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Effect of extrusion conditions on physical properties of an extruded snack incorporated with chicken meat, rice flour and jackfruit bulb and seed powders

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Abstract
A study was undertaken to assess the effect of extrusion cooking parameters of an extruded snack incorporated with chicken meat, jackfruit bulb and seed powders and rice flour as base material. One control (With rice flour and Jackfruit bulb and seed powder in the ratio-80:20) and three treatment formulations (T1 – 62.69% rice flour, 15.62% jackfruit bulb and seed powder and 21.69% powdered chicken meat; T2- 62.23% rice flour, 15.5% jackfruit bulb and seed powder and 22.21% powdered chicken meat; T3- 57.32% rice flour, 14.33% jackfruit bulb and seed powder and 28.35% powdered chicken meat) were extruded employing screw speeds ranging from 230-262 rpm and barrel temperatures ranging from 120 °C to 140 °C. The physical characteristics that were studied were expansion ratio, bulk density and water absorption index. The results of the study indicated that with increasing proportions of powdered chicken meat in the feed mix, the extrudates obtained were relatively less expanded, denser and with lesser water absorption capacity. However, T1, T2, T3 were expanded respectively up to 86.0 percent, 88.0 percent and 59.0 percent of that of control. The principal factor that was found to exert an effect was feed composition, *i.e.* presence of absence of meat. It was shown that chicken meat may be included to produce nutritious extruded snack foods with the right ingredient selection and extrusion processing conditions.

Keywords: Chicken meat incorporated extruded snack, feed mix, screw speed, barrel temperature, expansion ratio, bulk density

Introduction
Snack foods have largely replaced meals in the diets of many people, especially youngsters, and they have an impact on overall nutrition. Due to their favorable expansion properties, cereals and grains are the main ingredients of the most popular extruded snacks, but they are typically deficient in protein and other essential nutrients. Consequently, there is a rising consumer desire for healthier snacks. Inclusion of meat in such snacks can increase the protein, mineral and vitamin levels and can improve their palatability.

Meat is a rich source of high-quality proteins, minerals like iron and zinc and various vitamins, especially B complex vitamins. Judicious intake of meat can eliminate deficiency of proteins and certain minerals and vitamins, especially in developing and underdeveloped countries where malnutrition is prevalent.

Rice, a major cereal grain of India, is widely exploited as it is an attractive ingredient because of its bland taste, attractive white color, hypo allergenicity and ease of digestion. Jackfruit (*Artocarpus heterophyllus*) is one of the tropical fruits, which grows abundantly in India, especially in Kerala, where it is the state fruit and is mostly underutilized. It has been found to exhibit antimicrobial, anti-diabetic, anti-inflammatory and antioxidant properties (Ranasinghe *et al*., 2019) [21].

The most common method used to produce snack foods is extrusion cooking technology Extrusion is a potent processing procedure that creates greatly expanded, low-density products with distinctive textural features by combining high temperature, pressure, and shear force. Several factors, including feed moisture, feed composition, feed particle size, feed rate, barrel temperature, screw speed, screw arrangement, and die geometry, must be closely regulated in the extrusion of snack foods. The degree of macromolecular changes that occur during extrusion is determined by these material and process variables, which in turn affect the rheological characteristics of the melt of food in the extruder and, ultimately, the properties of extrudates. Physical characteristics such as expansion and density are important parameters to evaluate the consumer acceptability of the final product (Patil *et al*., 2007) [18].

The objective of this study was to investigate the effects of extrusion conditions, screw speed, and barrel temperature, on the physical properties of a meat incorporated extruded snack.

Materials and Methods
Materials
The study was conducted at the department of Livestock Products Technology, College of Veterinary and Animal Sciences, Pookode, Wayanad, Kerala. The processing facilities and technical expertise of Fish Processing Division, ICAR- Central Institute Fisheries Technology, Kochi, Kerala were utilized.

Broiler chicken meat (skinless) procured from the local market in Kythira, Wayanad district was washed and cut into pieces of size 20 mm X 20 mm X 10 mm. The pieces of meat were subjected to 12 h of drying at 60 °C in a cabinet dryer. The dried meat was ground into a fine powder using a mixer grinder (Panasonic Corp., Japan). The powdered meat was packed in LDPE pouches and stored frozen until it was used. Jack fruit bulb and seed powders from fresh and fully matured un-ripened jackfruits were procured locally (M/S Nutritivo Food products, KINFRA Industrial Park, Chundale, Wayanad, Kerala). Rice flour (M/S Manjilas Food Tech Pvt. Ltd., Thrissur) was procured from the local market.

Preparation of extruded snacks
Three treatment formulations (incorporated with meat) and one control formulation (without meat) were prepared at the Division of Fish Processing, ICAR-Central Institute of Fisheries Technology, Kochi. The composition of the feed mix and process variables employed for extrusion cooking are given in table.1.

Table 1: The composition of the feed mixes and process variables employed for extrusion cooking.

Extrusion cooking Variables	Control	T1	T2	T3
Rice flour (% of feed mix)	80	62.69	62.23	57.32
Jackfruit bulb and seed powder in the ratio 1:1 (% of feed mix)	20	15.62	15.5	14.33
Powdered chicken meat (% of feed mix)	0	21.69	22.21	28.35
Barrel temperature (°C)	120	130	123	140
Screw speed (rpm)	250	262	254	230

Extrusion cooking was carried out using a laboratory model co-rotating twin screw extruder (Basic Technology Pvt. Ltd., Kolkata, India). The extruder had a length to diameter (L/D) ratio of 14.4:1 with a circular die having a diameter of 3.0 mm. The extruder had three-barrel temperature zones. Temperatures of the first two zones were maintained at 70 and 90 °C, respectively. The temperature of the last zone was adjusted to match the feed mix extruded and accordingly it varied between 120 °C for control, 130 °C for T1, 123°C for T2 and 140 °C for T3.

The three treatment blends and control blend were prepared by mixing rice flour, jackfruit seed and bulb powder and powdered chicken meat in required proportions by adding 2.5% of salt. Water was added by sprinkling to adjust the required moisture content (15%) and mixed thoroughly by hand mixing. The feed mixes after proper mixing were sieved through a 1 mm mesh to get uniform particle size. The sieved mixes were then kept for conditioning at low temperature (4 °C) for 30 min. Once the steady state was attained (30 min) in the last zone of the extruder, the mixes were fed one by one into the feed hopper and the feeding rate was adjusted for easy and non-choking operation. The barrel received feed material from the co-rotating feeder and it got cooked inside the barrel. The cooked material was driven to the die by the rotation of the screws (screw speed set at 250 rpm for control, at 262 rpm for T1, at 254 rpm for T2 and at 230 rpm for T3) and were extruded. The extruded products were immediately cut into pieces by an automatic cutting knife. The extrudates were collected in a tray and were dried at 100 °C for 2 minutes to remove the surface moisture.

Determination of physical properties
Expansion ratio
Expansion ratio of the extruded products was determined as per Ding *et al*. (2005) [6] as the ratio of the diameter of the extruded product to the diameter of the die. The diameter of the extruded sample was measured with a vernier caliper after the product reached ambient temperature. Six samples were used for each extrudate to calculate the average.

Bulk density
Bulk density was determined following Park *et al*. (1993) [20]. A 250 ml graduated cylinder was tired and gently filled with the extrudate. The bottom of the cylinder was repeatedly tapped gently until there was no further reduction of sample volume. Bulk density was calculated as the weight of sample/unit volume (mg/L). Each sample was determined in triplicate.

Water absorption index
The water absorption index of extruded products was determined by the method of Sosulski (1962) [26]. Analysis was carried out in duplicates. Five-gram samples of ground extrudate were transferred into tared 50-ml. centrifuge tubes. Thirty milliliters of distilled water were added to each sample, at the same time washing down the inside of the centrifuge tube. The suspension was rested for 10 min, during which the ground material adhering to the side of the centrifuge tube was scrubbed down with a glass rod to prevent it from drying. The suspension was centrifuged at 2300 rpm (Kemi Laboratory centrifuge, Ernakulam, Kerala) for25 minutes. The supernatant liquid was decanted, and the centrifuge tube was placed mouth down at an angle of l5°to 20° in a hot air oven. Allowed the tube to drain and dry for 25 minutes at 50 °C. It was then cooled in a desiccator and weighed. To calculate the percentage water absorption by the ground material, the following equation was used.

% Water absorption=(x+y- 5) X20,

Where, x= increase in weight of the ground extrudate, in g;
y=weight of ground extrudate used, in g.

Statistical analysis
Data recorded were analysed statistically using SPSS Software Version 21.0. One-way ANOVA followed by Duncan’s multiple range test, Pearson’s correlationwere used.

Results and Discussion

Effect of extrusion conditions on expansion ratio

Expansion ratios of extrudates are shown in table 2.

Table 2: Expansion ratio of control and treatment extrudates

Extrusion parameter	C	T1	T2	T3	F-value (P-value)
Expansion Ratio	4.74±0.04^{a}	4.09±0.03^{b}	4.15±0.02^{b}	2.78±0.04^{c}	636.060** (<0.001)

The values differed significantly (p<0.001) between control and treatment samples except between T1 and T2. C recorded the highest expansion ratio of 4.74 and T3 showed the lowest values. The percent expansion of T1, T2 and T3 in comparison to C were 86.0, 88.0 and 59.0 respectively.

Expansion ratios of extrudates assessed on the day of preparation differed significantly between control and treatment samples, indicating that the independent variables of extrusion cooking *viz*. proportions of meat powder as well as non-meat ingredients, barrel temperature and screw speed exerted a significant effect on the expansion of the feed mix. The best expanded extrudates were those made from control blend. The least expanded were the ones containing chicken meat in the highest proportion among the treatment blends.

As reviewed by Moraru and Kokini (2003) [16], extrudate expansion is the consequence of several events including material parameters (composition, molecular structure and interactions between components) and operational parameters (temperature, screw speed, screw geometry, mechanical energy, die geometry and air incorporation). While starch plays the major role in expansion, other ingredients (proteins, sugars, fats and fibres) act as diluents, with the maximum expansion observed with pure starch. Proteins have an effect on expansion through their ability to affect water distribution in the matrix, through their macromolecular structure and their ability to form insoluble polymers through covalent and non-bonding interactions that take place in extrusion which all can eventually affect melt viscosity.

Increased screw speed had been reported to lower the melt viscosity of the mix resulting in less dense, softer extrudates with higher expansion ratios (Ding *et al*., 2005; Panaswat *et al*., 2008) [6, 19]. Higher barrel temperatures had been cited to cause an increase in the degree of gelatinization and also the extent of superheated steam that caused the snacks to expand more (Korkerd *et al.*, 2016; Tumwine and Asiimwe, 2019) [10, 27]. Extrusion of feed materials with increased protein contents resulted in less expanded products as reported by Rhee *et al.* (1999) [23]; De Clindio *et al.* (2002) [3]; Basediya *et al*. (2013) [2]; Rao *et al.* (2018) [22] and Deepika *et al*. (2022) [5]. In the present study, rice flour and jackfruit flours had been utilized in the preparation of extrudates and it might be proposed that the rice and jackfruit with better content of amylose (Wong *et al*., 2021) [29] would have interacted with meat proteins resulting in a lesser expanded product.

In the present study, though the control extrudates were produced with a relatively lower barrel temperature, the increased screw speed and the presence of starch would have resulted in better gelatinization of the mix resulting in better expansion of the product. Although T3 was extruded at a relatively higher barrel temperature, the comparatively lesser screw speed and the presence of proteinaceous material in the feed mix eventually resulted in lesser expanded products. T1 and T2 were comparable in their expansion ratios as their content of meat powder was similar which had an upper hand over the dissimilar extrusion parameters.

Effect of extrusion conditions on bulk density

Bulk densities of extrudates evaluated on the day of preparation are shown in table 3. The mean and SE for bulk density for C was 110.5±0.20. The same for treatment samples, T1, T2 and T3 were 136.38±0.07, 137.43±0.12and 144.6±0.28, respectively. The values differed significantly (p<0.001) between control and treatment samples; however, no significant difference was noted between T1 and T2. C had the lowest and T3 had the highest values.

Table 3: Bulk density of control and treatment extrudates

Extrusion parameter	Control	T1	T2	T3	F-value (P-value)
Bulk density	110.5±0.20^{c}	136.38±0.07^{b}	137.43±0.12^{b}	144.6±0.28^{a}	407.203** (<0.001)

** Significant at 0.01 level; Means having different small letters as superscript differ significantly within a row

The process parameters *viz*. barrel temperature and screw speed as well as the mixture composition both were found to exert an effect on the bulk density of the extruded snacks which differed significantly on the day of production. The less dense and best expanded extrudates were the control samples, while T3 was found to have lesser expansion and increased bulk density.

Bulk density is a very important product quality attribute from the view of commercial production of extruded snacks. A high bulk density is generally associated with a low expansion index (Maskan and Altan, 2012) [14] which held true for the extrudates evaluated in the present study too. Bulk density was reported to have increased with increased level of addition of protein (Martinez–serna and Villota, 1992; Kuna *et al*., 2013) [13, 11] which had been ascribed to the protein interactions at higher concentration. The protein fractions reinforce the product cell wall and increase breaking strength and result in higher bulk density. Although, barrel temperatures and screw speed are found to affect bulk density (Martin *et al*., 2020) [12], the single most important factor in the present study appeared to be the presence or absence of meat powder and its proportion.

Effect of extrusion conditions on water absorption index

The comparison of water absorption index in the extrudates is shown in table 4. Water absorption index values differed significantly (p<0.01) among the samples with C having the highest and T3 having the lowest values.

Table 4: Water absorption index of control and treatment extrudates

Extrusion parameter	Control	T1	T2	T3	F-value (P-value)
Water absorption index	76.8±0.03[a]	66.6±0.03[b]	59.8±0.05[c]	47.0±0.02[d]	296.79** (<0.001)

**Significant at 0.01 level Means having different small letters as superscript differ significantly within a row

Water absorption capacity is a macroscopic parameter that relies on several factors like state of the starch molecules and protein and the range of void spaces accessible in the extrudate. The evaluation of water absorption index of extrudates revealed that addition of powdered chicken meat significantly influenced the water absorption capacities of extrudates. The lowest was observed in T3 and the highest was observed in C. This may be due to the increased number of hydrophilic constituents contributed by non-meat ingredients in C which bound water molecules and enhanced the gel forming capacity of macromolecular starch. This is in agreement with De Mesa *et al*. (2009) [4], Jozinović *et al.* (2012) [8], Rweyemamu *et al*. (2015) [24], Ali *et al*. (2016) [1] and Kaushal *et al*. (2019) [9] who observed decreased water absorption index with decreasing proportions of starch in feed materials. Eliasson (1983) [7] reported that the lack of protein in raw materials could make starch gelatinization easier, since protein was known to compete with starch in water absorption characteristic. Furthermore, all conditions that promoted a lower viscosity of the dough and accounted for enhanced gelatinization like high moisture content of feed, higher barrel temperature etc. were found to improve water absorption index (Oikonomou and Krokida, 2012; Ding *et al*., 2005) [17, 6]. Several researchers who studied starch gelatinization and its effects in complex food systems observed that water absorption index depended on the presence of relatively intact molecules, which retained their ability to bind water (van den Einde *et al*., 2003 and Seker, 2005) [28, 25]. Although a portion of the starch would be damaged in the extruder as in the present study, the remaining undamaged polymers would bind water to a much larger degree than the proteins and as the protein to starch ratio increased, the water absorption index decreased simply as a result of the decreased starch content.

Conclusion

With the objective of nutritional enhancement of extruded snacks, different proportions of rice flour, jackfruit bulb and seed powder and powdered chicken meat were extruded under different levels of screw speed and barrel temperature. The physical characteristics of the extruded snack were found to be influenced by changes infeed composition, screw speed and barrel temperature. The principal factor that was found to exert an effect was feed composition, *i.e.* presence of absence of meat and level of meat. It was found that even with an increased content of meat (28.5 percent) in T3, better gelatinization of starch was achieved with acceptable levels of expansion in all treatments. It was shown that chicken meat may be included to produce wholesome extruded snack foods with the right ingredient selection and extrusion processing conditions.

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