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Optimization of Process Parameters for Extruded Sorghum Products

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ABSTRACT

Sorghum (*Sorghum bicolor*) is an important staple crop in semi-arid regions of India and Africa because of its drought tolerance. This research work was focused on developing sorghum-based extruded snacks and their storage studies. Processing parameters of feed including moisture contents (12%, 14% and 16%), different blend ratios of sorghum, broken rice and green gram flours (7:2:1, 6:3:1 and 5:4:1), operational parameters of the extruder like barrel temperature (110, 120 and 140^{0}C) and screw speed (150, 200 and 250 rpm) were optimized for physical and sensory properties of sorghum based extruded products. The maximum value of expansion ratio and minimum bulk density was observed for the sample prepared from sorghum, broken rice and green gram flour in the ratio of 5:4:1 at 110^{0}C barrel temperature and 150 rpm of screw. The sensory evaluation of the extrudates showed that products prepared from 5:4:1 blend ratio were more acceptable.

Key words : Bulk density, Extruded snack, Expansion ratio,Sorghum.

Millets are minor cereals and form the staple food for a large segment of the population in India and Africa. Utilization of millet for food is still mostly confined to the traditional consumers and population in lower economic strata; partly because of non-availability of these grains in ready-to eat forms. Millets are not only nutritionally comparable but are also superior to major cereals with respect to protein, energy, vitamins and minerals.

Sorghum (*Sorghum bicolor*) is the world's fifth leading grain in production and is a staple food for many in the arid, dry climates of Africa and Asia. Sorghum species (*Sorghum vulgare* and *Sorghum bicolor*) are members of the grass family. Sorghum probably originated in North Africa about 3000 BC. Asia and Africa contribute about 65 percent of the total grain sorghum production in the semi-arid tropics. Sorghum produced in India is consumed mostly in the form of *roti* (Unleavened bread) and *sankati* (Thick porridge). Besides traditional uses, sorghum can also be used as popped and flaked products by extrusion. Sorghum is less expensive than other cereals. Because of its lower cost, sorghum is an attractive ingredient for the production of extruded snacks or breakfast cereals. Utilization of sorghum in the form of ready-to-eat snack foods is likely to increase its consumption significantly.

Rice is grown as a monocarp annual plant in tropical areas. Rice an important part of the diet of many people worldwide, including India. Rice provides more than one fifth of the calories consumed worldwide by humans. The main by-products of rice milling is broken rice. Broken rice possibly due to non-availability of technology for its conversion to value added products and developments of taste and social consideration, they are used in flour form in traditional recipes or used as animal feed.

Legumes are particularly high in protein, mineral, cholesterol-free, high in dietary fibers and low in saturated fat. India is the largest producer of mungbean (*Vigna radiata*) and is 3rd most important pulse crop of India (Choudhary *et al*., 2011) which is rich in quality proteins, minerals and vitamins. It is an inseparable ingredient in the diets of vast majority of population in the Indian subcontinent.

Extrusion cooking, as a multi-step, multi-functional and thermal/mechanical process, has permitted a large number of food applications. An extruder conveys, mixes, kneads, cooks and forms in one continuous process. In addition, the extrusion process denatures undesirable enzymes; inactivates some anti-nutritional factors (Trypsin inhibitors, haemagglutinins, tannins and phytates). Sorghum proteins contain more cross-linked prolamines than other cereals, which reduce digestibility and functionality of sorghum flour. Therefore, there is a need for sorghum-based foods with higher protein content and digestibility. Extrusion processing of sorghum flour has been shown to improve sorghum protein solubility and functionality. High-temperature, short-time extrusion cooking could be used to produce sorghum-based snack products of high nutritional quality and in a ready-to-eat form. In view of these, the project was undertaken to optimize process parameters for extrusion cooking of sorghum based products.

MATERIALS AND METHODS

The study was conducted at College of Agricultural Engineering, Bapatla and Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur, India. A twin screw extruder (BTPL-EB-10 Lab Model) with co-rotating screws was used for conducting experiments. The raw materials were procured from local markets of Vijayawada, Andhra Pradesh, India. The blend levels were selected based on the conclusions of previous studies (Pawar *et al.,* 2009).

Preparation of samples

The samples were prepared from process parameters including three different blends of sorghum, broken rice and green gram in the ratios of (7:2:1, 6:3:1, 5:4:1) at feed moisture content (12%, 14%,16%) and operational parameters of the extruder like barrel temperature (110, 120 and 140^{0}C) and screw speed (150, 200 and 250 rpm). All the flours were weighed and the moisture was adjusted by sprinkling water in the flours and mixed to prepare a homogeneous mix. After mixing the samples were stored in polyethylene bags at room temperatures for 12- 24 hrs. The samples were sieved and poured in to feed hopper and extruded. A die diameter of 3 mm was selected and the product was collected at the die end.

Evaluation of extrudates

Expansion ratio

The expansion ratio (ER) for the extrudates was calculated by dividing the square of extrudate diameter (D) by the square of die diameter (d_{die}). Each value was an average of ten samples with three measurements. The diameter of the sorghum based extruded products was measured using digital callipers.

$$\text{Expansion ratio} = \frac{D^2}{d^2}$$

D= diameter of the sample, mm

D= diameter of the die, mm

Bulk density

A cylindrical section of extrudate was weighed and the diameter was measured using a vernier calliper. The bulk density of the sorghum based extruded products were then calculated as the ratio of the weight of the extrudate to the volume of extrudate.

$$\rho = \frac{w}{\pi d^2 \frac{l}{4}}$$

l= length of extrudates, mm

d= diameter of extrudate, mm

m= mass of the sample, g

Sensory evaluation

Sensory evaluation of samples was carried out for consumer acceptance and preference using 7 untrained panellists selected at random from the College of Agricultural Engineering, ANGRAU, Bapatla. Taste, color and overall acceptability of the samples were rated using a 9-point hedonic scale where 9 and 1 represent like extremely and dislike extremely respectively. Sensory evaluation was carried out at ambient conditions in a comfortable and quiet area without disturbance under fluorescent lighting. Water was supplied to cleanse the palate between samples.

RESULTS AND DISCUSSIONS

A total of 81 samples were prepared from different process parameters and different operational parameters and were optimized for physical and sensory properties.

Evaluation of extrudates

Expansion ratio of the sorghum based extruded products

The expansion ratios of the samples prepared from 12% m.c (w. b) are shown in Table 1. The expansion ratio of the products ranged from 1.82 cm to 0.95 cm (Fig 1). From the graph it was observed that the treatment S_3 has the highest expansion ratio. The expansion ratios of the products prepared from 14% m.c (w. b) moisture content are shown in Table 2&Fig 2. From the

Table 1. Expansion ratio and Bulk density of the sorghum based extruded samples at 12% m.c (w. b) at different process parameters.

SNo.	Treatment	Blends	Moisture content (w. b)	Screw speed (rpm)	Temperature (^{0}C)	Expansion ratio	Bulk density(g/cc)
1	S_1	1	12	150	110	1.46	0.53
2	S_2	2	12	150	110	1.61	0.49
3	S_3	3	12	150	110	1.82	0.45
4	S_4	1	12	200	110	1.50	0.51
5	S_5	2	12	200	110	1.60	0.5
6	S_6	3	12	200	110	1.78	0.47
7	S_7	1	12	250	110	1.48	0.51
8	S_8	2	12	250	110	1.58	0.51
9	S_9	3	12	250	110	1.61	0.49
10	S_{10}	1	12	150	120	1.48	0.51
11	S_{11}	2	12	150	120	1.50	0.51
12	S_{12}	3	12	150	120	1.61	0.49
13	S_{13}	1	12	200	120	1.40	0.57
14	S_{14}	2	12	200	120	1.62	0.48
15	S_{15}	3	12	200	120	1.57	0.51
16	S_{16}	1	12	250	120	1.38	0.57
17	S_{17}	2	12	250	120	1.53	0.51
18	S_{18}	3	12	250	120	1.60	0.49
19	S_{19}	1	12	150	140	1.48	0.52
20	S_{20}	2	12	150	140	1.45	0.53
21	S_{21}	3	12	150	140	1.62	0.48
22	S_{22}	1	12	200	140	1.35	0.57
23	S_{23}	2	12	200	140	1.44	0.56
24	S_{24}	3	12	200	140	1.55	0.51
25	S_{25}	1	12	250	140	1.30	0.58
26	S_{26}	2	12	250	140	1.45	0.55
27	S_{27}	3	12	250	140	1.48	0.53

Fig 1. Effect of various treatments on expansion ratio of the sorghum based extruded samples at 12 % m.c (w. b)

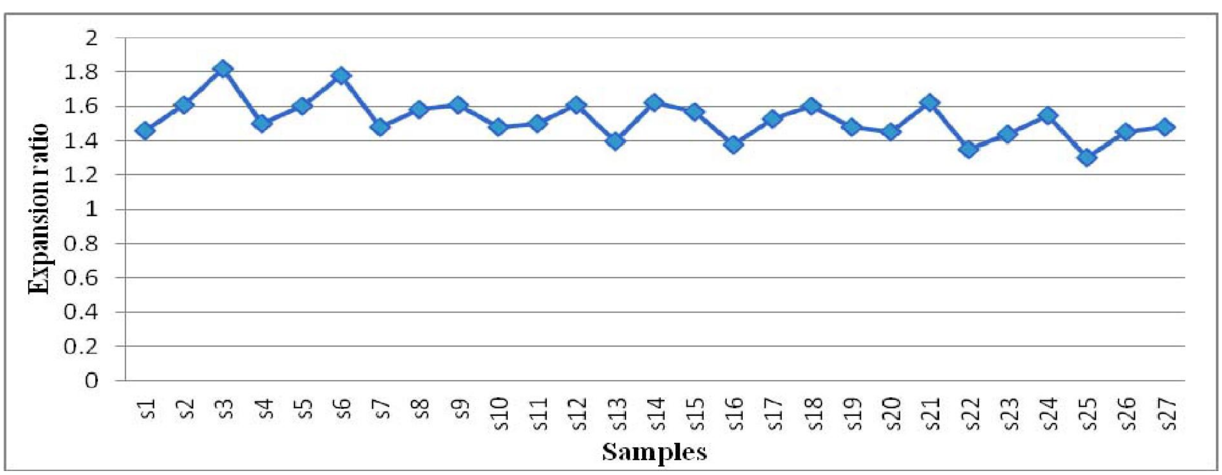


Table 2. Expansion ratio and Bulk density of the sorghum based extruded samples at 14%m.c (w. b) different process parameters.

SNo.	Treatment	Blends	Moisture content (w. b)	Screw speed (rpm)	Temperature (^{0}C)	Expansion ratio	Bulk density(g/cc)
1	M_1	1	14	150	110	1.31	0.65
2	M_2	2	14	150	110	1.39	0.62
3	M_3	3	14	150	110	1.31	0.65
4	M_4	1	14	200	110	1.26	0.66
5	M_5	2	14	200	110	1.30	0.62
6	M_6	3	14	200	110	1.34	0.64
7	M_7	1	14	250	110	1.25	0.66
8	M_8	2	14	250	110	1.15	0.61
9	M_9	3	14	250	110	1.32	0.64
10	M_{10}	1	14	150	120	1.38	0.62
11	M_{11}	2	14	150	120	1.38	0.62
12	M_{12}	3	14	150	120	1.37	0.63
13	M_{13}	1	14	200	120	1.39	0.62
14	M_{14}	2	14	200	120	1.43	0.61
15	M_{15}	3	14	200	120	1.47	0.59
16	M_{16}	1	14	250	120	1.32	0.65
17	M_{17}	2	14	250	120	1.34	0.64
18	M_{18}	3	14	250	120	1.33	0.61
19	M_{19}	1	14	150	140	1.27	0.66
20	M_{20}	2	14	150	140	1.35	0.64
21	M_{21}	3	14	150	140	1.48	0.57
22	M_{22}	1	14	200	140	1.48	0.57
23	M_{23}	2	14	200	140	1.38	0.62
24	M_{24}	3	14	200	140	1.47	0.58
25	M_{25}	1	14	250	140	1.33	0.65
26	M_{26}	2	14	250	140	1.40	0.62
27	M_{27}	3	14	250	140	1.46	0.60

Fig 2. Effect of various treatments on expansion ratio of the sorghum based extruded samples at 14% m.c.(w. b).

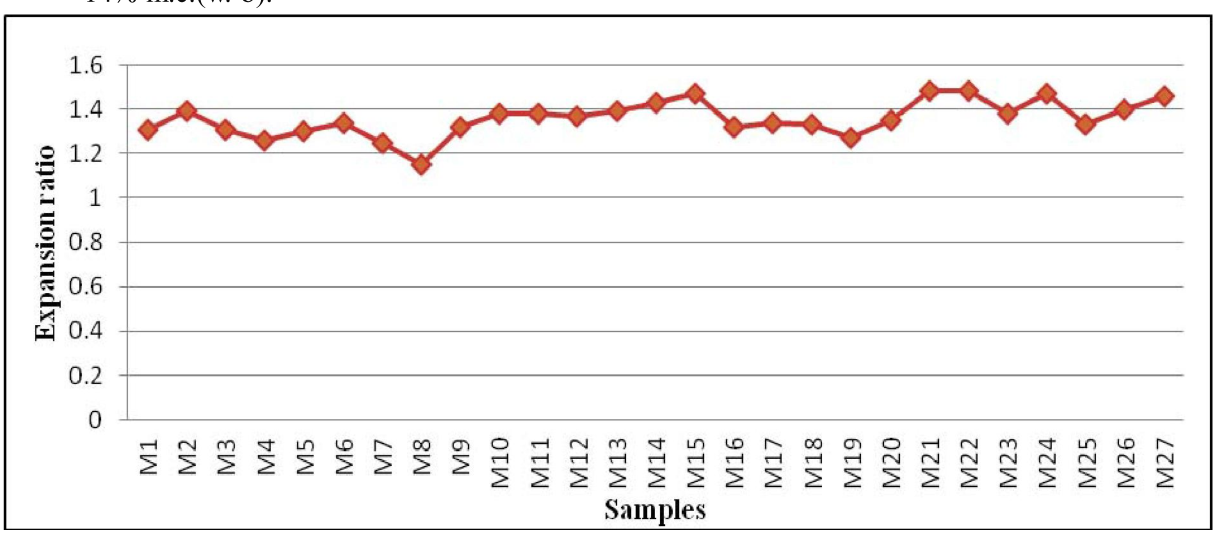


Table 3. Expansion ratio and Bulk density of the sorghum based extruded samples at 16 %m.c (w. b) different process parameters.

SNo.	Treatment	Blends	Moisture content (w. b)	Screw speed (rpm)	Temperature (^{0}C)	Expansion ratio	Bulk density (g/cc)
1	L_1	1	16	150	110	1.1	0.84
2	L_2	2	16	150	110	0.95	0.90
3	L_3	3	16	150	110	0.98	0.89
4	L_4	1	16	200	110	1.19	0.80
5	L_5	2	16	200	110	1.23	0.77
6	L_6	3	16	200	110	1.27	0.72
7	L_7	1	16	250	110	1.15	0.83
8	L_8	2	16	250	110	1.16	0.82
9	L_9	3	16	250	110	1.16	0.82
10	L_{10}	1	16	10	120	1.09	0.85
11	L_{11}	2	16	150	120	1.01	0.86
12	L_{12}	3	16	150	120	1.1	0.84
13	L_{13}	1	16	200	120	1.14	0.83
14	L_{14}	2	16	200	120	1.19	0.80
15	L_{15}	3	16	200	120	1.09	0.76
16	L_{16}	1	16	250	120	1.22	0.77
17	L_{17}	2	16	250	120	1.21	0.79
18	L_{18}	3	16	250	120	1.26	0.73
19	L_{19}	1	16	150	140	1.06	0.86
20	L_{20}	2	16	150	140	1.05	0.86
21	L_{21}	3	16	150	140	1.14	0.69
22	L_{22}	1	16	200	140	1.14	0.83
23	L_{23}	2	16	200	140	1.24	0.75
24	L_{24}	3	16	200	140	1.36	0.68
25	L_{25}	1	16	250	140	1.19	0.80
26	L_{26}	2	16	250	140	1.22	0.78
27	L_{27}	3	16	250	140	1.31	0.69

Fig 3. Effect of various treatments on expansion ratio of the sorghum based extruded samples at 16%m.c.(w. b)

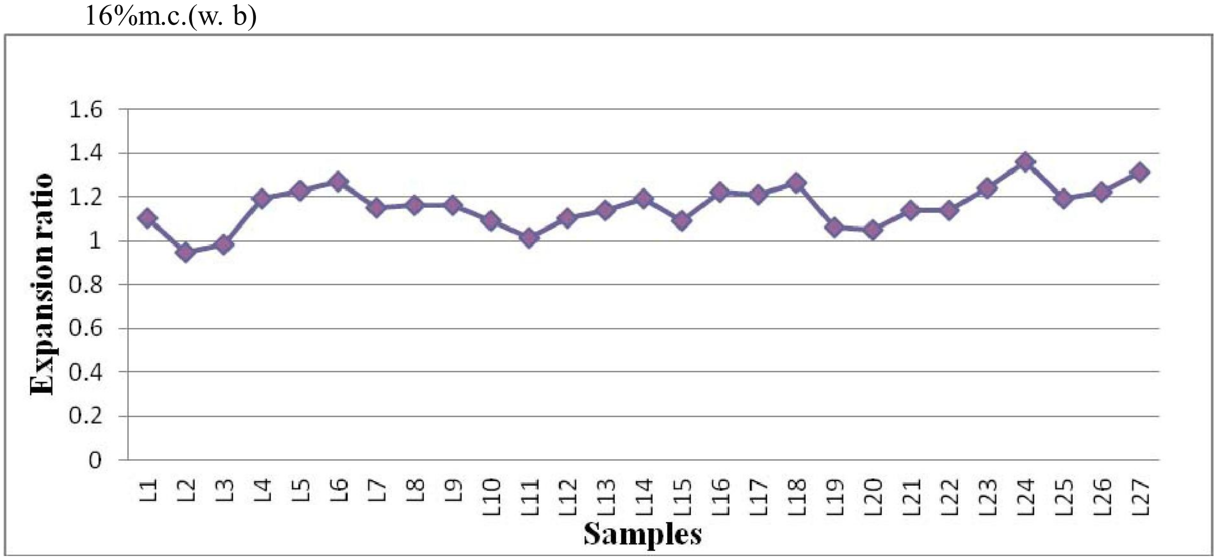


Fig 4. Effect of various treatments on bulk density of the sorghum based extruded samples at 12 % m.c.(w. b).

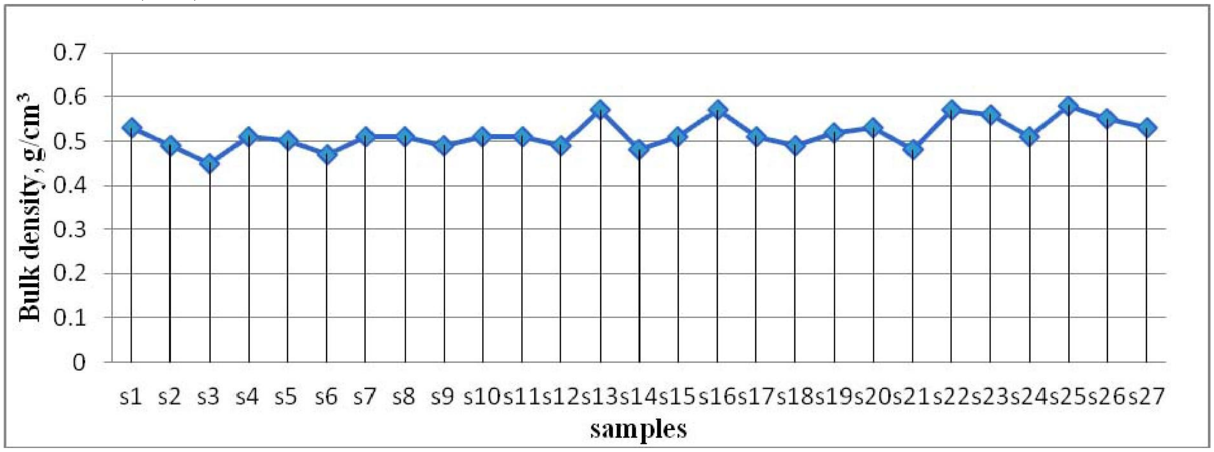


Fig 5. Effect of various treatments on bulk density the sorghum based extruded samples at 14%m.c (w. b).

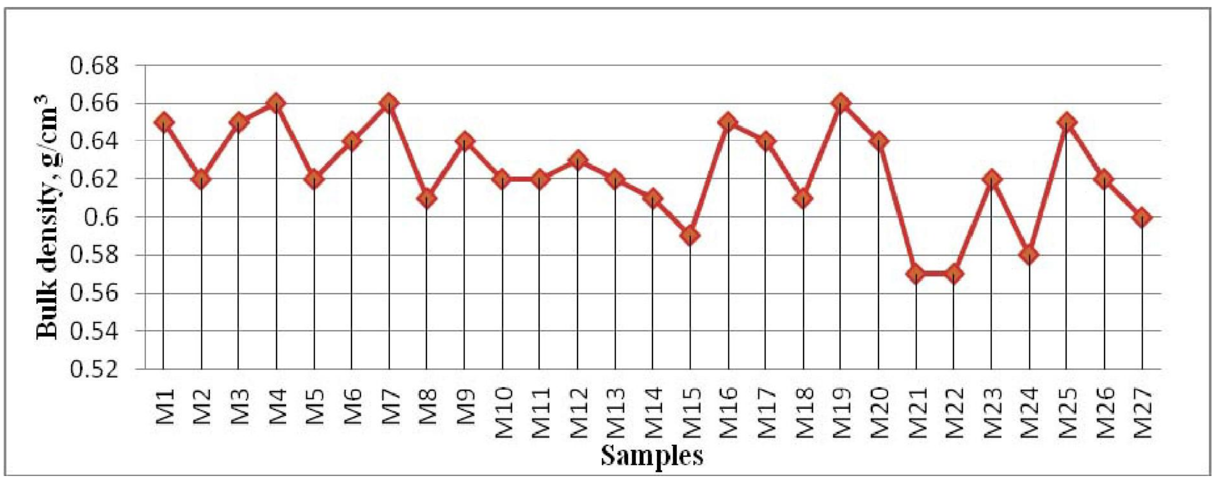


Fig 6. Effect of various treatments on bulk density the sorghum based extruded samples at 16 % m.c (w. b).

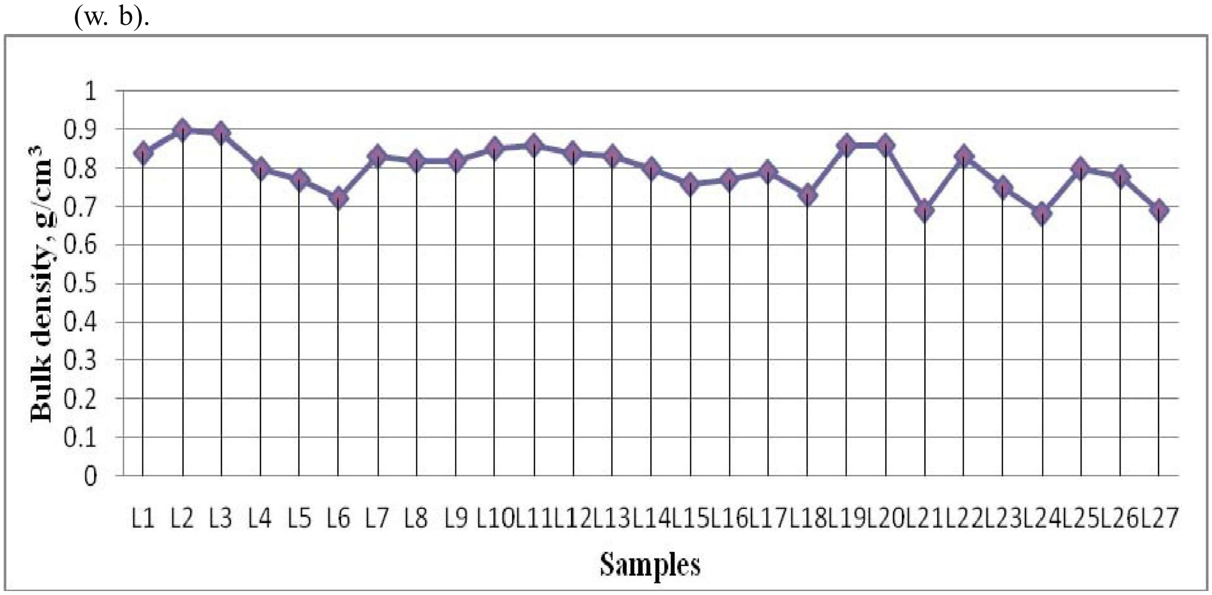
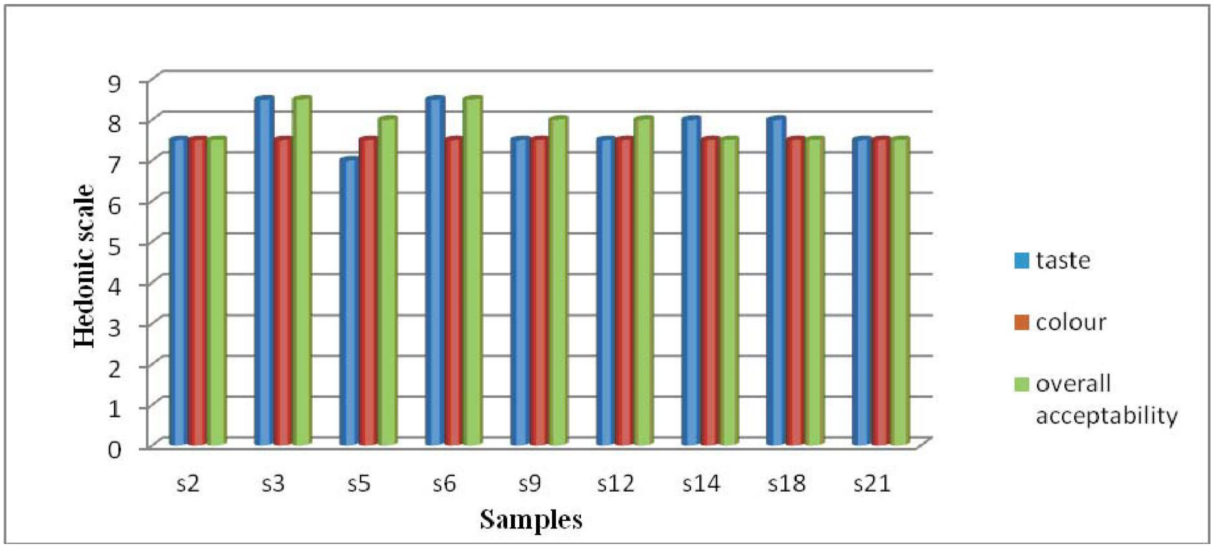


Fig 7. Organoleptic evaluation of the sorghum based extruded product samples.



graph it was observed M_{21} &M_{22} has the highest expansion ratios. The expansion ratios of the products prepared from 16% m.c (w. b) moisture content are shown in Table 3&Fig 3. From the graph it was observed L_{24} has the highest expansion ratio.

Expansion is the most important physical property of the snack food. Starch, the main component of cereals plays major role in expansion process (Kokini *et al*., 1992). Increasing the level of rice flour and decreasing the level of sorghum protein will facilitate formation of starch matrix and increase water trapping, thus increasing expansion. The increase in the feed moisture and barrel temperature decreased the expansion ratio of the extrudate. Similar trend was observed in sorghum based extrudates (Mahesh *et al.,* 2012).

Bulk density

The bulk density of the samples ranged from 0.45 g/cm^3 to 0.90 g/cm^3. The bulk density decreases with increase in barrel temperature which may be attributed to higher starch gelatinization at higher temperature resulting in greater expansion. The bulk density increased with the increase in moisture content at higher temperatures only, which might be due to change in the molecular structure of extrudates. Similar reduction of rice extrudates density caused by increased barrel temperature has been reported by (Ilo *et al.,* 1999). The bulk density of the samples prepared 12-16 % m.c. (w.b) are shown in Fig 4-6.

Sensory evaluation

The samples with higher expansion ratio and lower bulk density values were taken for sensory analysis. The sensory evaluation showed that the extrudates prepared from 5:4:1 blend ratio were more acceptable.

Conclusions

After complete evaluation of extrudate characteristics like expansion ratio, bulk density and sensory evaluation it was found that the increase in moisture content of the feed reduced expansion ratio with increased bulk density, while increase in temperature also reduced expansion ratio. The screw speed had negligible effect. The expansion ratio was higher for sample prepared at 12% moisture content (w. b), 110^{0}C and 150 rpm. The bulk density was lower for sample with higher expansion ratio. The samples with higher expansion ratio and lower bulk density values were selected for sensory evaluation. The optimum conditions for acceptable extrudates was 12% moisture content (w. b), 110- 140^{0}C barrel temperature and 150- 250 rpm screw speed and 6:4:1 blend ratio.

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