Asian Journal of Biological and Life Sciences Original Research

Physical and functional evaluation of puffedsnack prepared from whole oleaster powder and navy bean powder

Samane Gazerani[1], Sayed Ali Mortazavi[2], Elnaz Milani*[3], AmirHosein Elhami Rad[1], Arash Koochaki[2]

1 Department of Food Science and Technology, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran.
2 Department of Food Science and Technology Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran.
3 Department of Food Processing, Academic Center for Education Culture and Research (ACECR), Mashhad, Iran.

E-mail : samane.azerani@gmail.com Contact No. : +989151244883, +989153105362

Submitted : 15.08.2017 Accepted : 21.11.2017 Published : 30.12.2017

Abstract

Expanded snack was prepared from whole oleaster powder (WOP) and navy bean powder (NBP). Design expert was used to investigate the effects of extrusion conditions including feed moisture content (15- 25%), screw rate (150- 250 rpm), and different levels of WOP: NBP (20:50, 50:50, and 65:35 %)on water activity (aw), water absorption index (WAI), water solubility index (WSI), oil absorption index (OAI) of expanded product. Results showed that increasing oleaster content caused an increase in the WAI, WSI, awand soluble dietary fiber and a decrease in insoluble dietary fiber andOAIof the snacks. Optimum condition was found to be the blends of WOP/ NBP (20:80), screw rate of 200 rpm, and feed moisture content of 20% with 85.1% desirability. The extrusion process led to flours with high water and oil absorption, low water solubility and with potential for application in bakery, gluten free products.

Key words : Extrusion, oleaster, navy bean, physical properties.

INTRODUCTION

Oleaster (*Elaeagnus angustifolia*L.) belongs to *Elaeagnus*L. genus and *Elaeagnaceae*family. This species shows a broad geographical range, existing widely in Asia and Europe, particularly in Turkey, Caucasia and Central Asia. It is widely cultivated for its edible fruits in Middle and East Anatolia[1].

Oleaster powder may be obtained from dried fruits and its powder may be used as a functional ingredient in the production of bakery products, yoghurt, ice cream, infant food, chocolate, confectionery etc. thanks to its floury structure, specific taste and functional properties like dietary fiber, mineral content and phenolic compounds[2].Whole Oleaster powder as a functional ingredient gives interesting health benefits with very low allergenic property and a good fiber source which is divided into two fractions, soluble and insoluble in water [3].

Pulses are the edible seeds of plants belonging to the *Leguminosae* family which has 16,00019,000 species in approximately 750 genera[4]. Navy beans have low sodium content and saturated fatty acids but are rich in unsaturated fatty acids (linoleic acid). They are also a good source of soluble and insoluble dietary fiber and display health benefits which include reduced risk of heart disease and colon cancer[5].Among the various technologies, short time high- temperature extrusion cooking is a well-known cost - effective industrial process. Extrusion combines high pressure with a moderately high temperature and usually high shear for a short period of time. Extrusion processing completely gelatinizes the starch and partially or completely destroys antinutritional factors present in many legumes [5]. Extrusioncooking technology is a versatile and efficient method of converting raw materials into finished food products. It can replace many conventional processes in food and feed industries. It has been used to develop various types of snack foods, mainly from corn meal, rice, wheat flour, or potato flour in many shapes and variety of textures. Several reports show that bean starches have very good expansive and functional properties under extrusion conditions[6].

Extrusion is a high temperature/short time technology (HTST) that offers numerous advantages including versatility, high productivity, low operating costs, energy efficiency, high quality of resulting products, and an improvement in digestibility and biological value of proteins[7]. Advantages of extrusion are adaptability, product shapes, high product quality, energy competence, production of new foods, and no effluent or waste material[8]. Extrusion gives the snack-food producer a flexibility and variety of processing technologies[9].

Therefore, the goal of our research was to examine puffed snack from extruded oleaster fruit and Navy bean to investigate its functional and physical properties (a_w, water absorption index (WAI), water solubility index (WSI) and oil absorption index (OAI))and choosing optimized product supplemented with various levels and compositions of whole oleaster powder and Navy bean powder.

MATERIALS AND METHODS

Sample Preparation

Oleaster (*Elaeagnus angustifolia* L.) and whole navy bean were provided from local market in Sabzevar. Whole oleaster powder(WOP) and navy bean powder (NBP) were ground by hammer miller (Polymix, model PX-MFC 90 D, Switzerland) into a fine particle size powder to pass through a 50-mesh screen, separately.

The composite powder of extruded snacks was prepared as incorporating WOP at different levels to NBP (20:80, 50:50and 65:35).

The individual moisture contents of the WOP and NBP were determined and the total moisture of the blends was adjusted to the desired level of water as described by Zasypkin and Tung-Ching (1998):

$$cWOP=((rWOP\times M\times (100\text{-}w)))/(100\times (100\text{-}wWOP))$$

$$cNBP=((rWBP\times M\times (100\text{-}w)))/(100\times (100\text{-}wNBP))$$

Table 1: The proximate compositions of WOP and NBP

	Fiber	Ash	Fat	Humidity	Carbohydrates	Sugar	Protein
WOP (%)	21.3	18.4	1.8	17.8	62.5	46.5	5.6
NBP (%)	24.2	1.2	1.3	7.2	60.7	4.2	22.3

wX=M- cWOP- cNBP

Where cWOP and cNBP are the mass of WOP(g) and of NBP (g) respectively, rWOP and rWBP are percentages of WOP and NBP respectively, M is the total mass of the blend (g), M, the total mass of the blend(g), w is the moisture content of final blend(%),w is the moisture content of final blend(%); Wx is the weight of water added (g) and wWOP and wNBP are the moisture contents of WOP and NBP, respectively. The samples were packed in polyethylene bags which were kept at room temperature to equilibrate overnight before extrusion.

Chemical composition

Ash, protein, fiber and fat analysis of raw materials were measured according to standard procedures of AOAC(11). All analyses are expressed as the mean (±SD) of triplicate analysis. Moisture content of prepared blends was determined by infrared moisture analyzer (Sartorius, Germany) at 105°C. The compositions of Whole Oleaster Powder(WOP) and Navy BeanPowder (NBP) are shown in Table 1.

Extrusion processing

The extrusion experiments were carried out on a pilot-scale, co-rotating, twin-screw food extruder typed DS56 (Jinan Saxin., China) with the following parameters: length 80 cm, diameter 16 mm, the maximum rotation speed 320 rpm, and die diameter (D) 3 mm. Steady-state conditions were reached after 20 min. Based on preliminary experiments, barrel temperature zones profile and feed rate was kept constant at 140°C and 40kg/h respectively, the following conditions were set according to Table 2. After extrusion, extruded products were dried in oven model FD 115 (Binder, Germany) with forced convection at105°C for 30 min, then cooled immediately and placed in appropriate laminated bags in room temperature for further analysis[12].

Determination of product properties

Water activity

Water activity was measured using an AquaLab 4TE series apparatus by Decagon Devices Inc. (Pullman, USA).

Water absorption (WAI) and solubility indices (WSI)

The water absorption index (WAI) was measured according to the method of Anderson, Conway, and Peplinski (1970): 5 mL of distilled water was added to 0.2 g of sample in a weighed 15 mL glass centrifuge tube. The tube was agitated on a Vortex mixer for 2 min and then centrifuged for 20 min at 700g. The supernatant liquid was poured into an evaporating dish as a percentage of the original weight of sample; The WSI was the weight of dry solids in the supernant expressed as a percentage of the original weight of sample. The water solubility index (WSI) was determined from the amount of dry solids recovered by evaporating the supernatant from the water absorption test as:

WSI= (Weight of dissolved solids in supernatant)/ (weigh of sample)

The WAI was the weight of gel obtained after removal of the supernant per unit weight of original dry solids. The remaining gel was weighed and the WAI was calculated as:

WAI= (Weight of hydrate gel)/ (weight of sample)

Oil absorption index (OAI)

Oil absorption index (OAI) as well as water solubility index (WSI) was determined according to methodology described by Slamoni*et al* (2004), with modifications for OAIin which distilled water was replaced by oil.

$$OAI\ (\%) = (W_1\ \ W_2) / W_3 \times 100$$

Where W_1 is the weight of wet precipitate, W_2 is the weight of dried precipitate; W_3 is the weight of sample.

Dietary fiber determination

Total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were determined according to the enzymatic-gravimetric (Phosphate buffer) AOAC methods. Briefly, sample (1 g of each duplicate powdered sample) was homogenized in phosphate buffer (pH 6.0) and incubated at 100°C with a heat-stable α-amylase under constant agitation and then at 60°C treated with a protease and amyloglucosidase to remove protein and starch, respectively. To determine the TDF content, the enzyme-digested samples were treated with 95% (v/v) ethanol (ethanol/sample ratio, 4:1, v/v) at room temperature for 1 h to precipitate soluble fiber. The residues were filtered on fritted crucible and washed sequentially with 78% (v/v) ethanol, 95% (v/v) ethanol and absolute acetone and dried overnight at 105°C. To determine IDF and SDF content, the enzyme-digested sample was filtered and the insoluble material washed twice with preheated water at 60°C and then treated as above to give IDF. 4 volume of 95% (v/v) ethanol were then added to the filtrate and placed at room temperature for 1 h. After filtration, the recovered precipitate, SDF, was dried at 105°C. TDF, IDF and SDF were corrected for residual protein (Kjeldhal method) and ash (525°C, 5 h) [11].

Experimental design and statistical analysis

TheResponse Surface Methodology (RSM) was chosen to investigate the relationships between the process conditions (screw rate, feed moisture content) and formulation (ratio of WOP: NBP). A D-optimal design was chosen of experiment with two independent process variables including screw rate (150-250 rpm), feed moisture content (15-25%), and ratio of WOP and NBP(20:80, 35:65 and 50:50), design experiments were selected based on preliminary tests. Table 2 illustrated coded levels and actual values of the independent variables. Totally 20 different combination were used to investigate the effect of component and process condition variables on the response variables (Table 2). The data obtained from the experiment was processed in trial Design Expert version 7.0.1. The best model that fitted the response was selected during analysis of measurements. Analysis

Table 2: The results of regression analysis in terms of coded variables

Std	Run	Block	Oleaster (%)	Screw rate (rpm)	Feed Moisture (%)
6	1	Block 1	50	150	25
15	2	Block 1	35	200	20
1	3	Block 1	20	150	15
13	4	Block 1	35	200	15
17	5	Block 1	35	200	20
3	6	Block 1	20	250	15
7	7	Block 1	20	250	25
14	8	Block 1	35	200	25
12	9	Block 1	35	250	20
20	10	Block 1	35	200	20
8	11	Block 1	50	250	25
2	12	Block 1	50	150	15
11	13	Block 1	35	150	20
10	14	Block 1	50	200	20
5	15	Block 1	20	150	25
16	16	Block 1	35	200	20
18	17	Block 1	35	200	20
9	18	Block 1	20	200	20
19	19	Block 1	35	200	20
4	20	Block 1	50	250	15

of variance (ANOVA) was carried out on each response model to identify the coefficient (R_2), lack of fit, and significant difference ($p<0.05$).Second-order models were established for the dependent variables to fit experimental data for each response.

Where Yi is the predicted response, xi (i = 1, 2, 3) is independent variables (screw rate, feed moisture and ratio of WOP and NBP), respectively, b0, bi, bii and bij are coefficient for the intercept, linear, quadratic and interactive effects, respectively and ε is the error term of the model. Canonical analysis of the predicted model was performed to locate extrusion conditions where the extruded snack would have a maximum WAI, aw, OAI, and minimum WSI.

RESULTS

Effects of extrusion conditions on the structural and functional properties of extrudates were investigated; the results of regression analysis in terms of coded variables are shown in Table 2. The regression models for product responses had high coefficient of determination ($R^2 > 0.9$) and none showed significant lack of fit ($P>0.05$), indicating that all the second-order polynomial models correlated well with the measured data. These can be used to estimate the relationship between the operating conditions and product properties and can then be applied to optimize the preparation process of flat Bread enhanced with WOP[15, 16, 17]

Effect of extrusion parameters on a_w

Elimination of the water phase from the product during extrusion did provide the product with different mechanical and biochemical characteristics, but also with marked changes in stability [18, 19, 20].Based on the conducted analyses it was stated that water activity (aw) of extrudates increased with an addition of WOP ranged from 20 to 50. It was shown that with an increase in the feed moisture in the extruded mixture, irrespective of the proportions of oleaster and navy bean powder preparation, the value of aw in the extrudates was more than 0.25 (Fig. 1).The wetting rate (20 and 50%) of a mixture of WOP and NBP preparation does have a statistically significant effect on a_w in extrudates. The low and constant water activity of extruded products contributes to a limitation in the rate of chemical changes, mainly fat oxidation and non-enzymatic browning [20]. It is assumed that the optimal range of water activity for products based on oleaster powder contant is 0.25-0.53. This range results from the state of carbohydrate contained in the oleaster powder.Analysis of variance (ANOVA) was demonstrated in Table 3. The value of R_2 and adj-R_2 were 0.97 and 0.94, respectively, which showed higher coefficient of determination

Table 3: Analysis of variance of aw, WAI, WSI, and OAI of extruded snack.

Parameter	Term	aw	WAI	WSI	OAI
x_1	Oleaster	0.0251	0.0001***	0.0001***	0.0466
x_2	Screw Rate	0.0001	0.0035	0.0836	0.0001***
x_3	Feed Moisture	0. 361	0.1577	0.0028	0.0419
$x_1 x_2$	Oleaster×Screw Rate	0. 582	0.0347	0.1657	0.0001***
$x_1 x_3$	Oleaster×Feed Moisture	0. 132	0.05933	0.4568	0.0029
$x_2 x_3$	Screw Rate×Feed Moisture	0.113	0.9796	0.4056	0.1149
model					
F Value		0.0001***	0.0001***	0.0001***	0.0001***
R^2		0.97	0.97	0.95	0.96
Adjust R^2		0.94	0.95	0.91	0.93
Lack of fit		0.1177	0.347	0.4475	0.1265

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

(Table 3). The F-value for WAI was significant (P<0.001), whereas lack-of-fit was not significant (P > 0.05). It was shown that the metastable amorphous sugar (fructose) crystallizes as a consequence of the action of the driving force, resulting from an increase in particle mobility in the visco-elastic state[21]. This phenomenon causes the release of water, dissolving newly formed crystals and leading to powder caking. This process is intensified at an elevated relative humidity during further storage [20].Thus, not only technological procedures, but also further storage conditions and oleaster content may significantly alter quality attributes of the extruded product [22].

Effect of extrusion parameters on WAI and WSI

WAI is an index of starch gelatinization that depends on the availability of hydrophilic groups of the biopolymers [23, 24]. It was the volume occupied by the starch granule after swelling in excess of water [23]. The WAI determines the absorption and retention of water and its effect on various processing conditions [6, 25]. It measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion [26, 27, 28, 29].The effect of extrusion parameters on the WAI and WSI of the extrudates are presented in 3-D surface plot(Fig.2 and 3). Statistical analysis showed that the WAI of extrudates was affected by oleaster content (P<0.001) and screw rate speed (P<0.05) (table 3).The value of R_2 and adj-R_2 were 0.97 and 0.95, respectively, which showed higher coefficient of determination (Table 3). The F-value for WAI was significant (P < 0.001), whereas lack-of-fit was not significant (P > 0.05). As a result, response surface graphs (Fig. 2) showed that WAI increased rapidly with increasing oleaster and screw rate.

WSI is often used as an indicator of degradation of molecular components and measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharide released from starch component after extrusion[30]. During the extrusion of the oleaster/navy bean powder, water is absorbed and bound to the starch molecule with a resulting change in the starch granule structure. Decrease in WAI could probably be due to dextrinization which also could have led to increase in WSI[12, 31, 32]. In this research it was observed that WOP and feed moisture content had a strong effect on WSI. Anincrease in WOP

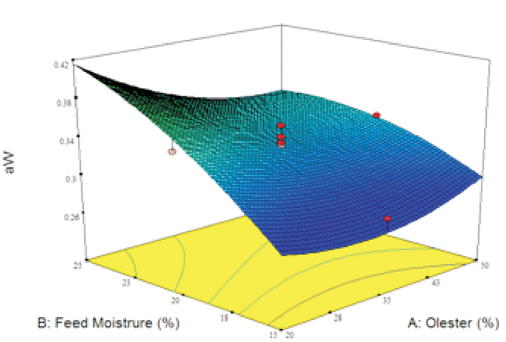

Fig 1 : Effect of feed moisture and oleaster on a_w

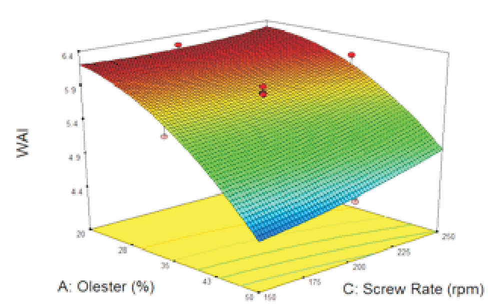

Fig 2 : Effect of screw rate and oleaster on WAI

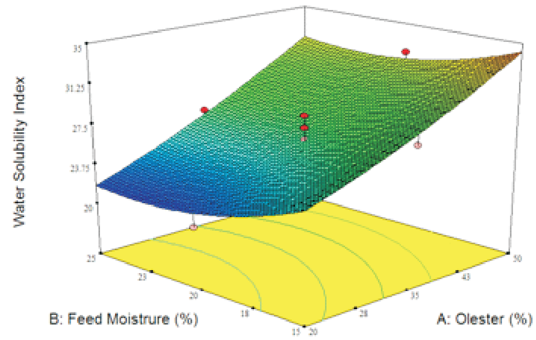

Fig 3 : Effect of feed moisture and oleaster on WSI

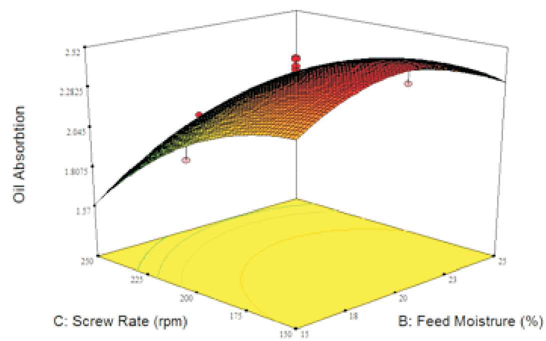

Fig 4a : Effect of screw rate and feed moisture on OAI

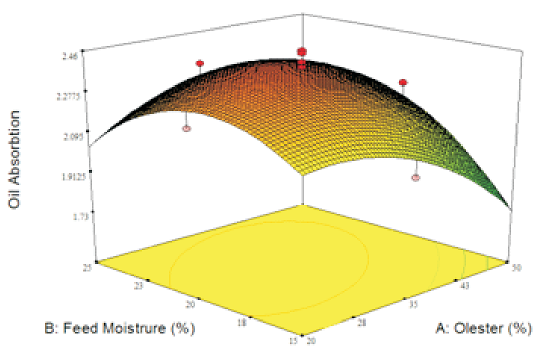

Fig 4b : Effect of feed moisture and oleaster on OAI

content resulted in an extrudate with higher water solubility as shown in Fig.3, due to its higher carbohydrate and fiber. The WSI varied from 20/7 to 36/36 within the combinationof variables studied. Analysis of variance showed WSI was dependent significantly on linear quadratic terms of WOP (X_1) at P<0.001, and feed moisture (X_3) at P<0.05. The value of R_2 and adj-R_2 were 0.95 and 0.91, respectively, which showed higher coefficient of determination (Table 3).Extrusion has also been shown to decrease protein-protein cross-linking such as the inhibitory effects of trypsin and chymotrypsin resulting in an increase in protein digestibility by increasing protein denaturation [33, 34, 35, 36, 37].

Effect of extrusion parameters on OAI

The OAI is associated with the hydrophobic groups of extruded products and with the ability to maintain a certain amount of oil in its structure. In the extrusion process, starch granules undergo gelatinization and the hydrophilic/ hydrophobic balance is changed, thus changing the oil absorption [13].The model equation predicting OAI is given in Table 3. Analysis of variance showed OAI was dependent significantly on linear quadratic terms of WOP (X_1) at P<0.05, and screw speed (X_2) at P<0.001. The interaction term (X_1X_2) between WOP and screw speed were significant (P<0.001). The value of R_2 and adj-R_2 were 0.96 and 0.93, respectively, which showed higher coefficient of determination (Table 3).

Increasing in oleaster content had significant effect (P≤0.05) on the OAI of powders; with increasing in the amount of it OAI was decreased (Fif 4a,4b). On other hand, when the amount of moisture was increased the OAI was increased too, but after 25% of moisture it decreased again. The best amount of OAI was shown in 25% of moisture. The extrusion process had little effect on the oil absorption of oleaster/navy beenpowder, as the Fig.4 shown. Bryant et al. (2001) studied the functional and digestive characteristics of extruded rice flour and found OAI values ranging from 0.8 to 1.2 gprecipitate gdry matter-1 for ERF, which are lower than those found in this study. A higher content of gelatinized starch in the extruded flour would possibly increase the OAI value [38, 39, 40].

Optimization

Numerical optimization was used to determine the optimum combination of WOP, NBP. The goal was to obtain maximum aw,

Table 4: Constraints, criteria for optimization, solution along with predicted and actual response values

Name	Goal	Lower limit	Upper limit	Predicted values	Actual response values*
Whole oleaster powder (g/100 g blend)	Is in range	20	50	20	--
Neavy bean powder (g/100 g blend)	Is in range	80	50	80	--
Feed moisture (%)	Is in range	15	25	20	--
Screw rate (rpm)	Is in range	150	250	200	--
a_w	maximize	0.34	0.58	0.51	0.5 ± 0.01
WAI	maximize	1.01	2.56	2.1	2.1 ± 0.36
OAI	maximize	4.37	6.15	5.2	5.2 ± 0.03
WSI	minimize	20.7	36.36	21.6	25.18 ± 0.18

Table 5: The proximate compositions of raw WOP/NBP flour and extruded WOP/NBP flour

	Optimized raw WOP/NBP flour(%)	Optimized extruded WOP/NBP flour(%)
TDF	20.62	20.81
IDF	13.31	11.2
SDF	7.32	9.61
Ash	4.38	4.61
Fat	1.58	1.39
Humidity	16.38	5.2
Carbohydrates	61.82	68.7
Sugar	25.36	28.61
Protein	18.95	20.32

WAI, minimum WSI, maximum OIA. Among the solutions obtained, the solution with the maximum desirability was selected.

The predicted responses are presented in Table 3. The optimized values (per 100 g blend) were 20.0 g:80 g WOP and NBP, respectively, 20% feed moisture and 200 rpm screw rate with 85.1% desirability. The obtained formulation was used to develop the extrudates and the actual response values (obtained as an average of three replications) are given in Table 4. The main criteria for constraint optimization were desirable dominant characteristics of WOP/NBP flour good physical properties such as high WAI, OAI, and low WSIwith better functional properties such as higher dietary fiber. WAI and OAI are important parameters for defining the application of extrudate as ingredients and in predicting how the material might behave if further processed especially in bakery product [15]. The developed extrudates had 61.82± 0.05% carbohydrates, 28.61 ± 0.03% sugar, 20.32± 0.1% protein, 1.39± 0.6% fat, 5.2 ± 0.4% humidity and 4.61± 0.05% total ash contentper 100 g (db). The extrudates also had 20.81±0.05%total fiber (TDF), 9.61± 0.03%soluble dietary fiber (SDF) and11.2± 0.01%insoluble dietary fiber per 100 g (db) which are 20.62 ± 0.05%, 7.32 ± 0.02% and 13.31 ± 0.3% respectively in raw material without any process (Table 5).

Discussion

The results obtained in this study indicated that it is possible to enrich extruded snacks with WOP which is source of fiber and protein. The functional and physical properties of extrudates produced from WOP/ NBP using a twin-screw extruder were influenced by the raw material, screw rate, and feed moisture content. The good characteristics of extruded snack (high WAI, high aw, low WSI and highOAI) were produced at loweroleaster content, and high feed moisture content. It was observed that feed moisture content was the most important parameter with significant effect on the responses studied such as WAI, WSI andOAI[41, 42, 43, 44]. The highest preference levels for characteristics of physical and functional is obtained with inclusion of 20% WOP in our extrudate formulation (screw rate of 200 rpm and feed moisture content of 20%).Thissample shows satisfied color too. The earlier report found that the properties of dietary fiber are affected by food processing. Some of previous research found a decrease in the content of insoluble dietary fiber during extrusion cooking and an increase in the content of soluble fiber which resulted from shear stress caused by the high screw speed[3, 45, 46]. The effect of oleaster contact, feed moisture ranges and process in this research were significant on dietary fiber. The observation was significant on soluble dietary fiber content as shown in table 4 that extrude process resulted in lower insoluble and total dietary fiber and higher soluble dietary fiber of extrudates.

CONCLUSION

The findings of our research demonstrate the feasibility of developing value added products from WOP and NBP by extrusion processing, but further studies are necessary to assess the sensory attributes of the property of product. The best sample was made from WOP/NBP (20%/80%), 20% humidity and 200 rpm screw rate, and have more soluble fiber, and high WAI, OAI, aw, and low WSI. Additionally these products can be suitable for diabetic and celiac diseases. Although this finding can lead to investigate acceptable flour to prepare gluten free bread, bakery product, or other functional food.

REFERENCES

1. Akbola D, Ertekin C, Menges H O, Guzel E Ekinci K. Physical and Nutritional Properties of Oleaster (*Elaeagnus angustifolia*L.) Growing in Turkey. Asian Journal of Chemistry.2008;20(3): 2358-2366.

2. Sahan Y, Gocmen D, Cansev A, Celik G, Aydin E, Dundar A N, Dulger D, Kaplan H A, Kilci A, Gucer S. Chemical and techno-functional properties of flours from peeled and unpeeled oleaster (*Elaeagnus angustifolia*L.). Journal of Applied Botany and Food Quality. 2015; 88: 34 - 41.

3. Repo-Carrasco-Valencia R, Pena J, Kallio H, Salminen S. Dietary fiber and other functional components in two varieties of crude and extruded kiwicha (*Amaranthus caudatus*). Journal of Cereal Science. 2009;49: 21922.

4. Hoover R, Hughes T, Chung H, Liu Q. Composition, molecular structure, properties, and modification of pulse starches: A review. Food Research International. 2010;43: 399413.

5. Rocha-Guzman N E, Gallegos-Infante J A, Gonzalez-Laredo R F, Cardoza-Cervantes V, ReynosoCamacho R, Ramos-Gomez M, Garcia-Gasca T, De Anda Salazar A.Evaluation of culinary quality and antioxidant capacity for Mexican common beans (*Phaseolus vulgaris*L.) canned in pilot plant. International Food Research Journal. 2013; 20(3): 1087-1093.

6. Seddiq M, Harte J, Dolan K D, Kelkar S, Nyombaire G,Suniaga H. Use of low-temperature extrusion for reducing phyt hemagglutinin activity (PHA) and oligosaccharides in beans (*Phaseolus vulgaris*L.) cv. Navy and Pinto. ResearchGate. 2012; 1- 5.

7. De Mesa N J E, Alavi S, Singh N, Shi YC, Doghan H, Sang Y. Soy protein-fortified expanded extrudates. Baseline study using normal corn starch. J. Food Eng. 2009;90: 262- 270.

8. Altan A, MaskanM. Development of Extruded Foods by Utilizing Food Industry By-Products. In Advances in Food Extrusion. CRC Press, New York, 2011;121-168.

9. Altan A, Mccarthy K L, Maskan M. Evaluation of snack foods from barleytomato pomace blends by extrusion processing. J. Food Eng. 2008; 84: 231-242.

10. Zasypkin D V, Tung- Ching L. Extrusion of soybean and wheat flour as affected by moisture content. Journal of Food Science. 1998; 63(6): 1058-1061.

11. AOAC. 2000. Official Methods of Analysis, 15th Ed., Association of Official Analytical Chemists, Washington, DC.

12. Hashemi N, Mortazavi S A, Milani E, Tabatabayi F. Microstructural and textural properties of puffed snack prepared from partially defatted almond powder and corn flour. Journal of Food Processing and Preservation. 2016; 1-12.

13. Salamoni Becker F, Da Costa Eifert E, Soares Soares Junior M, Souza Tavares J A, Vânia Carvalho A. Physical and functional evaluation of extruded flour obtained from different rice genotypes. Ciênc. Agrotec., Lavras.2014; 38(4): 367-374.

14. Salata C, Leonel M, Moretti F, Trombini R, Mischan M. Extrusion of blends of Cassava Leaves and Cassava Flour: physical characteristics of extrudates. Food Science and Technology. 2014; 34(3): 501- 506.

15. Gomes L, Santiago R, Carvalho A, Carvalho R, Oliveira I,Bassinello P. Application of extruded broken bean flour for formulation of gluten-free cake blends. Food Science and Technology.2014; 35(2): 307-313.

16. Manonmani D, Soumya S, Bhol J,Bosco D. Effect of Red Kidney Bean (*Phaseolus vulgaris* L.) Flour on Bread Quality. Open Access Library Journal. 2014; 1: 1-6.

17. Mona M, Aly A, Hinar A. Gluten-Free Flat Bread and Biscuits Production by Cassava, Extruded Soy Protein and Pumpkin Powder. Food and Nutrition Sciences. 2015; 6: 660-674.

18. Hood-Neifer S D, Tyler RT. Effect of protein, moisture content and barrel temperature on the physicochemical characteristics of pea flour extrudates. Food Research International.2010; 43: 659- 663.

19. Majumdar R K, Singh R K R. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of fish-based expanded snacks. J. Food Process. Preserv.2014; 38:864- 879.

20. Makowska A, Sokolinska D, Lasik A. Effect of technological factors on water activity of extruded corn product with an addition of whey protein. Acta Sci. Pol, Technol. Aliment.2014; 13(3): 243-247.

21. Bronlund J, Paterson T. Moisture sorption isotherms for crystalline, amorphous and predominantly crystalline lactose powders. Int. Dairy J. 2004; 14: 247-254.

22. Duizer LM. A review of acoustic research for studying the sensory perception of crisp, crunchy and crackly textures. Trends Food Sci. Techn.2001; 12: 17-24.

23. Sun Y, Muthukumarappan K. Changes in functionality of soy-based extrudates during single-screw extrusion processing. International Journal of Food Properties.2002; 5: 379- 389.

24. Taverna L G, Leonel M, Mischan M M. Changes in physical properties of extruded sour cassava starch and quinoa flour blend snacks. Ciênc. Tecnol. Aliment.2012; 32(4): 826- 834.

25. Lobato L P, Anibal D, Lazaretti M M, Grossmann M V E.Extruded puffed functional ingredient with oat bran and soy flour. LWT-Food Sci Technol.2011; 44: 933- 939.

26. De Pilli T, Derossi A, Talja RA, Jouppila K, Severini C. Starchlipid complex formation during extrusion-cooking of model system (rice starch and oleic acid) and real food (rice starch and pistachio nut flour). Eur Food Res Techno. 2012; 234: 517-525.

27. De Pilli T, Legrand J, Derrosi A, SeveriniC. Effect of proteins on the formation of starchlipid complexes during extrusion cooking of wheat flour with the addition of oleic Acid. Int. J. Food Sci. Technol. 2015;50: 515- 521.

28. Ding Q B, Ainsworth P, Plunkett A, Tucker G, Marson H. The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. J. Food Eng.2006; 73: 142- 148.

29. Ding Q B, Ainsworth P, Tucker G, Marson H. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice based expanded snacks. J. Food Eng. 2005; 66: 283-289.

30. Omwamba M, Mahungu S M. Development of a protein-rich ready-to-eat extruded snack from a composite blend of rice, sorghum and soybean flour. Food and Nutrition Sciences.2014; 5: 1309-1317.

31. Peloula-Adeyemi O, Idowo M, Sanni L, Bodunde G. Effect of some extrusion parameters on the nutrient composition and quality of a snack developed from cocoyam (*Xanthosoma Sagittifolium*) flour. African Journal of food science.2014; 510-518.

32. Peluola-Adeyemi O A, Idowu M. Effect of extrusion Parameters on the Physical and Functional Properties of Cocoyam (*Colocasia esculenta*) Flour. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2014; 8: 29- 34.

33. Altan A, Mccarthy K L. Maskan M. Effect of screw configuration and raw material on some properties of barley

extrudates. J. Food Eng. 2009; 92: 377-382.

34. Becker F, Eifert E, Soares M S, Tavares J, Carvalho A. Physical and functional evaluation of extruded flours obtained from different rice genotypes. Ciênc. Agrotec., Lavras. 2014; 38(4): 367-374.

35. Yagci S, Gogus F. Selected physical properties of expanded extrudates from the blends of hazelnut flour-durum clear flour-rice. International Journal of Food Properties.2009b; 12: 405-413.

36. Yagci S, Gogus F. Quality Control Parameters of Extrudates and Methods for Determination. In Advances in FoodExtrusion, (M. Maskan & A. Altan eds), p. CRC Press, New York. 2011; 297-326

37. Zhang Y, Liu, W, Liu C, Luo S, Li T, Liu Y, Wu D, Zuo Y. Retro gradation behavior of high-amylose rice starch prepared by improved extrusion cooking technology. Food Chemistry.2014; 257- 261.

38. Razzaq M R, Anjum F M, Khan M I, Rafiq Khan M, Nadeem M, Sammen Javed M, Sajid M W. Effect of temperature, screw speed and moisture variations on extrusion cooking behavior of Maize (*Zea mays.* L). Pak. Journal Food Science.2012; 22(1): 12- 22.

39. Charunuch C, Limsangouan N, Prasert W, Wongkrajang K. Optimization of extrusion conditions for ready-to-eat breakfast cereal enhanced with defatted rice bran. International Food Research Journal.2014; 21(2): 713-722

40. Obatolu V A, Skonberg D I, Camire M E, Dougherty M P. Effect of moisture content and screw speed on the physical chemical properties of an extruded crab-based snack. Food Science Technology International.2005; 11: 121-127.

41. Stojceska V, Plunkett A, Ibanglu S. The effect of extrusion cooking using different water feed rates on the quality of ready-to-eat snacks made from food by-products. Food Chemistry.2009; 114: 226- 232.

42. Chen F L, Wei Y M, Zhang B, Ojokoh AO. System parameters and product properties response of soybean protein extruded at wide moisture range. J. Food Eng. 2010; 96: 208- 213.

43. MengX, Threinen D, Hansen M, Driedger D. Effects of extrusion conditions on system parameters and physical properties of chickpea flour-based snack. Food Research International. 2010; 43: 65- 658.

44. Pansawat N, Jangchud K, Jangchud A, Wuttijumnong P, Saalia F K, Eitenmiller R R, Phillips R D. Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks. LWT. 2008; 41: 632641.

45. Gualberto D G, Bergman C J , Kazemzadeh M, Weber C W. Effect of extrusion processing on the soluble and insoluble fiber, and phytic contents cereal brans. Plant Foods for Human Nutrition. 1997; 51: 187-198.

46. Camire M E. Nutritional Changes during Extrusion Cooking. In Advances in Food Extrusion, CRC Press, New York.2011; p. 87-102.