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Original Article

Optimization of Physicochemical Characteristics of Corn-Based Extruded Snacks Containing Pomegranate Seed Powders

Kowsar Kakaei[1], Mohammad Noshad[1*], Behzad Nasehi[2], Mohammad Hojjati[1], Shahram Beiraghi-Toosi[3]

1- Department of Food Science and Technology, Faculty of Animal Science and Food Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

2- Department of Agricultural Engineering and Technology, Payame Noor University (PNU), Iran

3- Food Processing Research Department, Food Science and Technology Research Institute, Academic Centre for Education, Culture and Research (ACECR), Mashhad, Iran

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ABSTRACT

Background and Objectives: The extruded snacks with high content of calorie and fat and low content of protein, fiber is considered as a deleterious and harmful foodstuff for most of the consumers. Today, various techniques have been proposed to improve the quality of snacks. The use of fruits processing by-products to extruded snacks is one of the most important technologies that is proposed. In this research, pomegranate seed powder was used to improve quality attributes of extruded snacks.

Materials and Methods: In this research, the effect of pomegranate seed powder (0–20 %), extruder temperature (120-160°C) and screw rotation speed (120–180 rpm) as an independent variable on physical characteristics (sensory evaluation, expansion index, texture propeties,) and functional characteristics (water solubility index, moisture content, total fiber content, oil absorption index, fattyy acids profile) of an expanded corn snack was measured.

Results: Amongst the experimental situations applied in this research, the optimum value of factors is the subsequent addition of fiber complementary 11.6 %, the temperature of the extruder 160 °C, the screw speed of 125 (rpm), the moisture content 3.63%, the fiber content 11.88%, WSI 5.64, hardness of 1.42 (N), expansion ratio of 0.45 and OAI 2.56. The results showed the hardness, total fiber, and overall acceptance of samples were increased by increasing the amount of pomegranate seed powder from 0.63 ± 0.1 to 2.93 ± 0.2 (N), 1.28 ± 0.14 to 27.9 ± 0.84 (%) and 3.9 ± 0.16 to 4.9 ± 0.11, respectively.

Conclusions: According to the results of this study, the incorporation of pomegranate seed powder improves the functional characteristics of extruded snack.

Keywords: Pomegranate seed powder, Extruder, Functional characteristics, Optimization

Introduction

In the past years, snack uses in all age groups, especially children, have increased due to their low costs and easy intakes. Generally, these products have high starch contents but low nutrients such as vitamins, minerals, amino acids (AA) and fibers. In fact, most of the snacks are known as foods with high energy contents and glycemic indices but low nutritional values (1–3). Therefore, improvement of the nutritional value and quality of these products is highly important (4, 5). Addition of fruit processing by-products to extruded snacks improves nutritional values due to the high contents of dietary fibers, bioactive compounds and minerals of these by-products (6–8). Pomegranate (*Punica granatum* L.) is a perennial plant generally cultivated in tropical and subtropical regions. This fruit includes functional compounds such as polyphenols, flavonoids, anthocyanin, ascorbic acid, carotenoids and tannins (9, 10). The pomegranate seed is one of the pomegranate processing by-products including approximately 15–20% of the total fruit (11). Furthermore, the pomegranate waste is a good source

***Address for correspondence:** Mohammad Noshad, Department of Food Science and Technology, Faculty of Animal Science and Food Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran. E-mail address: Noshad@ramin.ac.ir

of nutrients and antioxidants. The positive effects of pomegranate seeds are possible associated to the presence of bioactive compounds, particularly polyphenols, which have been known for their antioxidant effects (12). Pomegranate seeds include 36.5–42.4% of fibers, 13.5–16.9% of lipids, 8.5–11.3% of proteins and 24.09–33.41% of carbohydrates (9, 13). Therefore, pomegranate by-products are rich in bioactive compounds and dietary fibers and can be used as a functional ingredient. Since no studies have been carry out on using pomegranate seed powders in snacks, the current study was carried out to Optimization of physicochemical characteristics of corn-based extruded snacks containing pomegranate seed powders.

Materials and Methods

Raw materials: Pomegranate fruits were purchased from markets in Khuzestan Province, Southern Iran. After peeling the pomegranates, arils were pressed. The remaining pomaces were dried at 50 °C for 48 h. Dried pomaces were powdered using mixer grinder. The corn grits (Golden Corn, Iran) were prepared. The moisture and chemical component of the raw materials were assessed.

Extrusion process conditions: A twin-screw extruder (model DS56; Jinan Saixin, China) was used to formulate snacks. In this study, effects of adding pomegranate seed powder (0–20%), extruder temperature (120–160 °C) and screw rotation speed (120–180 rpm) on the samples were investigated. Therefore, the moisture content of the input feed was adjusted to 15% and the feeding speed to 40 (kg/h). Ready extruded samples were gathered instantly and transferred to a tunnel dryer with a temperature of 140°C and then packed in thick polyethylene plastic pouch and stored at 4 °C until further analysis.

Moisture and total fiber contents: Moisture content of the extruded samples was assessed using verified AACC methods (44–16). The total dietary fiber (TDF) was assessed using AOAC methods (991.43).

Water solubility index (WSI): First, 2.5 g of the powdered sample were blended with 25 ml of distilled water (D.W.) at 800 rpm for 30 min at room temperature and then at 3000 g for 15 min. Supernatant of the solution was dried at 105°C until reached a stable weight. The following equation was used to calculate water solubility index (2):

$$\text{Water solubility index} = \frac{\text{Weight of the dried supernatant liquid}}{\text{weight of the primary dried sample in 100 (g)}}$$

Oil absorption index (OAI): Briefly, 0.5 g of the powdered sample was mixed with 6 ml of sunflower oil in a centrifuge tube (model Z206A, Germany) for 60 s. After 30 minutes, tube was centrifuged at 3000 g for 25 min and the separated oil was egressed (14).

Textural attributes of the extruded samples: Penetration test using 6-mm probe, 1 mm s^{-1} test speed and 5 g trigger force was used to investigate hardness of the extruded samples by a texture analyzer (TA-XT-PLUS, Micro stable system, UK) (15, 16).

Expansion index: Randomly from each treatment, ten extruded products were chosen and three points of them were assessed using calipers and the mean values were recorded (17).

Sensory evaluation: Snakes were evaluated for their organoleptic characteristics (color, flavor, taste, texture and overall acceptability) using a 5-point hedonic test by trained panelists (12 women and four men). The panelists were asked to appraised the samples and score them from 1 (most disliked) to 5 (most liked).

Fatty acid profile: Gas chromatography (GC; Agilent 6890, USA) was used to assess fatty acid profiles. After a constant oven temperature of 198 °C for 6 min, the temperature increased to 210 °C at a slope of 20 °C/min using nitrogen as carrier gas. Temperatures of the injector and detector were set at 250 and 280 °C, respectively.

Experimental design: Response Surface Methodology (RSM) was used to discover the best formulation of extruded snacks based on corn and pomegranate seed powder using Design Expert software v.10 (Stat-Ease, USA).

Results

Moisture content: In general, cereal based products such as bread, cakes and cookies include high moisture contents. In contrast, bulk snacks include lower moisture contents making them further durable. Based on Table 1, linear and quadratic effects of the pomegranate seed powder addition to the formula were significant on moisture contents (*P*<0.001).

Water solubility index (WSI): The WSI indicates the rate of starch granule breakdown and dextrin production during the extrusion process (18). Based on Table 1, linear and quadratic effects of pomegranate seed powder addition to the formula and nonlinear and quadratic effects of screw speed and extruder temperature raise were significant on WSI (*P*<0.001).

Oil absorption index (OAI): The OAI of foods depends on protein configuration, hydrophilicity-hydrophobicity of the proteins and presence of hydrophilic carbohydrates (19). Based on Table 1, linear and quadratic effects of screw speed and nonlinear and quadratic effects of pomegranate seed powder addition to the formula and extruder temperature increase were significant on OAI (*P*<0.05). By increasing the screw speed from 135 to 150 rpm and the proportion of pomegranate seed powder from 5 to 15%, OAI increased significantly (Fig. 1).

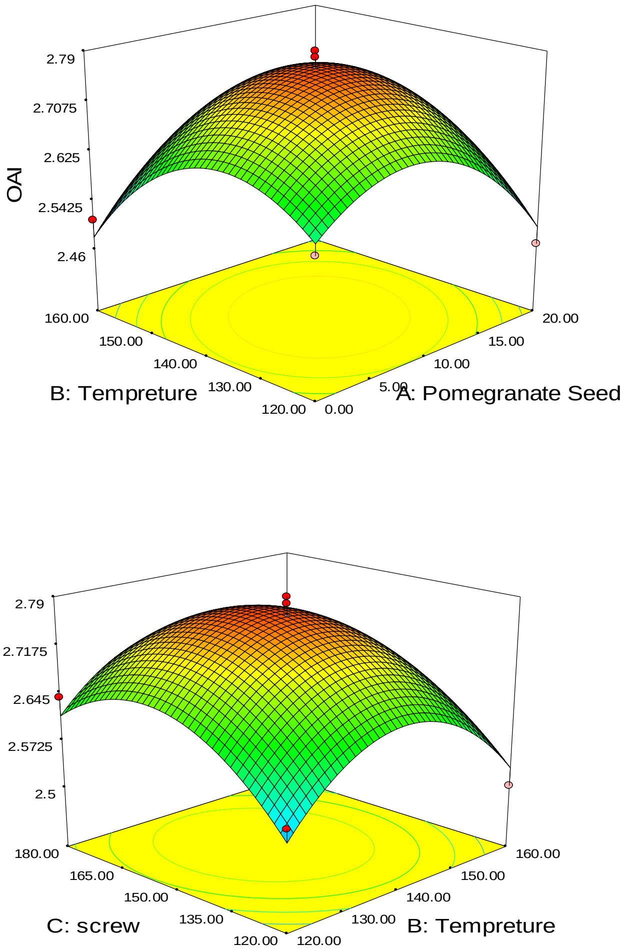

Figure 1. Effects of pomegranate seed powder, screw speed and extruder temperature on OAI

Expansion ratio (RE): The RE (cross-sectional size) is one of the major factors in extruded products, indicating snack size of the cross-sectional area and its expansion rate when extruded. Based on Table 1, quadratic effects of pomegranate seed powder and interaction between the pomegranate seed powder and temperature included statistically significant effects on RE (*P*<0.05).

Texture: Hardness is described as the maximum force needed to crush or break the product using texture analyzers (15). Based on Table 1, linear quadratic effects of pomegranate seed powder addition to the formula was significant on hardness (*P*<0.01). As shown in Fig. 2, it can be concluded that increased proportion of pomegranate seed powder increased hardness of the samples.

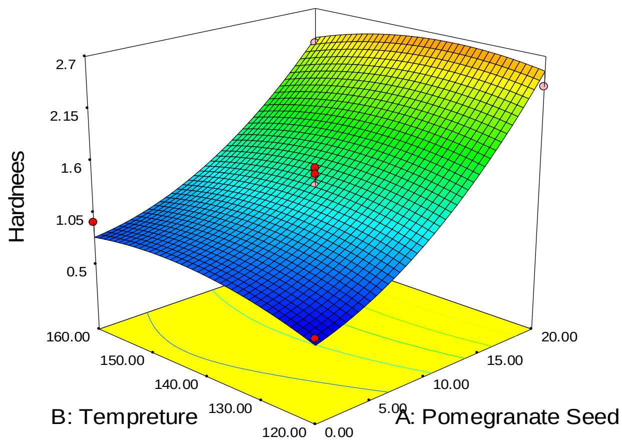

Figure 2. Effects of pomegranate seed powder and extruder temperature on hardness

Crude fiber (CF): Addition of dietary fibers to bulk snacks considerably affects quality of the products, depending on the type and quantity of fibers as well as the molecular weight (MW) of polymers, fiber structures and their ability to absorb water during mixing and shear stress during extruding (5). Based on Table 1, linear and quadratic effects of pomegranate seed powder addition to the formula were significant on CF (*P*<0.0001).

Overall acceptance: Based on Table 1, linear quadratic effects of pomegranate seed powder addition to the formula were significant on overall acceptance (*P*<0.01).

Table 1. Effects of pomegranate seed powder, extruder temperature and screw speed on physicochemical characteristics

Parameter	WSI (%)	OAI (%)	Overall acceptability	ER	Fiber (%)	Moisture content	Hardness (N)
Model (*P*-value)	0.0001***	0.0002***	0.004***	0.001**	0.001**	0.001**	0.002**
A-pomegranate	0.0001***	0.071^{ns}	0.001***	0.0001***	0.001**	0.001**	0.001**
B-temperature	0.248^{ns}	0.25^{ns}	0.12^{ns}	0.47^{ns}	0.38^{ns}	0.897^{ns}	0.849^{ns}
C-screw	0.08^{ns}	0.036*	0.14^{ns}	0.722^{ns}	0.45^{ns}	0.845^{ns}	0.595^{ns}
AB	0.45^{ns}	0.02*	0.037*	0.641^{ns}	0.142^{ns}	0.588^{ns}	0.275^{ns}
AC	0.051^{ns}	0.294^{ns}	0.054^{ns}	0.061^{ns}	0.31^{ns}	0.461^{ns}	0.13^{ns}
BC	0.027*	0.487^{ns}	0.97^{ns}	0.488^{ns}	0.396^{ns}	0.267ns	0.886^{ns}
A^2	0.0001***	0.0001***	0.0096**	0.0023**	0.001**	0.001**	0.0078**
B^2	0.0001***	0.0001***	0.25^{ns}	0.26^{ns}	0.58^{ns}	0.451ns	0.092^{ns}
C^2	0.0001***	0.0004***	0.069^{ns}	0.352^{ns}	0.396^{ns}	0.695	0.766^{ns}
Lack of fit	0.095ns	0.076^{ns}	0.35^{ns}	0.216^{ns}	0.259^{ns}	0.264	0.255^{ns}
R^2	0.983	0.966	0.959	0.975	0.998	0.998	0.97
Adj-R^2	0.962	0.924	0.907	0.944	0.995	0.996	0.932
CV(%)	1.33	1.15	2.38	3.31	6.24	3.08	11.85

*Significant at $P<0.05$; **significant at $P < 0.01$; ***significant at $P<0.001$; NS, non-significant

Optimization: The aim of this study was to optimize the extruded samples fortified with pomegranate seed powder to achieve the maximum physicochemical characteristics. Based on the results of optimization, snacks produced under the following conditions included were the best formulation. These conditions included fiber supplementary incorporation of 11.6%, extruder temperature of 160 °C, screw speed of 125 rpm, moisture content of 3.63%, fiber content of 11.88%, WSI of 5.64, hardness of 1.42 N, expansion ratio of 0.45 and OAI of 2.56.

Fatty acid profile: Results from the assessment of major fatty acids in control and optimized snacks are shown in Table 2. The fatty acid profiles in control and optimized samples were not different; both including high nutritional-value fatty acids such as oleic acid and linoleic acid.

Table 2. Major fatty acid contents of the treatments

	Fatty acids (%)					
	C16	C18	C18:1	C18:2	C18:3	C20
Pomegranate seed powder	16.05	10.9	33.17	31.5	4.04	2.5
Control	13.28	3.41	33.66	46.26	2.29	0.63
Optimized	13.66	4.4	34	44.65	2.2	0.97

Discussion

Moisture content: By increasing proportion of the pomegranate seed powder, the product moisture contents decreased; possibly due to high insoluble fiber contents of the pomegranate seed powder such as apple residues. Therefore, free water of the product and the matrix were trapped. As a result, available water for the expansion of gases (water vapor) and moisture contents of the product decreased (20, 21).

Water solubility index (WSI): Increasing process variables (pomegranate seed powder, cooking temperature and screw speed) increased the sample WSI. This possibly occurred due to changes in molecular structure of the fibers and starches during the extrusion process as a result of increased temperature, force and shear pressure which led to production of compounds with lower molecular weights in samples (22, 23).

Oil absorption index (OAI): By increasing screw speed, OAI of the samples increased; possibly due to the starch dextrinization by increased shear stress and consequently smaller molecule formation; hence, presence of these molecules increased the OAI. Furthermore, increased temperature increased the OAI of the samples, which possibly occurred due to the protein denaturation and presence of more hydrophobic groups on the protein surface. Increased proportion of the pomegranate seed powder increased the OAI of the samples, which was possibly seen due to the presence of non-polar AA in the pomegranate seed powder. The presence of greater quantities of non-polar AA and side chains in extruded products may absorb the oil hydrocarbon chains, resulting in increased OAI (4, 14).

Expansion ratio (RE): By increasing the proportion of pomegranate seed powder, the RE decreased, which was possibly observed due to proteins in pomegranate seeds. Based on the research (24), addition of proteins to feeds decreases the expansion ability of starch polymers in extruder molds; thereby, decreasing the expansion ratio of products.

Furthermore, presence of fibers forces cell walls to break down and prevents the expansion of air bubbles to their maximum sizes. Similar results have been reported on corn based snacks incorporated with bean flours (25).

Texture: Considering the current results, it can be concluded that increased proportion of pomegranate seed powder increased hardness of the samples. This might be seen due to the high quantities of oils and proteins in the pomegranate seed powder. Researchers have reported that use of food ingredients with high fat, protein and fiber contents increases tissue hardness of the products (17, 26).

Crude fiber (CF): By increasing the proportion of pomegranate seed powder, CF of the samples increased; possibly due to the high CF of the pomegranate seed powder.

Overall acceptance: The highest overall acceptance was seen for treatments with the highest quantities of pomegranate seed powders. This was perhaps seen because of the flavor resulting from the addition of pomegranate seed powder. Furthermore, increased temperature increased the overall acceptance of samples; possibly due to the increased Maillard reaction as a result of increased temperature. Relatively, resulted components from the Maillard reaction improved aroma, taste and color of the samples (1).

Conclusion

After a perfect assessment of all the characteristics for physicochemical and functional attributes, incorporating pomegranate seed powder was shown to include a poweful effect on quality of the extruded snacks. Based on the optimization results, the optimum values of the factors includes addition of a fiber supplementary of 11.6%, extruder temperature of 160 $^{\circ}$C, screw speed of 125 rpm, moisture content of 3.63%, fiber content of 11.88%, WSI of 5.64, hardness of 1.42 N, expansion ratio of 0.45 and OAI of 2.56. Based on the results from the present study, incorporation of pomegranate seed powder improves the functional characteristics of the extruded snacks.

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Financial disclosure

The authors declare no conflict of interest.

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