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Nutritional and functional characteristics of calcium rich extruded snacks from Finger Millet, Bengal Gram and Skim Milk Powder

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Abstract

Finger millet (*Eleusine coracana* (L.) Gaertn), popularly known as 'Ragi' is an important staple food in the eastern and central Africa as well as some parts of India Brown and white finger millet from local farmers and maize, Bengal gram flour and skimmed milk powder from local market were used for the present study. The extrudates of different combination were prepared by using twin screw extruder. Nutritional and functional characteristics of extruded snacks prepared from finger millet based composite blends were assessed. Functional properties of the extrudates such as bulk density, expansion ratio, colour and hardness were found to be influenced by the variations in the composition of the raw blends. The overall moisture content of the extrudates varied from 6.00 – 6.89 g. The protein content of the extrudates which was in the range of 9.96-16.64 decreased while crude fiber which ranged from 0.98-1.99 increased with an increase in the amount of finger millet flour in the blends. The composite blend consisting of 40:50:10 of Brown Finger millet: Maize: Skimmed milk powder produced extruded snacks with the highest sensory score for texture, taste and overall acceptability. Hence the present study revealed that, the composite blend consisting of 40:50:10 of Brown Finger millet: Maize: Skimmed milk powder produces acceptable calcium rich extruded snacks.

Keywords: Finger millet, Bengal gram, skim milk powder, twin screw extruder

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn), popularly known as 'Ragi' is an important staple food in the eastern and central Africa as well as some parts of India (Majumder et al., 2006).). It is rich in protein, calcium, iron, phosphorus, fibre and vitamin content. By virtue of its composition, finger millet is comparable to wheat or rice with respect to its nutritive value and it's calcium content is higher than all cereals. Finger millet has good quality protein along with the presence of essential amino acids, vitamin A, vitamin B and phosphorus (Gopalan et al., 2004). Thus finger millet is a good source of diet for growing children, expectant mothers, old people and patients. 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. Finger millet is usually used for preparation of flour, pudding, porridge and roti (Chaturvedi and

Srivastava, 2008). Traditionally, finger millet is processed either by malting or fermentation (Rao and Muralikrishna, 2001). Malting of finger millet improves its digestibility, sensory and nutritional quality viz., vitamin C is elaborated, phosphorus availability is increased an d lysine and tryptophan are synthesized (Dulby an d Tsai, 197 6), as well as, it has pronounced effect in lowering the antinutrients. Malt based foods possess good nutrition and high calorific value (Malleshi and Desikachar, 1986).

Maize, commonly known as corn, is the world's most widely grown cereal, cultivated across a range of latitudes, altitudes, moisture regimes, slopes and soil types (Smale and Jayne, 2003). In many African and Middle Eastern countries, corn is used for various food preparations and these foods serve as major sources of calories and nutrients (Akinrele, 1970).

Some results of cooking during the extrusion process are the gelatinization of starch, denaturation of proteins, inactivation of many native enzymes and microbes which cause lowering of food deterioration during storage and inactivation of antinutrient factors. Product quality can vary considerably depending on the extrusion processing conditions such as extruder type, screw configuration, feed moisture, temperature profile in the barrel sections, screw speed, and feed rate. With the advantages of economic and versatility, extrusion cooking has been widely used to manufacture snacks and break- fast cereals (Harper 1981).

With the growing awareness of the beneficial effects of healthy diet on the quality of life as well as on cost-effectiveness of health care, the food industry is facing the challenge of developing new products with special health enhancing characteristics. Although less common in food formulations than other cereals, finger millet has the ability to promote good consumer health through its nutritional components such as fiber (both soluble and insoluble), antioxidants and B-vitamins.

Therefore, the aim of this research was to investigate possibilities of finger millet utilization through the production of finger millet based snack food using extrusion process.

Materials and methods

Raw materials

Brown and white finger millet from local farmers and maize, Bengal gram flour and skimmed milk powder from local market were purchased. Finger millet and maize were ground separately in the laboratory model hammer mill. Malt from brown finger millet was prepared by soaking the grains in water for 24 hours, germinating them for 48 hours, drying them, roasting and milling.

Preparation of Composite blends

Blends were prepared by using brown and white finger millet flour, brown finger millet malted flour, maize flour, Bengal gram flour and skimmed milk powder in varying proportions on a dry weight basis as shown in 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 s was determined by hot air oven method AOAC (1990).

Table 1: Flour formulation of finger millet based composite blends.

Flour Formulation							
Sr. No.	**Brown finger millet flour**	**White finger millet flour**	**Brown finger millet malt**	**Maize flour**	**Bengal gram flour**	**Skimmed milk powder**	**Total**
1	10	0	0	50	20	20	100
2	20	0	0	50	10	20	100
3	30	0	0	50	0	20	100
4	40	0	0	50	0	10	100
5 control	0	0	0	50	30	20	100
6	0	10	0	50	20	20	100
7	0	20	0	50	10	20	100
8	0	30	0	50	0	20	100
9	0	40	0	50	0	10	100
10	0	0	10	50	20	20	100
11	0	0	20	50	10	20	100
12	0	0	30	50	0	20	100
13	0	0	40	50	0	10	100

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. Out of these five sections, four sections had a length of 75 mm each and 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 140^0C. Screw speed was set up at 275 rpm and equipped with 3-mm restriction die or nozzle to extruder. Constant feeding rate was kept throughout the experiment. Three replicate samples were extruded and dried to about 6-7% moisture level. The dried samples were applied chat masala moistened in edible oil.

Determination of Functional properties of the extrudates

Bulk density

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

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

Where, ρ_b is bulk density (g/cm^3), w (g) is weight, *d* is diameter (cm), and *l* is the length of the extrudate (cm).

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 follows;

$$\text{Expansion Ratio} = \frac{\text{Diameter of extrudate}}{\text{Die diameter}} \quad (2)$$

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 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 recorded for each sample.

Chemical composition of the extrudates:

Protein, fat, crude fibre, ash, moisture, calcium and iron contents of the raw composite blends and extrudates were analyzed according to official methods of analysis (AOAC 1990). The content of the available carbohydrate was determined by difference i.e. by subtracting from 100 the sum of the values (per 100 g) for moisture, protein, fat, crude fibre and ash. Energy was determined in a Bomb Calorimeter.

Sensory analysis

A semi-trained panel of 15 judges from the Department of Agricultural Process Engineering, CAET, Dr. BSKKV, Dapoli evaluated the extruded snacks for appearance, taste, colour, texture and overall acceptability on a 9-point hedonic scale (1 = dislike extremely to 9 = like extremely; Meilgaard *et al.*, 1999). Samples were coded using random three-digit numbers. Panelists were provided with a glass of water and instructed to rinse and swallow water between samples and were served biscuit to break the monotony in taste of the extrudates.

Result and Discussion

Nutritional Composition of raw finger millet based composite blends

Table2 shows the Nutritional composition of raw finger millet based composite blends. The overall moisture content of the blends varied from 5.61 -7.25 g. The protein content of the raw finger millet based composite blends which was in the range of 12.19-18.72 decreased while crude fibre which was in the range of 1.63-2.65 increased with an increase in the amount of finger millet flour in the blends. However, the protein, ash and calcium contents of the blends containing skimmed milk powder were found to be higher than the blends without skimmed milk powder. No particular trend was found in case of carbohydrates, energy and iron contents of the composite blends.

Functional characteristics

The flour particle size, moisture level, feed rate, temperature, screw speed and die diameter were kept constant throughout the experiment. Functional characteristics of finger millet based extrudates are presented in Table 3.

Bulk density

Bulk density is a very important parameter for the production of expanded and crispy food products which considers expansion in all directions. It ranged from 0.1839 - 0.6225 g/ cm^3. Bulk density did not follow any particular trend and was minimum for extruded Sample–D (0.1839 g/ cm^3) followed by Sample–B (0.2075 g/ cm^3) while it was maximum for Sample–F (0.6225 g/ cm^3). The high bulk density of the extrudates could be due to the increased amounts of protein because of the presence of skimmed milk powder and Bengal gram flour in the composite blends which reduce the puffing quality of the extrudates.

Table 2: Nutritional Composition of raw finger millet based composite blends.

Treat--ment	Moisture (g)	Protein (g)	Fat (g)	Crude fibre (g)	Ash (g)	Carbohy drate (g)	Energy (Kcal)	Ca (mg)	Fe (mg)
1	5.82	17.48	3.17	1.81	2.95	68.77	373.53	320	3.28
2	6.03	16.24	2.76	1.99	2.96	70.02	369.88	344	2.61
3	6.23	14.99	2.28	2.17	2.96	71.37	365.96	369	1.93
4	6.99	12.35	2.29	2.46	2.55	73.36	363.45	262	2.03
5	5.61	18.72	3.72	1.63	2.94	67.38	377.88	296	3.96
6	5.88	17.44	3.24	1.8	2.87	68.77	374.00	333	3.38
7	6.16	16.16	2.77	1.97	2.8	70.14	370.13	371	2.8
8	6.43	14.88	2.29	2.14	2.73	71.53	366.25	359	2.23
9	7.25	12.19	2.31	2.42	2.25	73.58	363.90	314	2.43
10	5.86	17.58	3.25	1.86	2.96	68.49	373.53	316	3.39
11	6.12	16.45	2.76	2.08	2.98	69.61	369.08	336	2.83
12	6.37	15.32	2.29	2.31	2.99	70.72	364.77	356	2.27
13	7.16	12.77	2.3	2.65	2.59	72.53	361.90	246	2.47

Table 3: Functional characteristics of finger millet based extrudates.

Sr. No	**Sample code**	**Bulk Density (g/cm^3)**	**Expansion Ratio**	**Hardness N**
1	**A**	0.2095 ± 0.05	3.05 ± 0.13	48.85 ± 4.29
2	B	0.2075 ± 0.05	3.15 ± 0.13	32.83± 1.84
3	C	0.2871 ± 0.04	3.02 ± 0.24	70.90 ± 2.87
4	D	0.1839 ± 0.02	3.29 ± 0.02	15.38 ± 0.21
5	E	0.3402 ± 0.04	2.74 ± 0.13	51.59 ± 3.68
6	F	0.6225 ± 0.12	1.93 ± 0.22	42.09 ± 0.94
7	G	0.3652 ± 0.02	2.64 ± 0.05	64.92 ± 0.31
8	H	0.3085 ± 0.05	2.87 ± 0.21	48.22 ± 11.80
9	I	0.2696 ± 0.01	3.11 ± 0.07	38.17 ± 0.42
10	J	0.3037 ± 0.03	2.72 ± 0.04	42.19 ± 0.71
11	K	0.3405 ± 0.01	2.71 ± 0.05	31.85 ± 1.37
12	L	0.2966 ± 0.02	2.93 ± 0.10	54.78 ± 5.14
13	M	0.2525 ± 0.06	3.07 ± 0.0	58 .21 ± 6.37

Crude fiber in the composite blends also contributes to higher bulk density. Similar findings have been reported by Singh *et al.* (1996).

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 visco-elastic material is forced through the die so that the sudden pressure drop causes part of the water to vaporize, giving an expanded porous structure. Expansion ratio varied between 1.93 and 3.29. Protein is found to affect expansion through its ability to effect water distribution in the matrix and through its macro molecular structure and confirmation. Sample –D (3.29±0.02) had the highest expansion ratio while sample – F (1.93 ± 0.22) had the lowest value. Bulk density has been linked with the expansion ratio in describing of puffing of extrudates.

Hardness

The hardness of finger millet based extrudates was determined by measuring the force required to break the extrudates. Higher the value of force required to breakdown the sample meant higher was the hardness of the sample. Hardness of the extrudates varied between 15.38 and 70.90 N. Sample D which contained the highest amount of whole brown finger millet flour had the least hardness value which meant, it had the maximum crispiness while sample C, which contained whole brown finger millet flour but skimmed milk powder double the amount present in sample D, was the hardest of all the samples.

Nutritional composition of the extrudates

Table 4 shows the proximate composition of the finger millet based extrudates. The overall moisture content of the extrudates varied from 6.00 – 6.89 g. The protein content of the extrudates which was in the range of 9.96-16.64 decreased while crude fibre which ranged from 0.98-1.99 increased with an increase in the amount of finger millet flour in the blends. On extrusion, a decrease in the contents of protein, fat, crude fibre and energy was observed while there was an increase in ash, carbohydrates, calcium and iron contents of the extrudates as compared to their respective raw composite blends. However, the protein, ash and calcium contents of the extrudates containing skimmed milk powder were found to be higher than the extrudates without skimmed milk powder. No particular trend was found in case of carbohydrates, energy and iron contents of the blends. When the finger millet based extrudates were compared with the control (sample E), it was observed that all the finger millet based extrudates had higher amounts of calcium and crude fibre than the control.

Table 4: Nutritional Composition of finger millet based extrudates.

Sr. No	Sample code	Moisture (g)	Protein (g)	Fat (g)	Crude fibre (g)	Ash (g)	Carbo-hydrate (g)	Energy (Kcal)	Ca (mg)	Fe (mg)
1	A	6.25	15.32	1.98	1.49	3.58	71.38	364.62	323	3.32
2	B	6.60	14.78	1.62	1.51	3.61	71.88	361.22	345	2.67
3	C	6.78	13.02	1.59	1.82	3.23	73.56	360.63	372	1.93
4	D	6.66	9.96	1.76	1.99	3.08	76.55	361.68	271	2.05
5	E	6.21	16.64	2.18	0.98	3.59	70.40	367.79	297	3.98
6	F	6.25	15.27	2.04	1.38	3.37	71.69	366.20	341	3.40
7	G	6.38	14.09	1.81	1.47	3.08	72.71	363.49	379	2.82
8	H	6.00	12.59	1.66	1.53	2.98	75.24	366.62	362	2.24
9	I	6.25	10.73	1.79	1.64	2.71	76.88	366.59	317	2.45
10	J	6.88	15.31	2.09	1.59	3.39	70.74	363.01	322	3.41
11	K	6.89	14.23	1.94	1.72	3.42	71.80	361.58	341	2.85
12	L	6.67	13.18	1.78	1.81	3.68	72.87	360.22	358	2.28
13	M	6.34	10.85	1.69	1.96	3.34	75.82	361.89	251	2.49

Table 5: Mean sensory scores of finger millet based extrudates.

Sr. No	Sample code	Appearance	Colour	Texture	Taste	Overall acceptability
1	A	7.40± 0.83	7.20± 0.94	7.07± 0.88	7.33± 1.05	7.47± 1.19
2	B	7.13± 0.99	7.13± 0.83	7.20± 0.86	7.60 ± 0.83	7.67±0.82
3	C	7.13 ± 0.99	6.73± 0.96	7.00± 0.93	7.13± 1.06	7.27± 0.88
4	D	7.33 ± 1.05	7.27± 0.80	7. 87±0.92	8.13 ± 0.74	7.87± 1.06
5	E	7.40± 0.98	7.60± 0.99	6.67± 0.98	6.80± 0.86	7.00±0.85
6	F	6.87± 0.74	6.93 ± 0.80	6.87± 0.64	7.07± 0.80	7.07± 0.80
7	G	6.73± 0.70	6.73 ± 0.80	6.87± 0.64	6.87 ± 0.83	6.87± 0.74
8	H	7.13± 0.74	7.07± 0.46	7.07± 0.70	7.20± 0.77	7.07± 0.59
9	I	7.00± 0.93	6.27± 0.46	7.07± 0.80	7.07± 0.70	7.40± 0.83
10	J	7.33± 0.61	7.60± 0.74	7.40± 0.83	7.60± 0.63	7.60± 0.74
11	K	7.53± 0.92	7.53± 0.99	7.40± 0.83	7.60± 0.83	7.60± 0.74
12	L	7.87± 0.83	7.73± 0.80	7.13± 0.92	7.73±0.96	7.73± 0.88
13	M	7.60± 0.91	7.87± 0.64	7.13± 0.92	7.87± 1.06	7.67± 0.82

Sensory evaluation

A panel of 15 semi- trained judges were given the extruded snack food samples for evaluation of organoleptic characteristics viz. appearance, colour, taste, texture and overall acceptability. Table 5 shows the average scores given by the judges. The mean scores of sensory evaluation showed that all the extruded products prepared from composite blends were within the acceptable range. Sample-D(extrudates with highest amount of brown finger millet flour) had highest score for texture (7.87±0.92),taste (8.13 ± 0.74) and overall acceptability (7.87 ±1.06) while sample L had highest score for appearance (7.87 ±0.83) and the extrudates containing the highest amount of malt (sample M)had highest score for colour (7.87±0.64).

Conclusion

Nutritional and functional characteristics of extruded snacks prepared from finger millet based composite blends were assessed. Functional properties of the extrudates such as bulk density, expansion ratio, colour and hardness were found to be influenced by the variations in the composition of the raw blends. The protein content of the extrudates which was in the range of 9.96-16.64 decreased while crude fibre (ranged from 0.98-1.99) increased with an increase in the amount of finger millet flour in the blends. On extrusion, a decrease in the contents of protein, fat, crude fibre and energy was observed while there was an increase in ash, carbohydrates, calcium and iron contents of the extrudates as compared to their respective raw composite blends. However, the protein, ash and calcium contents of the extrudates containing skimmed milk powder were found to be higher than the extrudates without skimmed milk powder. All the finger millet based extrudates had higher amounts of calcium and crude fibre than the extrudates without any type of finger millet flour (control). The composite blend consisting of 40:50:10 of Brown Finger millet: Maize: Skimmed milk powder produced extruded snacks with the highest sensory score for texture, taste and overall acceptability. Hence the present study revealed that, the composite blend consisting of 40:50:10 of Brown Finger millet: Maize: Skimmed milk powder produces acceptable calcium rich extruded snacks.

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