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PROCESS OPTIMISATION OF EXTRUDED BREAKFAST CEREAL FROM RICE MILL BROKENS - FINGER MILLET - MAIZE FLOUR BLENDS

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ABSTRACT

The effect of extrusion on the physical, functional and textural properties of broken rice extrudates blended with finger millet and maize flours of various formulations were studied. The density of blends ranged from 0.11 to 0.44 g/cm^3, expansion ratio (1.54-2.46), true density (78.91-477.84 kg/m^3), porosity (28.13-37.95%), WAI (5.0-8.05 g/g), WSI (0.2-8.7%) and hardness (1.35-10.09 N). It was observed that the increase in feed moisture content resulted in extrudates with a lower expansion ratio and WAI, higher density, WSI and hardness. Among the various combinations investigated the blend with broken rice (30), finger millet (60) and maize (10), 16 per cent moisture addition, 110°C barrel temperature and 290 rpm screw speed yielded good sensory results. The results obtained from the experiments were significantly different at ($P \leq 0.01$) of all combinations.

Keywords: Extrusion, broken rice, optimization, physical properties.

INTRODUCTION

Because of its low cost and continuous processing capability extrusion cooking has been accepted as one of the most useful technologies during the recent years in the field of food processing. Extrusion cooking is used worldwide for the production of expanded snack foods, modified starches, ready to eat cereals, baby foods, pasta and pet foods (Deshpande and Poshadri, 2011). 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.

Rice (*Oryza sativa*) is the staple food crop for a large part of the world's population, making it the second most consumed cereal grain. Cereals have been popular raw materials for extrusion because of their functional properties, low cost and ready availability. Owing to high protein content, millets can be effectively utilized for enhancing the nutritional quality of cereal based extruded food.

Finger millet (*Eleusinacoracana*) is an exceptional grain with high nutritive value, rich dietary fibre and phytochemicals. It is an important cereal because of its excellent storage properties and nutritive value, which is higher than that of rice and equal to that of wheat. Finger millet offers a great opportunity for value addition compared to other cereals because of its comparatively lower cost, higher nutritive value and easy availability. However, finger millet could not provide sufficient iron in the diet, as most of it is unavailable due to presence of tannins (0.04 to 3.47 per cent catachin equivalent) and phytates (myo-inositol-6-phosphate) (Hallberg *et al.*, 1987).

Since maize flour is widely used to elaborate extruded products, there is a need to improve the nutritional value of this kind of food. The appropriate degree of maize replacement is needed to increase the nutritional contribution of extruded broken rice-finger millet-maize flours, which in turn can help to keep consumer acceptance high. Among all flour components, starch plays a key role. The extrusions of starchy foods result in gelatinization, partial or complete destruction of the crystalline structure and molecular fragmentation of starch polymers. During extrusion, protein structures are disrupted and altered under high shear, pressure and temperature. Protein solubility decreases and cross-linking reactions occur possibly due to some covalent bonds formed at high temperature (Areas, 1992), as well as protein denaturation and formation of complexes between starch and lipids and between protein and lipids. Recent studies concentrated on extrusion cooking processing effects for creating new products and evaluation of physical and chemical properties. The objective of this research was to get optimum percentage of broken rice substitution in the standard broken rice: finger millet: maize based snack. It hoped that the snack would be beneficial for consumers, snack processors and the most important is to add value to broken rice.

MATERIAL AND METHODS

PREPARATION OF FEED

Broken rice, finger millet and maize were purchased from Rice mill, Kangeyam, Tirupur District, Tamil Nadu, Millets Department and Maize Department TNAU, Coimbatore respectively.

Blends were prepared by mixing broken rice, finger millet and maize flours in the different ratios on a weight basis shown in the Table 1. The blends were tempered, sealed and stored in food grade plastic containers at 4°C for 48 h. Blends were allowed to reach (room temperature) prior to extrusion processing. This preconditioning procedure was employed to ensure uniform mixing, 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- Levels of processing variables and different flours quantities (g / 100 g total mix)

Sl. No.	Addition of flour (per cent)	Proportions of composite flour samples					
		A	B	C	D	E	F
1	Broken rice	100	10	20	30	10	30
2	Finger millet	0	80	60	40	60	60
3	Maize	0	10	20	30	30	10

EXTRUSION PROCESS

Several reports had attempted to relate extrusion parameters to chemical and physical properties of extrudates such as raw material composition, feed moisture content, screw speed and barrel temperature (Hagenimana *et al.*, 2006). Extrusion was performed in a co-rotating twin screw extruder (M/S. BTPL, Kolkata, India). The broken rice: finger millet: maize blend was prepared for extrusion process (Table 1). The extruded products were cut into small pieces, dried in hot air oven and were cooled before being stored into plastic bags for future analysis. All experiments were conducted in triplicate.

PHYSICAL PROPERTIES OF EXTRUDATES

DENSITY

Density of the extrudates was determined using vernier caliper from the weight and the actual dimensions of the extrudates (Rodriguez-Miranda *et al.*, 2011).

$$Density \quad (g / cm^3) = \frac{4W}{\pi d^2 l}$$

Where,

W = weight, g
d = diameter, cm
l = length of the extrudate, cm

POROSITY AND TRUE DENSITY

True volume of extrudates was determined using multivolume pycnometer (Micromeritics model USA: model 1305). The true density was calculated as the ratio of mass of the sample to the true volume.

$$P = \frac{p_1 - p_2}{p_2}$$

$$\rho_t = \frac{w}{V_t}$$

Where,

ρ_t = true density (kg/m^3)
w = weight of the samples (kg)
V_t = true volume (m^3)

EXPANSION RATIO

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate (Rodriguez-Miranda *et al.*, 2011). The extrudate expansion ratio was calculated as

$$Expansion \quad ratio = \frac{Extrudate \quad diameter \quad (mm)}{Die \quad diameter \quad (mm)}$$

FUNCTIONAL PROPERTIES OF EXTRUDATES

The samples were evaluated for Water Absorption Index (WAI), Water Solubility Index (WSI), Solubility index (So) and Swelling Power (Sp) was determined by the method of (Anderson *et al.*, 1969). The WAI, WSI, solubility index and swelling power were determined using the formulae:

$$WAI = \frac{Weight \quad of \quad sed\,iment}{Weight \quad of \quad dry \quad solids}$$

$$WSI = \frac{Weight \quad of \quad dissolved \quad solids \quad in \quad supernat\,ant}{Weight \quad of \quad dry \quad solids} \times 100$$

$$SO = \frac{Weight \quad of \quad su\,pernata\,nt \quad dried}{Sample \quad weight} \times 100$$

$$SP = \frac{Weight \quad of \quad sed\,iment}{Sample \quad weight} \times (100 - SO)$$

TEXTURE MEASUREMENT

Texture analyzer was used to conduct hardness and fracturability was measured with Stable Micro System TA-XT2 texture using three point bend rig. The distance at the point of break is the resistance of the sample to bend and so relates to the 'fracturability' of the sample *i.e.* a sample that breaks at a very short distance has a high fracturability.

EXPERIMENTAL DESIGN

A four factors experiment design was employed to investigate the influence of feed moisture, barrel temperature, screw speed and formulations. Duncan's multiple range tests was used to estimate significant differences using the IRRISTAT.

SENSORY EVALUATION

The sensory assessment was conducted with a panel of 25 members with the age between 19 to 50 years consisted of staff, under graduate and post graduate students of the Agricultural Engineering College and Research Institute, TNAU, Coimbatore. The panelists were not known to project objectives. They were given written instructions and asked to evaluate the products for acceptability based on its flavour, texture, taste, colour and overall acceptability using nine-point hedonic scale 1 = dislike extremely to 9 = like extremely (Meilgaard *et.al.*, 1999).

RESULTS AND DISCUSSION

PHYSICAL CHARACTERISTICS OF EXTRUDATES

EXPANSION RATIO

A temperature increase leads to higher expansion ratio values, resulting in lower densities. The expansion ratio of extrudate product is presented in Table 2 as a function of extrusion characteristics. The expansion ratio was found to depend mostly on feed moisture content, product temperature and screw speed (residence time). The expansion ratio of broken rice-finger millet-maize extruded product ranged from 1.54 to 2.46. Feed moisture content had a significant effect on the expansion ratio. The expansion ratio decreased with increased feed moisture content. Thymi *et al.* (2005) suggested that expansion was most dependent on the melt elasticity. The stored energy was released in the expansion process, increasing the expansion ratio. Increased feed moisture content during extrusion would change the amylopectin molecular structure of the starch-based material, reducing the melt elasticity that decreases the expansion ratio. The increase of residence time results in a degradation of amylopectin networks in the material that changes the expansion. The increase of melt temperature significantly increased the expansion ratio for all the examined feed moisture contents.

DENSITY

The density is an index of the extent of puffing and values for the dry extrudates were between 0.11 and 0.44 g/cm^3. The lowest density value was obtained when broken rice-finger millet-maize flour was extruded at lower moisture contents and higher temperatures, whereas the highest value was obtained at higher moisture contents and lower temperatures. Density values decreased when the extrusion temperature and the screw speed increased probably due to starch gelatinization Hagenimana *et al.* (2006) (Table 2). This proposal is in agreement with our observations. Further, the density increased with an increase in moisture content at low extrusion temperatures, whereas the opposite effect occurred at high temperature. A similar observation was reported by Sacchetti *et al.* (2004). Moreover, low shear screw configurations resulted in a higher extrudate density than high shear screw configurations. Analysis of variance attributed ($P \leq 0.01$) of total density to the dependent variables.

TRUE DENSITY

The true density of the extrudate product is decreased for every feed moisture, barrel temperature and screw speed levels increased from 16-20%, 90-110°C and 230-290 rpm for formulations. This should be expected since particle density ranges between the density of water and the dry solid density. Thus, for the extruded product of very low moisture content, the particle density reaches the value of the dry solid density (Table 2). Increasing the moisture content changes the amylopectin molecular structure in the starch-based material reducing the melt elasticity that decreased the radial expansion ratio and increased the density. A similar observation was reported by Thymi *et.al.* (2005) for corn grits extrudates.

POROSITY

The porosity is presented as a function of screw speed for various moisture contents and product temperatures (Table 2). The porosity increased slightly as the screw speed and temperatures increased and there was a negative effect on feed moisture contents. Increased feed moisture content during extrusion decreased the porosity. A similar observation was reported by Shemi George *et.al.* (2012) in formulation of pumpkin flour incorporated bread.

FUNCTIONAL PROPERTIES OF EXTRUDATES

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 20:60:20 (8.05 g/g). Table 3 showed that the water absorption index of the extrudates varies with increase in feed moisture from 16 to 20 per cent (w.b), the overall WAI decreased from 7.19 to

Table 2- Effect of extrusion process parameters on physical properties and colour values of extrudates

Variables	Levels	Physical properties				Colour values			
		Expansion ratio	Density (g/cm^3)	TD (kg/m^3)	Porosity (%)	*L**	*a**	*b**	Δ*E*
Feed moisture (%, w.b.)	16	2.17 [a]	0.18 [b]	303.32 [a]	33.27 [a]	41.2 [a]	4.93 [b]	10.42 [a]	42.79 [a]
	18	2.02 [a]	0.22 [ab]	198.26 [b]	33.22 [a]	40.97 [a]	4.93 [b]	11.14 [a]	42.77 [a]
	20	1.86 [ab]	0.28 [a]	152.65 [bc]	32.48 [a]	39.78 [a]	5.41 [a]	10.28 [a]	41.48 [a]
Barrel temperature (°C)	90	1.90 [a]	0.27 [a]	246.90 [a]	31.62 [b]	42.85 [a]	5.79 [a]	11.93 [a]	44.87 [a]
	100	2.04 [a]	0.23 [ab]	218.04 [ab]	32.64 [a]	39.17 [a]	4.84 [a]	9.99 [a]	40.74 [b]
	110	2.11 [a]	0.18 [b]	189.30 [b]	34.72 [a]	39.93 [a]	4.63 [a]	9.92 [b]	41.42 [ab]
Screw Speed (rpm)	230	1.99 [a]	0.23 [a]	231.83 [a]	32.19 [a]	41.15 [a]	5.19 [a]	10.74 [a]	42.87 [a]
	260	2.01 [a]	0.22 [a]	218.69 [ab]	33.24 [a]	40.44 [a]	5.15 [a]	10.87 [a]	42.21 [a]
	290	2.05 [a]	0.22 [a]	203.72 [b]	33.55 [a]	40.36 [a]	4.93 [a]	10.22 [a]	41.95 [a]
Addition of broken rice: maize: finger millet (%)	10:80:10	1.97 [a]	0.22 [a]	191.40 [b]	33.01 [a]	39.34 [a]	4.91 [a]	9.75 [b]	40.85 [b]
	20:60:20	2.02 [a]	0.22 [a]	214.13 [ab]	33.02 [a]	40.58 [a]	5.15 [a]	10.44 [ab]	42.25 [a]
	30:40:30	2.04 [a]	0.23 [a]	229.58 [a]	33.12 [a]	40.87 [a]	5.01 [a]	11.18 [a]	42.69 [a]
	10:60:30	2.03 [a]	0.23 [a]	227.47 [a]	32.91 [a]	41.84 [a]	5.21 [a]	11.35 [a]	43.68 [a]
	30:60:10	2.02 [a]	0.22 [a]	227.82 [a]	32.90 [a]	40.63 [a]	5.16 [a]	10.34 [ab]	42.25 [a]
LSD		0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.05

TD: True density

In a column means followed by a superscript common letter are not significantly different at the 5% level by DMRT

Table 3- Effect of extrusion process parameters on functional and textural properties of extrudates

Variables	Levels	Functional properties				Textural properties	
		WAI (g/g)	WSI (per cent)	Swelling power	Solubility index	Hardness (N)	Fracturability (mm)
Feed moisture (%, w.b.)	16	7.19	2.75	7.51	33.02	6.1	3.2
	18	7.34	1.71	7.57	20.57	6.3	2.8
	20	7.01	2.46	7.17	28.26	6.3	2.5
Barrel temperature (°C)	90	6.86	2.06	7.21	24.5	7.2	2.9
	100	7.46	1.74	7.58	20.93	6.1	2.9
	110	7.23	3.12	7.46	36.41	5.3	2.7
Screw Speed (rpm)	230	6.84	2.26	7.50	25.18	7.0	3.1
	260	7.36	2.56	7.22	26.63	5.6	2.8
	290	7.35	2.12	7.54	30.04	6.0	2.6
Addition of broken rice: maize: finger millet (%)	10:80:10	7.04	2.65	7.29	30.86	5.4	2.9
	20:60:20	7.37	1.93	7.59	22.72	6.0	2.9
	30:40:30	7.17	1.56	7.34	18.47	6.5	2.7
	10:60:30	7.13	2.86	7.41	34.01	6.5	3.0
	30:60:10	7.2	2.54	7.45	30.35	6.6	2.8
LSD		0.04	0.0	0.02	0.01	1.8	2.1

7.01 g/g and WSI decreased from 1.71 to 2.75 per cent (Table 3) in the composite mixes. The water solubility index was more for the extrudates made from composite mix sample 10:80:10 (8.7%) and it was less for the sample 30:40:30 (0.2%). The water solubility index of the extrudates increased as feed moisture content, barrel temperature and screw speed increased from 16 to 20%, 90 to 110°C and 230 to 290 rpm in the composite mix samples. These results are in conformity with the observations made by (Shirani and Ganeshranee, 2009).

The swelling power is determined by the ability of starch granules to swell in the presence of excess water when heated. Swelling power ranges from 5.12 to 8.32 g/g and solubility index ranges from 2.4 to 95.7 per cent of broken rice-finger millet-maize extrudates. Generally speaking, swelling power of starches reflects the interactions between water molecules and starch chains in amorphous and crystalline domains, respectively.

TEXTURAL MEASUREMENT

The textural characteristics of extrudates were measured using a Stable Micro System TA-XT2 texture. The hardness of broken rice-finger millet-maize 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 broken rice-finger millet-maize based extrudates varied between 1.35 and 10.09 N and fracturability 1.35 to 4.39 mm. As is shown in table 3 increasing feed moisture content, barrel temperature and decreasing screw speed resulted in increase in peak force and distance of extrudates. This is in agreement with the experiments by Sawant *et al.* (2013) on composite flours mixes.

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. 4.). 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 10:80:10 had significantly better appearance (7.3), colour (7.1), flavour (7.0), hardness (7.1), crispness (7.4), taste (7.3) and overall acceptability (7.1) when all the prepared extruded samples were compared with the commercial control. It was revealed from the scores of the overall acceptability that the broken rice, finger millet and maize can be successfully mixed to the level of 10:80:10 to produce a better acceptable product.

Table 4- Mean sensory scores of broken rice blended with finger millet and maize extrudates

Sensory parameters	Sensory score							
	A	B	C	D	E	Control	G_1	G_2
Crispiness	7.4	7.3	6.8	6.4	6.5	6.6	5.7	5.5
Appearance	7.3	7.1	6.5	6.4	6.9	7.1	6.0	5.8
Hardness	7.1	6.8	6.5	6.2	6.3	6.4	5.7	5.6
Flavour	7.0	6.9	6.6	6.2	6.5	6.9	5.7	5.2
Colour	7.1	7.1	6.4	6.4	6.3	7.1	6.3	5.9
Taste	7.3	7.1	6.6	6.4	6.6	7.0	5.7	5.8
Overall Acceptability	7.1	7.2	6.6	6.4	6.6	6.2	5.9	5.8
Mean Score	7.2^a #	7.1^a	6.5^b	6.3^b	6.5^b	6.8^b	5.9^c	5.7^c

Control→100:00:00; A→10:80:10; B→20:60:20; C→30:40:30; D→10:60:30; E→30:60:10;
G_1→Commercial; G_2→ Commercial, # Best among different formulations

CONCLUSION

The present study revealed that composite flour (broken rice: finger millet: maize) in the ratio of 10:80:10 best suits to the sensory point of view. The physico-chemical properties and sensory characteristics of broken rice-finger millet-maize based extrudate was dependent on process variables, *viz*., moisture content, feed rate, screw speed and barrel temperature. The utilization of broken rice as a substituting raw material in broken rice: finger millet: maize based snack that would be beneficial for consumers, snack processors and the most important is to add value to broken rice.

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REFERENCES

- Anderson, R. A., Conway, H. F., Pfeife, F. F. And Griffin Jr, E. L. Gelatinization Of Corn Grits By Roll-And Extrusion-Cooking. *Cereal Science Today*, 1969, 14: 11-12.
- Aoac. Official Methods of Analysis, 18th Edition, Association of Official Analytical Chemists, Washington. Dc, 1990, P. 71-72.
- Areas, J. A. G. Extrusion Of Food Proteins. *Crit. Rev. Food Sci. Nutri.*, 1992.32: 365-392.
- Deshpande, H. W. And Poshadri, A. Physical And Sensory Characteristics of Extruded Snacks Prepared From Foxtail Millet Based Composite Flours. *Int. Food Res. J.*, 2011, 18: 751-756.
- Hagenimana, A., Ding, X. And Fang, T. 2006. Evaluation Of Rice Flour Modified By Extrusion Cooking. *J. Cereal Sci.*, 43: 38-46.

- Hallberg, L., Rossander, L. And Skanberg, A. B. Phytates And The Inhibitory Effect Of Bran on Iron Absorption In Man. American Journal Of Clinical Nutrition. 1987, 45:988-996.
- Shemi George and Nazni.P , Formulation and optimization of functional bread by employing response Surface methodology, (2012), International Journal of Current Research, Vol. 4, Issue, 06, pp.008-014.
- Ilo, S. And Berghofer, E. 1999. Kinetics of Colour changes during Extrusion Cooking of Maize Grits. *J. Food Engineering*, 39: 73-80.
- Meilgaard, M, Civille, G. V. And Carr, B. T. Sensory Evaluation Techniques. 3rd Edn. Crc Press, Boca Raton. 1999
- Rodriguez-Miranda, J., Ruiz-Lopez, I. I., Herman-Lara, E., Martinez- Sanchez, C. E., Delgado-Licon, E. And Vivar-Vera, M. A.. Development Of Extruded Snacks Using Taro (*Colocasia Esculenta*) And Nixtamalized Maize (*Zea Mays*) Flour Blends. *Lwt - Food Sci. Technology*, 2011, 44: 673-680.
- Sacchetti, G., Pinnavaia, G. G., Guidolin, E. And Dalla Rosa, M.. Effects of Extrusion Temperature And Feed Composition On The Functional, Physical And Sensory Properties of Chestnut And Rice Flour-Based Snack-Like Products. *Food Res. International,* 2004, 37: 527-534.
- Sawant, A., Thakor, A, N. J., Swami, S. B. And Divate. A. D. Physical and Sensory Characteristics of Ready-To-Eat Food Prepared From Finger Millet Based Composite Mixer By Extrusion Cooking. *Agril. Engineering Int.: Cigr J.*, 2013, 15: 100-105.
- Shirani, G. And Ganesharanee, R. Extruded Products With Fenugreek (*Trigonella Graecium*), Chick Pea And Rice: Physical Properties, Sensory Acceptability And Glycemic Index, *J. Food Engineering*, 2009, 90: 45-52.
- Thymi, S., Krokida, M. K., Pappa, A. And Maroulis, Z. B. Structural Properties of Extruded Corn Starch. *J. Food Engineering*, 2005, 68: 519-526.
- Vanithasri, J., Kanchana, S., Hemalatha, G., Vanniarajan, C. and Sahulhameed, M. Role of Millets and Its Importance In New Mellinium. *Int. J. Food Sci. Technology*, 2012, 2: 35-47.