Food Technology Research Journal, Vol. 1, issue 2, 50-63, 2023

FTRJ

Effect of Some Operating Parameters on Quality of Corn Flakes Supported by Some Additives

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Original Article

Article information
Received 12/2/2023
Revised 26/2/2023
Accepted 3/3/2023
Published 7/3/2023
Available online 8/3/2023

Keywords
corn, soybean, oat, die, expansion ratio, water absorption capacity

ABSTRACT

The main objective of this work was to study the effect of some operating parameters on quality of corn flakes supported by some additives. Extruded snacks were prepared using different blends (A, B and C) of grits corn, flakes defatted soy bean and flakes oats [A (50:30:20), B (40:35:25) and C (30:40:30)] respectively, with different moisture contents depend on wet basis (12, 17, 22, 27 and 32 %) and two extruder die diameters (0.6 and 1.0 cm). The chemical compositions of the three blends were determined. It was found that blend C had the higher protein, fibers, fat, moisture content and ash. The results showed that the changing of die diameter and moisture content affected the physical properties of extrudates (expansion ratio, bulk density, hardness, water absorption capacity, water activity, color) for all different blends (A, B and C). Sensory evaluation was subjected (odor, texture, taste, color and overall acceptability), the overall acceptability was 9 for blend (C) with moisture content 22%.

1. Introduction

Extrusion is a process in which many food and feed products can be manufactured (DanYang Ying et al., 2017) is defined as multi-functional, multi-step and mechanical/thermal process during which the food is exposed to a high temperature for a short period of time. Extrusion is extensively utilized for the production, modification and quality improvement of many products in food industry including ready-to-eat snacks, breakfast cereals bakery products, baby foods, pastas (Schmid et. al., 2022). It has many advantages such as high productivity, low cost of production and product quality with significant nutrients retention (Dalbhagat et. al., 2019; Wang et. al., 2019).

The thermo-mechanical cooking takes place in a screw-barrel in which a combination of temperature and pressure leads to produce mechanically shaped extrudate with chemical, physical and structure changes (Rodriguez-Miranda et. al., 2011). Alterations in the chemical and physical characteristics of food ingredients, particularly lipid, protein and starch through the extrusion process have been reported by (Frías et al., 2011)

On other hand extrusion technology have the efficacy to inactivate the population of microorganisms in both low and high moisture foods several studies approved that (Verma et al., 2018; Verma and Subbiah, 2019) it also denatures undesirable enzymes, inactivates some antinutritional factors (haemagglutinins, trypsin inhibitors, phytates and tannins); sterilises the final product; and keeping the natural colours and flavours of extruded foods (Singh et al., 2007). The effect of different extrusion operation factors on the quality and nutritional value of the extruded products has been studied by many researchers (Anton et al. 2009; Kaur et al. 2015; Yağcı and Evci, 2015; Rathod and Annapure, 2016).

The properties of extruded products are greatly of Rice-flour pellets, they are significantly affected by moisture content and at specific temperature.

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Sokhey et.al. (1997) studied the effects of die dimensions on extruder performance, they found that the die diameter affected the radial expansion of the extrudate and Specific mechanical energy. In a recent study El-Adly et. al. (2022) found that die hole diameter has noticeable effect on extruder productivity and the specific energy consumption.

Recently numerous studies have fortified extruded snacks with combination of more nutritious food to increase their nutritional value. Corn is an important cereal crop, it is considered as a main ingredient in extrusion processing to manufacture snacks and breakfast cereals due to its nutritional value and special taste (Yang et. al., 2018). Considering the high levels of fiber in corn it can help lower cholesterol and also reduce the risk of colon cancer (Cueto et al. 2010; Hamid and Kalsoom, 2017)

Oat (*Avena sativa*) contains a unique nutritious value because it has good lipid profile with unsaturated fatty acids, high content of protein, contains high amount of vitamins and minerals (Ahmad and Zaffar, 2014) and greater amount of soluble fiber compared to other cereals, it is also a good source of functional ingredients like β-glucan and antioxidants (Singh et. al., 2013). Many studies reveal that oats have beneficial effects on health (Wani etal., 2014). Moreover, β-glucan in oat has great physiological benefits due to its impact on lowering serum cholesterol effects, it is also effective in decreasing the potential dangers of developing chronic diseases (Woleveretal., 2010; Zhou et. al., 2022) and glycemic control (Sayanjali et al., 2017). Oat contains about 4.5-5.5% of β- glucan (Ajithkumar et al., 2005).

Soybean has considerable potential as human food and already is an integral part of the human daily diet. It contains high levels of protein with good quality and all the macro nutrients desired for balanced nutrition, protein 40 %, dietary fiber 15 % and fat 18 %. Soluble carbohydrate 18 % vitamins and minerals are present as well (Singh et al., 2009). The nine essential amino acids are all found in soy beans and it also have the ability to decrease blood cholesterol, diabetes, obesity and reduce the risk of certain types of cancer (Kingsley et. al., 2017and Demmer et. al., 2016).

Oat, soybean and corn were used separately and sometimes two of them with other ingredients to produce extruded foods (Zheng et. al., 2020; Guo et. al., 2018) whereas composite foods with proteins and fiber and other functional components provide a nutritional psycho-social beneficial quality that promotes acceptance of extruded foods. Combining oat, soybean and corn will result in desirable nutritional profiles and improvement in acceptance of snack products.

The aim of this study is to investigate the effect of different operating parameters (moisture, components ratio and die diameter) on the quality attributes of extruded snacks to obtain high nutritional value extrudates from oat, soybean and corn.

2. Materials and Methods

Materials

The raw materials under study (grits corn, flakes oats) were procured from local market, and flakes defatted soy bean was obtained from Food Technology Research Institute. The initial moisture content of grits corn, flakes oats and flakes defatted soy bean were 6.55, 7.0 and 7.5% respectively. The ratios of blends (grits corn: flakes defatted soy bean: flakes oats) were A (50:30:20), B (40:35:25) and C (30:40:30) using different initial moisture content of blends were applied by adding water to achieve different moisture contents (12, 17, 22, 27 and 32 %).

Methods

Single screw extruder

The corn flakes was obtained using a single screw extruder (Insta Pro model 600, USA) was used in this study for snack manufacture. The performance of the extruder depends upon the increase of the pressure imposed by the extruder on raw materials accompanied by the increasing of temperature generated by the friction between extruder's screw surfaces and the blends used.

The extruder barrel length is 45.50 cm and the temperatures in the extruder during the process were found to be 90 ºC, 110 ºC and 140ºC for three extruder's zones (feeding, kneading and cooking zones) respectively. The die area is the section of the extruder that occurs after the material leaves the screw and it serves as a restriction device at the end of the barrel which can control barrel fill, pressure, and temperature. Two dies were used in this study with 0.6, 1.0 cm diameter and 6.5 cm length.

The moisture content of raw material was adjusted using a required amount of water and mixed with raw material at the initial zone of the extruder and pumped by the screw of the feeding device into the extruder barrel.

Chemical composition of blend components extrudates

Chemical compositions of extrudates (moisture content, ash, fat content, protein content, total carbohydrates and crude fibers) were determined according to standard procedures outlined by Association of Official Analytical Chemists (AOAC, 1990).

Expansion ratio (ER)

Expansion ratio was determined by using vernier caliper as per methods described by Meng et al. (2010). The basic formula used for calculation of lateral expansion is given in the following equation:

$$ER = \frac{\text{Diameter of extrudate} - \text{Diameter of Die}}{\text{Diameter of Die}} \times 100 \qquad (1)$$

Bulk density (BD)

Bulk density of the expanded products was estimated using method suggested by (Patil et al., 2007) and calculated using the formula given in the following equation.

$$BD = \frac{4m}{\pi d^2 L} \qquad (2)$$

Where; m is mass (g); length L (cm); d is diameter (cm) of extruded snack product

Water Absorption Capacity (WAC)

The method described by Kaur and Singh (2006) was used to determine WAC. The basic formula used for calculation of WAC is given in the following equation:

$$\text{WAC} = \frac{\text{Weight of sediment}}{\text{weight of dry solids}} \qquad (3)$$

Hardness

Instrumental hardness, maximum peak force of all the extruded puffs was measured in triplicate using C3 Texture analyzer, (Brookfield Ametek, USA).

Water activity

The water activity of extrudates were measured using Rotronic Hygrolab 3 CH-8303, Switzerland.

Color attribute

The chromaticity of extrudate was measured in terms of L* (the degree of lightness), a* (degree of greenness) and b* (degree of yellowness) values, using Chroma meter (Konica Minolta, model CR 410, Japan).

Sensory evaluation

Extrudates samples with different treatments were evaluated for their sensory characteristics (color, texture, taste, odor and overall acceptability) according to Idowu, et al. (2013).

Statistical analysis

A randomized complete block design with three factors were used to analyze all data with three replications for each parameter. The treatment means were compared by least significant difference (L.S.D.) test as given by (Silva and Azevedo, 2009) using Assistat program.

3. Results and Discussion

Chemical composition of blend components and extrudates

Chemical compositions of initial blend components (Corn grits, Flakes defatted, Flakes oats soybean) are shown in Table 1. The chemical composition of three different blends A, B and C were determined and were varied according to the initial moisture content of the mixtures and the final moisture content of extrudates.

Table 2 shows an example of chemical analysis of extrudates with initial moisture content 17 % and final moisture content of 7-7.5%. It was found that the maximum value of protein was 31.0% for blend

C, then 24.7% for blend B and 24.6% for blend A, while the values of fat contents were 9.42, 7.22, 6.97% for C, A and B respectively. The moisture contents (MC) were 7.5, 7.2, and 7.0% for blends C, B and A respectively. The maximum value of ash was 4.1% for blend C and 3.1% for blends A and B. The values of total carbohydrates (TC) were 58.08, 58.03, and 47.98% for blends A, B and C respectively. The values of crude fiber (CF) were 3.17, 2.91, and 2.62% for blends C, A, and B respectively. The insoluble dietary fibers (IDF) were 12.3, 8.5, and 7.5% for blends C, B and A respectively, while soluble dietary fibers (SDF) were 9.2, 7.8, and 7.2% for blends C, B and A respectively.

Table 1. Chemical composition of blend components

Blend components	Protein %	Fat %	Fiber %	Total carbohydrates, %	Moisture content %
Corn grits	8.35	5.20	7.0	72.90	6.55
Flakes defatted soybean	47.1	7.0	7.1	31.8	7.0
Flakes oats	12.4	5.2	12.1	62.8	7.5

Table 2. Chemical composition of extrudates.

Blend	IDF %	SDF %	Total dietary fibers %	Protein %	Fat %	MC %	Ash %	TC %	CF %
A	7.5	7.2	14.7	24.6	7.22	7.0	3.1	58.08	2.91
B	8.5	7.8	16.3	24.7	6.97	7.2	3.1	58.03	2.62
C	12.3	9.2	21.5	31.0	9.42	7.5	4.1	47.98	3.17

Physical properties of extrudates

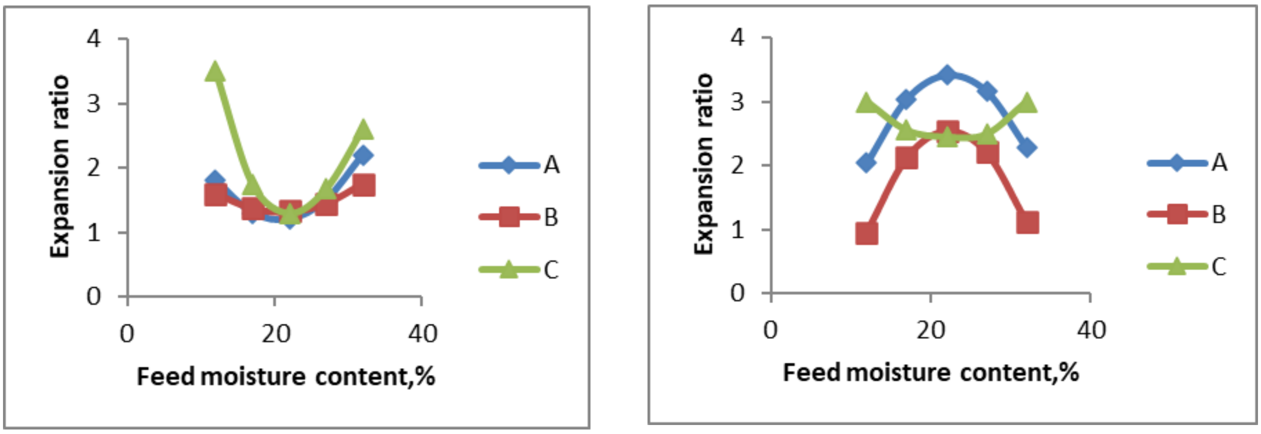
Expansion ratio (ER)

The expansion ratio of extrudates was determined, there is an inverse relation between expansion ratio and bulk density, where increasing ER caused decrease in bulk density. Also, higher values of ER are preferable properties for the extrudates which depend on moisture content, extrusion temperature and die diameter, expansion ratio measures the puffing of extrudates (Seth et al., 2013). Table 3 and Figure 1. show the values of expansion ratio at different moisture contents (12, 17, 22, 27 and 32%) and die diameter (1.0 and 0.6 cm).

Temperature at extruder die was measured using a thermocouple it was found that at 1 cm die the temperature was 140 ºC, decreasing the die diameter from 1 to 0.6 cm leads to increasee in pressure inside the extruder and raise die temperature to 160 ºC this could be due to internal friction between raw material and die wall.

The higher ER when using die diameter 1 cm and 140 ºC was 2.2, 1.75, 2.6 for blends (A, B and C) respectively. Also decreasing die diameter to 0.6 cm and 160 ºC leads to increase in ER which was 3.42, 3.95, 3.06 for blends (A, B and C) respectively. This can be a result of the high temperature (160 ºC) when using die diameter 0.6 cm which cause increase in ER for extrudate blends (A, B and C). Moisture is the main plasticizer of cereal flours, which enables them to undergo a glass transition during the extrusion process and thus facilitates the deformation of the its expansion. The changing in moisture content led to a fluctuation in expansion ratio for all blends A, B and C, which agree with (Bhattacharyya et al., 2006).

From Table 3 and Figure 1, it was observed that the expansion ratio decreased with the increase in moisture content of the feeds. This is due to the fact that low moisture feeds can exhibit more drag and therefore exert more pressure at the die, resulting in greater expansion at the exit of the die than high moisture feeds (Ding et al., 2005; Oluwole, 2008; Rodríguez-Miranda et al., 2011). According to Ilo et al. (1996), an increase in moisture content during extrusion decreases apparent viscosity and expansion ratio during extrusion of maize grits. However, at higher screw speed 550 rpm, expansion is expected to reduce due to reduced residence time (Hsieh et al., 1990), reduced degree of gelatinization of starch and hence reduce expansion (Onwulata and Konstance, 2006; Oluwole, 2008).



Die diameter 1.0 cm **Die diameter 0.6 cm**

Figure 1. Expansion ratio of extrudates at different feed moisture content for different blends (A, B and C).

Bulk density of extrudates (BD)

Bulk density is the property of extrudates which indicates the expansion and changing in cell structure. The values of bulk density ranged from 0.553 to 0.750 g/cm^3 for blend (A) at different moisture contents and die diameter 1.0 cm at 140 ºC, while these values decreased at die diameter 0.6 cm and 160 ºC where it ranged from 0.500 to 0.590 g/cm^3. For blend (B), the bulk density values ranged

from 0.616 to 0.790 g/cm^3 using 1.0 cm die diameter at 140 ºC, while the bulk density values using die diameter 0.6 cm at 160 ºC were ranged from 0.446 to 0.580 g/cm^3. The bulk density values of blend C ranged between 0.440 and 0.770 g/cm^3 using 1.0 cm die diameter at 140 ºC while it ranged from 0.410 to 0.570 g/cm^3 using 0.6 cm die diameter at 160 ºC as shown in Table 3.

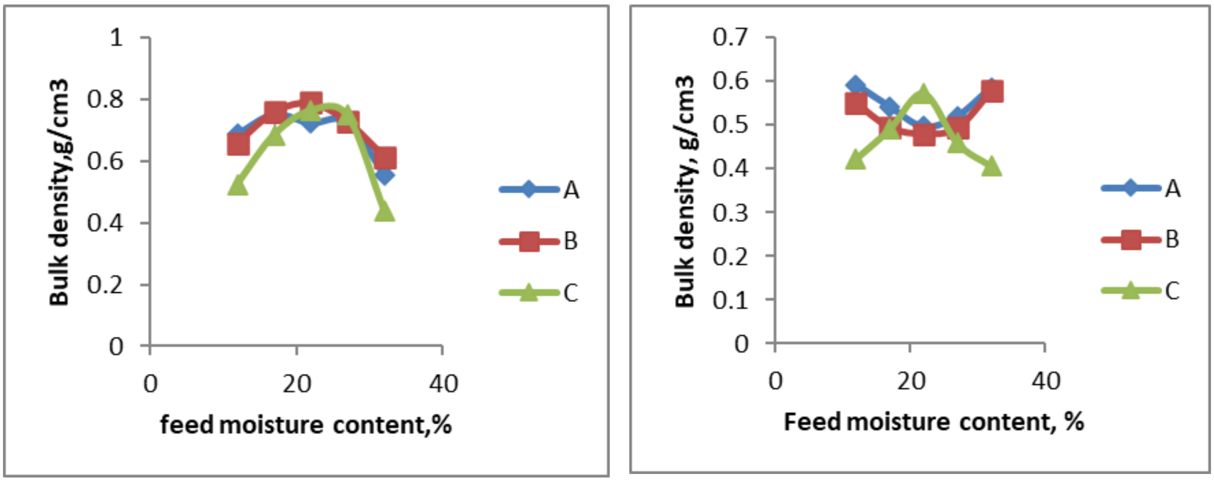
Figure 2 shows the bulk density of different blends (A, B and C) using die diameter 1.0 and 0.6 cm. The results indicated that, as moisture content increased, there was a fluctuation of bulk density values, this may be due to limited bubbles formed in blends at high moisture content during extrusion process thus increasing bulk density. On other side, at low moisture content the melt viscosity and porosity formation of the blends increases, so the values of bulk density were decreased and these agree with (Mridula et al., 2017). Also, (Singh and Muthukumarappan, 2016) reported that the decrease bulk density with increasing moisture content and temperature due to superheating of moisture content which reduce the melt viscosity and increase the formation of bubbles.

Water absorption capacity of extrudates (WAC)

Water absorption capacity becomes important property because the extrudate products are consumed as ready snack food used with many beverages.

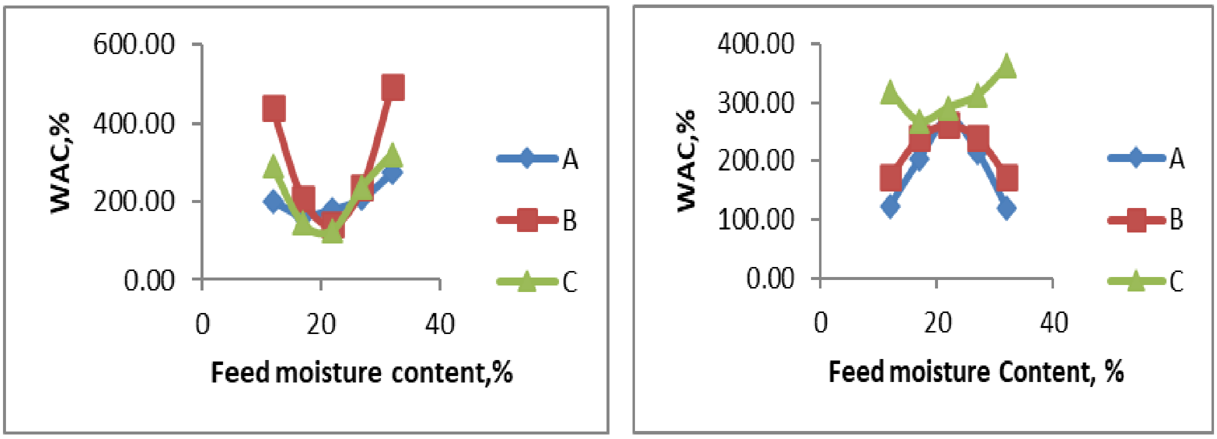
Table 3 and Figure 3 show the WAC values for different blends (A, B and C) and different moisture contents using 1.0 and 0.6 cm die diameter. The WAC for blend A ranged from 163.633 to 274.27 % using 1.0 cm at 140 ºC. By changing die diameter to 0.6 cm at 160 ºC the WAC values ranged from 118.23 to 273.803 %. WAC values for blend (B) ranged from 141.27 to 292.26 % using die diameter

1.0 cm at 140 ºC, while it was ranged from 171.807 to 262.103 % using die diameter 0.6 cm at 160 ºC. For blend C WAC ranged from 126.697 to 321.04 % using 1.0 cm die diameter at 140 ºC. By changing die diameter to 0.6 cm and 160ºC WAC values ranged from 267.533 and 365.007 %. The highest values of WAC were for blend C using 0.6 cm die diameter at 160 ºC due to high content of protein 31.0% which allow to keep more of water molecules in the structure formed after extrusion process, also higher content of total dietary fibers 21.5% led to increase binding of water which may explain the increase of WAC for blend C (Nikmaram et al 2015). (Ackar et al 2018 and Philip et al 2017) reported that blend with high protein and fibers content increase the expansion ratio and WAC in the other cereal-based extrudates.



Die diameter 1.0 cm **Die diameter 0.6 cm**

Figure 2. Bulk density of extrudates at different feed moisture content for different blends (A, B and C).



Die diameter 1.0 cm **Die diameter 0.6 cm**

Figure 3. Water absorption capacity of extrudates at different feed moisture content for different blends (A, B and C).

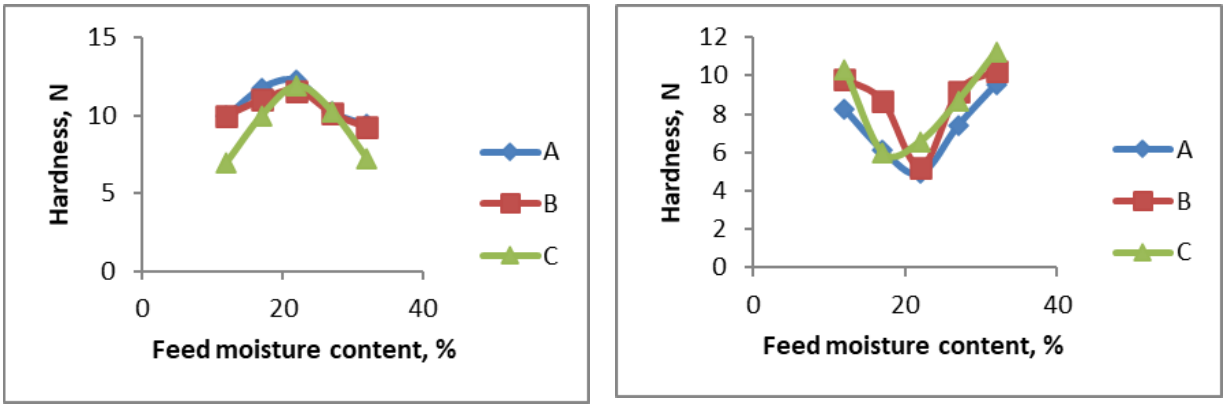
Table 3. Physical properties of extrudates

Die, cm	Blends	Feeding moisture content, %	ER, %	BD, g/cm^3	WAC, %	H, N	AW
1.0	A	12	1.8	0.690	201.167	10.01	0.45
1.0	A	17	1.3	0.750	163.633	11.6	0.473
1.0	A	22	1.2	0.620	178.173	12.216	0.497
1.0	A	27	1.52	0.730	207.58	10.15	0.506
1.0	A	32	2.2	0.553	274.27	9.43	0.556
1.0	B	12	1.6	0.660	239.663	10.09	0.676
1.0	B	17	1.37	0.760	209.297	11.03	0.617
1.0	B	22	1.33	0.790	141.217	11.63	0.55
1.0	B	27	1.45	0.730	235.587	10.23	0.543
1.0	B	32	1.75	0.616	292.26	9.24	0.497
1.0	C	12	3.5	0.526	289.043	6.98	0.58
1.0	C	17	1.76	0.686	144.717	10.09	0.626
1.0	C	22	1.3	0.770	126.657	11.9	0.603
1.0	C	27	1.67	0.716	236.697	10.3	0.677
1.0	C	32	2.6	0.440	321.04	7.21	0.660
0.6	A	12	2.05	0.590	123.067	8.29	0.504
0.6	A	17	3.04	0.540	202.82	6.09	0.504
0.6	A	22	3.42	0.500	273.803	4.88	0.517
0.6	A	27	3.18	0.520	215.523	7.63	0.514
0.6	A	32	2.29	0.586	118.23	9.75	0.527
0.6	B	12	3.95	0.550	171.807	9.85	0.534
0.6	B	17	2.13	0.493	239.463	8.73	0.534
0.6	B	22	2.58	0.446	262.103	5.25	0.543
0.6	B	27	2.21	0.490	239.713	9.12	0.557
0.6	B	32	1.12	0.580	172.303	10.18	0.554
0.6	C	12	3	0.420	320.677	10.31	0.497
0.6	C	17	2.55	0.490	267.533	5.94	0.513
0.6	C	22	2.45	0.570	291.347	6.59	0.517
0.6	C	27	2.52	0.460	312.733	8.73	0.53
0.6	C	32	3.06	0.410	365.007	11.2	0.547
LSD		**Die**	0.396	0.0064	0.0933	0.108	0.0085
		Blends	0.486	0.0079	0.114	0.132	0.0105
		Moisture	0.627	0.0102	0.145	0.171	0.0135
		Die × Blends	0.687	0.0112	0.1616	0.187	0.0148
		Die × moisture	0.887	0.0144	0.209	0.242	0.0191
		Blends × moisture	1.086	0.0176	0.256	0.296	0.0234
		Die × blends × moisture	1.536	0.05	0.361	0.419	0.0331

ER: Expansion Ratio, BD: Bulk Density,WAC: Water Holding Capacity, H: Hardens, a_W: Water Activity

Hardness of extrudates (H)

The hardness of extrudates is a sensory perception of the humans and is associated with expansion and cell structure of extrudates (Wani and Kumar 2016). It is the average force required for a probe to penetrate the extrudate. The hardness for different blends (A, B and C) at different moisture content and die diameter were shown in Table 3 and Figure 4 For blend A, the hardness ranged from 9.43 to 12.216 N using 1.0 cm die diameter at 140 ºC. By changing die diameter to 0.6 cm at 160 ºC the hardness values ranged from 4.850 to 9.750 N. Hardness values for blend (B) ranged from 9.24 to 11.63 N when using die diameter 1.0 cm at 140ºC, on the other hand when using die diameter 0.6 cm at 160ºC the hardness ranged from 5.250 to 10.180 N. For blend (C) hardness ranged from 6.980 to 11.9 N using 1.0 cm die diameter at 140 ºC. By changing die diameter to 0.6 cm at 160 ºC hardness values ranged from 5.94 and 12.2. It was observed that decreasing in die diameter and increasing in temperature caused to decreasing hardness of extrudates due to increasing in expansion ratio (Kumar et al., 2010 and Meng et al., 2010).



Die diameter 1.0 cm **Die diameter 0.6 cm**

Figure 4. Hardness of extrudates at different feed moisture content for different blends (A, B and C).

Water activity of extrudates (AW)

Water activity of extrudates was determined at different moisture content and die diameters as shown in Table 3. For blends A and C, water activity increased as moisture content increased from 5 to 25 % using 1.0 cm die diameter. By changing die diameter to 0.6cm and 160 ºC, water activity approximately increased with increasing moisture content for all blends (A, B and C). Higher water activities were found as evaporated water decreased using die diameter 1.0 cm and 140 ºC during extrusion, which could be an indicator for susceptibility to microorganism growth. Thus the produced food with high water activity values more than 0.600 were excluded due to risk of spoilage (Belitz et al., 2009).

Color of extrudates

Color is an important property for acceptance the snack food. Color components are represented by L*, a* and b* values. The effect of blends (A, B and C), die diameter (1.0 and 0.6cm) and moisture content (5, 10, 15, 20 and 25%) on color is presented in Table 4. The symbol L* is for (black/white), a* is for (green/red) and b* is for (blue/yellow) are recorded for extrudates with different treatments and the results are given in Table 4. For blend A, the values of L* ranged from 45.680 to 72.350, while the values of a* ranged from 8.330 to 10.210 and the values of b* ranged from 13.420 to 20.760 at different moisture content using die diameter 1.0 cm (140 ºC). By changing die diameter to 0.6 cm (160ºC), the values of L* ranged from 48.540 to 85.230, while the values of a* ranged from 8.740 to 12.00 and the values of b* ranged from 16.740 to 19.230. For blend B, the values of L* ranged from 64.320 to 70.640, while the values of a* ranged from 8.550 to 13.950 and the values of b* ranged from 8.750 to 32.380 at different moisture content using die diameter 1.0 cm (140ºC). By changing die diameter to 0.6 cm (160ºC), the values of L* ranged from 52.780 to 82.050, while the values of a* ranged from 10.190 to 11.060 and the values of b* ranged from 12.350 to 22.480. For blend C, the values of L* ranged from 54.780 to 71.640, while the values of a* ranged from 9.310 to 11.380 and the values of b* ranged from 16.470 to 20.530 at different moisture content using die diameter 1.0 cm (140ºC). By changing die diameter to 0.6 cm (160ºC), the values of L* ranged from 62.290 to 69.390, while the values of a* ranged from 10.290 to 12.200 and the values of b* ranged from 18.280 to 23.780. In general, lightness value of the extrudates were increased, while a* and b* values were decreased by increasing moisture level from 17 to 32% for extrudates obtained by 1.0 and 0.6 cm die diameters.

Table 4. Color components of extrudates for different blends A, B and C.

Die diameter, cm	blends	Feeding moisture content, %	L*	a*	b*
1.0	A	12	45.680	10.210	20.760
1.0	A	17	53.600	9.750	18.560
1.0	A	22	56.460	8.870	18.180
1.0	A	27	66.730	9.020	15.160
1.0	A	32	72.350	8.330	13.420
1.0	B	12	70.640	8.750	8.750
1.0	B	17	67.830	8.550	15.460
1.0	B	22	68.850	13.950	19.070
1.0	B	27	64.730	10.860	19.880
1.0	B	32	64.320	13.480	32.380
1.0	C	12	71.640	10.940	16.470
1.0	C	17	62.880	10.080	18.640
1.0	C	22	68.110	11.380	18.740
1.0	C	27	56.660	9.310	19.370
1.0	C	32	54.780	9.440	20.530
0.6	A	12	48.540	8.740	19.150
0.6	A	17	60.540	9.430	17.870
0.6	A	22	61.130	10.540	19.230
0.6	A	27	78.860	11.050	16.740
0.6	A	32	85.230	12.000	16.740
0.6	B	12	82.050	11.060	12.350
0.6	B	17	70.550	10.860	15.760
0.6	B	22	75.730	10.560	15.570
0.6	B	27	55.890	10.420	20.850
0.6	B	32	52.780	10.190	22.480
0.6	C	12	62.290	10.290	18.280
0.6	C	17	66.320	10.480	20.690
0.6	C	22	67.260	11.180	20.630
0.6	C	27	68.350	11.670	20.250
0.6	C	32	69.390	12.200	23.780
LSD		**Die**	0.4240	0.0450	0.1090
		Blends	0.5190	0.5560	0.1340
		Moisture	0.6710	0.0718	0.0609
		Die × Blends	0.7350	0.0787	0.1890
		Die × moisture	0.9490	0.1020	0.2440
		Blends × moisture	1.1630	0.1240	0.2990
		Die × blends × moisture	1.6400	0.1759	0.4230

L* for (black/white) a* for (green/red) b* for (blue/yellow)

Sensory evaluation

The extrudates with different treatments were subjected to sensory evaluation for odor, texture, taste, color and overall acceptability as shown in table (5). The results showed that high overall acceptability (8.00) was obtained for blend C with moisture content 12, 17% when using 1.0cm die diameter and 140ºC. By changing die diameter to 0.6 cm, the overall acceptability was (9.00) at 22% moisture content for blend C which agree with other physical properties studied. It can be observed that the overall acceptability decreased significantly with increasing die diameter and decreasing temperature.

Table 5: Sensory evaluation of extrudates

Die diameter, cm	Blends	Feeding moisture content, %	Odor	Texture	Taste	Color	Overall
1.0	A	12	8.000	4.670	6.340	5.670	5.670
1.0	A	17	7.340	6.340	5.670	4.000	6.000
1.0	A	22	7.340	6.670	5.670	3.670	5.000
1.0	A	27	8.000	3.670	6.670	6.000	5.340
1.0	A	32	8.000	5.000	5.340	5.340	4.670
1.0	B	12	7.670	4.670	7.670	6.670	7.000
1.0	B	17	7.670	7.000	6.000	4.000	6.670
1.0	B	22	8.000	7.600	5.600	4.000	4.000
1.0	B	27	7.340	6.000	6.000	5.000	6.340
1.0	B	32	7.670	4.670	5.000	6.000	6.340
1.0	C	12	8.670	5.340	8.670	5.340	8.000
1.0	C	17	7.340	7.340	8.340	5.000	8.000
1.0	C	22	8.330	7.340	8.000	5.000	7.670
1.0	C	27	8.670	7.340	7.340	6.000	7.340
1.0	C	32	8.000	7.340	7.340	7.000	7.000
0.6	A	12	7.670	5.670	7.340	6.000	5.670
0.6	A	17	7.670	7.340	6.670	8.340	7.670
0.6	A	22	7.670	8.000	6.000	9.000	8.340
0.6	A	27	7.670	8.340	5.670	8.340	8.000
0.6	A	32	7.000	6.670	5.000	5.670	4.670
0.6	B	12	7.340	6.630	7.340	7.000	8.000
0.6	B	17	8.000	8.000	8.340	8.000	7.340
0.6	B	22	9.000	8.670	8.340	9.000	6.670
0.6	B	27	7.000	7.340	8.000	8.000	6.670
0.6	B	32	7.670	6.000	6.000	6.670	6.000
0.6	C	12	8.000	6.670	8.340	8.340	8.000
0.6	C	17	8.340	7.670	8.340	8.000	8.000
0.6	C	22	8.340	9.000	8.670	8.670	9.000
0.6	C	27	8.340	7.340	8.000	7.000	7.000
0.6	C	32	8.000	6.670	7.670	7.670	7.670
LSD		**Die**	0.2980	0.3050	0.3000	0.2650	0.2490
		Blends	0.3650	0.3730	0.3680	0.3240	0.3050
		Moisture	0.4710	0.4820	0.4750	0.4190	0.3940
		Die × Blends	0.5160	0.5280	0.5200	0.4590	0.4320
		Die × moisture	0.6660	0.6810	0.6720	0.5920	0.5570
		Blends × moisture	0.8160	0.8340	0.8220	0.7250	0.6830
		Die × blends × moisture	1.1500	1.1800	1.1600	1.0300	0.9700

4. Conclusion

Corn grits, flakes soybean and flakes oat were used as blends with ratios (50:30:20), (40:35:25) and (30:40:30) using different feed moisture contents (12, 17, 22, 27 and 32 %). These blends were manufactured by single screw extruder using two die diameters (1.0 and 0.6 cm). The chemical components, physical properties and sensory evaluation of extrudates were determined. Moisture content has a significant effect on the extrudates. Decreasing die diameter caused higher values of expansion ratio and WAC and lower values of hardness and bulk density at the same blend.

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