JAP&T
TPA-Timisoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2018, *24* (2), 54-62

Journal of Agroalimentary Processes and Technologies

Quality properties of corn snacks enriched with red corncobs powder

Elsebaie Essam Mohamed , Rowida Younis Essa

Food Technology Department, Faculty of Agric. Kafrelsheikh University, Egypt.

Abstract

This work was carried out for two main targets, the first one is to study the possibility of preparing high-quality snacks made of corn grits and supplemented with different levels of red corncobs powder (5%, 8%, and 10%). The second one is to evaluate this product chemically, physically and nutritionally. The received data revealed that red corncobs powder has a high dietary fiber and polyphenols with a low level of anti-nutritional factors. In addition, according to obtained data significant increases in total dietary fiber; total phenolics and water absorption index values were observed for products extruded with higher levels of red corncobs powder. Also, increasing the red corncobs powder level produced less expanded and water solubility index extrudates with a darker appearance. According to the sensory evaluation scores, red corncobs powder could be utilized up to the percentage of 10% in order to produce high- quality snacks with acceptable sensory characteristics. Therefore, this investigation recommended that red corncobs could successfully be used to produce functional food (corn snacks) rich in crude fiber and phenolic compounds.

Keywords: Corncobs, antioxidants, fiber and functional snacks

1. Introduction

Corncobs are considered a by- product of sweet corn manufacture in Egypt, representing about 15% of the overall corn production with the total yield of about 54,424 tons in 2008 [1]. There are several methods to consume corncobs all over the world such as eating as corn or without grains like vegetables, or supplied as canned food [2]. More mature cobs are either thrown out as waste or burnt, an application with low added value, resulting dangerous environmental problems [3]. Some studies revealed that corncobs are a good source of components with a positive effect on human health such as anthocyanins, ferulic acid, rutin, quercetin, naringenin, kaempferol, with anti-oxidative activity and capability to promote endogenous antioxidant enzymes as well as dietary fiber [4, 5]. It is well-known that dietary fiber is considered the most important element in human health, promoting several physiological and metabolic positive effects [6]. In addition, fibers possess some technical characteristics such as its ability to swell, hold oils and water, hence improve the physicochemical properties of the produced food [7].

One option is to use these by-products as active ingredients in food processing, such as extrusion process, that has some advantages such as widespread use, high production, low-cost, low energy consumption, effluents reduction [8]. The extrusion process tend to starch depolymerization, which helped to increases the digestion rate of carbohydrates and generates a high glycemic index products [9]. Recently, efforts have been done to provide more fibers in extruded products through adding fiber to Starch [10]. Fibers played an active part in decreasing the expansion ratio of extruded products by destroying cellular structures [11]. Nowadays different studies have clarified that fiber can be added in extruded products at the levels lower than 5 g / 100g without affecting the eating quality properties [12]. However, adding high rate of fiber leads to aggregate fibers and cell wall rupture [13]. On the other hand, different by

Corresponding author: *e-mail:* Essam.ahmed@agr.kfs.edu.eg

products such as tomato pomace, grape seed, orange peels, and carrot pomace were integrated with extruded products as a fiber and bio-active component sources [14, 15]. In addition, it was concluded that snacks enriched with fiber have obtained a high acceptability. So, there are many advantages of supporting snacks with corncobs, since they have high levels of fibers and phenolic compounds. This work was carried out to study the possibility of using corncobs for preparing healthy snacks and evaluate this product chemically, physically and nutritionally.

2. Materials and Methods

Corn (*Zea mays*) variety Hagen Farde 10 was obtained in August 2016 from the local field of Kafrelshiekh governorate, Egypt.

Corn grits (Bunge Milling, St. Louis, MO, USA) was obtained from a local store and used as a bulk ingredient. Corn oil was purchased from Tanta Company for Oils and Soap, Tanta city, Egypt.

All chemicals (2, 2-Diphenyl-1- picryl-hydrazyl (DPPH), gallic acid and Folin–Ciocalteu reagent) used in this study were obtained from Sigma-Aldrich (St. Louis, MO, USA). All other chemicals used were HPLC grade and acquired from El-Gomhoria Company for Chemicals and Drugs, Tanta city, Egypt.

2.1.Corncobs preparation

Upon collecting corn (*Zea mays*) from the local field of Kafrelshiekh governorate, Egypt. Kernels were removed manually; red cobs were dried in an air oven at 60ºC to a final moisture content of 5.12 ± 0.36 % then, ground in a mill (Brabender Automat Mill Quandrumat Senior, Germany) to pass through 100 mesh screen sieve and packed in polyethylene bags then kept at 4 °C until use.

2.2.Chemical analyses

Moisture, protein, crude fat and ash contents of red corncobs powder, corn flour and snacks were preformed according to AACC [16] where dietary fiber, soluble and insoluble dietary fiber contents were analyzed according to A.O.A.C. [17].

2.3. Determination of polyphenols and their antioxidant activity:

The concentration of total polyphenols was determined using Folin-Ciocalteu reagent and calibrated against Gallic acid.

The results are expressed as Gallic Acid Equivalent (mg GAE/100gm) that described by *Singleton et al* [18]. Free radical scavenging activity was estimated using DPPH radical solution as outlined by Hara et al [19].

2.4. Functional properties

Water holding and oil holding capacities were estimated as outlined by *Heywood et al* [20]. Water or oil holding capacity is expressed as water or oil bound per one gram of red corncobs powder.

2.5. Anti-nutritional factors

Phytate, oxalate, tannin, and trypsin inhibitor content of red corncobs was carried out following the methods of *Inuwa et al* [21].

2.6. Extrusion process:

Extrusion process were carried out using the procedure of *Selani et al* [22] was used for the extrusion process. According to primary experiments, corn grits were replaced by red corncobs powder at levels of 5, 8 and 10%. The moisture content of all treatments was modified to 18% by adding an amount of water and oil (1:2 ratio v/v). The extrusion process was carried out using a Brabender Laboratory twin=screw extruder, 2150510, serial 94011 equipped with a die opening of 4mm and a screw speed of 249 rpm. The extruder screw had a compression ratio of 3:1, a length/diameter ratio of 20/1, length of 38 cm, and a diameter of 19 mm. The temperature of the first (feed) zone was set to 80 °C, while the second (metering) was set to 90 °C and the third zone was set to 140°C.

2.7. Physical Properties

2.7.1. Bulk density

The bulk density of twenty pieces of extruded snacks was calculated according to Huang and Ma [23] using the following equation:

$$\text{Bulk density} = \frac{4M}{\Pi\, LD^2}$$

Where M (gm) is the average weight of twenty pieces of extruded snacks, L(cm) is the average length of twenty pieces of extruded snacks and D (cm) is the average diameter of twenty pieces of extruded snacks. All of length and diameter of twenty pieces of extruded snacks were measured using a caliper (Mitutoyo, Tokyo, Japan).

2.7.2. Water solubility and absorption index

Water solubility and absorption index were estimated using the method mentioned by *Huang and Ma* [23]. As follows: Snacks samples were crushed to a fine powder. A centrifuge tube was weighed after adding two grams of snacks fine powder. 25 ml of distilled water or corn oil was added. A mixing process was performed for 2 minutes; the mixture was left at 30° C for 30 minutes with shaking for every 10 minutes for 5 seconds and centrifuged (Kubota KN-70 Centrifuge, Japan) for 10 minutes at 3000×g. After that, the supernatant poured carefully into an aluminum dish and the centrifuge tube was weighted again. The water solubility and absorption index were calculated from the following equations:

$$\text{Water solubility index (\%)} = \frac{\text{Dry solids weight in supernatant}}{2} \times 100$$

$$\text{Water absorbation index (g/g)} = \frac{\text{Weight gain of gel}}{2}$$

2.7.3. Radial expansion

Radial expansion were determined as outlined by Huang and Ma [23] using the following equation:

$$\text{Bulk density} = \frac{D}{D_2}$$

Where D (cm) is the average diameter of cross-sectional of twenty extruded snacks pieces and D2 (cm) is the diameter of die nozzle. The diameter of cross-sectional was measured using a caliper (Mitutoyo, Tokyo, Japan).

2.7.4. Color

Snacks products were crushed in a blender (Brabender Automat Mill Quandrumat Senior, Germany) and sieved at 60 mesh then the color measured with a Hunter Lab Colorimeter (MiniScan XE Plus, Reston, VA) according to the method described by *Al-Subhi* [24].

2.8. Sensory Evaluation of Products

The sensory evaluation was carried out in order to get consumer response for overall acceptability of the 5%, 8% and 10% red corncobs powder incorporated snacks compared to the control snacks using a 9-point hedonic-scale (1= dislike extremely, 9 like extremely). 30 panelists from Food Technology Department, Faculty of Agriculture, Kafrelshiekh University evaluated appearance, taste, color, odour, crispness, and overall acceptability according to the method described by *Al-Okbi et al* [25].

2.9. Statistical Analysis

Statistical analysis was carried out by SPSS10 program. Data were expressed as means ± SEM and the Statistical analysis was performed using one-way analysis of variance followed by Duncan's tests [26].

3. Results and Discussions

3.1. Chemical composition of red corncobs powder and corn grits

Results in Table (1) indicated that the red corncobs powder contained lower percentages of moisture, protein, crude fat and total carbohydrate (5.12, 3.24, 0.54 and 55.72%, respectively) compared with corn grits which contained 14.20, 9.20, 0.98 and 88.45%, respectively. These results were agreed with the findings of *Muazu and Stegemann* [27], *Wachirapakorn et al* [28], *Biswas et al* [29] who found that the contents of moisture, protein, crude fat and total carbohydrate were ranged between 5.00 to 9.64 %, 2.64 to 3.98%, 0.52 to 0.76% and 51.09 to 59.41%, respectively. Whereas, red corncobs powder was higher in crude fiber and ash (39.67 and 0.83%, respectively) when compared with corn grits which contained 0.70 and0.67%, respectively. These results were in agreement with those of *Ashour et al* [1] and *Zheng et al* [30] who stated that corncobs crude fiber and ash contents were ranged between 35.92 to 41.26% and 0.69 to 1.2%, respectively. Apparent also from the same Table that, the main component of red corncobs powder was total dietary fibers (91.18±1.75%), where the soluble and insoluble dietary fiber were 1.56 and 89.62%, respectively. These results are in agreement with the findings reported by Arif et al [31].

Moreover, it should be noted also that the red corncobs powder has a high content of phenolics (513.20mg GAE /100gm), where the highest value of free radical scavenging activity (DPPH) 77.91% in comparing with corn grits (31.50%). The results are in line with those of *Vicas et al* [32] and Monroy et al [33] who reported that phenols was found to be between 290 and 703.98mg GAE /100gm. Thus, corncobs can be considered a high-fiber food as healthy products.

Table 1.Chemical composition of red corncobs powder and corn grits (on dry weight basis)*.

Samples / Components	Red Corncobs	Corn grits
Moisture (%)	5.12 ± 0.36[b]	14.20±0.98[a]
Protein (%)	3.24±0.18[b]	9.20±0.29[a]
Crude fat (%)	0.54±0.06[b]	0.98±0.05[a]
Crude fiber (%)	39.67±1.59[a]	0.70±0.12[b]
Ash (%)	0.83±0.09[a]	0.67±0.04[b]
**Total carbohydrates (%)	55.72±0.59[b]	88.45±0.78[a]
Total dietary Fiber (%)	91.18±1.75[a]	2.49±0.86[b]
Soluble Dietary Fiber (%)	1.56±0.20[a]	0.65±0.05[b]
Insoluble Dietary Fiber (%)	89.62±0.31[a]	1.84±0.27[b]
Total phenolics (mg /100gm)	716.20[a]	121.62[b]
DPPH· Scavenging activity (%)	77.91[a]	31.50[b]

*All data are the mean±SD of three replicates. Mean followed by different letters in the same row differs significantly (P≤0.05).

**Calculated on dry weight basis as 100 – Ash + Protein + Fiber + Fat.

3.2. Functional properties

Results given in Table (2) indicated that red corncobs powder has a high water holding capacity (4.47±0.53 g water/g sample), which is higher than those of *Aniola et al* [4], who reported that corncobs water holding capacity was ranged between 2.53 to 4.31 g water/g sample. There are several factors affecting the hydration characteristics such as the chemical structure of the polysaccharides found, particle size, porosity, ionic form, temperature, pH and ionic strength [7].

Table 2.Functional properties of red corncobs powder

Sample / Properties	Corncobs powder
Water holding capacity (g/g dry matter)	4.47±0.53
Oil holding capacity (g/g dry matter)	1.97±0.15

In addition, data in the same Table showed that oil holding capacity was 1.97±0.15 g oil /g sample, which is in agreement with *Aniola et al* [4]. This property is a function of the overall charge density, surface properties, hydrophobic nature [34].

3.3.Antinutritional factors

Anti-nutritional factors are components which decrease the nutritional utilization of plants or its products as food for human [35]. Data given in Table (3) showed that phytate, oxalate and tannin content in red corncobs powder were 1.220±0.020, 0.074±0.006 and 0.018±0.002 mg/g dry matter, respectively. These results were agreed with the findings of Olagunju et al [36] and [37] who found that phytate, oxalate, and tannin were ranged between 1.05 to 1.32 mg/g, 0.08 to 0.09 mg/g and 0.02 to 0.04 mg/g (dry weight basis), respectively.

Table 3. Anti-nutritional factors content of red corncobs powder

Sample / Components	Corncobs powder
Phytate (mg/g dry matter)	1.220±0.020
Oxalate (mg/g dry matter)	0.074±0.006
Tannin (mg/g dry matter)	0.018±0.002
Trypsin Inhibitor(TIU/mg)	0.050±0.010

Furthermore, data in the same Table revealed that trypsin Inhibitor content of red corncobs was 0.050±0.010 TIU/mg. This result was in harmony with those obtained by *Yusuf et al* [37]**.** According to the given data in Table (3), anti-nutritional factors in red corncobs powder were in the lower levels so it can be safely added to foods without any serious nutritional problems.

3.4. Evaluation of produced snacks:

3.4.1.Chemical composition of the produced snacks

Chemical composition and total phenolic content of the produced snacks were determined and the results were tabulated in Table (4). It is clear that addition of red corncobs powder caused an increment in the moisture percentages of the snacks in comparing with the control. This might due to the capability of fibers for keeping water in the final product. The same trend was noticed for crude fat contents which could be explained by the fact of the fiber-lipid composite formation. Also, there was a slight decrement in protein content of the snacks integrated with adding red corncobs powder to produce snacks. The lower amount of protein is result of of the low protein content in corncob in comparison to grits. In addition, data in the same Table revealed that there was a significant increment in the ash and fiber content of corn snacks integrated with corncobs. This is mainly due to the high content of ash and fiber in corncobs. Polyphenolic components play a serious role in preventing lipid oxidation because of thier antioxidant activity [38]. It is suggested that polyphenolic components positivelly affect carcinogenesis and mutagenesis in humans when the taken dose reached up to 1.0 g daily ingested from a diet rich in vegetables and fruits [39].

The total phenols content of the snacks fortified with red corncobs powder increased as the amount of red corncobs powder increased. The snacks with 10% red corncobs powder had the highest percent of phenols (137.52±1.27 mg/100gm) and DPPH radical scavenging activity compared with control (52.60 ±2.15%). *Melo-Silveira et al* [40] suggested that the red corncobs powder can be applied in foods as antioxidant source.

3.4.2.Physical Properties of Corn Snacks

Bulk Density

No-statistical significant was recorded in bulk density of snacks upon adding red corncobs powder up to 10% (Table 5). This is mainly could be attributed to the fiber and sugar content of corncobs. According to [41], these component have a high water absorption capacity, which can cause an increment in the density of the final product. Also, fiber addition may cause a reduction in extruded snacks expansion, compacted volume. Similar results were found during extrusion with grape peel, orange peel, tomato pomace and orange peel [14].

Table 4. Chemical composition of the produced snacks integrated with red corncobs powder

Treatment	Control	Snacks with 5% red corncobs powder	Snacks with 8% red corncobs powder	Snacks with 10% red corncobs powder
Moisture	8.95±0.11 ^{c}	9.07±0.05^{bc}	9.32±0.19^{ab}	9.51±0.21^{a}
Crude fat (%)	0.78±0.06 ^{d}	0.82±0.08^{cd}	0.89±0.12 ^{bc}	0.98±0.06^{ab}
Protein (%)	8.49±0.30^{a}	8.19±0.71 ^{bc}	8.06±0.59 ^{c}	7.96±0.66 ^{d}
Crude fiber (%)	0.86±0.19^{d}	2.83±0.25 ^{c}	3.99±0.36 ^{bc}	4.70±0.58 ^{a}
Total dietary Fiber (%)	2.84±0.26^{d}	4.76±0.18 ^{c}	7.35±0.28 ^{b}	9.48±0.72 ^{a}
Ash (%)	1.14±0.22 ^{a}	1.15±0.36 ^{a}	1.16±0.23 ^{a}	1.17±0.14 ^{a}
*Total carbohydrates (%)	88.73±0.98^{a}	87.01±1.10^{b}	85.90±0.95^{bc}	85.19±1.03 ^{c}
Total phenolics (mg /100gm)	98.28±0.31^{d}	115.06±0.87 ^{c}	128.41±0.98 ^{b}	137.52±1.27 ^{a}
DPPH· Scavenging activity (%)	23.16±1.20^{d}	38.62±0.99 ^{c}	46.59±1.71 ^{b}	52.60 ±2.15 ^{a}

*All data are the mean±SD of three replicates.
Mean followed by different letters in the same row differs significantly (P≤0.05).
*Calculated on dry weight basis as 100 – Ash + Protein + Fiber + Fat.

Table 5. Physical Properties of corn Snacks integrated with red corncobs powder

Property \ Treatment	Control	5% red corncobs powder	8% red corncobs powder	10% red corncobs powder
Bulk Density (g/cm^{3})	0.358±0.09 ^{a}	0.360±0.05 ^{a}	0.363±0.07 ^{a}	0.365±0.06 ^{a}
Water Solubility Index (%)	18.13±0.74 ^{a}	16.46±0.85^{b}	15.71±0.55 ^{c}	14.12±1.06 ^{d}
Water Absorption Index (g gel/g)	6.54±0.42 ^{d}	7.09±0.84 ^{c}	8.31±0.66 ^{b}	9.35±0.94 ^{a}
Expansion Ratio (%)	3.59±0.17 ^{a}	3.34±0.25 ^{a}	2.93±0.15 ^{b}	2.81±0.19 ^{b}
Colour				
L*	85.6±0.25 ^{a}	77.32±0.55	73.64±0.84	69.22±0.97
a*	2.05±0.31 ^{b}	2.45±0.24^{ab}	2.98±0.59 ^{a}	3.36±0.45 ^{a}
b*	27.90±0.2 5 ^{a}	25.47±0.67 ^{b}	25.05±0.25 ^{b}	24. 82±0.73 ^{c}

*All data are the mean±SD of twenty replicates.
Mean followed by different letters in the same row differs significantly (P≤0.05).

Table 6. Effect of red corncobs powder on the sensory acceptability of corn snacks.

Treatment / Sensory	Control	5% red corncobs powder	8% red corncobs powder	10% red corncobs powder
Appearance	8.19±0.47 a	8.10±0.33a	7.95±0.39 ab	7.65±0.94 b
Taste	8.01±0.25 a	7.97±0.92 a	7.83±0.32 a	7.49±0.70 ab
Colour	7.70±0.32 a	7.68±0.85 a	7.43±0.61 a	7.34±0.63 a
Odour	7.77±0.21 a	7.73±0.71 a	7.48±0.52 a	7.38±0.52 a
Crispness	8.10±0.43 a	8.05±0.66 a	7.51±0.73 a	7.20±0.17 b
Total acceptability	7.95±0.47a	7.91±0.82a	7.64±0.88 a	7.41±0.62 a

*All data are the mean±SD of thirty replicates.
Mean followed by different letters in the same row differs significantly (P≤0.05).

Water solubility index

Water solubility index (WSI) determined soluble components released via extrusion process [42] and it is predominately utilized as an index for starch disintegration (dextrinization) [43]. According to Brennan et al [9] extrusion process may cause an increment in dietary fiber water solubility as a result of changing in its molecular structure. Water solubility index (WSI) percentages of produced snacks are presented in Table (5). The given data ranged from 14.12% for the snacks integrated with 10% red corncobs powder to 18.13% for the control. As the percentages of red corncobs powder integration were increased from 0 to 10%, the Water solubility index (WSI) decreased by 22.12%. This decrement may be due to the high dietary fiber content of corncobs, that represent 98.29% as water-insoluble fraction, besides these blends have a low starch content. These results are in the same line with those of *Anton et al* [44], who found a decrement in WSI values of corn snacks integrated with carrot pomace.

Water Absorption Index

Water Absorption Index of produced snacks values are tabulated in Table (5). Increasing the added level of red corncobs powder from 0 to 10% increased the water absorption index by 42.97%. The difference in WAI values between extruded products fortified with red corncobs powder and the control sample could be due to the high water absorption capacity of corncobs powder. In fact, the higher water absorption is the characteristic feature of fiber supplemented flours as reported elsewhere [45]. Dietary fiber may interact with water by means of polar and hydrophobic interactions, hydrogen bonding, and enclosure. The results of these interactions vary with the flexibility of the fiber surface. This agrees with the findings of El-Din [46] who pointed out that the addition of pea hulls fiber to corn snacks gave significantly higher WAI values compared with samples containing corn grits only.

Expansion ratio:

Data in Table (5) indicated that the expansion ratio decreased by 21.73% when the integration ratio of red corncobs powder increased from 0 to 10%. Also, decreasing of expansion ratio (ER) of extruded products could be attributed to the increase of dietary fiber content by adding red corncobs powder, which causes rupturing the cell wall before the bubbles of gas expanded to their complete potential. These results were in harmony with those obtained by *Dehghan-Shoar et al* [41].

Colour of snacks:

According to data in Table (5), with increasing the percentages of red corncobs powder integration from 0 to 10% the lightness (L*) and redness (b*) values were decreased by 19.14% and 11.04%, respectively meanwhile, the yellowness (a*) values were decreased by 63.09%.

The decrement in L* values may be due to the high levels of fiber and the browning reaction meanwhile, the Increment in redness a* values may be due to adding red corncobs powder [46]. The obtained results were in the same trend with those obtained by *El-Samahy et al* [47].

Sensory evaluation of snacks:

One of the limiting factors for consumer acceptableness is the sensory evaluation of the various attributes. Therefor, the organoleptic evaluation test of the samples attributes was done to determine the acceptability of such products and give out a final decision on the preferences of the newest products in comparison with the control (Table 6).

Results presented in Table (6) indicated that snacks with red corncobs powder had lower sensory scores in comparing with control. There was no significant difference between control sample and snacks supplemented with 5% red corncobs powder. Meanwhile, there was a significant difference in all sensory attributes score between control and snacks integrated with 8% and 10% red corncobs powder. Generally, all samples were accepted for human consumption.

4. Conclusion

According to the above-mentioned results, red corncobs has a high content of bioactive compounds such as polyphenols and dietary fiber. Moreover, the anti nutritional factors in red corncobs powder were in the safe levels. The addition of corncobs powder with percentages up to 10% increases the nutritional quality of the snacks and improved its physical properties without any significant effect on their overall acceptability.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

References

1. Ashour, A., M. Amer, A. Marzouk, K. Shimizu, R. Kondo, and S. El-Sharkawy, Corncobs as a potential source of functional chemicals. *Molecules*, **2013**, *18*(11), 13823-13830.
2. Zych, D., The viability of corn cobs as a bioenergy feedstock. A report of the West Central Research and Outreach Center, University of Minnesota, **2008.**
3. Mullen, C.A., A.A. Boateng, N.M. Goldberg, I.M. Lima, D.A. Laird, and K.B. Hicks, Bio-oil and bio-char production from corn cobs and stover by fast pyrolysis. Biomass and bioenergy, **2010**, *34*(1), 67-74.
4. Aniola, J., J. Gawecki, J. Czarnocinska, and G. Galinski, Corncobs as a source of dietary fiber. P*olish Journal of Food and Nutrition Sciences*, **2009**, *59*(3).
5. Limsitthichaikoon, S., B. Khampaenjiraroch, K. Saodaeng, T. Rimdusit, and S. Thapphasaraphong, Quality evaluation of purple waxy corn cobs for health use. *The Official Journal of Asian Association of Schools of Pharmacy*, **2014**, *3*, 326-332.
6. Raninen, K., J. Lappi, H. Mykkänen, and K. Poutanen, Dietary fiber type reflects physiological functionality: comparison of grain fiber, inulin, and polydextrose. *Nutrition reviews*, **2011**, *69*(1), 9-21.
7. Elleuch, M., D. Bedigian, O. Roiseux, S. Besbes, C. Blecker, and H. Attia, Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food chemistry*, **2011**, *124*(2), 411-421.
8. Altan, A., K.L. McCarthy, and M. Maskan, Evaluation of snack foods from barley–tomato pomace blends by extrusion processing. *Journal of Food Engineering*, **2008**, *84*(2), 231-242.
9. Brennan, M.A., E. Derbyshire, B.K. Tiwari, and C.S. Brennan, Ready-to-eat snack products: the role of extrusion technology in developing consumer acceptable and nutritious snacks. I*nternational Journal of Food Science & Technology*, **2013**, *48*(5), 893-902.
10. Alam, M., J. Kaur, H. Khaira, and K. Gupta, Extrusion and extruded products: changes in quality attributes as affected by extrusion process parameters: a review. *Critical reviews in food science and nutrition*, **2016**, *56*(3), 445-473.
11. CAMIRE, M.E. and C. King, Protein and fiber supplementation effects on extruded cornmeal snack quality. *Journal of Food Science*, **1991**, *56*(3),760-763.
12. Bénézet, J.-C., A. Stanojlovic-Davidovic, A. Bergeret, L. Ferry, and A. Crespy, Mechanical and physical properties of expanded starch, reinforced by natural fibres. *Industrial Crops and Products*, **2012**, *37*(1), 435-440.
13. Ganjyal, G., N. Reddy, Y. Yang, and M. Hanna, Biodegradable packaging foams of starch acetate blended with corn stalk fibers. J*ournal of Applied Polymer Science*, **2004**, *93*(6), 2627-2633.
14. Yağcı, S. and F. Göğüş, Response surface methodology for evaluation of physical and functional properties of extruded snack foods developed from food-by-products. *Journal of Food Engineering*, **2008**, *86*(1), 122-132.
15. Kumar, N., B. Sarkar, and H.K. Sharma, Development and characterization of extruded product using carrot pomace and rice flour. I*nternational Journal of Food Engineering*, **2010**, *6*(3).
16. AACC, AACC international approved methods of analysis (10thed). 2000, St. Paul, M.N., USA: American Association of Cereal Chemist.
17. A.O.A.C., Association of Official of Analytical Chemists, Official Methods of Analysis. 18th Ed., Pub. By the A.O.A.C. 2010: Arlington, Virginia, 2220 USA.

18. Singleton, V.L., R. Orthofer, and R.M. Lamuela-Raventós, Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in enzymology*, **1999**, *299*,152-178.
19. Hara, K., T. Someya, K. Sano, Y. Sagane, T. Watanabe, and R. Wijesekara, Antioxidant activities of traditional plants in Sri Lanka by DPPH free radical-scavenging assay. Data in Brief, 2018.
20. Heywood, A., D. Myers, T. Bailey, and L. Johnson, Functional properties of low-fat soy flour produced by an extrusion-expelling system. *Journal of the American Oil Chemists' Society*, **2002**, *79*(12), 1249-1253.
21. Inuwa, H., V. Aina, B. Gabi, I. Aimola, and A. Toyin, Comparative determination of antinutritional factors in groundnut oil and palm oil. *Advance Journal of Food Science and Technology*, **2011**, *3*(4), 275-279.
22. Selani, M.M., S.G.C. Brazaca, C.T. dos Santos Dias, W.S. Ratnayake, R.A. Flores, and A. Bianchini, Characterisation and potential application of pineapple pomace in an extruded product for fibre enhancement. *Food chemistry*, **2014**, *163*, 23-30.
23. Huang, Y.-L. and Y.-S. Ma, The effect of extrusion processing on the physiochemical properties of extruded orange pomace. *Food chemistry*, **2016**, *192*, 363-369.
24. Al-Subhi, F.M.M., Using Extrusion to Prepare Snacks Food High Nutrition Value Fortified with Soybean and Spinach for Children. *Middle East Journal of Applied Sciences*, **2014**, *4*(4), 959-966.
25. Al-Okbi, S.Y., A. Hussein, I.M. Hamed, D.A. Mohamed, and A.M. Helal, Chemical, Rheological, Sensorial and Functional Properties of Gelatinized Corn-Rice Bran Flour Composite Corn Flakes and Tortilla Chips. J*ournal of food processing and preservation*, **2014**, *38*(1), 83-89.
26. SPSS, Statistical package for Social Sciences. SPSS for Windows, Version 10, SPSS Inc., Chicago, IL, USA. 2000.
27. Muazu, R.I. and J.A. Stegemann, Effects of operating variables on durability of fuel briquettes from rice husks and corn cobs. *Fuel Processing Technology*, **2015**, *133*, 137-145.
28. Wachirapakorn, C., K. Pilachai, M. Wanapat, P. Pakdee, and A. Cherdthong, Effect of ground corn cobs as a fiber source in total mixed ration on feed intake, milk yield and milk composition in tropical lactating crossbred Holstein cows. *Animal Nutrition*, **2016**, *2*(4), 334-338.
29. Biswas, B., N. Pandey, Y. Bisht, R. Singh, J. Kumar, and T. Bhaskar, Pyrolysis of agricultural biomass residues: Comparative study of corn cob, wheat straw, rice straw and rice husk. *Bioresource technology*, **2017**, *237*, 57-63.
30. Zheng, A., Z. Zhao, S. Chang, Z. Huang, K. Zhao, G. Wei, F. He, and H. Li, Comparison of the effect of wet and dry torrefaction on chemical structure and pyrolysis behavior of corncobs. *Bioresource technology*, **2015**, 176, 15-22.
31. Arif, M., M. Riaz, C.J. Martin, Y. Reinprecht, L. Simon, B. Dean, and K.P. Pauls, *Technology and Sustainability of Crop Fibre Uses in Bioproducts in Ontario*, Canada: Corn Stalk and Cob Fibre Performance in Polypropylene Composites, in Knowledge-Driven Developments in the Bioeconomy. 2017, Springer. p. 233-255.
32. Vicas, S., A. Teusdea, M. Muresan, M. Sabau, E. Marian, T. Jurca, D. Gitea, I. Borza, and L. Vicas, Preliminary study regarding to the total polyphenols and antioxidant capacity of yellow maize corncobs. Analele Universității din Oradea, F*ascicula: Protecția Mediului*, **2014**, *23*, 179-184.
33. Monroy, Y.M., R.A. Rodrigues, A. Sartoratto, and F.A. Cabral, Influence of ethanol, water, and their mixtures as co-solvents of the supercritical carbon dioxide in the extraction of phenolics from purple corn cob (*Zea mays* L.). *The Journal of Supercritical Fluids*, **2016**, *118*, 11-18.
34. Figuerola, F., M.a.L. Hurtado, A.M.a. Estévez, I. Chiffelle, and F. Asenjo, Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment. *Food chemistry*, **2005**, *91*(3), 395-401.
35. Kumar, R., Anti-nutritional factors, the potential risks of toxicity and methods to alleviate them. Legume trees and other fodder trees as protein source for livestock. *FAO Animal Production and Health Paper*, **1992**, *102*, 145-160.
36. Olagunju, A., E. Onyike, A. Muhammad, S. Aliyu, and A. Abdullahi, Effects of fungal (Lachnocladium spp.) pretreatment on nutrient and antinutrient composition of corn cobs. *African Journal of Biochemistry Research*, **2013**, *7*(11), 210-214.
37. Yusuf, K., O. Ajeigbe, A. Oyebo, R. Aderinboye, and C. Onwuka, Nutrients and anti-nutrients content of some crop by-products and residues for ruminant feeding in Nigeria. *Journal of Animal Production Research*, **2017**, *29*(1), 321-334.
38. Yen, G.-C. and H.-Y. Chen, Antioxidant activity of various tea extracts in relation to their antimutagenicity. *Journal of Agricultural and Food Chemistry*, **1995**, *43*(1), 27-32.
39. Tanaka, T., Y. Matsuo, and I. Kouno, Chemistry of secondary polyphenols produced during processing of tea and selected foods. *International journal of molecular sciences*, **2009**, *11*(1), 14-40.
40. Melo-Silveira, R.F., G.P. Fidelis, R.L.S. Viana, V.C. Soeiro, R.A.d. Silva, D. Machado, L.S. Costa, C.V. Ferreira, and H.A. Oliveira Rocha, Antioxidant and antiproliferative activities of methanolic extract from a neglected agricultural product: corn cobs. *Molecules*, **2014**, *19*(4), 5360-5378.

41. Dehghan-Shoar, Z., A.K. Hardacre, and C.S. Brennan, The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. *Food chemistry*, **2010**, *123*(4), 1117-1122.
42. İbanogˇlu, Ş., P. Ainsworth, E.A. Özer, and A. Plunkett, Physical and sensory evaluation of a nutritionally balanced gluten-free extruded snack. *Journal of Food Engineering*, **2006**, *75*(4), 469-472.
43. Ding, Q.-B., P. Ainsworth, A. Plunkett, G. Tucker, and H. Marson, The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. *Journal of Food Engineering*, **2006**, *73*(2), 142-148.
44. Anton, A.A., R.G. Fulcher, and S.D. Arntfield, Physical and nutritional impact of fortification of corn starch-based extruded snacks with common bean (Phaseolus vulgaris L.) flour: Effects of bean addition and extrusion cooking. *Food chemistry*, **2009**, *113*(4), 989-996.
45. Shirani, G. and R. Ganesharanee, Extruded products with Fenugreek (Trigonella foenum-graecium) chickpea and rice: Physical properties, sensory acceptability and glycaemic index. *Journal of Food Engineering*, **2009**, *90*(1), 44-52.
46. El-Din, F.B.M., Ahmed, Z. S., Latief, A. R. A., El-Akel, A. T., & Abou-Raya, S. H., Chemical, Physical, Nutritional and Sensory Properties of High Fiber Healthy Corn Snacks Food, **2009**, *3*(1), 53-57.
47 El-Samahy, S., E.A. El-Hady, R. Habiba, and T. Moussa-Ayoub, Some functional, chemical, and sensory characteristics of cactus pear rice-based extrudates. *JPACD*, **2007**, *9*, 136-147.