture by spraying with a calculated amount of water and mixing continuously at medium speed in a blender. The feed material was then allowed to stay for 2 h 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 composite mixes was determined by hot air oven method AOAC (1990).

Table 1　Standardization of formulation

Sr. No.	Ingredients	Proportion of Composite mixes						
		A	B	C	D	E	F	G
1	Brown finger millet flour	20	30	40	10	20	30	40
2	Maize flour	50	50	50	50	50	50	50
3	Rice flour	20	10	-	-	-	-	-
4	Full fat soy flour	10	10	10	-	-	-	-
5	Bengal gram flour	-	-	-	20	10	-	-
6	Skimmed milk powder	-	-	-	20	20	20	10

2.3　Extrusion process

Extrusion was performed in a laboratory-scale co-rotating twin screw extruder (M/S. BTPL, Kolkata, India). The screw had five sections with total 18 turns, and out of these five sections, four had a length of 75 mm each and the fifth section had a length of 43.5 mm. There was a clearance of 1.5 mm between barrel length and screw length. The extruder had self wiping system for easy cleaning of the machine. Based on the most stable product expansion and stability of the extruder conditions, the extrusion conditions were used. The temperature of the barrel of extruder was set at 140℃. Screw speed was set up at 130 r min^{-1} 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 6% - 7% moisture level. The dried samples were mixed with spices and edible oil.

2.4   Product properties

2.4.1   Bulk density

Bulk density of the extrudates was calculated by measuring the actual dimensions of the extrudates. The diameter and length of 50 pieces of randomly selected extrudate samples were measured by Vernier caliper. The weight of these extrudate pieces would be determined by electronic weighing balance having an accuracy of 0.001 g. The bulk density would then calculate using the following formula, assuming a cylindrical shape of extrudate.

$$\rho_b = \frac{4W}{\pi d^2 l} \qquad (1)$$

where, ρ_b is bulk density, g/cm^3; w is weight, g; d is diameter, cm; and l is the length of the extrudate, cm.

2.4.2   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

$$Expansion\ ratio = \frac{diameter\ of\ extrudate}{die\ diameter} \qquad (2)$$

2.4.3   Water Absorption Index (WAI) and Water Solubility Index (WSI)

WAI and WSI were determined in triplicate following the method described by Carine et al., 2010. Each sample (1 g) would suspend in 20 mL of distilled water in a tared 45 mL centrifuge tube and be stirred with glass rod then put in water bath for 30 min at 30℃ temperature then centrifuge at 3,000 r min^{-1} for 15 min. The supernatants would pour into dry evaporator dishes of known weight and stored overnight at 120℃ for the process of evaporation. WAI and WSI would be calculating using following equations:

$$WSI = \frac{Weight\ of\ sediment}{Weight\ of\ dry\ solid} \qquad (3)$$

$$WSI = \frac{Weight\ of\ dissolved\ solids\ in\ supernant}{Weight\ of\ dry\ samples\ in\ the\ original\ sample} \times 100$$

$$(4)$$

2.4.4   Color

Colour (L*, a*, b* values) of the samples was determined by using Hunter Colour Flex Meter. L* is known as the lightness and extends from 0 (black) to 100 (white). The other two coordinates a* and b* represent redness (+ a) to greenness (- a) and yellowness (+ b) to blueness (-b), respectively were recorded. Three measurements were taken for each sample and their means were reported.

2.4.5   Hardness of extrudates

The peak force as an indication of hardness was measured with Texture Pro CT V1.3 Build Texture Analyzer (Brookfield Engineering Labs, Inc., USA) using TA3/1003 probe. The test speed was 0.5 mm s^{-1} and the distance between two supports was 22 mm. The curve was recorded and analyzed by Texture Exponent 32 software program (version 3.0). Ten measurements were performed on each sample.

2.5   Sensory analysis

A semi-trained panel of 15 students and from faculty of the Agricultural Process Engineering Department at University of Dr. BSKKV, Dapoli evaluated the extruded snacks for appearance, taste, color, and overall acceptability on a 9-point hedonic scale. The panelists were naive to project objectives. Samples were coded using three-digit random numbers and served with the order of presentation counter-balanced. Panelists were provided with a glass of water, and were instructed to rinse and swallow water between samples. They were given written instructions and asked to evaluate the products for acceptability based on its appearance, texture, taste, color, and overall acceptability using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely; Meilgaard et al., 1999).

3   Result and discussion

3.1   Physical characteristics

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

Table   2   Physical properties of extrudates

Composite mixes samples	Bulk Density /g cm^{-3}	Expansion Ratio	Water Absorption Index/%	Water solubility Index/%	Colour			Hardness N
					L	a	b	
A	0.1618± 0.03[1]	3.50 ± 0.05	5.08 ± 0.04	8.89 ± 0.10	35.82 ± 0.13	3.51 ± 0.16	12.39± 0.16	23.37 ± 1.78
B	0.2231± 0.02	3.19 ± 0.02	6.01 ± 0.02	7.43 ± 0.01	32.41 ± 1.27	2.05 ± 0.05	9.44 ± 0.29	43.88 ± 4.63
C	0.2820 ± 0.02	2.90 ± 0.01	6.87 ± 0.03	5.67 ± 0.08	31.39 ± 0.24	3.38 ± 0.11	10.07 ± 0.16	59.68 ± 1.68
D	0.3946 ± 0.02	2.42 ± 0.02	3.96 ± 0.04	9.21 ± 0.52	45.79 ± 0.04	3.83 ±0.02	17.49± 0.09	48.85 ± 4.29
E	0.2075 ± 0.05	3.15 ± 0.13	5.22 ± 0.58	8.30 ± 0.64	38.22 ± 0.09	4.55 ± 0.37	14.22 ± 0.34	32.83 ± 1.84
F	0.2871 ± 0.04	3.02 ± 0.24	4.82 ± 0.03	8.28 ± 0.55	36.44 ± 0.03	2.22 ± 0.06	11.34 ± 0.10	70.90 ± 2.87
G	0.1839 ± 0.02	3.29 ± 0.02	5.45 ± 0.01	5.98 ± 0.03	33.59 ± 0.14	3.18 ± 0.10	11.21 ± 0.17	15.39 ± 0.21

Note: [1]Mean±SD ($n = 6$).

3.1.1   Bulk density

Bulk density is a very important parameter in the production of expanded and formed food products. Bulk density, which considers expansion in all directions, ranged from 0.1618 to 0.3946 g cm^{-3}.   Bulk density was minimum for extruded Sample –A (1.1618 g cm^{-3}) followed by extruded Sample – G (0.1839 g cm^{-3}) while maximum bulk density for extruded Sample– D (0.3946 g cm^{-3}) followed by extruded Sample – F.   The higher bulk density may be due to the presence of skimmed milk powder and bengal gram flour in the composite mixes sample which reduces the puffing quality of extrudates. More crude fiber in the composite flour sample also results in higher bulk density.   Similar types of results were observed by Singh et al. (1996), Deshpande et al. (2011).

3.1.2   Expansion ratio

In extrusion cooking, expansion is the primary quality parameter associated with product crispiness, water absorption, water solubility, and crunchiness.   During extrusion cooking of biopolymers, the viscoelastic material is forced through the die so that the sudden pressure drop causes part of the water vaporize, giving an expanded porous structure.   Expansion ratio varied between 2.42 and 3.50.   The result of expansion ratio of extrudates indicates that expansion ratio decreased with increased level of cereals starch and amount of proteins decreased in the composite mixes.   This decrease in expansion ratio could be because of high level of finger 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 –A (3.50 ±0.05) has more expansion ratio than extruded sample – C (2. 90 ± 0.01) and extruded sample-G (3.29 ± 0.02).   Similar findings were reported by Singh et al. (1996), Deshpande et al. (2011).

3.1.3   Water Absorption Index (WAI) and Water Solubility Index (WSI)

It measures the volume occupied by the extrudate starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion.   It describes the rate and extent to which the component of powder material or particles dissolves in water.   The water absorption index was found to be more for extruded sample –C (6.87 ± 0.03) followed by extruded sample –B (6.01 ± 0.02).   Table 2 showed that the water absorption index of the extrudates increased with increase of finger millet flours in the composite mixes.   The water solubility index was more for the extrudates made from composite mix sample – D (9.21 ± 0.52) followed by extruded sample –A (8.89 ± 0.10), and WSI was less for the extrudates prepared from composite mix sample C - (5.67 ± 0.08).   The water solubility index of the extrudates increased when Bengal gram flour incorporation increased from 10% to 20% in the composite mix samples.   These results are in conformity with the observations made by Shirani and Ganeshranee (2009).

3.1.4   Colour

Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extrudate products.   Color changes can give information about the extent of browning reactions such as caramelization, maillard reaction, degree of cooking and pigment degradation

during the extrusion process (Ilo and Berghofer, 1999). The lightness (L*) is an indication of the brightness. The lightness value of the products ranges from 31.39 to 45.79.   Table 2 shows that the lightness of the extruded samples decreases with increasing level of finger millet flour in respective composite mixes.   Colour parameter a*, indicative of the redness of sample varied from 2.05 to 4.55.   Dark color is also developed during caramelization of sugar from the maillard reaction that why redness (a*) value is high as the temperature increases.   The yellowness value (b*) of extruded products varied from 9.44 to 17.49.   The change in yellowness during extrusion cooking was most induced by the effects of nonenzymatic browning and pigment destruction reactions.   All these differences could have been due to the shear forces generated during extrusion which accelerated the chemical reactions between amino acids and reducing sugars (maillards reaction) that take place during extrusion (Guy, 2001).

3.1.5   Hardness

The hardness of finger millet based extrudates was determined by measuring the force required to break the extrudates.   The higher the value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of the sample to fracture.   Hardness of finger millet based extrudates varied between 15.39 and 70.90 N. As is shown in Table 2 increasing finger millet flour level resulted in increase in peak force of extrudates.

3.2   Sensory characteristics

The panels of semi-trained judges consisting of 15 members were given the extruded snack food samples for evaluation of organoleptic characteristics viz. appearance, colour, taste, texture, and overall acceptability.   The average score recorded by judges was considered, presented, and discussed (Table 3).   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-A had significantly better appearance (7.87±0.64), colour (7.40±0.63), texture (7.27±0.79), taste (8.47±0.52) and overall acceptability (8.87±0.35).   It was revealed from the scores of the overall acceptability that the coarse millet grains and pulses can be successfully mixed to produce a better acceptable product.

Table 3   Mean sensory score values for the extruded snack food

Extruded samples	Sensory attributes				
	Appearance	Colour	Taste	Texture	Overall acceptability
A	7.87± 0.64[1]	7.40± 0.63	8.47± 0.52	7.27± 0.79	8.87 ± 0.35
B	7.80± 0.77	7.20± 0.56	8. 00± 0.53	7.13± 0.83	8.33 ± 0.49
C	7.20± 0.68	6.13± 0.64	8.00 ± 0.53	6.73± 0.96	7.40 ± 0.51
D	7.40±0.83	7.20±0.94	7.33± 1.05	7.07± 0.88	7.47± 1.19
E	7.13±0.99	7.13±0.83	7.60 ± 0.83	7.20± 0.86	7.67±0.82
F	7.13±0.99	6.73± 0.96	7.13± 1.06	7.00± 0.93	7.27± 0.88
g	7.33±1.05	7.27± 0.80	8.13 ± 0.74	7. 87±0.92	7.87± 1.06

Note: [1]Mean±SD (*n* = 6).

4   Conclusion

The present study revealed that composite flour (Finger millet: Maize: Rice: Soybean) in the ratios of 20:50:20:10 best suits to produce desirable qualities of the extrudates such as high expansion ratio, low bulk density, low hardness, and low moisture content with acceptable sensory properties.

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