Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 3457-3463
Received: 15-03-2018
Accepted: 20-04-2018

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Development and quality evaluation of little millet (*Panicum sumatrense*) based extruded product

Raviraj Saini and Kailash Chandra Yadav

Abstract
The present study was aimed to use little millet (*Panicum sumatrense*) along with other flour for production of ready-to-eat snack products using extrusion cooking. The composition of little millet (0-20%), corn flour (40-50%) and rice flour (40-50%), then developed the extruded product by using a twin-screw extruder. Extrusion cooking was carried out at optimized extrusion parameters namely temperature: 110 ^{0}C and 90 ^{0}C for two different heating zones, die diameter: 3 mm and screw speed: 350 rpm. Increasing proportion of little millet (0-20) % in the extrusion blend causes increase of moisture content (4.45-5.70) %, ash content (0.75-1.45) %, protein content (3.25-4.38) %, fat content (0.82-1.17) %, fiber content (1.05-2.88) %, bulk density, hardness (0.11- 0.24) N of the extruded products, where as decrease in Expansion ratio (4.01-2.63) carbohydrate content (89.65-84.42) % and calorific value (378.98-365.73) kcal. The results indicated that composite flour (Little millet; Rice; Maize in the ratios of 10:45:45) could be used to produce quality extrudates with acceptable sensory properties.

Keywords: twin screw extruder, little millet flour, millets, extruded product

1. Introduction
In the recent years there has been an increasing interest in the production of extruded foods, such as snacks, pastas, breakfast cereals, baby foods, pet foods etc. (Yadav and Chandra, 2015) [24]. Snacks consist essentially of a cereal blend extruded with a certain amount of water. Little millet (*Panicum sumatrense*) is also known as kutki (Hindi), samai (Tamil) and saame (Kannada).
Extrusion cooking is a high-temperature; short-time (HTST) technology applied in many food production processes and considered as a continuous cooking, mixing and forming process with low cost and high efficiency (Ryu *et al.* 1993) [13]**.** An xtruder is a thermodynamic unit which involves the combination of heat, pressure and mechanical shear. The process is achieved by screw and barrel tube mechanism. Feed material in granular form are fed into the extruder barrel then convey the material and compress and work in shear to transform the granular feed material into a semi-solid plasticized mass the food is then extruded through an interchangeable die either by rotating knives or subsequently by guillotine knives to form a variety of shapes. During extrusion, the cooking temperature could be as high as 180-190 °C and residence time is usually 20-40 seconds. Food extrusion is a processing which food/feed ingredients are forced to flow under one or several conditions of mixing, heating, shear through a die that forms and puff-dries the ingredients. Extrusion is cooking under pressure, moisture & elevated temperature.
Small millets are tasty with a mildly sweet, nut-like flavor and contain a myriad of beneficial nutrients. Small millets contain 9-14% protein, 70-80% carbohydrates and area rich source of dietary fiber (Malleshi and Hadimani, 1993) [21]. Even though the nutritional qualities of small millets have been well recorded (Hulse *et al.* 1980) [18], their utilization as food is confined to the traditional consumers in tribal population mainly due to non-availability of consumer-friendly, ready-to-use or ready-to-eat products as in rice and wheat. In recent years, small millets have received attention, mainly because they are recognized as high fiber foods and efforts are underway to take them to consumers in convenient forms. Exploratory studies conducted on popping and milling of small millets have been promising (Malleshi and Desikachar, 1986) [20].
Minor millets also referred to as small millets, have received far less attention in terms of cultivation and utilization. They include finger millet (*Eleusine coracana),* foxtail millet *(Setaria italica),* little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), common or proso millet (*Panicum miliaceum*) and barnyard millet (*Echinochloa crusgalli*) and sorghum (*Echinochloa corona*).

Millet flour using for preparing enriched nutrition source. It is rich in phosphorus, magnesium, manganese, zinc, copper, iron and selenium. The fiber in cornmeal helps to promote colon health and prevent constipation. The fiber in corn flour lowers cholesterol levels. Corn flour is gluten- free. It is beneficial for managing diabetes.

Rice (*Oryza sativa*) is a staple food crop for a large part of the world's human population, making it the second most consumed cereal grain. Rice provides more than 1/5th of the calories consumed worldwide by humans. Rice contains approximately 7.37% protein, 2.2% fat, 64.3% carbohydrate, 0.8% fiber and 1.4% ash content (Zhoul *et al.* 2002) [26].

2. Materials and Methods

This section describes the materials used, the methods applied, calculations used and factors considered in deveoping the extruded product by usinfg twin screw extruder.

2.1 Procurement of raw materials

The raw material namely little millet and rice (parmal long grain non-basmati) were procured from Kota local market. Maize (yellow) was procured from local commercial supplier. All raw materials were cleaned and grounded separately in the grinder and passed through 0.88 mm sieve and stored in the cool and dry atmosphere for further experiments.

2.2 Twin screw extruder

The extruder used for this experiment was laboratory co-rotating twin-screw extruder (Basic Technology Pvt. Ltd., Model EB-10). The extruder was preassembled and skid-mounted and placed on 3 inches raised platform. The raised platform helps cleaning the extruder. The machine components which directly come in contact with feed material like screw, barrel, die are made of stainless steel for better hygiene. The main drive is provided with the 7.5 HP variable speeds motor (440 V; 3 phase; 50 Hz). It was provided with SIEMENS/ABB frequency drive to control the rpm precisely according to the need of the process. The output shaft of worm-reduction gear is provided with a torque limiter coupling consisting of torque limiter and roller chain type coupling. The torque limiter is a protective device that limits torque transmitted by the output shaft of worm-reduction gear.

First of all five trial run experiments were conducted to fix the feed combination of raw material as shown in Table 1. Here little millet was fixed to (0-10) % as more fortification of it may injurious to the baby's health and maize was varied from (40-50) % and rice from (40-50) %. For these trial experiments we had kept barrel temperature fixed at 110 ^{0}C, screw speed at 350 rpm, feed moisture content at 10% (wb), feeding screw at 24 rpm, cutting knife speed at 26 rpm.

Samples were poured into feed hopper and the feed rate was adjusted for easy and non-choking operation. The automatic cutting knife was fixed on a rotating shaft of knife powered by D.C. motor. The cutter was driven by variable speed by D.C. motor which was controlled by a knob placed on the panel board. The speed of cutter was fixed at 350 rpm for all experiments. Extrudates were cut with a sharp knife, at the exit end of the die and left to cool at room temperature for about 20 min. The cylindrical extrudates were dried at 50 °C for about 2 h to obtain dry extrudates (Bhattacharya, 1997).

2.3 Composite flour preparation

The blend of flour were prepared first by mixing little millet, rice and maize and calculated amount of water and flour was allowed to equilibrate for 15 min. First of all five trial run experiments were conducted to fix the feed combination of raw material as shown in Table 1. Here little millet was fixed to (0-10) % as more fortification of it may injurious to the baby's health and maize was varied from (40-50) % and rice from (40-50) %. For these trial experiments we had kept barrel temperature fixed at 1100C, screw speed at 350 rpm, feed moisture content at 10% (wb), feeding screw at 24 rpm, cutting knife speed at 26 rpm. The samples were put in buckets and stored at 4 °C overnight. The feed material was then allowed to stay for 3 h to equilibrate at room temperature prior to extrusion. This pre-conditioning procedure was employed to ensure uniform mixing and proper hydration and to minimize variability in the state of feed material. The moisture content of samples was determined by hot air oven method (AOAC, 2005) [5].

Table 1: Composite flour used for the preparation of extruded product

S. No	Sample Code	Rice and Maize (Flour %)	Little millet Flour (%)	Temp-Erature (^{0}C)	Screw speed (rpm)
1	T_0	50 : 50	0	110	350
2	T_1	47.50 : 47.50	5		
3	T_2	45 : 45	10		
4	T_3	42.5 : 42.5	15		
5	T_4	40 : 40	20		

2.4 Process flow chart of extruded product

Receiving of ingredients (Rice, Corn, & Little Millet Flour) ⟹ Weighing ⟹ Pre-conditioning addition of water (22%) Blending ⟹ Extrusion (90-110 °C Temp & 320-350 rpm) ⟹ Drying (50 °C for 2 hr) ⟹ Oil spraying and spicing ⟹ Oil spraying and spicing ⟹ Packaging in LDPE bags ⟹ Storage at an ambient temperature.

Fig 1.2: Flow chart for development of extruded product

2.5 Chemical Analysis

2.5.1 Moisture

The moisture content of the developed extrudate was determined by the method described by AACC (2000). 5g sample was weighed in a previously weighed and tared dish. The dish with its lid underneath will be placed in an oven maintained at 130-133 °C for 2 hr. The sample was removed after 2 hours, cooled in desiccator and weighed.

$$\text{Moisture (\%)} = \frac{(w2-w3)}{(w2-w1)} \times 100 \qquad \text{....Eq. 1}$$

Where

W3= weight of the dishin grams

W1= weight of the dishin grams with the material before drying

W2= weight of the dishin grams with the material after drying

2.5.2 Ash

The dried material in the dish left after the determination of moisture was ignited with the flame of the burner till charred.

It was transferred to a muffle furnace maintained at 550-600 ^{0}C and continued ignition was conducted till grey ash is obtained. Sample was allowed to cool in a desiccator and weighed again, and the ash content was expressed in terms of the oven-dried weight of the sample (AOAC 1995) [6].

$$\text{Total Ash} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100 \qquad \text{….Eq. 2}$$

2.5.3 Protein

The phenolic group of tyrosine and tryptophan residues (amino acid) in a protein will produce a blue purple color complex, with maximum absorption in the region of 660 nm wavelength, with Folin-Ciocalteau reagent which consists of sodium tungstate molybdate and phosphate. Thus the intensity of color depends on the amount of these aromatic amino acids present and will thus vary for different proteins. Most proteins estimation techniques use Bovin Serum Albumin (BSA) universally as a standard protein, because of its low cost, high purity, ready availability. The method is sensitive down to about 10 µg/ml and is probably the most widely used protein assay despite its being only a relative method, subject to interference from Tris buffer, EDTA, nonionic and cationic detergents, carbohydrate, lipids and some salts. The incubation time is very critical for a reproducible assay. The reaction is also dependent on pH and a working range of pH 9 to10.5 is essential.

2.5.4 Fiber

The sample (2g) was accurately weighed into the fiber flask and 100 ml of 0.25N H2SO4 was added. The mixture was heated under reflux for 1hour with the heating mantle. The hot mixture was filtered through a fibre sieve cloth. The filtrate obtained was thrown off and the residue was returned to the fiber flask to which 100 ml of (0.31N NaOH) was added and heated under reflux for another 1 hr. The mixture was filtered through a fibre sieve cloth and 10 ml of acetone was added to dissolve any organic constituent. The residue was washed with about 50 ml hot water twice on the sieve cloth before it will finally be transferred into the crucible. The crucible and the residue was oven-dried at 105°C overnight to drive off moisture. The oven dried crucible containing the residue were cooled in a desiccator and later weighed to obtain the weight W1. The crucible with weight W1 was transferred to the muffle furnace for ashing at 550 °C for 4 hours. The crucible containing white or grey ash (free of carbonaceous material) was cooled in the desiccator and weighed to obtain W2. The difference W1 - W2 will give the weight of fibre. The percentage fibre was obtained by the formula (AOAC 1990) [7].

$$\text{Fiber\%} = \frac{\text{w1} - \text{w2}}{\text{weight of sample}} \times 100 \qquad \text{…Eq. 3}$$

2.5.5 Fat

The dried sample (1g) was weighed into fat free extraction thimble and plugged lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 ml soxhlet flask which was previously dried in the oven, cooled in the Dessicator and weighed. The soxhlet flask was then filled to 3/4 of its volume with petroleum either (boiling pointof 40-60 °C) and the soxhlet flask extractor plus condenser set was placed on the heater. The heater was put on for six hours with constant running water from the tap for condensation of ether vapour. The ether was left to siphon over several times at least 10-12 times until it is short of siphoning. After this it was noticed that any ether content of the extractor is carefully drained into the ether stock bottle. The thimble-containing sample was then removed and dried on a clock glass on the bench top. The extractor flask with condenser was replaced and the distillation was continued until the flask is practically dried. The flask which now contains the fat or oil was detached, its exterior was cleaned and dried to a constant weight in the oven. If the initial weight of dry soxhlet flask is W_o and the final weight of oven dried flask + oil/fat is W_1, percentage fat/oil is obtained by the formula (AOAC 1990) [7].

$$\text{Fat \%} = \frac{\text{w1} - \text{w0}}{\text{weight of sample}} \times 100 \qquad \text{….Eq. 4}$$

2.5.6 Carbohydrate

The carbohydrate content of the sample was estimated as the difference obtained by subtracting the values of organic protein, lipid, ash and fiber from the total dry matter.

Carbohydrates = (100 - moisture + protein + fat + ash + crude fiber) …Eq. 5

2.5.7 Calorific Value

The calorific value of the sample will be obtained by multiplying the values of the crude protein, lipid and carbohydrate by the factors 4, 9 and 4 respectively and taking the sum of the products.

Calories = (carbohydrates × 4 kcal) + (protein × 4 kcal) + (fat × 9 kcal ….Eq.6

2.6 Physical Analysis

2.6.1 Expansion Ratio

The ratio of the diameter of the extrudate and the diameter of the die was used to express the expansion of extrudate (Fan *et al.* 1996; Ainsworth *et al.* 2006) [3]. Six lengths of the extrudate (approximately 120 mm) were selected at random during collection of each of the extruded samples and allowed to cool at room temperature. The diameter of the extrudates was measured, at three different positions along the length of each sample, using a digital vernier caliper with least count of 0.1mm and their average was taken as the mean diameter of the extrudate. The experiments were repeated thrice and calculated mean expansion ratio was calculated using the equation as follows:

$$\text{Expansion ratio} = \frac{\text{Diameter of extruded product}}{\text{Diameter of die hole}} \times 100 \qquad \text{….Eq.7}$$

2.6.2 Bulk Density

The bulk density (kg/m^3) was calculated by measuring the actual dimensions of the extrudates (Chinnaswamy *et al.* 1986). The diameter and length of the extrudates were measured by using digital vernier caliper with least count of 0.1mm. The weight per unit length of the extrudate was determined by weighing measured lengths (about 1 cm). The bulk density was then calculated by using the following formula, assuming a cylindrical shape of extrudate. Ten pieces of the extrudate were randomly selected and average bulk density was taken (AOAC, 2005) [5]. The experiments were repeated thrice and mean bulk density was calculated by using the equation as follows:

$$\text{Bulk density \%} = \frac{4\text{m}}{\pi d^2 \text{l}} \times 100 \qquad \text{.... Eq. 8}$$

Where, m is the mass (kg) of the extruded product, L and dare the length (m) and diameter (m) of the extrudate.

2.6.3 Texture Profile Analysis (TPA)

Textural Analyzer (TA.XT Plus/TA.HD Plus) was used for measuring textural properties of extruded product. The experiments were carried out by different tests that generated a plot of force (kg) vs. time (s), from which texture values for the extruded product were obtained. Three replications of each combination were taken for analysis. During the testing, the samples were held manually against the base plate and the different tests were applied according to TA settings. The textural properties such as hardness, fracturability, stickiness and work of shear were measured by using different tests viz. penetration test and bending test (Stable Micro Systems). A 2 mm cylindrical probe was used for the measurement of hardness of the extrudates and three-point bend ring was used for bending test.

2.7 Sensory Evaluation

Sensory evaluation indicates the acceptability of the product. Acceptability of extrudate was judged, on a nine-point hedonic scale. The sensory evaluation was carried out on the basis of color, flavor, taste, hardness and overall acceptability of the developed product. The sensory evaluation of the extruded product revealed that there were significant differences among the treatments for the organoleptic qualities (Ranganna, 1995) [22].

3. Results and Discussions

3.1 Chemical Characteristics

The chemical properties of a developed extruded product such as moisture, ash, protein, fat, crude fiber, carbohydrate, calorific value were determined. The average values of chemical properties of little millet based extruded product for all treatments are given in Table 2.

Table 2: Chemical properties of little millet based extruded product

S. No.	Tret-Ments	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)	Carbohydrate (%)	Calorific Value (kcl)
1	T_0	4.45	0.75	3.25	0.82	1.05	89.65	378.98
2	T_1	4.90	0.96	3.31	1.02	1.65	88.17	375.10
3	T_2	5.03	1.27	3.27	1.05	1.93	87.35	372.33
4	T_3	5.43	1.38	4.02	1.10	2.56	85.23	366.90
5	T_4	5.70	1.45	4.38	1.17	2.88	84.42	365.73
	C.D. at 5%	0.024	0.019	0.007	0.085	0.019	0.159	6.345

3.2 Physical characteristics

The physical properties of a developed extruded product such as expansion ratio, bulk density, texture and hardness were determined. The average values of physical properties of little millet based extruded product for all treatments are given in Table 3.

Table 3: Physical properties of little millet based extruded product

S. No.	Treat-Ments	Expansion Ratio	Bulk Density (g/cm^3)	Hardness (N)
1	T_0	4.01	0.11	7.84
2	T_1	3.56	0.13	12.82
3	T_2	3.19	0.16	16.83
4	T_3	2.89	0.19	18.19
5	T_4	2.63	0.24	27.85
	C.D. at 5%	0.023	0.019	12.35

3.2.1 Expansion Ratio

The expansion is the most important physical property of the snack food. Starch is the main component in cereals which plays a major role during expansion process (Kokini *et al.* 1992) [19]. After the study fig.1 shows the decreasing pattern of expansion ratio with different extrusion treatments and table 3 shows the effect of different treatments on expansion ratio of extruded product. In the present study, it was observed that the expansion in sample T_0 was higher than the sample T_1, T_2, T_3 and T_4. The expansion of extruded product samples decreases with increasing the level of little millet flour as shown in Fig 1. The expansion ratio of the extrudate ranged from 2.63 to 4.01 as given in Table 3. The maximum expansion was found in T_0 (4.01).

The expansion ratio is one of the crucial parameters in determining the cereal product quality in case of extruded products. Expansion of cereal product has been reported to decrease with increasing amount of protein (Faubion *et al.* 1982) [17].

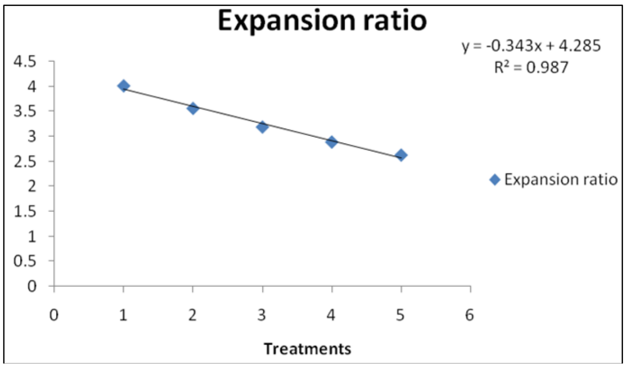

Fig 1

3.2.2 Bulk density

Bulk density is a major physical property of the extrudate product. The bulk density, which considers expansion in all direction, was ranged from 0.11 to 0.24 kg/m3 for the extrudates. In the present study, it was observed that the bulk density of an extrudate samples. Fig.2 shows the increasing pattern of bulk density with different extrusion treatments and Table 3 shows the effect of different treatments on the bulk density of extruded product. After the study it was seen that the bulk density in sample T_4 was higher than the sample $T_{0,}$ $T_{1,}$ $T_{2,}$ and T_3. The density of extruded product samples increases with increasing the level of little millet flour as shown in Fig. 2. The maximum density was found in T_5 (0.23) and minimum in T_0 (0.13).

The density of extrudates increased significantly with little millet flour addition. There are strong evidence in the literature that as high-fiber, high-protein materials are added to starch-based extruded products, density is expected to increase (Onwulata *et al.* 2001; Veronica *et al.* 2006) [10]. In our study, this parameter was inversely correlated with expansion ratio. (Gujska and Khan, 1991) [15] Suggested that the degree of expansion affects the density, fragility and overall texture of extruded products.

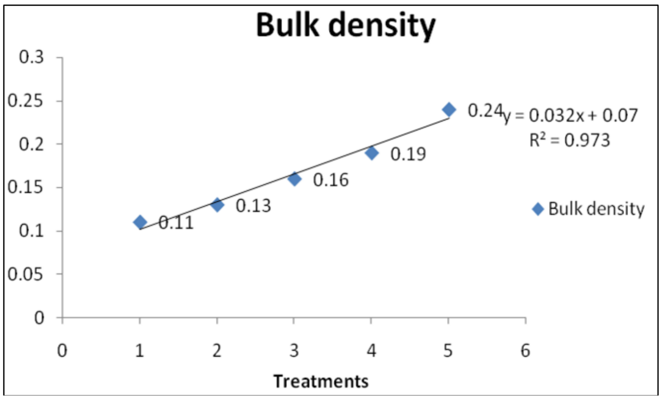

Fig 2

3.2.3 Textural properties of extruded product

The textural properties of extruded products are generally described by the hardness and crispness. The textural parameters studied were crispness, hardness and cutting strength and it was analyzed with help of textural analyzer (Yadav and Chandra, 2015) [24]. The hardness of an expanded extrudate was a perception of the human being and is associated with the expansion and cell structure of the product.

3.2.3.1 Hardness

The hardness of the extrudate was ranged between 7.84 and 27.85N. The maximum peak force from the texture analyzer represents the resistance of the extrudate to the initial penetration and is believed to be the hardness of the extrudate (Ding *et al.* 2005). For extruded foods, it was desirable to have low values for hardness. Hardness measured for all extrudates i.e T_0, T_1, T_2, T_3 and T_4 are 7.84N, 12.82N, 16.83N, 18.19N and 27.85N respectively.

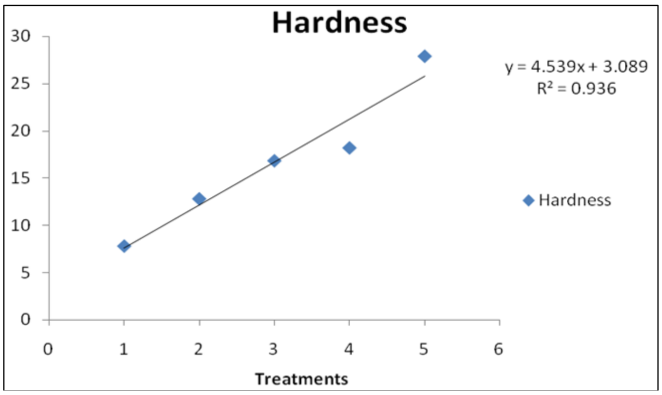

Fig 3

Table 4: Effect of little millet on TPA of sample T_2 (90:10)

Parameters	No.	Value	Units
Area-FT	1:2	1593	g.s
Grad-FT	1:2	-10.03	g/s
Mean-F	1:2	534.5	G
Time-diff.	1:2	2.975	S
Ratio	1:2	31.0	%
Travel	1:2	14.615	Mm
Force	1	1717.0	G
Travel	3:4	13.465	Mm
Ratio	3:4	108.2	%
Time-diff.	3:4	2.745	S
Mean-F	3:4	401.7	G
Grade-FT	3:4	0.2322	g/s
Area-FT	3:4	1105	G.S
Force	2	1566.6	G

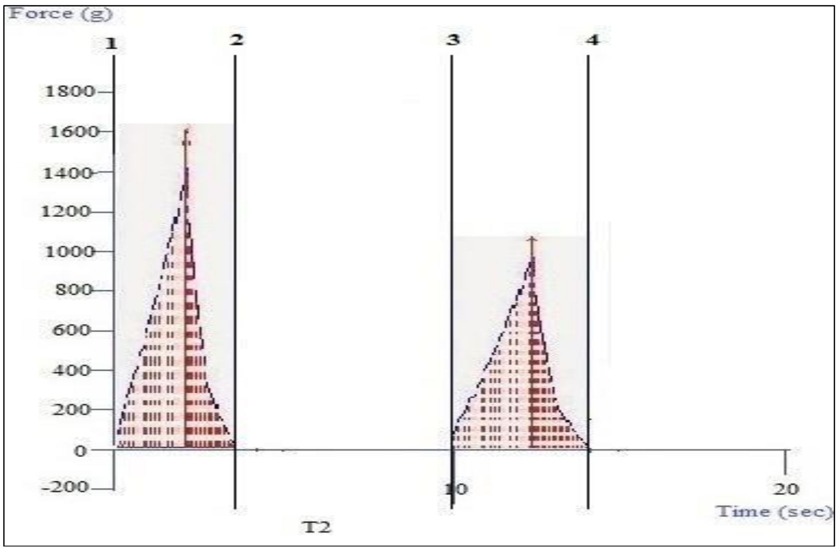

Fig 4

Table 5: Effect of little millet on TPA of sample T_3 (85:15)

Parameters	No.	Value	Units
Area-FT	1:2	1673	G.S
Grad-FT	1:2	-1.436	g/s
Mean-F	1:2	553.2	G
Time-diff.	1:2	3.820	S
Ratio	1:2	33.0	S
Travel	1:2	14.800	Mm
Force	1	1855.0	G
Travel	3:4	18.745	Mm
Ratio	3:4	169.5	%
Time-diff.	3:4	2.200	S
Mean-F	3:4	419.0	G
Grade-FT	3:4	2.967	g/s
Area-FT	3:4	924	G.S
Force	2	1551.6	G

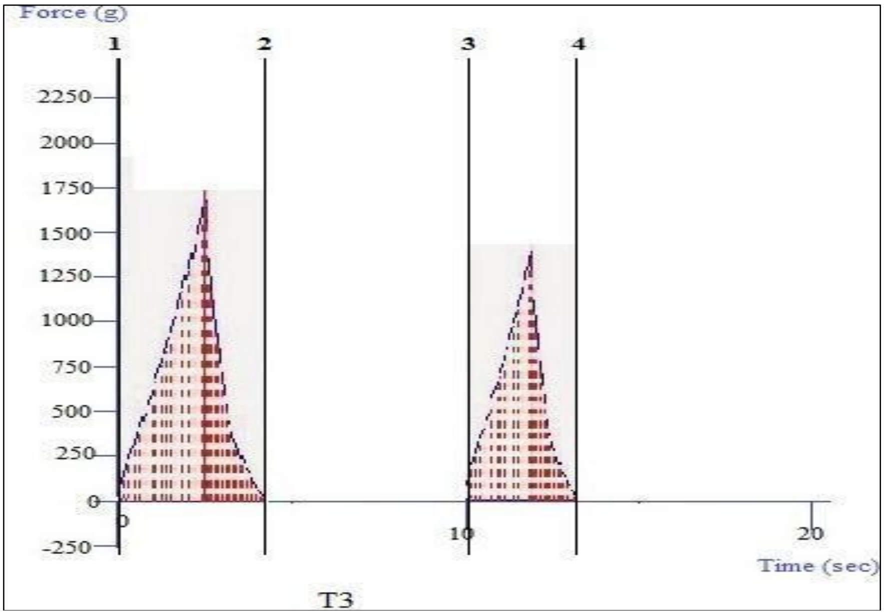

Fig 5

4. Sensory characteristics

Sensory evaluation indicates the acceptability of the product. Acceptability of extrudate was judged, on a nine-point hedonic scale. The sensory evaluation was carried out on the basis of color, taste, flavor, hardness and overall acceptability of the developed product. The sensory evaluation of the extruded product revealed that there were significant differences among the treatments for the organoleptic qualities. The quality was judged by the consumer panel team consisting of fifteen members. The treatment T_2 i.e. 110 °C temperature, 14% feed moisture and 350 screw rpm mostly accepted by sensory panel overall acceptability 8.28. The second best treatment selected by the sensory panel was T_1 i.e. 110 °C temperature, 12% feed moisture and 350 screw rpm with overall acceptability 7.96.

5. Conclusion

Little millet flour was incorporated with different proportions i.e. T_0 (0 %), T_1 (5 %), T_2 (10 %), T_3 (15 %) and T_4 (20 %). Physical and Chemical parameters of control and Little millet flour fortified extrudate were also analyzed after extrusion and showed the maximum and minimum chemical characteristics such as moisture, ash, protein, fat, crude fiber, carbohydrate, calorific values which are 5.70%, 1.45%, 4.38%, 1.17%, 2.88%, 89.65%, 378.98% and 4.45%, 0.75%, 3.25%, 0.82%, 1.05%, 84.42%, 365.73%. Physical characteristics of extruded product showed the maximum and minimum value such as expansion ratio, bulk density which are 4.01, 0.24 kg/m^3 and 2.63, 0.11 kg/m^3. The textural properties of developed composite flour showed the maximum hardness of 27.85 N and minimum 7.84 N.

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