INFLUENCE OF EXTRUSION CONDITIONS ON THE PRODUCT QUALITY CHARACTERISTICS OF CORN-PEANUT FLAKES

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Abstract
The study assessed the effect of extrusion cooking on physical properties, chemical composition, functional and sensory qualities of corn-peanut flakes. Corn is deficient in protein and peanut is rich in oil and protein. As a result, extruding corn and peanut flours enriches the flakes with protein and gives them a good texture. Corn (DH 540) and Peanut (Werer-964) flours were mixed in a proportion of 70:30 percent, respectively. Determination of proximate composition was done before and after extrusion. Corn-peanut extrudates and flakes were then produced using feed moisture contents (17% and 21%,) barrel temperatures (140°C, 160°C, and 180°C) and screw speeds (150, 200 and 250 rpm) in a double screw extruder using CRD in factorial arrangement with three replications, and data were subjected to one-way ANOVA . The physical and functional properties (WAI, WSI, WHC) were determined according to standard procedures. Combination of 180°C, 17% and 250 rpm produced flakes with the highest radial expansion (1.32 cm/cm) whereas 180 °C, 21%, 200 rpm formed the best specific length (2.27 cm/g). However, the acceptability test showed that 180°C, 17% and 150 rpm was the best processing condition at which WAI, WSI and WHC indices of the products were 5.30, 11.40 and 6.30, respectively indicating improvement of functional properties. Further, it contained a better crude protein (21.36%) for better growth and disease prevention than that of the mixed flour before extrusion (21.29%) and that of corn (8.03%). In conclusion, extrusion didn't negatively affect the overall quality of corn-peanut flakes. The product can be prepared in many forms for child feeding.

Keywords: corn-peanut, extrusion conditions, flakes, protein, quality.

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1. INTRODUCTION

Maize (*Zea mayis* L.) is one of the most important cereal crops in Ethiopia, ranking first in total production and second in area coverage next to *Tef* (CSA, 2006). Maize is used as human food, industrial raw material, and its stalk as animal feed in Ethiopia. Peanut is a good source of oil and is rich in protein. It can serve to enrich cereal products like corn flakes which are protein-deficient. In this case, mixing legume and cereal flours generally enhances the protein content and improves the physicochemical and sensory properties of food products. Blending corn and peanut flours is a good example of enrichment in food processing activities. As corn and peanut are commonly consumed separately in Ethiopia, it is wise to consider the study for application in all regions as it is not area-specific. Peanut is used as a raw material for the production of oil by some factories in Ethiopia, while many people regularly consume it roasted. Although the corn and peanut were taken from Melkassa and Pawe Agricultural Research Centers, respectively, they are widely consumed in Ethiopia.

Extrusion can be hot (extrusion cooking) or cold extrusion. Extrusion cooking technologies (in single and double screw extruders) are used to manufacture many forms of food stuff from cereals and other ingredients. Generally, extrusion improves the sensory and nutritional qualities of food products. However, the impact of processing conditions varies from product to product. Its effect on pure corn flake may not be the same as on corn-peanut flakes. The range of extruded products includes breakfast cereals, snack foods, breading crumbs and animal feeds. Ingredients, such as maize flour and grits, wheat flour and other food components, are passed through an extrusion

cooker under pressure, mechanical shearing stresses and elevated temperature, and expand rapidly as they are forced through the outlet die (Riaz, 2000; Cazzaniga *et al*., 2001).
Suknark *et al*. (1998) demonstrated that directly expanded, snack like products could be made from combinations of various starches and up to 30% defatted peanut flour can be added to cereal flour. Fully defatted peanut is used as one component raw material in this study to increase the protein content of the mixture during extrusion. Defatting is recommended to avoid backflow of extrudates in extruders (Guy, 2001). Typical product attributes of concern for extruded products include expansion ratio, bulk density, water absorption index, water solubility index, water holding capacity, nutritional value and sensory qualities (Anderson and Hedlund, 1991; Ilo *et al*., 1996; Ding *et al*., 2005; Ding *et al*., 2006).
Temperatures inside the barrel of an extruder can range from 100 to 200°C and moisture content can be from 13 to 30% depending on the characteristics of the required end-product (Cazanniga *et al*., 2001; Riaz, 2000). Two types of commercial products (rod shaped and puffed extrudates) are commonly used by researchers to be references for identifying optimum variables. In extrusion of cereal flour and starch based products, the qualities of the raw material such as the composition of starch, protein, lipid and fiber dictate product quality attributes, among others the expansion and functional properties. The objective of the study was therefore to evaluate the effect of extrusion variables (temperature, moisture content and screw speeds) on the chemical composition, physical and functional properties and sensory qualities of extruded corn-peanut flakes as well as to enhance the protein content of commonly consumed corn flakes.

2. MATERIALS AND METHODS

Corn (DH 540) and Peanut (Werer 964) crops obtained from *Melkassa* and *Pawe* research centers, Ethiopia, respectively, were used to prepare corn-peanut flakes. The corn and peanut crops were milled to obtain flour. They were converted into flour separately, and their chemical composition (Table 1) was determined following the standard procedures described in AOAC (2000). Accordingly, the moisture and protein content of the samples were determined using air oven and Kjeldahl methods, respectively. Crude fat was analysed using Soxhlet extraction method involving hexane as a solvent. Crude fiber was determined by the non-enzymatic gravimetric method. The total percentage of carbohydrate content was calculated by difference. The corn was milled using a small scale hammer mill at a sieve size of 100 - 500 µm. Peanut was also milled by a small scale commercial laboratory grinder. Milled peanut flour was fully defatted by Soxhlet using Hexane (analytical grade) to remove its high fat content. Fully defatted peanut flour (FDPF) was further milled at a sieve size of 100 - 125 µm. The corn and peanut flours were mixed at a proportion of 70% and 30%, respectively as recommended by Suknark *et al*. (1998). The composite flour was sealed in plastic bags and stored till the extrusion test was conducted. Ground flour samples were analyzed for proximate chemical composition before the extrusion in a double screw extruder.
Prior to the main extrusion test, preliminary tests were conducted to set the possible operating conditions. Accordingly, barrel temperatures(BT) of 140°C, 160°C and 180°C, feed moisture contents(MC) of 17% and 21%, screw speeds(SS) of 150, 200 and 250 rpm were selected based on the test findings and previous recommendations of Suknark *et al*. (1998) and Lazou and Krokida (2009). Extrusion was performed at Bahirdar University' laboratory on a pilot scale co-rotating twin screw food extruder (model Clextral, BC-21 N° 124, Firminy, France). The barrel has a smooth 300 mm useful length and consists of three modules each 100 mm long fitted with 25 mm diameter screws. Each zone-temperature was controlled by a Eurotherm controller (Eurroterm ltd., UK). Twin screw volumetric feeder (type KMV-KT20) delivered

the raw material into the extruder inlet. While operating, water at 22^{o}C was injected in the extruder via an inlet port by a positive displacement pump (DKM- Clextral, France). The end of the extruder was capped with a die plate, which held a die having circular openings. The die hole has 9 mm length and its diameter reduced from 5 mm to 2 mm. The pump was adjusted to give moisture contents of 21% and 17% in the mixes for a constant material feed rate of 7.3 kg/h using hydration equation suggested by Golob (2002) as:

$$W_a = S_w\left[\frac{m - m_o}{100 - m}\right]$$

where:
W_a - weight of water added (g);
S_w - sample flour weight (g);
m_o - original flour moisture content (% weight base);
m - required dough moisture level (% weight base).
During extrusion, samples were extruded as straight rope (rode) for a time interval of 10 s (Mason and Hoseney, 1986) so that approximately 100 cm long extrudate emerge from the die. Extruded samples were collected when the extrusion process parameters reach steady state in which there were no visible drifts in torque and die pressure (Garber *et al.*, 1997). The extruded products were placed on a table and allowed to cool for 30 minutes at room temperature for the measurement of weight, length and diameter (Ibanoglu, *et al.*, 2005) and to evaluate the expansion ratio (RE) and specific length of the products. Except the samples taken for moisture analysis, others were collected and sealed in plastic bags for 24 hr at ambient conditions. The corn-peanut flakes were prepared through cutting, shaping and subsequent oven drying of extrudates at a temperature of 85 ^{0}C.

Determination of the physical properties

The samples were stored at 22 to 24^{o}C, and physical properties determination and sensory evaluation were done within seven weeks after extrusion to avoid deterioration and loss of quality attributes. To measure the specific length and degree of expansion, sample products were extruded as straight ropes for a time interval of ten seconds. Length was measured by a pocket size steel tape of 1mm accuracy. The diameter of the extrudates was measured by a Vernier Caliper (Russia) having 0.05 mm accuracy. Weight was measured by a digital balance (ADAM, AFP 1200, South Africa) of 0.01 g sensitivity. A mean value of length (cm), weight (g) and diameter(cm) of 4, 4 and 10 measurements, respectively, was recorded for each experimental run to obtain accurate results. The expansion ratio (diametric) was calculated as the ratio of the diameter of the extrudate to the diameter of the die hole (Mason and Hoseney, 1986). The specific length of the extrudate was taken as the length (cm) of the extrudate per unit mass (g). The bulk density of the extrudates was calculated as described by Mason and Hoseney (1986):

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

where:
ρ - Bulk density (g/cm^3);
d - Diameter of extrudate (cm);
L - Length of extrudate (cm);
w - Weight of extrudate (g).

Functional properties

Functional properties: water absorbing index (WAI), water solubility index (WSI) and water hydration capacity (WHC) were determined as per the standard procedures. WAI and WHC are used as indicators of starch gelatinization and measures of quality attributes of extruded products (Lo *et al.*,1998; Ding *et al.*, 2005; Ding *et al.*,2006). Water solubility index (WSI) is used as a measure of starch degradation meaning that at lower WSI there is a minor degradation of starch and such condition leads to less numbers of soluble molecules in the extrudates (Hernandez-Diaz *et al.*, 2007). To determine WAI, 1.25 g sample was placed in about 40 ml centrifuge tube and suspended in 15ml distilled water. The sample was incubated by using a shaker (BI Barnstead lab/line) at about 25°C for 30 min and was centrifuged at 3000xg for 5 min. The mass of the whole centrifuged sample and that of the clear supernatant (after decantation) were individually recorded. The WAI was calculated as grams of absorbed water per gram of dry sample mass (1.25 g). The supernatant saved from WAI determination was evaporated at 105°C for overnight. The WSI was then calculated as a ratio of dry residue to the original mass (about1.25 g) used to estimate WAI and the result was expressed as percentage. The WHC of the puffed extruded product was estimated according to AACC (2000) official method of 56-20. To a sample (2.0 g) measured in about 100 ml centrifuge tube, 40 ml water was added, shook vigorously to thoroughly suspend the sample. After the sample suspension held for 10 min, it was centrifuged at 1000xg for 15 min. The clear supernatant was drained into pre - weighed and dried beaker for estimation of the WSI of the product. The residue and the tube were weighed and the hydration capacity was calculated as follows:

$$WHC = \frac{(W_T + W_{SAT})}{W_S}$$

where:
WHC - water hydration capacity;
W_T - weight of tube (g);
W_{SAT} - weight of sediment (g);
W_S - sample weight (g) (wet basis).

Experimental design and data analysis

The samples, in triplicate, were subjected to extrusion test at all combinations of the operating conditions (barrel temperature, feed moisture and screw speed) using CRD. A mixed factorial arrangement with 3(barrel temperatures:140°C, 160°C and 180°C) x 2(feed moistures:17% and 21%) x 3(screw speeds:150, 200 and 250 rpm) was used.

Data on proximate composition were collected before and after extrusion. The values of the physical, functional and sensory attributes were collected and subjected to one-way analysis of variance using SPSS version 18.0 statistical software (SPSS, 2009).

Sensory evaluation

Sensory evaluation consisting of twenty trained panelists (16 females and 4 males) was administered within seven weeks after extrusion using a 9-point Hedonic scale for color, flavor, texture and overall acceptance. Each panelist was asked to assign scores 1–9; 1 (dislike extremely) to 9 (like extremely), for visual color, flavor, texture (crispness /hardness) and overall acceptability. A sensory score of 5 or above was deemed acceptable and a sensory score below 5 was considered unacceptable. The evaluation was carried out within a week time after the production of the flakes. The coded flakes were arranged in a random order on white plates and served to the panelists. Panelists had rinsed their mouths between samples.

3. RESULTS AND DISCUSSION

Proximate chemical composition of the products

The chemical composition of the flours and extrudates at the most suitable processing condition (180°C barrel temperature, 17% moisture content and 150 rpm screw speed) as verified by overall acceptability test is presented in Table 1.

Table 1. Chemical composition of corn and defatted peanut flours before and after extrusion (g/100 g)

Component	Samples(mean ± SD)*			
	Corn Flour	Fully Defatted Peanut Flour (FDPF)	Mixture of the flours before extrusion	Extrudate/flakes after extrusion
Moisture	9.49 ± 0.02	9.67 ± 0.03	9.96 ± 0.1	5.25 ± 0.84
Crude fat	4.44 ± 0.04	2.22 ± 0.09	3.83 ± 0.01	2.24 ± 0.06
Crude protein	8.03 ± 0.04	53.54 ± 0.02	21.29 ± 0.05	21.36 ± 0.06
Crude fiber	2.13 ± 0.08	5.03 ± 0.02	2.85 ± 0.05	2.78 ± 0.09
Total ash	1.41 ± 0.05	4.17 ± 0.03	2.16 ± 0.07	2.16 ± 0.03
Total carbohydrates	76.63 ± 0.05	30.40 ± 0.04	62.76 ± 0.06	68.33 ± 0.03
Utilizable carbohydrate	74.50 ± 0.03	25.37 ± 0.07	59.91 ± 0.04	65.55 ± 0.02
Food energy (kJ/100g)	1506 ± 0.06	1459 ± 0.08	1487 ± 0.01	1516 ± 0.02

*Values except moisture are expressed in dry weight basis (DWB)

Crude protein content of FDPF (53.54%) was found to be nearly seven times greater than that of the corn (8.03%). The mixture of corn and fully defatted peanut flours after extrusion contained a better content of crude protein (21.36%) than that of the mixture of corn and FDPF before extrusion (21.29%) and corn's alone (8.03%). This shows that extrusion slightly improves but doesn't significantly increase the protein content of extrudates. Corn has the highest total carbohydrate (76.63%) and utilizable carbohydrate (74.50) than peanut which contained 30.40% total carbohydrate and 25.37% utilizable carbohydrate. It is because peanut is an oil crop and contains higher percentage of protein than corn.

Physical properties of the corn-peanut extrudates

Of all the properties, the expansion ratio (diametric) or radial expansion (RE) and specific length or axial expansion (SL or AE) are very important as extrusion is a size enlargement process. The physical properties of the samples during extrusion were affected by the changing operating conditions (Table 2). Barrel temperature significantly affected the radial expansion (P<0.01). The expansion ratio (RE) increased from 1.12 cm/cm to 1.28 cm/cm when temperature increased from 140°C to 180°C at constant MC(17%) and rpm (150) in the combination, from 140°C, 17% MC, 150 rpm to 180°C, 17% MC, 150 rpm. This is an indication that heating causes moisture loss and reduction of viscosity which in turn improves the expansion of extruded products. Ding *et al*., (2005) also reported that the viscosity of feed material decreased as barrel temperature increased which results in better expansion.

Previous studies showed that increasing temperature increases expansion ratio (RE) up to a certain temperature, then it tended to decrease usually because of product collapse (Kim and Maga, 1993). A product collapse may be seen at higher temperatures as extrusion temperatures may exceed 200°C. Generally, increasing feed moisture caused a decrease in radial expansion (example, 1.12 to 1.10cm/cm) which is due to reduction of elasticity of the starch based material. However, specific length (AE) increased with feed moisture (example, 1.28 to1.43cm/g). Similar observations were reported by Faubin and Hoseney (1982a) and Owusu-Ansah *et al*. (1984). Axial expansion increased as screw speed increased from 150 to 200 rpm and decreased afterwards at 250 rpm.

Table 2. Physical properties of the corn-peanut extrudates.

Operating conditions		Product physical properties at different screw speeds (mean ± SD)*														
		SS=150 rpm					SS=200 rpm					SS=250 rpm				
BT (^{0}C)	MC (%)	RE (cm/cm)	SL (cm/g) =AE	BD (g/cm^3)	DMC (%)	FMC (%)	RE (cm/cm)	SL (cm/g) =AE	BD (g/cm^3)	DMC (%)	FMC (%)	RE (cm/cm)	SL (cm/g) =AE	BD (g/cm^3)	DMC (%)	FMC (%)
140	17	1.12 ± 0.05	1.28 ± 0.01	0.79 ± 0.05	6.20 ± 0.12	15.36 ± 0.76	1.13 ± 0.15	1.59 ± 0.11	0.66 ± 0.05	8.34 ± 0.23	15.05 ± 0.88	1.25 ± 0.05	1.35 ± 0.22	0.61 ± 0.02	7.77 ± 0.33	14.84 ± 0.84
	21	1.10 ± 0.18	1.43 ± 0.03	0.84 ± 0.03	7.52 ± 0.56	19.00 ± 0.76	1.11 ± 0.29	1.87 ± 0.02	0.74 ± 0.01	7.67 ± 0.45	19.87 ± 0.66	1.12 ± 0.02	1.74 ± 0.22	0.67 ± 0.06	8.86 ± 0.56	19.43 ± 0.68
160	17	1.17 ± 0.11	1.51 ± 0.04	0.71 ± 0.01	5.75 ± 0.78	15.30 ± 0.18	1.18 ± 0.05	1.57 ± 0.02	0.63 ± 0.01	6.44 ± 0.89	14.98 ± 0.81	**1.29 ± 0.22**	1.36 ± 0.07	0.55 ± 0.02	5.46 ± 0.43	14.28 ± 0.18
	21	1.14 ± 0.13	1.05 ± 0.10	0.8 ± 0.01	6.07 ± 0.22	18.53 ± 0.22	1.17 ± 0.04	1.78 ± 0.05	0.6 ± 0.02	5.79 ± 0.54	15.30 ± 0.56	1.19 ± 0.06	1.71 ± 0.03	0.57 ± 0.013	4.62 ± 0.67	14.58 ± 0.45
180	17	1.28 ±0.09	1.09 ± 0.01	0.61 ± 0.02	5.25 ± 0.84	14.40 ±0.47	1.30 ± 0.03	1.61 ± 0.08	0.55 ± 0.05	4.44 ± 0.76	13.95 ± 0.60	1.32 ± 0.04	1.57 ± 0.21	0.38 ± 0.07	4.48 ± 0.25	12.03 ± 0.34
	21	1.20 ± 0.55	0.79 ± 0.15	0.65 ± 0.08	5.94 ± 0.65	18.11 ± 0.64	1.20 ± 0.06	2.27 ± 0.13	0.57 ± 0.04	4.71 ± 0.78	16.40 ± 0.72	1.28 ± 0.07	2.06 ± 0.03	0.50 ± 0.05	4.87 ± 0.18	14.23 ± 0.45

RE= radial expansion=expansion ratio(diametric), SL= specific length or AE=axial expansion, BD= bulk density, FMC= fresh extrudate moisture content, DMC =dry extrudate moisture content.

*Means of each physical property at all combinations of BT, MC and SS in each column are significantly different (P <0.05), *values are triplicate means ± SD, BT=barrel temperature,SS=screw speed, MC=moisture content.

In the present investigation, it was observed that radial expansion increased with screw speed at constant barrel temperatures and moisture contents. The same has been reported by other researchers (Chinnaswamy and Hana, 1990; Mezreb *et al*., 2003).
The combined effect of barrel temperature, moisture content and screw speed showed that the highest radial expansion (1.32) was observed at the lowest moisture content (17%), the highest temperature (180°C) and the highest screw speed (250 rpm). The lowest and highest barrel temperatures (140°C, 180°C) and the highest moisture content (21%) registered the lowest radial expansion (1.10). The expansion properties of cereals have been related to the degree of gelatinization. Higher expansion volume indicates a greater starch gelatinization. Specific length (cm/g) relates extruded product length to its weight and measures the axial expansion of the extrudute. Extruding at 180°C, 21% and 200 rpm results in high specific length, whereas extruding at 160°C, 17% and 150 rpm gave low specific length.
Screw speed significantly affected the specific length of the extrudates and the highest was recorded at 200 rpm. But, barrel temperature and feed moisture content did not significantly affect extrudates' specific length. Increasing screw speed up to 200 rpm and declined afterwards. Lo *et al.* (1998) reported that axial expansion increased with screw speed at the expense of radial puffing. This was believed to be due to less resistance at the die due to lower die-pressure observed at high screw speed. However this explanation could not be fully verified in the current study. The density of extruded products decreased with an increase in radial expansion. Earlier it was reported that the more the extrudates expand in either the axial and radial direction, the less dense they become indicating the higher proportion of starch gelatinization (Hsieh *et al*., 1993).
Lawton *et al*. (1985) reported that density decreases with increase in extrusion barrel temperature due to starch gelatinization. Increased gelatinization increases volume of products consequently bulk density decreased (0.84 to 0.38 g/cm^3) as observed in this work. This was due to low viscosity at increased temperature allowing the dough to expand. The result was in agreement with the work of Suknark *et al*. (1998), who reported that an increase in moisture content from 18% to 22% tended to increase the bulk density of extrudates. An increase in the barrel temperature increased the degree of superheating of water in the extruder encouraging bubble formation and also a decrease in melt viscosity leading to reduced density which was supported by the finding of Fletcher *et al*. (1985). Similar results have been observed by Lawton *et al*. (1985) and Mercier and Feillet (1975). Feed moisture has been found to be the main factor affecting extrudate density next to barrel temperature. The high dependence of bulk density and expansion ratio on feed moisture would reflect its influence on elasticity characteristics of the starch-based material.
Commercial corn products generally have a bulk density between 50 and 300 kg/m^3 (Harper, 1981). The results of the current investigation showed higher bulk densities reaching up to 840 kg/m^3. Products extruded at high temperature, which showed higher degree of gelatinization and lower density, retained the lowest moisture after puffing. The high bulk density of Corn and FDPF mix extrudate could be due to the relatively high level of protein content of peanut. Extruded volume of cereals and starches decreased with increasing amount of protein (Faubion and Hoseney, 1982a).

Functional properties of the extruded products

WAI and WSI were 4.51 and 14.18, respectively, at conditions of 17% moisture content, 180°C and 250 rpm showing comparative improvement of functional properties in a mix of Corn and FDPF. The WAI values varied between 4.51 and 5.42 when the temperature decreased from 180°C to 140°C at constant MC (17 %) and SS (250 rpm) in the three combinations involving 140°C, 160°C and 180°C. In this same

extrusion condition, the range of WSI values was found to be within 11.69 to 14.18 except that WAI decreased with temperature while WSI increased with the same. With each of the temperatures (140°C, 160°C and 180°C) in the combinations at constant MC (21%) and SS (150 rpm), the WAI values were 4.74, 5.12 and 5.25, respectively which justifies the findings of Lazou and Krokida (2009). But a constant rise of WAI values was not noted with increased temperature in the present investigation. Pure corn has WAI and WSI values of 5.7932 ± 0.064 and 11.7987 ± 1.417, respectively (Lazou and Krokida, 2009) at operating conditions of 16% moisture content, 200°C and 6.84 kg/h flow rate.
With an increase in screw speeds at constant temperatures of 140°C/160°C and 21% MC as well as 160°C and 17% moisture, the WHC values decreased. In general, the results showed no uniform increase or decrease of functional property values. However, there are indications about the influence of operating conditions on WAI, WSI and WHC. Details of the results are given in Table 3.

Sensory qualities of the products

Sensory evaluation in terms of color, flavor, texture and overall acceptance were conducted for 12 selected products (6 corn flour extrudates and 6 mixes of corn and FDPF extrudates). Extruded samples produced at constant temperature of 180 °C and 17% MC with varying screw speeds of 150, 200 and 250 rpm were considered for the evaluation because of their high radial expansion and effect on aflatoxin reduction (Aynadis and Adamu, 2014). Accordingly, the best combination of operating conditions which produced the most preferred sample was 180°C, 17% and 150 rpm registering an overall acceptance of 8.50 points for pure corn flakes and 5.64 for the corn-peanut flake. The mean sensory scores of these products are summarized in Table 4.
The sensory score for color, flavor, and texture indicated that all products have a mean value greater than 5, indicating that the products are well liked by panelists. Scores of color, flavor, texture, and overall acceptance revealed that differences exist between the products. All products processed at a moisture content of 21% had a relatively lower overall acceptance score. Clear differences in color and flavor were detected between the products from the two (corn, and mix of corn and FDPF) with a highest being for mix of corn and FDPF. Processing conditions of 180°C, 17% moisture content and 150 rpm screw speed provided the best score in texture. Generally extrudates of composite flour of corn and FDPF possessed better flavor and color than pure corn, though they had harder texture. As extrusion is a size enlargement process, especially higher radial expansion can be related to soft texture which ultimately enables products to gain acceptability by consumers. Extrusion at 180°C barrel temperature produces maximum radial and higher axial expansion resulting in lowest moisture after puffing, lowest bulk density and a softer extrudate.

Table 3. Functional properties of the flakes.

Operating conditions		Product functional properties (mean ± SD)								
		SS=150 rpm			SS=200 rpm			SS=250 rpm		
BT (°C)	MC (%)	WAI	WSI	WHC	WAI	WSI	WHC	WAI	WSI	WHC
140	17	4.42 ± 0.050	10.80 ± 0.035	6.31 ± 0.026	4.18± 0.015	15.06 ± 0.025	5.18 ± 0.045	5.42 ± 0.110	11.69 ± 0.035	6.42 ± 0.038
	21	4.74 ± 0.030	9.47 ± 0.025	5.74 ± 0.042	4.53± 0.013	9.84 ± 0.015	5.53 ± 0.023	5.00 ± 0.015	10.97 ± 0.033	5.10 ± 0.017
160	17	5.59 ± 0.025	10.77 ± 0.021	6.59 ± 0.019	5.51± 0.035	12.01 ± 0.022	6.51 ± 0.012	5.08 ± 0.045	13.53 ± 0.036	6.08 ± 0.016
	21	5.12 ± 0.015	9.89 ± 0.054	6.12 ± 0.029	5.07± 0.022	9.46 ± 0.025	6.07 ± 0.020	3.63 ± 0.031	16.10 ± 0.012	4.63 ± 0.037
180	17	5.30 ± 0.002	11.40 ±0.011	6.30 ± 0. 007	5.48± 0.011	11.20 ± 0.017	6.48 ± 0.009	4.51 ± 0.021	14.18 ± 0.004	5.51 ± 0.003
	21	5.25 ± 0.023	9.90 ± 0.001	6.25 ± 0.046	5.43± 0.016	12.17 ± 0.025	6.44 ± 0.030	5.23 ± 0.007	1.95 ± 0.045	6.23 ± 0.029

WAI=water absorbing index, WSI= water solubility index, WHC= water hydration capacity.
[*]Means of each functional property at all combinations of BT, MC and SS in each column are significantly different (P > 0.05).
*Values are triplicate means ± SD.

Table 4. Sensory values of the extruded products by Hedonic Test Scale*

Product	Operating conditions		Sensory values (N=20)*											
			SS=150 rpm				SS=200 rpm				SS=250 rpm			
	BT ^{0}C	MC %	Color	Flavor	Texture	Over all acceptance	Color	Flavor	Texture	Over all acceptance	Color	Flavor	Texture	Over all acceptance
Corn flour extrudate	180	17	8.08 ±1.82	7.65 ± 1.26	8.68 ±1.87	8.50	7.59 ±1.33	7.33 ± 1.54	8.55 ± 1.56	8.33	7.38 ± 1.45	7.21 ± 2.55	8.34 ± 1.23	8.12
		21	7.11 ± 1.23	7.16 ± 2.42	8.10 ± 1.76	7.78	7.07 ± 1.65	7.08 ± 2.11	7.68 ± 1.36	7.45	7.01 ± 1.33	7.00 ± 0.05	7.13 ±1.92	7.12
mix of Corn and FDPF	180	17	8.54 ± 1.25	8.50 ± 0.55	6.08 ± 1.39	5.64	8.23 ± 1.67	8.23 ± 0.45	5.90 ± 1.82	5.42	7.81 ± 1.89	8.08 ± 0.34	5.78 ± 1.35	5.22
		21	7.45 ± 0.98	7.56 ± 0.43	5.35 ± 1.66	5.14	7.33 ± 0.92	7.34 ± 1.55	5.15± 1.25	5.10	7.12 ± 1.77	7.21 ± 1.89	5.07 ±1.90	5.05

BT - barrel temperature, MC - moisture content, SS - screw speed.
*Samples were evaluated in rod form.
*1=extremely dislike, 5=neither like nor dislike, 9=extremely like.
* N=number of panelists, *means±SD.

With 140°C barrel temperature, extruded products were less expanded, more dense, very hard and had uncooked pasta- like appearance with high moisture puffing. Even if, products processed at 180°C, 17%, 250 rpm registered the highest radial expansion (1.32), 180°C, 17%, 150 rpm was found to be the best combination which produced the most preferred corn-peanut flakes.

4. CONCLUSION

Mixing corn and peanut flours with a proportion of 70% and 30%, respectively increased the protein content of flakes and produced good quality extruded product. The extruded corn-peanut product contained more protein (21.36 %) than corn (8.03 %). Therefore extruding cereals at higher temperature (180°C), lesser MC(17%) and lesser screw speed (150 rpm) gives a product with good chemical composition, physical and functional properties, safety and consumer acceptability.

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