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Development of extruded snacks and corn flakes using yellow corn and by-product broken beans

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ABSTRACT

The purpose of this paper is to investigate development of extruded snacks and corn flakes by using yellow corn and by-product broken white beans flour (BWBF). The methodology included in this paper is based on adding BWBF broken white beans flour (10, 20, 30, 40 and 50 %) as source of protein by a partial substitution of yellow corn flour and corn grits, all samples were evaluated for their physicochemical properties, minerals, amino acids content as well as sensory quality attributes, nutritional value compared with RDA and the production costs of different samples were also studied. The results indicated that BWBF percentage and also the extrusion condition (moisture and temperature) in flounced the physical color and functional (water absorption index and water solubility index) for corn Flakes and extruded snacks. The water activity was gradually decreased with increase adding BWBF in the blends for corn flakes and snacks. Therefore volume mass also density were significantly changed in the resultant corn flakes and snacks. Fortification with BWBF significantly increased in protein, ash, minerals and amino acids. While carbohydrates significantly decreased in corn flakes and snacks compared with control samples. corn flakes covers up to 38.85% of protein requirement, 22.6 %and 25.43% of energy requirement for male and female, 29.44% of phosphorus requirement, 66.25% of iron requirement, 63.63% of zinc and 6.91% of calcium, for children. Whereas, snacks cover up to 33.44% of protein requirement, 22.57 % and 25.39% of energy requirement for male and female, 28.86% of phosphorus requirement ,65.63% of iron requirement, 64.88% of zinc and 6.24% of calcium from RDA, for children of age 9-13 years. The fortification with (10, 20 and 30%) significantly enhanced attributes of resultant corn flakes and snacks. while 40 and 50 % treatment a chivied low score of acceptability. Prices are very suitable for the Egyptian market, the investigated extrudates were cheaper than market products and high nutritive value. Therefore, it could be recommended to consume corn flakes and snacks to provide children with part of their daily requirements of protein, energy, phosphorus, calcium, iron and zinc.

Keywords: Extrusion, corn flakes, snacks, Yellow corn, broken kidney white beans, nutritional value.

Introduction

Corn flakes and snacks are ready-to-eat, convenient snack that are consumed by the young population groups in many countries. The development of food products using composite raw materials has increased and is attracting much attention from researchers; especially in the production of Extruded products (Forsido *et al.,* 2019).

The increasing demand of the consumer market for new products stimulates the use of regional raw materials. The consumption of breakfast meals has increased considerably in recent years because products that are quickly prepared are in demand due to the lack of time characteristic of modern life (Bolanho *et al.,* 2014). These products can be produced through thermoplastic extrusion according to Santos *et al.,* (2020).

Extrusion cooking utilizes high temperature, high pressure, and high force to produce products with low density, high expansion and unique texture. In addition to the usual benefits of heat processing, extrusion offers the possibility of modifying the functional and rheological properties of food ingredients (Santos *et al.,* 2020). Food extrusion were among the most commercially successful extruded foods. The extruded foods market has been increasing rapidly worldwide. Extrusion is a process of industrial cooking that combines moisture, high pressure, heat and mechanic friction for a

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short period, causing physical and chemical alterations in the foods in order to benefit their technological characteristics (Carreiro *et al.,* 2008).

Extrusion is currently one of the most important food processing technologies that has the potential to be utilized for this purpose. The hightemperature-short-time (HTST) process employed during extrusion ensures the product safety without significantly altering the nutritional value (Arêas, Rocha-Olivieri, & Marques, 2016). Nevertheless, most extruded products are nutritionally inadequate due to the domination of starchy carbohydrates over its composition. Therefore, it allows the opportunity to integrate plant byproducts in an attempt to diversify the nutrients content of the extrudates. Past researches have successfully added plant by-products in extruded snacks and energy bars, with the main aims of improving nutritional value.

These days, predominantly, yellow corn was used as raw material for the manufacture of corn flakes and snacks. It is a source of nutrition as well as phytochemical compounds. It contains various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols (Rouf Shah *et al.,* (2016). The production of yellow corn in Egypt was (193810) tons according to Bulletin of The Agricultural Statistics (2018).

The general trend towards the use of by-products as some residues of agricultural crops such as broken white beans, broken chickpea seeds, broken rice, wheat germ, wheat bran, rice bran and etc, as by-products in the nutritional manufacture is increasing worldwide (Abd Rabo *et al.,* 2019).

Broken white beans are the wests of process of extracting beans seeds from their dry horns. Broken beans, fragmented part of seeds, are often neglected by the industry. Although they cost five times less than whole ones, and present similar nutritional characteristics, the broken seeds represent a serious economic problem, but show technological importance (Carvalho *et al.,* 2012a). Due to inherent physical and chemical characteristics, an alternative to add value to broken beans, and minimize the economic losses, would be the production of extruded broken beans flour (EBF) from this by-product.

Increasing amount of waste is generated from the crops processing industry (Sagar *et al.,* 2018). This creates a major concern over its management and disposal, due to the negative impact on the natural resources (Kummu *et al.,* 2012). However, most plant food-derived byproducts, such as broken white beans, are rich in nutrients, and therefore can be utilized to manufacture high nutrition value foods.

Dry beans (*Phaseolus vulgaris* L.) or common beans have been characterized as a nearly perfect food because of their high protein, fiber, prebiotic, vitamin B, and chemically diverse micronutrient composition. It is used throughout the world representing 50% of the seed legumes consumed as a human food source (Camara *et al.,* 2013). According to Agriculture Directorates of Governorates statics (2015), the production of white beans in Egypt was 95970 tons and the loses was (6.12) according to Bulletin of The Agricultural Statistics (2018).

The combination of cereals and legumes could be an alternative to develop snack foods with increased nutritional compounds for promoting healthy benefits. Cereal and legume diets make up the bulk of caloric sources for a majority of households in the developing world. They contain macro- and micronutrients as well as phytochemicals embedded as one matrix Kamau et al (2020). Also beans are source of protein rich in lysine (Rezende et al., 2018). While corn protein provides an important amount of sulfur amino acids.

Therefore, the present study aimed to develop extruded snacks and breakfast meals corn flakes enriched with broken beans flour. The utilization of beans loses in manufacture high nutrition value foods and low costs.

Materials and Methods

1. Source of Material:

Ingredients e.g. yellow corn was obtained from Dar Elbasha factory, Qusena City, Menofya governorate Egypt. Broken kidney white bean seeds was obtained from Horticulture Research Institute, Agriculture Research Center, Ministry of Agriculture, Giza, Egypt, sugar and salt were obtained from local markets at Giza, Egypt.

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2. Preparation of raw Material:

Yellow corn grains divided two parts. In the first part, the grains were milled to get whole meal flour for corn flakes preparation. In the second part, the yellow corn grains were crunched after removed the pericarp and germ to get cruncher corn for snacks preparation and then packed in polyethylene bags and kept at a room temperature until used. Broken white bean soaked in tap water (1:3) for 18 h., Drain the soaking water, Rinse the soaked broken seeds twice with tap water, dried in oven on 55- 60 °C over night.

3. Production of flour:

Dry yellow corn grains and dry cleaned broken white bean seeds were milled in Eleman miller, Saqqara at Giza, Egypt (using standard electric grinder, Janke and Kunkel Type: MFC, Germany) to get whole meal flour 60 mesh sieve was used to get fine flour. The resulting flour was stored at room temperature (28℃) in a high density polyethene bag for corn flakes and snacks preparation. The proximate composition of the flours was determined using AOAC (2016) methods.

4. Flour blending:

The method reported by Nwabueze *et al*. (2008) and Ocheme *et al.* (2011) was adopted for the blending. The blending was in ratio of 10,20,30,40 and 50% (broken white bean flour added to yellow corn flour and yellow corn grits) Table (1).

5. Sample preparation for extrusion:

The raw materials (yellow corn flour and broken white beans flour) was separately brought to 40% water addition through material balance. The prepared samples were extruded at selected constant extrusion condition: screw speed of 800 rpm and barrel temperature of 175-180℃ in a Brabender a twin-screw extruder (Yuninan Daily Extrusion, Yunnan, Republic of China).

Table 1: Ingredients % of Corn Flakes and Snacks.

	Corn Flecks						Snacks					
Ingredients %	**T0**	**T 1**	**T 2**	**T 3**	**T 4**	**T 5**	**S 0**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**
Yellow corn flour	100	90	80	70	60	50	---	---	---	---	---	---
Yellow corn grits	---	---	---	---	---		100	90	80	70	60	50
Broken beans flour	---	10	20	30	40	50	---	10	20	30	40	50
Sugar	7	7	7	7	7	7	---	---	---	---	---	---
Salt	1	1	1	1	1	1	1	1	1	1	1	1
Water	40	40	40	40	40	40	---	---	---	---	---	---

T0:100% corn flour and zero% BWBF. **T1:** 90% corn flour and 10% BWBF. **T2:** 80% corn flour and 20% BWBF. **T3:** 70% corn flour and 30% BWBF. **T4:** 60% corn flour and 40% BWBF. **T5:** 50% corn flour and 50% BWBF. **S_0**:100% corn grits and zero% BWBF. **S_1:** 90% corn grits and 10% BWBF. **S_2:** 80% corn grits and 20% BWBF. **S_3:**70% corn grits and 30% BWBF. **S_4:** 60% corn grits and 40% BWBF. **S_5:** 50% corn grits and 50% BWBF.

Table 2: Proximate chemical composition of raw materials.

Parameters g/ 100g dry weight	Moisture	Protein	Fat	Fiber	Ash	Carbohydrates
			Raw Materials			
Corn Flour	6.10±0.22	7.79±0.64	4.10±0.32	2.4±0.09	1.53±0.07	84.18±0.97
Corn Grits	6.28±0.03	7.68±0.71	2.14±0.22	0.71±0.07	0.30±0.13	89.17±1.08
White Bean Flour	5.00±0.07	21.80. ±1.50	1.25± 0.14	1.66±0.11	3.70±0.21	71.59±1.54

		Minerals mg/ 100g dry weight		
	Ca	**P**	**Fe**	**Zn**
Corn Flour	26±0.17	239±0.24	2.60±0.11	1.5±0.21
Corn Grits	33.09±0.15	376.46±0.43	2.65±0.14	1.98±0.15
White Bean Flour	110±0.41	415±0.32	7.22±0.32	3.40±0..9

6. Flake Manufacture:

The flour blend (corn flour and broken white beans flour) was mixed with 40% water then sugar and salt were added in a mixer with paddle for 1 min. The dough was placed in a pasta extruder attachment (Yuninan Daily Extrusion, Yunnan, Republic of China). As the dough was extruded it was cut into approximately 1.5 cm long pellets, trayed, and steamed at 18 psi for 20 min. After cooking, the pellets were tempered at 5 °C then placed in a circulating air oven at 40℃ to reduce the moisture content to 20 % The partially dried pellets were flaked through heavily spring- loaded 10-in. diameter steel rollers, with minimum gap of 0.05 mm The resulting flakes were toasted on pans at 215℃ for 3.5 min, cooled, and bagged for storage. The final moisture was kept below 5% Lu and Walker (1988**)** for corn flakes.

7. Snacks Manufacture:

The blends (corn grits and broken white beans flour) were mixed with 1% salt in a mixer with paddle for 1 min. The blend was placed in a extruder (a single extruder American type, American extrution) at different extrusion condition as follow

-Temperature of extruder was 180-210℃.
-Screw speed 900 rpm.
-Feeding rate 1.8 and 2 kg/min for snacks.

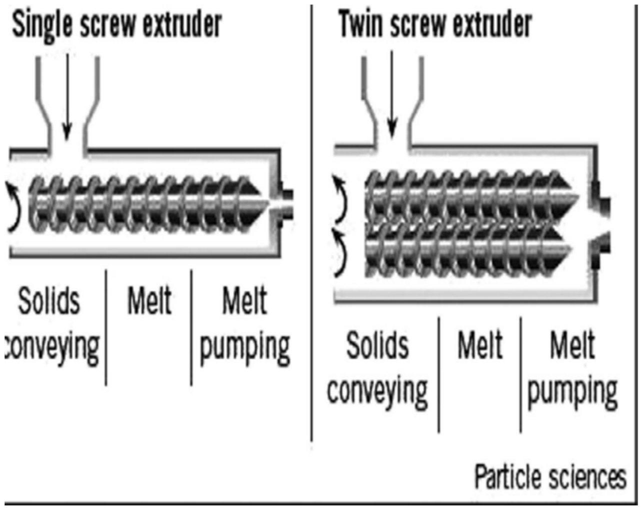

Fig. 1: A cross section of single screw (left) and twin screw (right) extruder barrels.

8. Physical properties of prepared corn flakes and snacks:

8.1. Color:

The flakes and snacks colors were measured by objective colorimeter Chroma meter (CR-400, Konica, Minolta, Tokyo, Japan) and was determined according to the procedure previously described by Filipović *et al.* (2015).

8.2. Water activity:

Water activity (^{a}w) was measured with a Rotronic Hygro Lap EAI0.SCS Switzerland ^{a}w meter the measurements were performed in triplicate.

8.3. Water absorption index (WAI) and Water solubility index (WSI):

Water absorption index (WAI) and Water solubility index (WSI) of the extruded snacks and corn flakes were determined by previously described method (Anderson *et al.,* 1969).

8.4. Expansion Ratio (ER):

Expansion Ratio (ER) was determined according to Kaludjerski and Filipovic (1998) and Kannadhason et al., 2009), where it was calculated as follows:

ER= flakes volume⁄crude flakes volume and ER= diameter of snacks⁄diameter of die nozzle extruder.

8.5. Density:

Density was measured by divided Volume mass⁄1000. Volume mass for corn flakes and snacks was analyzed using 1L baker with marks and scale ACCULAB L-Series. 1L baker was put no scale, tarred and extruded sample was poured in till its mark. Mass was recorded in three repetitions and average was calculated (Liene and Sandra, 2016).

9. Chemical analysis:

Moisture, protein, fat, crude fibers, ash and minerals contents of corn flakes and snacks samples were measured according to the AOAC (2016). Total carbohydrate was calculated by difference. Total calories were calculated as mentioned by Kerolles (1986) according to the following equation Total calories = 4 (protein + Carbohydrates) + 9 (fat).

10. Determination of amino acids:

Determination of amino acids was determined according to the method described in AOAC (2016) by using High Performance Amino Acid Analyzer. Chemical Score was calculated according to FAO (1991).

$$C.S = \frac{\text{mg of essential amino acid in g test protein}}{\text{mg of essential amino acid in requirement pattern}}$$

11. Sensory evaluation of corn flakes and snacks:

Sensory evaluation of the corn flakes and extruded snacks products were carried out at Food and Feed Research Institute, by ten panelists according to Kosutic *et al.* (2016) and Al Subhi (2014) for determining the variation of the tested attributes (taste, odor, texture, color and overall acceptability) of corn flakes and snacks. The panelists were provided with corn flakes and snacks on a white plate at ambient temperature.

12. Production Costs:

They were evaluated according to Kabil (2016).

Statistical analysis:

Statistical analysis was carried out by SPSS Vr. 20 program. Data were expressed as means ± S.D. and the statistical analysis were performed using one-way analysis of variance followed by Duncan's tests. (SPSS, 20) IBM Corp. Released (2011).

Results and Discussion

1. Physical properties of corn flakes and extruded snacks:

Table (3) shows the color parameters L*, a*, and b* for the corn flakes and extruded snacks as a function of the percentage of beans flours. This parameter (lightness L* were L* = 0, black; L* = 100, white), is important because consumers are more familiar with snacks of light color, such as corn or potato chips. L* value of S5 was 61.51 which is lower than that of S0 (70.67). These results agree with work by Gomes *et al.,* (2015) who explained the luminosity reduction to be a result from the extrusion process. The same is true for corn flakes samples, where L* was reduced from 68.42 for T0 to 56.12 for T5.

The color coordinates a* observed an increase with the increase in the percentage of bean flour T0 was 0.61 while T5 increased to be 5.77. Corn flakes sample follow the same trend. This can be, also, explained by the extrusion process caused a darkening of the product, chromaticity coordinates a* to increase. The color acquired by bean flour BF may be the result of sugar caramelization or the occurrence of Maillard reaction, since beans flour presents a large quantity of carbohydrates and proteins (Pelembe *et al.*, 2002; Carreiro *et al*., 2008). b* value of T5 was 39.01 which is lower than that of T0 (56.06) . The same is true for extruded snacks samples where b* was reduced from 25.97 for S0 to 19.77 for S5.

It is known that under extrusion, the changes in color can be attributed to the development of chemical reactions like browning, and that the extending of such reactions depends on the residence time and the temperatures in the extruder. ªW is shown in the same table.

Table 3: Color parameters and water activity for corn flakes and extruded snacks.

Treatment*	*L**	*a**	*b**	ªW
		Corn Flakes		
T0	68.42±0.20 a	0.61±0.10 f	56.06±0.05 a	0.39±0.00a
T1	67.06±0.16 b	1.90±0.05 e	50.31±0.10 b	0.38±0.01a
T2	65.49±0.09 c	2.44±0.10 d	46.03±0.07 c	0.36±0.01b
T3	64.01±0.14 d	4.87±0.12 c	42.73±0.12 cd	0.35±0.00bc
T4	64.52±0.10 d	5.23±0.06 b	40.61±0.14 d	0.35±0.01bc
T5	56.12±0.76 e	5.77±0.10 a	39.01±0.09 d	0.34±0.01**c**
		Extruded Snacks		
S0	70.67±0.29 a	0.46±0.21 e	25.97±0.40 a	0.40±0.00a
S1	69.87±0.28 b	0.66±0.05 de	25.76±0.24 a	0.40±0.00a
S2	66.81±0.20 c	0.74±0.03 d	23.22±0.21 b	0.38±0.01b
S3	65.51±0.11 d	1.24±0.12 c	21.51±0.12 c	0.37±0.01b
S4	64.22±0.21 e	3.03±0.16 b	20.94±0.05 d	0.36±0.00c
S5	61.51±0.16 f	5.32±0.22 a	19.77±0.14 e	0.36±0.01c

*See Table (1) for details. Values are mean ± SD; Values are taken in triplicate Alphabets with different superscripts shows significant difference at 5% level of significance

Physical properties such as water activity for prepared products are illustrated in Table (4). There were ranged from 0.34 to 0.39 and from 0.36 to 0.40 respectively in ªw in all samples for two products.

Lewicki *et al*. (2007) demonstrated that the range of water activity from 0.3 to 0.5 the crunchiness index for corn flacks was constant. At lower water activities, it decreased with increasing wetness of the material, but at higher water activities was close to zero. Li *et al*. (1998) mentioned that increase of water activity above 0.5 caused progressive loss of crispness.

Table 4: Physical properties of corn flakes and extruded snacks.

Treatment*	Moisture	Water Absorption Index	Water Solubility Index	Expansion Ratio	Density
			Corn Flakes		
T0	5.00±0.03f	3.83±0.04a	32.27±0.01f	6.40±0.02a	0.26±0.07e
T1	5.11±0.05e	3.81±0.02a	33.63±0.07e	5.74±0.03b	0.27±0.05d
T2	5.31±0.07d	3.64±0.06b	34.07±0.02d	5.41±0.15c	0.28±0.08c
T3	5.58±0.04c	3.43±0.08c	36.43±0.03c	5.09±0.08d	0.28±0.05c
T4	5.69±0.02b	3.37±0.09d	38.01±0.07b	4.47±0.05e	0.29±0.03b
T5	5.82±0.06a	3.24±0.03e	39.13±0.17a	4.04±0.07f	0.33±0.02a
			Extruded Snacks		
S0	3.50±0.04f	4.87±0.02a	30.46±0.01f	0.61±0.08a	0.029±0.07d
S1	3.97±0.06e	4.73±0.01b	31.33±0.05e	0.50±0.02b	0.053±0.05c
S2	4.04±0.05d	4.43±0.08c	31.63±0.03d	0.44±0.04c	0.060±0.07b
S3	4.13±0.11c	4.32±0.03d	32.23±0.08c	0.39±0.03d	0.063±0.03b
S4	4.26±0.02b	4.16±0.05e	32.63±0.11b	0.33±0.05e	0.66±0.01b
S5	4.34±0.08a	4.03±0.07f	33.23±0.04a	0.28±0.03f	0.071±0.04a

*See Table (1) for details. Values are mean ± SD; Values are taken in triplicate Alphabets with different superscripts shows significant difference at 5% level of significance.

The moisture content of products increases with the increase in white bean flour. Our results are lower than those reported by Estrada-Giron *et al.*, 2015. This may be due to the high-water absorption of white beans. Ding *et al.* (2005, 2006) reported that the increase in moisture content of raw materials result in extradites with lower water absorption.

Water absorption index (WAI) ranged from 3.81 to 3.24g/g for corn flakes and 4.73 to 4.03g/g for extruded snacks compared with control was 3.83 and 4.87 g/g. Wojtowicz and Moscicki, (2014) reported no clear relationships between amount or type of legumes added and WAI values. WSI of extrudates increased with increase in white bean flour. Changes in WSI with incorporation of white bean flour can be attributed to change in composition of the blends. Jones *et al.* (2000) reported that fiber, starch and protein contents affect the WSI. Lopes *et al.,* (2012) referred the solubility of a product to its chemical composition and the interaction between its constitution and water (depends greatly on proteins and starch). Universidade Estadual de Campinas, (2011) concluded that, may be the protein-water interaction is much more relevant than the amylose/amylopectin-water relation for WSI, since the flours with higher protein levels have gradually presented higher solubility.

The values of expansion ratio ER found in this research decreased with the increase of white bean flour (0.61 for control to 0.28 for samples of snacks with 50%) were lower than those reported for corn and rice starches (Bastos-Cardoso *et al.*, 2007), probably due to the addition of white bean flour in the blend that decreased the ER. The low ER was attributed to content of bean flour, which contains high amounts of protein. As reported by Estrada-Girón *et al.,* (2015), for soy protein concentrate, high levels (greater than 25%) reduce the radial expansion of the extrudates. Aguilar-Palazuelos *et al*. (2012) reported that in general, proteins act as diluents and reduce expansion due to their ability to affect water distribution in the matrix, and to the fact that their macromolecular structure and conformation affect the extensional properties of extruded meal. Increase in white bean flour level in extruded snacks causes an increase in the bulk density values. The increase in bulk density with increasing white bean flour level could be, as reported by Yagcı and Gogus (2008), due to the addition of increasing amounts of fiber and protein to the blend which might affect the extent of starch gelatinization and the rheological properties of the melted material in the extruder.While Algarni *et al.* (2019) explained that the increasing bulk density, caused by less expansion and more impact, was due to the presence of fiber particles which tended to rupture the cell walls before the gas bubbles had expanded to their full potential. Camire and King (1991) explained that the non-starch polysaccharides in fiber might bind water more tightly during extrusion than protein and starch did. This binding might inhibit water loss at the die and reduce expansion, and thus probably increase bulk density in his study on the protein and fiber supplementation effects on extruded cornmeal snack quality.

2. Chemical composition of corn flakes and extruded snacks:

Chemical composition of corn flakes and extruded snacks samples are presented in Table 5. It could be noticed that the addition of white bean flour resulted an increases in both protein and ash, but a decrease in all other parameters in corn flacks. While snacks samples were increased in protein, ash, fat and fiber. The change in chemical composition is a result of addition of white bean flour. Our results agree with work by Ramezani *et al.*, (2013). Tharanathan and Mahadevamma, (2003) who explained that the protein increase in samples containing white bean flour bread is generally due to the higher protein content of legume next to grains. So, adding the white beans flour in different amounts to bread increased the quantity of protein.

Table 5: Chemical composition of corn flakes and extruded snacks.

Treatment*	Protein	Fat	Fiber
		Corn flakes	
T0	7.54±0.13 e	3.73±0.08 a	2.57±0.04 a
T1	8.02±0.03 e	3.62±0.05 ab	2.51±0.03 a
T2	10.66±0.22 d	3.45±0.28ab c	1.92±0.06 b
T3	11.33±0.43 c	3.33±0.24bc d	1.86±0.05 b
T4	12.42±0.40 b	3.26±0.11 cd	1.67±0.06 c
T5	13.21±0.37a	3.07±0.06 d	0.97±0.04 d
		Snacks	
S0	6.12±0.12 f	1.47±0.12 e	0.42±0.03 e
S1	7.57±0.18 e	1.76±0.08 d	0.47±0.06 e
S2	8.31±0.12 d	2.01±0.06 c	0.92±0.07 d
S3	9.83±0.15 c	2.07±0.06 c	1.13±0.11 c
S4	10.37±0.08 b	2.23±0.08 b	1.34±0.09 b
S5	11.37±0.11 a	2.43±0.10 a	1.53±0.55 a

*See Table (1) for details. Values are mean ± SD; Values are taken in triplicate Alphabets with different superscripts shows significant difference at 5% level of significance.

Table 5: Continued

Treatment*	Ash	Carbohydrates	Calorie
		Corn flakes	
T0	2.53±0.17 c	86.19±0.28 a	408.54±0.44 a
T1	2.83±0.19bc	85.51±0.29 a	406.81±0.89 b
T2	2.93±0.32 b	82.95±0.27 b	405.54±0.42 c
T3	3.02±0.32 b	82.31±0.36 b	404.57±0.62 c
T4	3.22±0.01a b	81.09±0.28 c	403.42±0.53 d
T5	3.47±0.06 a	80.23±0.78 d	401.44±0.42 e
		Snacks	
S0	0.31±0.10e	92.07±0.43 a	406.09±0.0 7ab
S1	0.72±0.11d	89.95±0.21 b	405.92±0.20 bc
S2	0.97±0.08c	88.69±0.12 c	406.20±0.16 a
S3	1.32±0.08b	86.70±0.18 d	405.37±0.09 c
S4	1.57±0.12a	85.84±0.13 e	404.87±0.12 d
S5	1.71±0.06a	84.47±0.14 f	405.28±0.10 c

3. Minerals content of corn flakes and extruded snacks:

Mineral content of corn flakes and snacks samples are presented in Table 6. Calcium, phosphorus, iron and zinc content were analyzed for all samples. The data indicated that in all samples mineral content of corn flakes and snacks samples increased with increasing broken bean flour addition compared with control samples. Calcium content for samples were found to be from 60.85 to 89.84 mg/100g for corn flakes and from 60.50 to 81.12 mg/100g for snacks, results indicated that increased P with increasing broken bean flour addition compared with control samples and recorded from 296.90 to 367.95 and 295.80 to 360.80 mg/100g compared with control samples were 227.89 and 247.12 mg/100g for corn flakes and snacks.

The contents of iron and Zinc (Zn), of samples were ranged from 3.43 to 5.30 mg/100g, 3.47 to 5.25 mg/100g. Zinc content was 2.28 to 5.04 and 2.20 to 5.19 mg/100g compared with control samples which recorded 3.29 and 3.33, 1.48 and 1.42 for corn flakes and snacks.

Beans are essential source of micronutrients such as minerals and vitamins and considered superior to cereals as a source of micronutrients (Welch *et al*., 2000). Beans have the highest level of mineral content than other legumes. They are an important source of iron, zinc and phosphorous while other minerals are also found in appreciable amounts (Broughton *et al*., 2003; Shimelis and Rakshit, 2005). The level of iron is highest in beans with a range of 62.0–150 μg/g, which is mostly present in nonheme form (Vadivel and Janardhanan, 2000). The levels of zinc and phosphorus in different beans varieties are found to be in the range of 10.1–109 and 15.8–64.6 μg/g, respectively (Ojijo *et al*., 2000; Cabrera *et al*., 2003; Wu *et al*., 2005).

Table 6: Minerals content of corn flakes and extruded snacks (mg/100gm).

Treatment*	Ca	P	Fe	Zn
			Corn Flakes	
T0	45.88±0.11f	227.89±0.46f	3.29±0.07e	1.48±0.09f
T1	60.85±0.43e	296.90±0.49e	3.43±0.03e	2.28±0.11e
T2	68.99±0.28d	314.00±0.41d	3.95±0.07d	3.09±0.08d
T3	73.96±0.32c	331.10±0.09c	4.35±0.07c	3.95±0.14c
T4	80.80±0.31b	358.90±0.20b	4.95±0.15b	4.55±0.07b
T5	89.84±0.14a	367.95±0.04a	5.30±0.11a	5.04±0.04a
			Extruded Snacks	
S0	44.75± 0.13f	247.12±0.09f	3.33±0.07e	1.42±0.07f
S1	60.50±0.18e	295.80±0.14e	3.47±0.05e	2.20±0.09e
S2	69. 92±0.05d	320.14±0.12d	3.90±0.08d	3.19±0.11d
S3	72.17±0.13c	340.12±0.12c	4.30±0.11c	3.90±0.19c
S4	79.85±0.16b	352.90±0.08b	4.87±0.11b	4.57±0.12b
S5	81.12±0.10a	360.80±0.17a	5.25±0.06a	5.19±0.17a

4. Amino acids content and its chemical score of corn flakes and snacks:

Chemical score of corn flakes and snacks were determined, based on the amount essential amino acids. For Further nutritional evaluation of prepared corn flacks, the amino acids content as presented in Table (7a & 7b) results indicated that essential amino acids increased in corn flakes and snacks with increasing percentage addition white bean flour.

Table 7a: Amino acids content and chemical score of prepared Corn Flakes:

	Amino Acids	T 0		T 1		T 2	
		mg / 100 g	C.S (%)	mg / 100 g	C.S (%)	mg / 100 (g)	C.S (%)
Essential	Valine	40	0.8	55	1.1	58	1.16
	Isoleucine	31	0.78	39	0.98	50	1.25
	Leucine	82	1.17	95	1.36	97	1.39
	Lysine	26	0.47	36	0.65	46	0.84
	Methionine	19	0.54	21	0.60	24	0.69
	Phenylalanine	37	0.62	46	0.77	52	0.87
	Threonine	29	0.73	33	0.83	36	0.90
	Histidine	24		28		31	
	T.E.A.A.	228		353		394	
Non-Essential	Alanine	56		66		69	
	Arginine	49		56		61	
	Aspartic Acid	57		76		98	
	Cysteine	17		19		20	
	Glutamic Acid	120		142		188	
	Glycine	34		44		47	
	Proline	59		60		62	
	Serine	37		42		44	
	Tyrosine	37		44		48	
	N.E.A.A.	466		549		637	
Total amino acids		754		902		1031	

Table 7a: Continued:

	Amino Acids	T 3		T 4		T 5		WHO/FAO pattern for (9-13 year)
		mg / 100 g	C.S %	mg / 100 g	C.S %	mg / 100 g	C.S %	
Essential	Valine	62	1.24	66	1.32	71	1.42	50
	Isoleucine	52	1.30	59	1.48	64	1.6	40
	Leucine	101	1.44	108	1.54	116	1.66	70
	Lysine	47	0.85	62	1.13	71	1.29	55
	Methionine	25	0.71	27	0.77	29	0.83	35
	Phenylalanine	54	0.90	63	1.05	69	1.15	60
	Threonine	44	1.10	50	1.25	56	1.40	40
	Histidine	33		37		40		
	T.E.A.A.	418		472		516		
Non-Essential	Alanine	72		79		80		
	Arginine	64		72		79		
	Aspartic Acid	101		119		133		
	Cysteine	21		24		28		
	Glutamic Acid	199		218		235		
	Glycine	46		51		56		
	Proline	65		66		67		
	Serine	59		64		72		
	Tyrosine	44		49		51		
	N.E.A.A.	671		742		801		
Total amino acids		1089		1214		1317		

Table 7b: Amino acids content and chemical score of prepared Snacks:

	Amino Acids	S0		S1		S2	
		mg / 100 g	C.S %	mg / 100 g	C.S %	mg / 100 g	C.S %
Essential	Valine	33	0.66	36	0.72	42	0.84
	Isoleucine	20	0.5	26	0.65	31	0.65
	Leucine	78	1.11	84	1.20	88	1.26
	Lysine	9	0.16	16	0.29	27	0.49
	Methionine	16	0.46	17	0.49	17	0.49
	Phenylalanine	31	0.52	38	0.63	44	0.73
	Threonine	21	0.53	26	0.65	29	0.73
	Histidine	19	1.0	22	1.16	25	1.32
	E.A.A	227		265		303	
Non-Essential	Alanine	55		50		53	
	Arginine	23		27		36	
	Aspartic Acid	47		53		70	
	Cysteine	12		13		18	
	Glutamic Acid	113		129		139	
	Glycine	21		24		28	
	Proline	61		63		62	
	Serine	28		35		36	
	Tyrosine	28		29		32	
	N.E.A.A	388		423		474	
	T.A.A.	615		688		777	

Table 7b: Continued

	Amino Acids	S3		S4		S5		WHO/FAO pattern for (9-13 year)
		mg / 100 g	C.S (%)	mg / 100 g	C.S (%)	mg / 100 g	C.S (%)	
Essential	Valine	48	0.96	64	1.28	69	1.38	50
	Isoleucine	37	0.78	43	0.93	47	1.08	40
	Leucine	96	1.37	104	1.49	109	1.56	70
	Lysine	38	0.69	43	0.78	43	0.78	55
	Methionine	18	0.51	21	0.60	22	0.63	35
	Phenylalanine	51	0.85	57	0.95	62	1.03	60
	Threonine	35	0.88	37	0.93	45	1.13	40
	Histidine	29	1.53	32	1.68	35	1.84	
Non-Essential	E.A.A	352		401		432		
	Alanine	58		73		77		
	Arginine	44		53		55		
	Aspartic Acid	84		124		120		
	Cysteine	17		29		16		
	Glutamic Acid	156		164		187		
	Glycine	34		42		45		
	Proline	64		65		68		
	Serine	45		38		59		
	Tyrosine	36		39		40		
	N.E.A.A	538		627		667		
	T.A.A.	890		1028		1099		

The essential amino acids (EAA) content of two products were determined in comparison with that present in control samples. Results indicated that leucine represented the highest value in T 4, T5 and S 4, S5 for corn flacks and snacks while methionine represented the lowest value. Methionine being the most limiting amino acid in all samples for corn flacks and Snacks.

Also all nonessential amino acids content were amounts in T4, T 5 and S4, S5 for corn flakes and snacks (742, 801 and 627, 667 mg/100g) respectively compared with control samples were recorded 466 and 388 mg/100g for corn flakes and snacks. Results indicated that glutamic acid represented the highest value of N.E.A.A. in all samples while, cysteine represented the lowest value in all samples for corn flakes and snacks.

As can be seen from the data in Table 7a and 7b, along with the supplementation of yellow corn in corn flakes and extruded snacks with broken white bean flour, noticed that increase in the total protein content of the final products was observed. More distinct changes were observed in products with increasing addition broken bean flour. Extrudates supplemented with broken bean flour at the level of 10, 20, 30, 40 and 50% respectively compared with traditional corn flakes and snacks. The data in Table 6a and 6b also show that the addition of broken bean flour to the studied extrudates increased the content of essential amino acids such as lysine, methionine, cystine, leucine, isoleucine and valine and among nonessential amino acids glutamate content was observed. The supplementation of corn-based extrudates with broken bean flour affected to a higher degree the content of nonessential amino acids. The addition of experimental flour to corn-based extrudates resulted in the significant increase in the total essential amino acids along with increase in the level of supplementation.

5. Nutritional value of corn flakes and snacks comparing with RDA from some nutrients for children aged 9 -13 years old.

The percentages of the recommended dietary allowances (% RDA) are provided from 100g of corn flakes and snacks for children are showed in table 8. It could be observed that supplementation of corn flakes covers up to 38.85% of protein requirement, 22.3 %and 25.09 % of energy requirement for male and female, 29.44% of phosphorus requirement, 66.25% of iron requirement, 63.63% of zinc and 6.91% of calcium, for children. Whereas, snacks cover up to 33.44% of protein requirement, 22.52 %and 25.33% of energy requirement for male and female, 28.86% of phosphorus requirement ,65.63% of iron requirement, 64.88% of zinc and 6.24% of calcium, for children of age 9-13 years. Therefore, it could be recommended to consume corn flakes and snacks to provide children with part of their daily requirements of protein, energy, phosphorus, calcium, iron and zinc.

Table 8: Nutritional Value of corn flakes and snacks /100g.

Parameter		% RDA of Corn flakes					
		T0	T1	T2	T3	T4	T5
Protein		22.17	23.58	31.35	33.32	36.53	38.85
Fibers	Male	8.29	8.1	6.19	6	5.39	3.13
	Female	9.88	9.65	7.38	7.15	6.42	3.73
Carbohydrates		66.3	65.78	63.81	63.32	62.38	61.72
Energy	Male	22.7	22.6	22.53	22.48	22.41	22.3
	Female	25.53	25.43	25.35	25.29	25.21	25.09
Ca		3.53	4.68	5.31	5.69	6.22	6.91
P		18.23	23.75	25.12	26.49	28.71	29.44
Fe		41.13	43.00	49.38	54.38	61.88	66.25
Zn		18.50	28.50	38.63	49.38	56.88	63.63

Table 8: Continued

Parameter		% RDA of Snacks					
		S0	S1	S2	S3	S4	S5
Protein		18	22.26	24.44	28.91	30.5	33.44
Fibers	Male	1.35	1.52	2.97	3.65	4.29	4.94
	Female	1.62	1.81	3.54	4.35	5.12	5.88
Carbohydrates		70.82	69.18	68.22	66.69	66.01	64.98
Energy	Male	22.56	22.55	22.57	22.52	22.49	22.52
	Female	25.38	25.37	25.39	25.34	25.3	25.33
Ca		3.44	4.65	5.38	5.55	6.14	6.24
P		19.77	23.66	25.61	27.21	28.23	28.86
Fe		41.63	43.38	48.75	53.75	60.88	65.63
Zn		17.75	27.50	39.88	48.75	57.13	64.88

6. Sensory evaluation:

Sensory evaluation of corn flacks and snacks taste, odor texture, color, and overall acceptability of the extruded samples and control. Corn flacks and snacks were evaluated by a sensory panel and the results are reported in Table (9). The taste ratings for corn flacks and snacks ranged from 7.73 to 7.33 and 7.30 to 6.60 which indicates that formulation T1 and S1 had the highest rating from all the samples. T3, T4 and S3, S4 were not significantly different ($p > 0.05$) from each other and were neither liked nor disliked by the panellists. Differences in taste can be attributed to molecular changes in the flour due to the different processing conditions (soaking, dehulling and drying) that the raw materials specially broken white bean BWB were subjected to Fellows, (2009).

In terms of odor, product T_1 and S_1 were rated the highest (7.90 and 7.60) T_5 , S_5 (7.30 and 7.00) were the lowest as shown, significant difference ($p > 0.05$) existed between all samples for snacks. The odor of corn flakes and snacks from yellow corn and BWB formulations were liked by the panellists and they slightly neither liked T_5 for corn flakes nor disliked S_5 for snacks. The mean scores indicated that, the panelists were found to like more breakfast meals corn flakes and snacks with BWB flour substitution from 10 to 30%. This may be due to panellists' familiarity with the smell of maize and beans blends. As reported by Enwere (1998) meals prepared from un-dehulled beans may possess a beany odor which may be disliked by consumers. However, panellists did not detect any beany odor in the products, which indicates that the processing of the broken beans was able to remove the undesirable beany odor associated with beans products (Ampofo, 2009).

Mean score for texture of the corn flakes and extruded snacks prepared from the yellow corn and BWB flour formulations were within the range of 7.73 to 6.23 for corn flakes and 8.50 to 6.25 for snacks. There were significant differences ($p > 0.05$) amongst the formulated corn flakes and extruded snacks. This indicates that, T1, S1 to T4, S4 were liked. Panellists neither liked nor disliked the texture of T5 and S5. Texture of corn flakes and extruded snacks could be attributed to the high ratio of BWB flour content in blends.

Color, the mean scores from 8.71 to 6.47 and 7.60 to 6.90 were ranked by Panellists which indicate that the color of the formulations were liked and slightly liked for T5, S5. T0, S0 (control) had the highest ranking for color. In the formulations group products T1, S1 was highly rated followed by T2, S2. There was no significant different ($p > 0.05$) existing between them. Variations in the rating could be attributed to the chemical composition of the raw materials, the drying temperature and duration, as well as ratio of substitution of the individual flours (Belitz et al., 2009; Fellows, 2009). (McDonough et al., 2004) also reported that browning reactions can occur during processing of cereal grains which can impart on the color of cereal flours and meals prepared from them.

The overall acceptability of the formulations ranged from 8.46 to 7.53 and 8.00 to 7.60 for corn flakes and snacks respectively. The highest overall acceptability rating were recorded for T1 and S1 which were significantly different ($p < 0.05$) from the others. Significant differences ($p > 0.05$) were recorded for formulations T_2, T_3 and S_2, S_3.

The results revealed that addition of BWB flours to corn flakes and snacks formulated significantly improved their overall acceptability to 30%. High overall acceptability values indicate that the product has good chances of being patronized by consumers when launched on the market (Asante, 2015). Thus, formulation T_1, S_1 and T_2,S_2 can compete with formulation T0 (control) on the market. Similar results showed that the sensory evaluation had the lowest overall acceptability scores for the extruded samples No T5 and S5 for corn flacks and snacks.

Table 9: Sensory evaluation of prepared Corn Flakes and extruded Snacks:

Treatment	Taste (9)	Odor (9)	Texture (9)	Color (9)	Overall acceptability (9)
			Corn Flakes		
T0	8.00 ± 0.50a	8.00±0.50a	8.00±0.50a	8.73 ± 0.25a	8.50 ± 0.50a
T1	7.73 ± 0.75a	7.90±0.81a	7.73±0.25a	8.71 ± 0.26a	8.46 ± 0.50a
T2	7.52 ± 0.50a	7.80±0.60ab	6.93±0.51b	8.52 ± 0.50a	8.42 ± 0.14a
T3	7.47 ± 0.50a	7.79±0.51ab	6.50±0.50b	7.97 ± 0.50ab	8.00 ± 0.08ab
T4	7.36 ± 0.29a	7.47 ±0.50bc	6.43±0.51b	7.17 ±0.76bc	7.97 ± 0.06ab
T5	7.33 ± 0.29a	7.30±0.25c	6.23 ±0.25b	6.47 ± 0.50c	7.53 ± 0.50b
			Extruded Snacks		
S0	7.35±0.26a	7.70 ±0.50a	8.50±0.50a	7.60 ±0.26a	8.10± 0.50a
S1	7.30±0.29a	7.60 ±0.41a	8.50±0.00a	7.60±0.06ab	8.00± 0.50a
S2	7.20±0.25a	7.50 ±0.30a	8.00±0.50ab	7.50±0.00ab	7.90± 0.50a
S3	7.00±0.50a	7.30 ±0.21a	7.79±0.26b	7.10±0.06c	7.30±0.06b
S4	7.00±0.50a	7.20 ±0.31b	6.93±0.12c	7.03±0.25c	7.00±0.25b
S5	6.60±0.26a	7.00 ±0.25c	6.25±0.25d	6.90±0.04d	6.60±0.09c

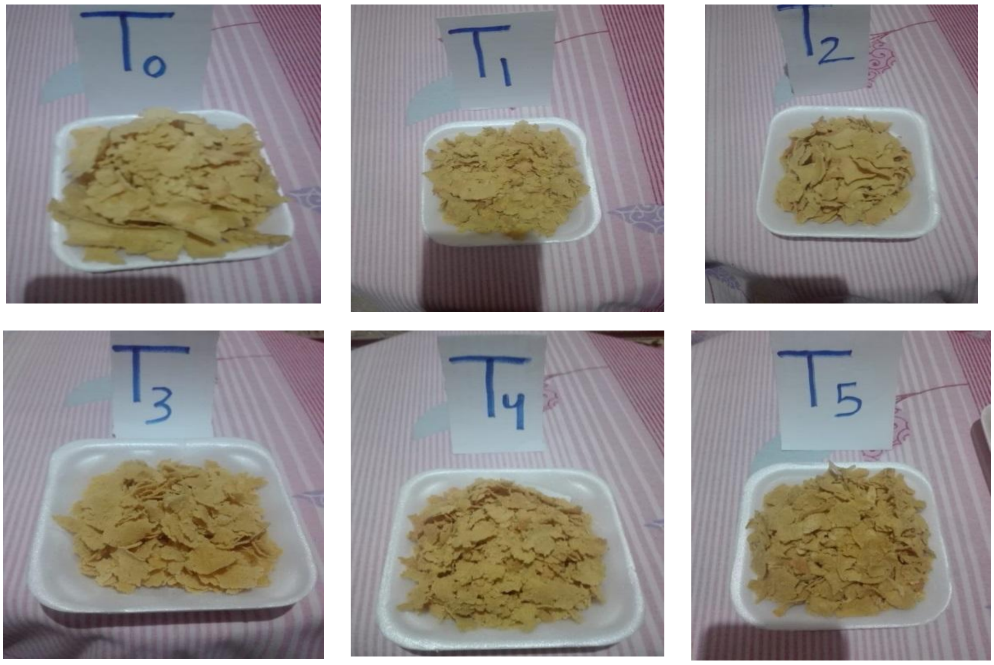

Fig. 1: Corn flakes made by using different concentrations from BWBF
T0:100% corn flour and zero% BWBF. T1: 90% corn flour and 10% BWBF. T2: 80% corn flour and 20% BWBF. T3: 70% corn flour and 30% BWBF. T4: 60% corn flour and 40% BWBF. T5: 50% corn flour and 50% BWBF.

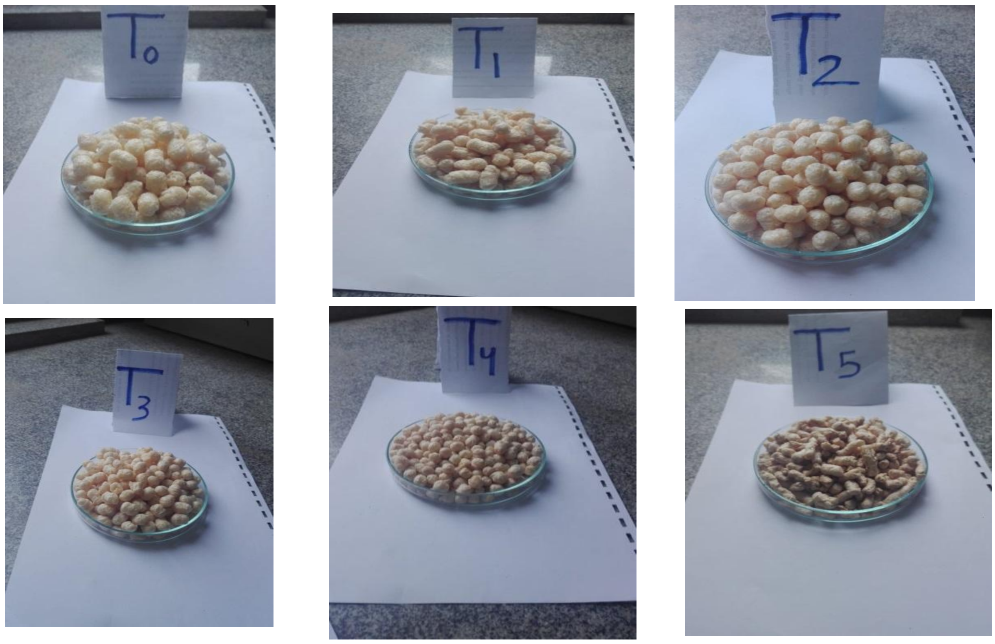

Fig. 2: snacks made by using different concentrations from BWBF
T0:100% corn grits and zero% BWBF. T1: 90% corn grits and 10% BWBF. T2: 80% corn grits and 20% BWBF. T3:70% corn grits and 30% BWBF. T4: 60% corn grits and 40% BWBF. T5: 50% corn grits and 50% BWBF.

7. Production costs of different treatments corn flakes and extruded snacks: (L.E./Kg)

Production costs of different samples were calculated and presented in Table (10). Data obtained showed that the cost reduction (%) noticeably increased as the ascriptions of broken white bean flour increased in the blend. From this table it could be noticed that, the cost for one/kg of the control samples were high costs, the total cost was 12.30 and 11.60 EGP/kg for corn flakes and extruded snacks .The highest cost price for the corn flakes samples Group (1) $T_{1,}$ the cost one kg were average (12.25 to 14.75

EGP/kg).The average price for samples Group (2) extruded snacks were (11.38 to 13.88). These prices are plausibly accepted when compared with the prices for commercial products such as (Temmy's and prada corn flakes) ranged from 72 to 80 EGP/kg compared with sample group(1).While the commercial samples (windows) cost average 55.56 EGP/kg compared with group samples (2). The investigated extrudates were completely cheaper and could be offered to consumers at a price of about quarter to third of market snacks.

It could be found that the prices are very suitable for the Egyptian market and thus these results and sensory evaluation recommend that the best rate is to add 10 to 30% experimental panelists for corn flakes snacks.

Table 10: Production costs of different treatments (L.E./Kg).

Group No.	Treatment	Price (L.E.)					
		Kg of Ingredient	Electricity and water	Service	Collection of cost	Profit %25	Kg of market samples
				Corn Flaks			
Group (1)	T0	5.80	1.50	5.00	12.30	3.18	15.38
	T1	5.30	1.50	5.00	11.80	2.95	14.75
	T2	4.80	1.50	5.00	11.30	2.83	14.13
	T3	4.30	1.50	5.00	10.80	2.7	13.50
	T4	3.80	1.50	5.00	10.30	2.58	12.88
	T5	3.30	1.50	5.00	9.80	2.45	12.25
				Extruded snacks			
Group (2)	T0	5.10	1.50	5.00	11.60	2.9	14.50
	T1	4.60	1.50	5.00	11.10	2.78	13.88
	T2	4.10	1.50	5.00	10.60	2.65	13.25
	T3	3.60	1.50	5.00	10.10	2.53	12.63
	T4	3.10	1.50	5.00	9.60	2.40	12.00
	T5	2.60	1.50	5.00	9.10	2.28	11.38
Temmy's corn flakes prada corn flakes (like Group1)							72.00 80.00
Window (like Group2)							55.56

Conclusion

In this study, the high percentages of white bean flour, from a nutritional point of view, contribute to increasing the protein content in the extruded products; however, lower amounts of white bean flour, may be more beneficial to achieve better expansion.

From the obvious results, it could be concluded that the extruded corn flacks and snacks showed an increase in protein and minerals than that control corn flacks and snacks. Moreover, physical characteristics, water absorption index of extruded corn flacks and snacks than control. Also, the sensory evaluation showed that the samples No. T4, S4 and T5, S5 (the lowest in overall acceptability scores in corn flacks extruded snacks) may be due to the increasing concentration of BWB powder. Extruded blends No.T1, S1 toT3 S3 made from 10 to 30% broken white beans flour were most like by the taste panelists.

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