Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 1356-1361
Received: 05-05-2018
Accepted: 10-06-2018

Dayakar Rao B
Principal Scientist, ICAR-Indian Institute of Millets Research, Telangana, India

Suneetha A
Research associate, ICAR-Indian Institute of Millets Research, Telangana, India

Srenuja D
Senior research fellow, ICAR-Indian Institute of Millets Research, Telangana, India

Kiranmai E
Senior research fellow, ICAR-Indian Institute of Millets Research, Telangana, India

Correspondence
Dayakar Rao B
Principal scientist, ICAR- Indian Institute of Millets Research, Telangana, India

Standardization of sorghum based extruded snacks by using hot extrusion technology

Dayakar Rao B, Suneetha A, Srenuja D and Kiranmai E

Abstract
The present study was focused on the utilization of Sorghum millet with the composite flours for developing Ready-To-Eat foods in snacks category by using hot extrusion cooking technology. The ultimate objective is to value addition to Sorghum millet and other subtropical crops to enable their commercialization and also to conduct storage studies for the developed extruded products. Composite flours were prepared using whole Sorghum millet flour and other flours namely rice flour, besan flour, corn flour and corn semolina. Extrusion cooking was carried out using a twin screw extruder at optimized extrusion parameters. Effect of process parameters like temperature (135 °C), screw speed (25 Hz) and feeder speed (11Hz) on physical properties (expansion ratio, bulk density and hardness) of extrudate samples and proximate composition (Moisture, ash protein and fat) were investigated. Effect of extreme and initial process conditions on functional and proximate quality of the extrudates were also evaluated. And also storage characteristics of the extruded sorghum products were conducted. The products were packed in LDPE (Low density polyethylene) and ALPE (Aluminum lined polyethylene) and stored for 3 months and analyzed for every 15 days interval. The moisture content, protein, fat, hardness and sensory score were analyzed. The moisture content of the samples packed in LDPE showed increase in moisture content.

Keywords: twin screw extrusion, composite flour, physical properties, sensory evaluation

Introduction
Millets are important ecological food security crops known for their nutritional quality and can be an immediate subsistence food for a nutrient-scarce community. Millets are known for drought resistance and need very little resources for their growth (Joshi *et al*. 2008). Although recognized as nutritious cereals, they are generally absent in commercial channels; rather they are little explored for the possibility of developing novel food products using new processing technologies.

Sorghum is a tropical plant belonging to the family of *Poaceae*, is one of the most important crops in Africa, Asia and Latin America (Anglani, 1998). More than 35% of sorghum is grown directly for human consumption. The rest is used primarily for animal feed, alcohol production and industrial products (FAO, 1995 and Awika and Rooney, 2004a). Sorghum (*Sorghum bicolour* L.) is the fourth most important cereal consumed and cultivated in India during both rainy (kharif) and post-rainy (rabi) seasons. And it is a cheap source of energy, protein, iron and zinc next only to pearl millet among all cereals and pulses. However, it is popularly grown for feed, fodder and more recently for bio-fuel purposes in the world. As sorghum is rich in starch and protein (*kafirin*), it can be regarded as substitute for the cereals that are presently used for the production of ready to eat (RTE) snacks. High temperature, short-time (HTST) extrusion cooking could be used to produce sorghum-based extruded snacks of high nutritional quality and in a ready-to-eat form.

Extrusion is one of the commonly adopted processing techniques by food industries which employ mixing, forming, texturing and cooking to develop a novel food product (Singh *et al*., 2016; Gulati, 2016) [11]. Extrusion technology is now widely used in the agri food processing industry, where it is referred to as extrusion cooking. Food material reaches to its melting point or plasticizing point when shear energy exerted by rotating screw heats the barrel. It is one of the contemporary food processing technologies applied for development of variety of snacks, specialty and supplementary foods and offers advantages of preparation of ready-to-eat foods of desired shape, size, texture and sensory characteristics at very low processing cost. The extrusion process has a potential in generating quality snack products. The effect of extrusion variables on the properties of extrudates has been studied extensively. A good quality snack is the result of right combination of all the process parameters which needs to be studied and optimized. This neglected millet can be explored for value addition by extrusion cooking. Thus Sorghum millet-composite flour blend was extruded to investigate the effect of process parameters viz., screw speed, feeder speed and temperature on attributes like bulk density, expansion ratio, hardness, and crispiness. Extreme and initial process conditions were selected within the range studied to study the effect of selected process conditions on proximate and functional properties of the extrudates.

Materials and Methods

Sample preparation

Sorghum was collected from Indian Institute of Millets Research stores and Maize was procured from Maize Research Institute- Hyderabad. Both the grains were cleaned then ground to pass Sorghum 22 µ and Maize 16 µ through sieve. Other raw materials ware procured from local market of Hyderabad and analyzed for moisture, protein, fat, and ash contents (AOAC 1984).

Composite flour preparation

Blends were prepared by mixing Sorghum millet flour and other flours namely; rice flour, besan flour, corn flour and corn semolina 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 mixed continuously. The feed material was then allowed to stay for half an hour 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) [1].

Table 1: Composite flours compositions

Name of ingredient	Composite Flours Preparation			
	T_1	T_2	T_3	T_4
Jowar semolina	48.00	49.00	50.00	49.00
Corn semolina	28.43	35.00	15	0.00
Corn flour	0	0	20.00	35.00
Bengal gram flour	4.73	8.00	8.00	8.00
Rice flour	9.47	6.00	5.00	6.00
Wheat flour	6.37	0.00	0	0
Salt	2.00	2.00	2.00	2.00

Packaging materials

HDPE is defined by a density range of 0.940 to 0.965 g/cm^3. It is not reactive at room temperatures, except by strong oxidizing agents, and some solvents cause swelling. It can withstand temperatures of 80 °C continuously and 95 °C for a short time. Made in translucent or opaque variations, it is quite flexible and tough and moisture resistant.

Aluminum's ability to form any shape and its protective qualities has made it the most versatile packaging material in the world. An aluminum lined polyethylene is a type of food packaging made from a laminate of flexible plastic and metal foils. It allows the sterile packaging of a wide variety of foods. It is hygienic, non-toxic, retains flavor and protects from moisture, light and gases.

Extrusion cooking

Extrusion is a compressive deformation process in which a block of metal is squeezed through an orifice or die opening in order to obtain a reduction in diameter and increase in length of the material block. 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 (Deshpande *et al*., 2011) [13]. The temperature of the four barrel zones of extruder from feeder end were set at 30oC and 150oC respectively. Samples were collected at the most stable die temperature which was around 135oC. Screw speed was set up at 320 rpm and equipped with 3-mm restriction die to extruder. Constant feeding 12 rpm 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 physical characteristics

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

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

Bulk density

Bulk density (BD) was measured by measuring the actual dimensions of the extrudates and calculated as ratio of weight of product to its volume (Asare *et al*. 2004).

$$\text{Bulk density} = \frac{4 \times \mathrm{m}}{\pi \times \mathrm{d}^2 \times \mathrm{l}}$$

Where,
L =Length of extrudate (cm)
d =Diameter of extrudate (cm)
m=Mass of sample (g)

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 gms 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,

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

$$\text{WSI} = \frac{\textit{Weight of Dissolved in Supernatant}}{\textit{Weight of Dry solids}}$$

Estimation of moisture content

Moisture content of the samples was determined by using hot air oven method for every 15 days. A sample of 5gm was accurately measured into a clean and dry moisture boxes of known weight and dried in a hot air oven at 105^{0}C for 12-15 hrs, cooled in a desiccators and weighed (AOAC, 1990) [1].

$$\text{Moisture content} = \frac{\text{Initial weight} - \text{final weight}}{\text{Sample weight}} \times 100$$

Estimation of protein content by micro kjeldahl method (AOAC, 1990) [1]

Reagents

The reagents required for digestion, distillation and titration are given below respectively.

Digestion

1. 98% pure concentrated Sulphuric acid 10ml per sample.
2. Catalyst mixture or digestion mixture or activator (5:1) for each tube. Potassium sulphate (100gm) and copper
3. sulphate (20gm).

Distillation

1. 40% NaOH (400gm of NaOH in 1liter of distilled water)-40ml per sample.
2. 4%Boric acid: 40gm in lit of distilled water-25ml/sample.
3. Mixed indicator: 2parts of methyl red indicator, 1 part of Bromocresol green.

Titration

1. 0.1N HCl or H_2 $S0_4$

Calculations

The percentage of nitrogen present in the given sample

$$= \frac{(\text{sample titre value} - \text{blank titre}) \times \text{No o f acid} \times 14 \times 100}{Sample\ weight \times 1000}$$

The percentage of protein present in the given sample = % N × 6.25 factor

Sensory evaluation

The sensory assessments were conducted in COE laboratory, Indian Institute of Millets Research. The panel of 20 members consisted of staff and project trainee students of the College of Food Technology, Bapatla and Central University of Agriculture, Dehradun. The panelists were naive to project objectives. Samples (T_1, T_2, T_3 & T_4) flavored with Magic masala spice powder was used in the evaluation. Samples were coded randomly and served with the order of presentation counter-balanced. Panelists were provided with a glass of water and instructed to rinse and swallow water after testing every sample. Panelists are evaluated all samples based on its the based for acceptability based on its flavor, texture, taste, color and overall acceptability using seven-point hedonic scale (1 = dislike very much to 7 = like very much; Meilgaard *et al*., 1999).

Results and Discussion

Physical and Chemical characteristics

All the trails T_1, T2, T3 and T_4 have been done at constant machine operation settings and standard product quality parameters likewise feed rate, temperature and screw speed and flour particle size and moisture respectively. The effects of composite flours on physical and chemical properties of samples are tabulated in Table 2. Water absorption index (WAI) measures the volume occupied by the extrudate starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. The water absorption index was found to be more for extruded sample – T4 (6.1±0.11) followed by extruded sample –T3 (5.7±0.079). Table 2 showed that the water absorption index of the extrudates increased with increase of Sorghum flours in the composite mixes. The water solubility index was more for the extrudates made from composite mix sample – T1 (0.5±0.018) followed by extruded sample –T2 & T3(0.4±0.011& 0.41±0.01), and WSI was less for the extrudates prepared from composite mix sample T3 - (0.33±0.011). The water solubility index of the extrudates increased when Bengal gram flour incorporation in the composite mix samples. These results are in conformity with the observations made by Shirani and Ganeshranee (2009) [11].

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 0.06 to 0.166 g cm-3. Bulk density was minimum for extruded Sample –T4 (0.06 g cm-3) followed by extruded Sample – T3 (0.1 g cm-3) while maximum bulk density for extruded Sample– T1 (0.166g cm-3) followed by extruded Sample – T2. The higher bulk density may be due to the presence 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) [11], Deshpande *et al.* (2011) [13].

Table 2: Physical and Chemical characteristics of different Sorghum based extrudates

Parameters	T_1	T_2	T_3	T_4
WAI	4.8±0.11	4.6±0.18	5.7±0.079	6.1±0.11
WSI	0.5±0.018	0.4±0.011	0.41±0.018	0.33±0.011
Expansion ratio	2.76±0.02	3.155±0.023	3.28±0.13	3.247±0.03
Bulk Density	0.166±0.002	0.106±0.002	0.1±0.001	0.06±0.001
Hardness	5080±656	5682±750	4625±766	4761±215
Fracturability	1198±367	1763±821	4761±215	1978±271
Moisture%	3.01±0.05	5.21±0.09	3.53±0.01	2.48±0.02
Protein (g)	15.41±1.016	15.18±0.122	16.01±0.122	12.81±0.214
Ash%	0.55±0.02	0.55±0.01	0.45±0.01	0.45±0.01
Fat%	2.16±0.10	2.22±0.07	2.13±0.03	1.9±0.04

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. There no significant change in expansion ratio of T3, T4 and T3 fallowed by sample T1. This decrease in expansion ratio could be because of high level of Sorghum 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. Similar findings were reported by Singh *et al.* (1996) [11], Deshpande *et al.* (2011) [13].

The moisture level was the highest in T2 followed by T3, T1 and T4 samples. However, optimum moisture level was seen (<14 %) in all the extrudate samples. The protein content was highest in T3, followed by T1, T2 and T4.The ash content was highest in T1& T2 followed by T3& T4 samples. Fat is high in T2 followed by T1, T3 and T4.

Sensory characteristics

After seasoning all the samples (T_1, T_2, T_3 & T_4) were evaluated for sensory analysis by 20 Panelists. In the present study color, flavor, texture, taste, mouth feel and overall acceptability were selected parameters for the Sensory evaluation by using Seven-point hedonic scale (1 = dislike very much to 7 = like very much; Meilgaard *et al.*, 1999). All scores are tabulated in Table.3 and graphically shown in Figure. 1. T_2 sample was good in Color parameter next falling to T_3, T_4 and T1 samples. Flavor has appealed great in T_3 sample followed by T_2, T_4 and T_1 samples. Texture was highly significant for T_3 sample than T_4, T_2 & T_1 samples. T_3 sample gave very fine taste when compared to other samples T_2, T_4& T_1 samples. For Mouth feel parameter T_3 sample has scored better when compared to other samples T_2, T_4&T_1 samples. For T_3 sample overall acceptabilityis 5.69 which has attained well scoring and followed by T_2 (5.10), T_4 (4.07) & T_1 (3.10). By conducting sensory evaluation, it has shown that T_3sample was par excellence than other samples T_2, T_4 and T_1.

Table 3: Sensory evaluation of different trails Sorghum based extrudates

Parameters	T_1	T_2	T_3	T_4
Color	3.00	5.40	5.30	3.84
Flavor	3.25	4.84	5.20	3.30
Texture	2.75	5.15	5.90	5.76
Taste	3.33	5.30	5.70	3.91
Mouth feel	3.00	4.60	6.00	3.15
Overall acceptability	3.10	5.10	5.69	4.07

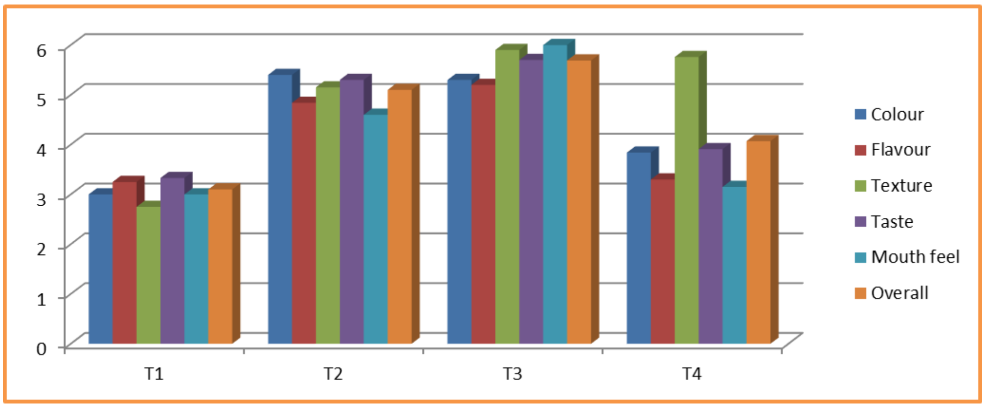

Fig 1: Graphical representationon Sensory evaluation of different trails Sorghum based extrudates

Effect of packaging material on Sensory parameters for T_3 selected sample

Among all trail samples, T3 trail sample has got good score by using 7-point hedonic scale. So,T3 sample was selected for Shelf life study with two different packaging materials. The shelf life study was conducted up to 90 days and analyzed samples for every 15 days of interval. All values are noted and tabulated in Table.4 and graphically shown in Figure.2

Table 4: Effect of packaging material on Sensory parameters for T3 selected sample

	0th day	15th day		30th day		45th day		60th day		90th day	
Parameters		**ALPE**	**HDPE**	**ALPE**	**HDPE**	**ALPE**	**HDPE**	**ALPE**	**HDPE**	**ALPE**	**HDPE**
Color	6.10	6.10	6.33	6.00	6.09	6.10	5.14	6.11	5.14	6.01	5.13
Flavor	6.50	6.60	6.22	6.10	5.27	5.70	4.14	5.66	4.14	5.00	3.80
Texture	6.50	6.70	6.22	6.10	6.27	5.60	4.71	5.22	5.14	4.10	3.10
Taste	6.60	6.60	6.33	6.20	5.54	5.80	4.85	5.55	4.14	4.00	3.00
Mouth feel	6.40	6.60	6.20	6.20	5.72	5.80	4.85	5.44	4.42	4.00	3.00
Overall	6.50	6.50	6.40	5.80	5.63	5.70	5.00	5.55	4.71	4.00	3.00

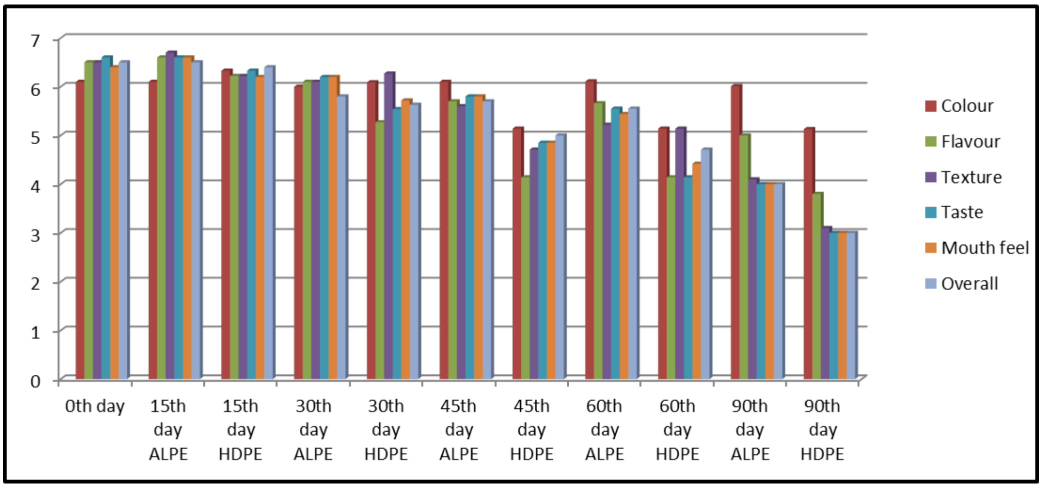

Fig 2: Graphical representation of packaging material effects in sensory parameters of T_3 samples

Effect of physical and chemical parameters during shelf life study for T_3 sample

All T3 samples were analyzed for both physical and chemical parameters likewise Hardness, Fracturability, WAI & WSI and moisture, ash, protein & fat respectively. Moisture is highly inclined in HDPE than ALPE packaging. Protein is decreased in both packaging materials but slightly stable in ALPE than HDPE material. Ash content in both packaging materials is standard and slightly varies.

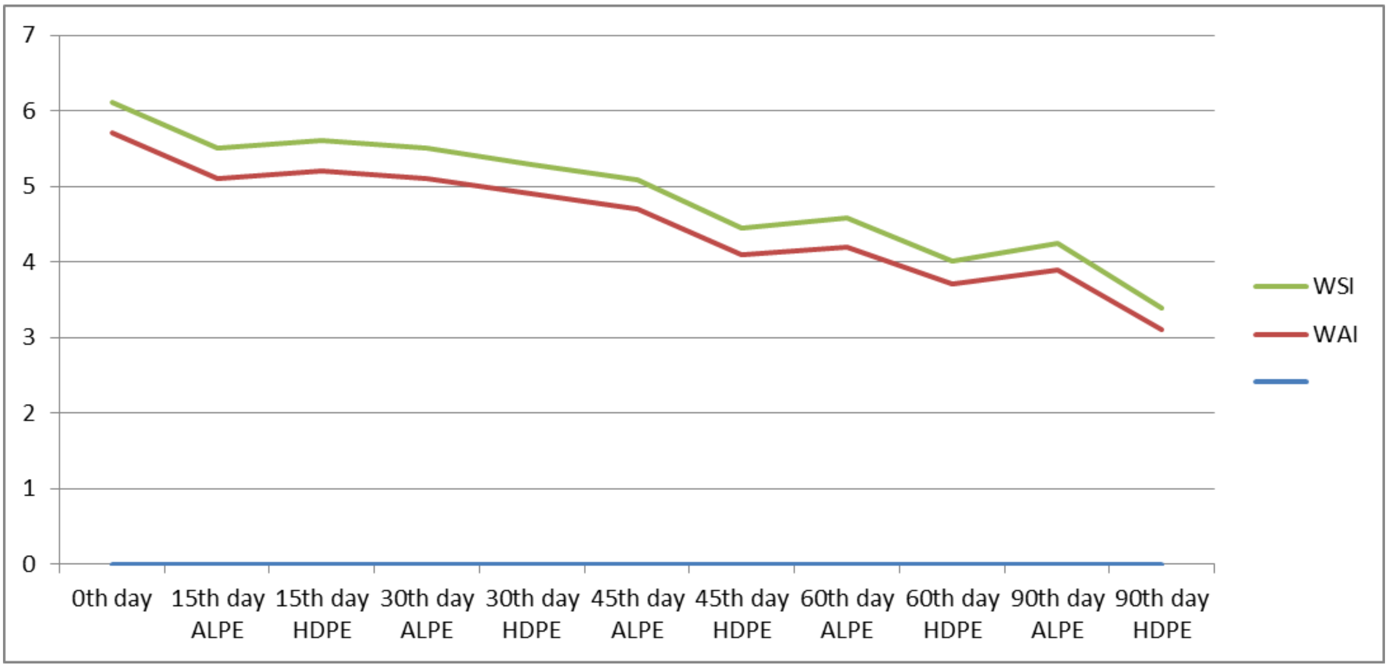

Fig 3: Graphical representation of analysis variations of WSI & WAI for T_3samples in ALPE and HDPE packaging materials

Table 5: Effect of packaging material on Physico-chemical Properties

	0th day	15th day		30th day		45th day		60th day		90th day	
Parameters		ALPE	HDPE	ALPE	HDPE	ALPE	HDPE	ALPE	HDPE	ALPE	HDPE
Moisture %	3.53	4.10	4.50	4.94	5.31	4.90	5.40	5.30	5.80	5.60	5.90
Protein (g)	12.87	13.99	13.45	13.94	13.54	13.89	13.66	13.54	13.53	12.99	12.96
Ash %	0.45	0.40	0.43	0.42	0.43	0.42	0.43	0.44	0.41	0.42	0.42
WAI	5.70	5.10	5.20	5.10	4.90	4.7	4.10	4.20	3.70	3.90	3.10
WSI	0.41	0.41	0.40	0.41	0.38	0.39	0.35	0.39	0.31	0.35	0.29
Fat%	6.08	6.12	6.35	6.31	6.64	6.35	6.78	6.43	7.20	6.90	7.30
Hardness	4625	3831.67	4851.67	3553.33	6885.00	3660.33	6308.67	4135.00	5348.33	4108.33	6138.67
Fracturability	4761	475.00	1515.00	455.00	4045.00	507.00	3361.33	568.33	3313.33	1629.67	1388.33

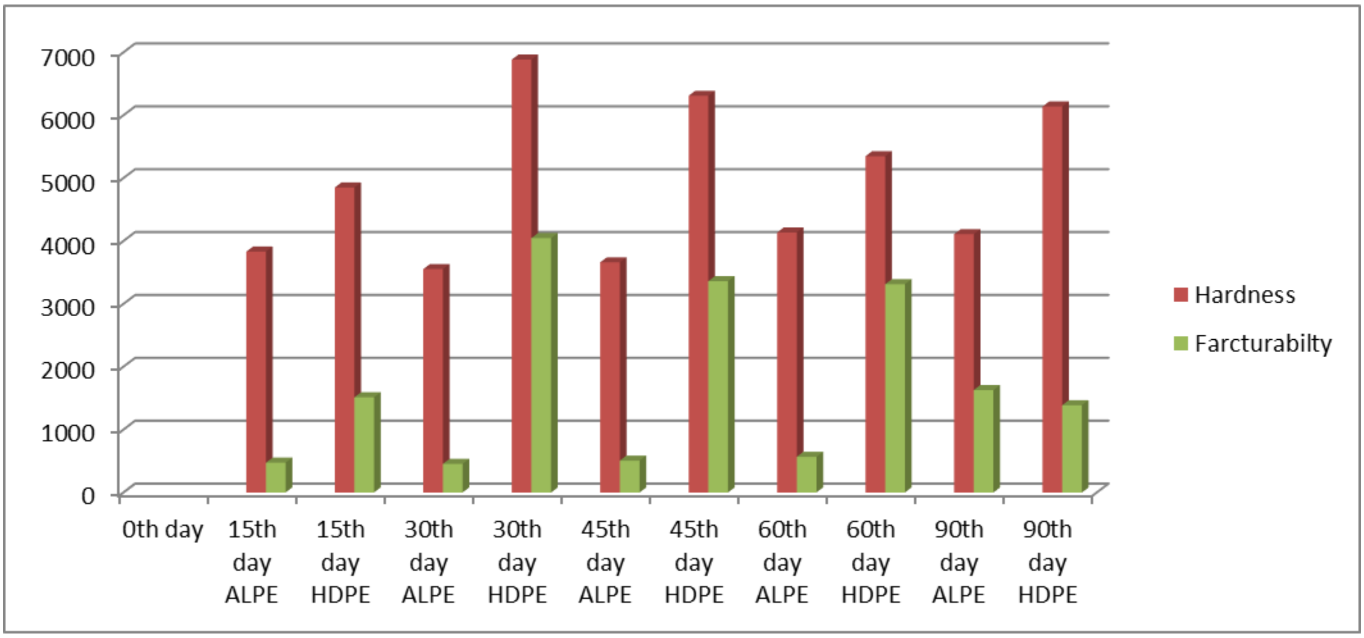

Fig 4: Graphical representation of Hardness and Fracturability analysis variations of T_3 samples in ALPE and HDPE

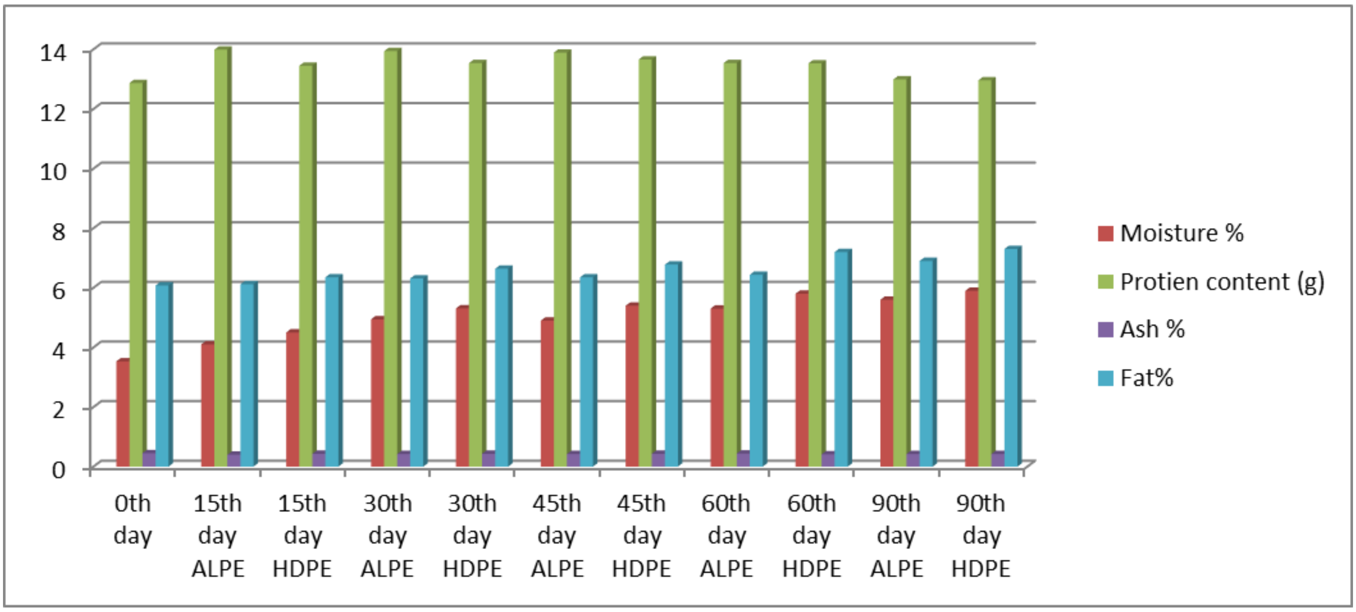

Fig 5: Graphical representation of proximate analysis variations of T_3 samples in ALPE and HDPE

Conclusion

The present study revealed that, composite flour (whole Sorghum millet flour and rice flour, Bengal gram flour. flour, corn flour and corn semolina) could be used to produce quality extrudates with acceptable sensory properties. And also the effect of two different packing materials LDPE and ALPE on the shelf life of the products were studied. The extruded products were packed and stored at ambient temperatures. After evaluating the samples it was observed that the moisture content of the samples packed in LDPE showed increase where, samples packed in ALPE showed decrease in moisture content. The study showed that the shelf life of the extruded products at ambient temperatures can be increased by using ALPE which have better barrier properties.

References

1. Association of Official Analytical Chemists (AOAC). Official methods of analysis of AOAC. Volume II, Association of Official Chemists, Washington. 1990.
2. Association of Official Analytical Chemists (AOAC). Official Methods of Analysis of the AOAC International. 18th edn. Gaithersburg, MD, USA, 2005.
3. Abbott P. Co-extrusion: Recent developments using cooking Extruder. Cereal Foods World. 1987; 32:816-819.
4. Anderson RA. Water absorption and solubility and amylograph characteristics of roll-cooked small grain products. Cereal Chemistry. 1982a; 59:265-269.
5. Camire ME, Camire A, Krumhar K. Chemical and Nutritional changes in foods during extrusion CRC Reviews Food Science Nutrition. 1990; 30:35-45.
6. Chandrasekher G, Suryaprasad RD, Pattabiraman TN. Natural plant enzyme inhibitors, a Amylase inhibitors in millets. Journal of the Science of Food and Agriculture 1981; 32:9-16.
7. Kokini J, Chang C, Karwe M. Food Extrusion Science and Technology. Marcel Dekker Inc. New York, USA, 1992.
8. Mahasukhonthacha K, Sopade PA, Gidley MJ. Kinetics of starch digestion and functional properties of twin screw extruded sorghum. Journal of Cereal Science. 2010; 51:392-401.
9. Moraru CI, Kokini JL. Nucleation and expansion during extrusion and microwave heating of cereal foods. Comprehensive Reviews in Food Science and Food Safety. 2003; 2:120-138.
10. Onwulata CI, Smith PW, Konstance RP, Holsinger VH. Incorporation of whey products in extruded corn, potato or rice snacks. Journal of Food Research International. 2001; 34:679-687.
11. Singh S, Shirani G, Lara W. Nutritional aspects of food extrusion: a review. International Journal of Food Science and Technology. 2007; 42:916-929.
12. Srinivasan K. Role of spices beyond food flavouring: Nutraceuticals with multiple health effects. Food Reviews International. 2005; 21:167-188.
13. Deshpande HW, Poshadri A. Physical properties and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. International Food Research Journal. 1999; 18(10):10-16.