Development and quality evaluation of foxtail millet (Setaria italica) based extruded product using twin screw extruder

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Abstract
The current study aims at the development and quality evaluation of Foxtail Millet based Extruded product. Foxtail millet is potentially important source of protein. Foxtail Millet flour exhibit good extrusion characteristics which give smooth surface and crunchy texture. Both foxtail millet are rich in fiber, vitamins, energy, and protein. A total of five treatments with different proportions (100:0, 95:5, 90:10, 85:15, and 80:20) of the foxtail millet were given for development of product. Analysis of Physico-chemical parameters such as protein, fat, fiber, moisture, ash content and along with sensory evaluation for all the treatments was performed. Protein and Fat content increased gradually with increase in the Foxtail millet content whereas Moisture content % (max. 4.79 and min. 3.62), Ash content % (max. 0.55 and min. 1.42) and crude fiber % (max. 2.35 and min. 1.32), increased with an increase in the foxtail millet proportion. On optimization and evaluation of all the parameters and considering the results of sensory evaluation, T3 sample containing (85:15) ratio of millet was found foxtail millet be the most optimum treatment.

Keywords: extrusion, foxtail millet, physico-chemical parameters, foxtail millet

1. Introduction
Food extrusion is a form of extrusion used in food processing. It is a process by which a set of mixed ingredients are forced through an opening in a perforated plate or die with a design specific to the food, and is then cut to a specified size by blades. The machine which forces the mix through the die is an extruder, and the mix is known as the extruded. Food products manufactured using extrusion usually has high starch content.

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). India, minor millets are still the staple food to large section of people in the semi-arid regions, especially in the state of Karnataka where the foxtail millet is grown widely even under irrigation with yield as high as 3 t/ha (Bala Ravi, 2004). Minor millets account for less than 1% of the food grains produced in the world today. Thus they are not important in terms of world food production, but they are essential as food crops in their respective agro-ecosystems. They are mostly grown in marginal lands or under agricultural conditions where major cereals fail to give sustainable yields. They are considered as crops of food security because of their sustainability in adverse agro-climatic conditions. Foxtail millet (Setaria italica), also called as Korralu (Telugu), Navane (Kannada) and Thinai (Tamil), is the second most widely planted species of millets and the most important in East Asia.

In India, foxtail millet cultivation is confined mainly to the states of Karnataka (49%), Orissa (11%), Maharashtra (16%), Tamil Nadu (9%) and Andhra Pradesh (7%). In Karnataka, the area and production of foxtail millet are 42436 ha and 14001 tonnes, respectively (Anon, 2016). It is a good source of phosphorous, iron and vitamins like thiamine, riboflavin, folin and niacin.

In the extruder, the food mix is thermo-mechanically cooked at high temperature under pressure and shear stress generated in the screw barrel assembly. The cooked melt is then texturized and shaped in the die. The thermo-mechanical action during extrusion brings about starch gelatinization, protein denaturation, and inactivation of enzymes, microbes and many anti nutritional factors. All this occurs in a shear environment, resulting in a plasticized continuous mass (Battacharya et al. 1994). Based on type of construction extruders are classified into: Single screw and twin screw extruder. A typical single-screw extruder consists of a live bin, feeding screw, preconditioning cylinder, extruder barrel, die and knife. The live bin provides a buffer of raw material so the extruder can operate without interruption. For more flexibility & better control we use twin...
screw extruders since single screw extruders have relatively poor mixing ability. These are generally categorized according to the direction of screw rotation and to the degree to which the screws intermesh. 1. Counter-rotating twin-screw extruders 2. Co-rotating twin screw extruders. In the counter-rotating position the extruder screw rotates in the opposite direction, whereas in the co-rotating position the screw rotates in the same direction.

Extrusion cooking as a continuous cooking, mixing, and forming process, is a versatile, low cost, and very efficient technology in food processing. It combines several unit operations including mixing, shearing, conveying, heating, puffing and partial drying, depending on the extruder design and process conditions. (Gordon L. Robertson et al. 1993)

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).

2. Materials and Methods

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

2.1 Procurement of raw materials

The raw material namely foxtail millet and rice (parmal long grain non-basmati) were procured from Maharashtra 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 foxtail 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 °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 pored 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. Extruded 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 extruded were dried at 50 °C for about 2 h to obtain dry extruded (Bhattacharya, 1997).

2.3 Chemical analysis

1. Moisture Content

Moisture content was determined by using hot air oven drying method 5 gm. of sample was taken in pre-weighed empty Petri plate and dried in hot air oven at 100 °C for peel & at 60 °C for juice till constant weigh were obtained. Plates were cooled in desiccators. The moisture content was calculated by using formula. (Ranganna, 1986).

\[ \text{Moisture content (\%)} = \frac{(W_2 - W_1)}{W} \times 100 \]

Where,

- \( W_2 \) = Final weight of flask + fat
- \( W_1 \) = Initial weight of round flask
- \( W \) = Weight of sample

2. Crude fiber

The sample was treated with acid and acrylic to remove proteins and carbohydrates other than cellulose crude fiber or cellulose matter determined by trying to constant weight, weighing then ashing and then again weighing. The difference termed as crude fiber content expressed in percentage. (Ranganna, 1986).

3. Ash content

Ash content was done by the use of muffle furnace 2 gm. of dried sample was ignited is muffle furnace for 4-6 hrs. At 550 °C. Total ash can be expressed as percentage. The ash was calculated using following formula. (Ranganna, 1986).

\[ \% \text{ Ash} = \frac{\text{Weight of crucible after ashing-Weight of empty crucible}}{\text{Weight of sample}} \times 100 \]

4. Determination of Fat content

The fat content of the sample was determined by the procedure as described in AOAC (1990) [8].

Procedure

5g of sample was weighed accurately, placed in thimble and plugged with cotton. The extractor-containing thimble was placed over a pre-weighed extraction flask (A). Fat content was determined by extracting the sample with solvent petroleum ether 60-80 °C for 8 hr using Soxhlet extraction procedure. After extraction the excess of solvent was distilled off and the residual solvent was removed by heating at 80 °C in oven for 4-6 hr. The fat content was determined as below.

\[ \text{Fat content (\%)} = \frac{W_2 - W_1}{W} \times 100 \]

Where,

- \( W_2 \) = Final weight of flask + fat
- \( W_1 \) = Initial weight of round flask
- \( W \) = Weight of sample

Determination of Fat Content

About 2 g of sample was weighted accurately and transferred to a Micro-Kjeldahl flask. Then 4 grams of CuSO₄ and 10 g of Na₂SO₃ was added to the flask. 25 ml of concentrated H₂SO₄ was added. The flask is heated gently in an inclined position till the light blue colour solution was obtained. Then
the flask was heated on a high flame for three hours. Then the digestion mixture was cooled at the room temperature. The digest was wash into the distillation flask with distilled water. The distillation assembly was arranged to the receiving flask and 50 ml of 0.01N HCl with 2-4 drops of methyl red indicator was added. The distillation apparatus was connected with a delivery tube dipping in an HCl solution. Zn metal pieces are added to the distillation flask which was carefully added to the digestion mixture. It was rinse with water. Around 50-60 ml of 50% NaOH was added to it. Sufficient water was added to the flask. The H2O was started through the condenser. The solution was heated and it liberates NH3. The liberated NH3 was distilled into HCl solution. The heating was continuing was thrice, the initial volume of HCl in the receiving flask. The tap was open and washes down the condenser and the delivery tube into the receiver. The burner was put off. The distillate with 0.1N NaOH is titrated and slight pin was obtained. Conduct with blank determination.

2.4 Preparation of foxtail Millet Flour
Firstly good quality of foxtail millet was taken than it was clean to remove impurities present in it. After that sorting should be done and then milling is done through which we get flour and then sieving was carried out by using 30 mesh sieves and then stored in air tight container.

2.5 Composite flour preparation
The blend of flour were prepared first by mixing foxtail 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 foxtail 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) Table 1 Feed compositions used in trial runs.

2.6 Foxtail Millet Based Extruded Product
The raw materials foxtail millet flour and maize flour, rice flour was procured from the local market. Foxtail millet flour and maize, rice flour was used for the formation of the basic blend for the extruded. The mixture was sieved twice to ensure removal of any gritty material or any foreign particle, if present, and also for proper mixing of the all the ingredients. Predetermined quantity of distilled water was added. The blend was then mixed to distribute the water throughout the mass. It was again sieved twice to break down the lumps formed due to water addition. The product development was made by mixing of foxtail millet flour. The ratios were taken for the development and quality evaluation of foxtail millet extruded product. The foxtail millet flour in different ratio, were taken for the development of extruded product, which are mentioned as follow T0 (50:50), T1 (95:05), T2 (90:10), T3 (85:15), T4 (80:20).

2.7 Physical analysis

2.7.1 Expansion ratio
After the study it was seen that the expansion ratio of an extruded samples.
2.7.2 Bulk density
After the study it was seen that the bulk density of an extruded samples.

\[
\text{Bulk density} \% = \frac{4m}{\pi d^2 l} \times 100
\]

2.7.3 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, factorability, 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 extruded and three-point bend ring was used for bending test.

2.7.4 Sensory Evaluation
The Sensory characteristics of the product such as general appearance, colour, taste, and flavour were evaluated by panel of judges using nine point hedonic scale as per IS: 6273 (PART-II), 1971.

3. Results and Discussion
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 foxtail millet based extruded product for all treatments are given in Table 1.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Combination</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Fiber (%)</th>
<th>Carbohydrate (%)</th>
<th>Calorific Value(kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T₀</td>
<td>3.62</td>
<td>0.55</td>
<td>5.31</td>
<td>0.82</td>
<td>1.32</td>
<td>88.27</td>
<td>382.69</td>
</tr>
<tr>
<td>2</td>
<td>T₁</td>
<td>3.81</td>
<td>0.68</td>
<td>5.80</td>
<td>1.02</td>
<td>1.57</td>
<td>87.08</td>
<td>381.06</td>
</tr>
<tr>
<td>3</td>
<td>T₂</td>
<td>4.08</td>
<td>0.93</td>
<td>6.15</td>
<td>1.02</td>
<td>1.74</td>
<td>85.89</td>
<td>379.05</td>
</tr>
<tr>
<td>4</td>
<td>T₃</td>
<td>4.37</td>
<td>1.23</td>
<td>6.63</td>
<td>1.10</td>
<td>1.95</td>
<td>84.48</td>
<td>376.5</td>
</tr>
<tr>
<td>5</td>
<td>T₄</td>
<td>4.79</td>
<td>1.42</td>
<td>7.02</td>
<td>1.17</td>
<td>2.35</td>
<td>82.86</td>
<td>373.56</td>
</tr>
</tbody>
</table>

After the analytical study The nutritional composition of extruded product manufactured by twin screw extruder raw materials grains which was include foxtail millet flour, maize flour, rice flour. The moisture percentage with different extrusion treatments was found to be in the range of 3.62 to 4.79%. After the study it was seen that the presence of moisture in sample T₀ was higher than the sample T₀ T₁, T₂ and T₃. The moisture of extruded product samples increased with increasing the level of Foxtail Millet. The ash percentage with different extrusion treatments was found to be in the range of 0.55 to 1.42%. The maximum ash was found in T₄ (1.42) whereas minimum in T₀ (0.55). The Protein percentage with different extrusion treatments was found to be in the range of 5.31 to 7.02%. The maximum Protein was found in T₄ (7.02) whereas minimum in T₀ (5.31). The Fat percentage with different extrusion treatments was found to be in the range of 0.93 to 1.56%. The maximum fat was found in T₄ (1.56) whereas minimum in T₀ (0.93). The fiber percentage with different extrusion treatments was found to be in the range of 1.32 to 2.35%. The maximum fiber was found in T₄ (2.35) whereas minimum in T₀ (1.32). Carbohydrate percentage with different extrusion treatments was found to be in the range of 82.86 to 88.27%. The maximum Carbohydrate was found in T₀ (88.27) whereas minimum in T₄ (82.86). The maximum calories content was found in T₀ (382.69kcal) whereas minimum in T₄ (373.56kcal). It was observed that

3.2 Physical Characteristics of product
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 Foxtail mille based extruded product for all treatments are given in Table 2.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Treatments</th>
<th>Expansion ratio</th>
<th>Bulk density (g/cm³)</th>
<th>Hardness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T₀</td>
<td>4.34</td>
<td>0.14</td>
<td>7.84</td>
</tr>
<tr>
<td>2</td>
<td>T₁</td>
<td>4.07</td>
<td>0.16</td>
<td>8.23</td>
</tr>
<tr>
<td>3</td>
<td>T₂</td>
<td>3.78</td>
<td>0.16</td>
<td>10.46</td>
</tr>
<tr>
<td>4</td>
<td>T₃</td>
<td>3.32</td>
<td>0.20</td>
<td>12.36</td>
</tr>
<tr>
<td>5</td>
<td>T₄</td>
<td>2.98</td>
<td>0.26</td>
<td>14.81</td>
</tr>
</tbody>
</table>

3.3 Expansion ratio
After the study it was seen that the expansion ratio of an extruded samples. Fig. shows the decreasing pattern of expansion ratio with different extrusion treatments and Table shows the effect of different treatments on expansion ratio of extruded product. After the study it was seen that the expansion in sample T₀ was higher than the sample T₁, T₂, T₃ and T₄. The expansion of extruded product samples decreases with increasing the level of foxtail millet flour as shown in Fig. The maximum expansion was found in T₀ (4.34) whereas minimum in T₄ (2.98).
3.4 Bulk density
After the study it was seen that the bulk density of an extruded samples. Fig.4.10 shows the increasing pattern of bulk density with different extrusion treatments and Table 4.9 shows the effect of different treatments on bulk density of extruded product. After the study it was seen that the bulk density in sample T5 was higher than the sample T0, T1, T2, T3 and T4. The density of extruded product samples increases with increasing the level of kidney bean flour as shown in Fig. 4.10. The maximum density was found in T5 (0.23) whereas minimum in T0 (0.13).

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) [18]. The hardness of an expanded extruded is a perception of the human being and is associated with the expansion and cell structure of the product.

4. Conclusion
The result of this dissertation concluded that the rice and maize and foxtail millet based extruded product was found optimum for the consumption by all age groups. The product is rich in protein content (7.02%) and fiber content (2.35%), hence it has a high nutritive value. This study can further be used for developing fiber rich snacks and ready to eat foods. As the fat content (1.42%) was low, thus it can be a good diet food also.

5. References