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Evaluation of the quality characteristics of the instant porridge (Harireh) powder based on oatmeal- Almond produced by extrusion technology

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ABSTRACT

Revival of native food, introducing it to the industrial cycle in accordance with the current modern lifestyle and the tendency to consume prepared foods, will play an effective role in maintaining the correct food pattern, increasing public health and offering it at the international level. Among them, cereal porridge (Harireh) containing almonds and rice flour is recommended as a traditional and beneficial food with high nutritional value for most age groups of the society. The production of this product is associated with limitations such as lack of quick preparation, non-uniform texture and short shelf life. Therefore, it is important to modify the formulation and process to supply local food to the market. In this research, extrusion technology was used to fabricate instant porridge from almond- oatmeal composite flour. For this purpose, the effect of humidity (12-16%) and the ratio of almond- oatmeal flour (10:90- 30:70) on the physicochemical and functional properties were evaluated using rotatable central composite design (CCD). The results showed, the simultaneous increase in moisture and the level of whole almond flour due to the increase in fiber and fat fraction caused an increase in density. Also, the porosity index was the highest at the maximum levels of almonds and humidity. At the level of 30% of almond powder, the antioxidant activity was at the maximum level 29.3%. according to the optimization results; In order to have a product with the highest porosity, antioxidant capacity and water absorption along with the lowest density, the optimal treatment including feed moisture 13%, rotation speed 150 rpm and whole almond flour 22.3% was determined. This product, in addition to having suitable microstructure features, also has a favorable performance feature.

1. Introduction

The study of native foods is one of the important information circles in explaining food patterns. Native foods provide a suitable platform of diversity in the food system of developing countries. This variety of food has been accepted as a sustainable method to improve malnutrition and food security. Revival of native food is considered a prerequisite for improving the nutritional health of communities and can be an opportunity for entrepreneurship and income generation.

According to the latest recommendations of the World Health Organization (UNICEF), in the field of supplementary nutrition for children, cereals along with nuts (almonds) are recommended as the first food for infants, which are consumed in the form of porridge [1]. Quick preparation of soft and fully cooked curd is the concern of mothers. Instant food products are referred to powdered compounds that are ready to be consumed quickly in combination with water or milk [2]. The variety of instant powders in the country's market is limited. Most of these food products are imported and due to the quick preparation, besides the high price, they also have a high consumption. Most nutrition experts recommend the use of whole grains because of the fiber in them and to prevent cancer, heart diseases and diabetes [3].

Whole wheat flour (oats) is rich in soluble dietary fiber, especially beta-glucan, protein, vitamins, minerals, antioxidants, and plays an effective role in regulating intestinal function, reducing cholesterol and blood glucose levels, and controlling body weight [4]. Sweet almonds contain calcium, phosphorus, iron and magnesium, protein, fiber, manganese, riboflavin, zinc, selenium, phosphorus, essential fatty acids, photochemicals and antioxidants. The presence of high fat in almonds reduces its shelf life; Therefore, the processing of almond flour causes the shelf life of the product [5]. Unfortunately, at the level of research and the domestic market, attention to such products is limited and neglected. In the production of ready-to-eat powdered food products (semi-prepared flour, baby food, soup and instant puree), the extrusion process is used due to the high production capacity and power; It has a special place. Rapid creation of high viscosity and little tendency to become lumpy are the characteristics of instant powders produced by extrusion [6]. The penetration of steam during the extrusion cooking process causes the creation of hydrogen bonds of water with the opened branches of starch molecules, as a result, the production compound has favorable solubility, high dispersibility in cold liquid (water or milk) and high viscosity [7]. Due to shear stress, pressure and heat during extrusion cooking, starch molecules become gelatinized and depolymerized and side branches break in protein and fibers. The digestibility of protein and starch and the proportion of soluble fiber produced increases dramatically [7, 5]. Sandrin et al. (2018), in order to produce baby food from a mixture of Jodusar wholemeal flour and rice flour, investigated the effect of extrusion process parameters, including spiral rotation speed and temperature, on the physicochemical properties and stickiness of the final product. The results showed; By optimizing the conditions of the extruder, it is possible to use the mixture containing higher levels of iodine in the preparation of food products with higher nutritional value [8].

The aim of this study was to investigate the effect of formulation variables including the ratio of two flour samples and the moisture content of the extruder feed on the characteristics of the instant silk obtained from joduser-almond composite flour.

2- Materials and methods

2-1- Raw materials

Whole oat flour from Zarin and Badam Company was purchased from a local store. In order to achieve uniform granulation, all the materials after initial cleaning were milled (Khorasan Tosshak hammer mill) and passed through 30 mesh.

2-2- Input feed formulation and extrusion cooking

Jodoser flour and almond flour were prepared in a certain ratio and then Pearson's square relationship was used to determine the water required to reach 12, 14 and 16% moisture. After mixing for 20 minutes in polyethylene plastic, they were kept in the refrigerator for 24 hours [8].

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In order to prepare the product, Jinan Saxin co-rotating spiral pair extruder (model DS56, made in China) available in the extrusion pilot of the Research Institute of Food Science and Technology of Khorasan Razavi University was used. The moisture content of the input feed was 12, 14 and 16% and the mixing ratio of almond flour: 10:10, 80:20 and 70:30 of almond flour were the formulation variables. Based on the pre-treatments, the optimal constant conditions of the extrusion process include the ratio of length to diameter (L/D) 15, the diameter of the outlet opening 3 mm, the flow rate 150 kg/h, the temperature of the third stage of baking 150 degrees Celsius and the rotation speed of the spindle 150 rpm. The minute was meant. The samples coming out of the extrusion machine were placed on the tunnel dryer conveyor with a temperature of 80 degrees Celsius to dry and reach the same humidity. The output samples were kept in coded plastics until the first phase test [5].

2-3- Measurement of chemical compounds, humidity level

The moisture level was obtained from the standard method (AACC) number 14-15. Fat was measured by Soxhlet method according to AACC standard method number 25-30 and ash amount was measured (according to AACC standard method 08-01) using electric furnace method. The amount of protein was measured using a Gerhardt chloral automaton (model VAP20, made in Germany) [9]. The amount of soluble, insoluble and total dietary fiber was measured by enzymatic method based on AOAC standard [3].

2-4- Mass density

Barosh displacement of millet seeds was calculated based on AACC standard (2000) [10].

2-5- Porosity

Image processing method was used to measure the porosity of extruded snacks. Photographing of the samples was done using a Canon EOS 1000D digital camera in a dark room where there was no light reflection. The number of 10 fluorescent lamps inside the chamber was on. Photography was done with EOS utility software. The top surface of the sample was separated from the background using Photoshop software, and then the porosity of the samples was measured with image J software [11].

6-2- water absorption index

2 grams of the powdered product was poured into a 15 ml falcon tube with a specified weight and weighed. After adding 5 ml of distilled water to it, it was vortexed for 2 minutes and then centrifuged at 700 rpm for 20 minutes. After centrifugation, the supernatant was transferred into a Petri dish and the remaining gel was weighed. Finally, the amount of absorption index was determined by the formula [10].

WATER=mg/ms

mg and ms are respectively the weight of the remaining gel and the original sample.

2-7- Microstructure

The scanning electron microscope is one of the best analytical methods, which provides the possibility of examining and analyzing the chemistry, composition, surface and internal microstructure in micron and nanometer dimensions. Scanning electron microscope model LEO1450 VP (LEO Electron Microscopy Ltd., Cambridge, UK) was used to photograph the cross-section of the given tissue sample. The basis of the function is the interaction of the electron beam with the material, which results in the emission of electrons and photons from the material [5].

2-8- total phenolic compounds

Measurement of the total amount of phenolic compounds was measured by Folin Ciocalto method and some modifications. For this purpose, concentrations of 1000, 10000, 12000 and 14000 of the sample were prepared with the help of 96% alcohol. 1 milliliter of each of the mentioned concentrations was added to 2.5 milliliters of 10% folin reagent and after 2.5 minutes, 2 milliliters of 7.5% sodium carbonate solution was added to the samples and the materials were mixed together. were combined After 1 hour, the absorbance of the samples was read with a spectrophotometer made in England, PG instrument, at a wavelength of 725 nm. [12].

9-2- Antioxidant activity (free radical inhibition methodDPPH)

In this method, the ability to regenerate oxidizing compounds was measured by evaluating the degree of discoloration of the purple solution of 2,2-diphenyl-1-picrylhydrazyl reagent. At first, 1 ml of extracted extract was mixed with 3 ml of

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DPPH reagent and placed in the dark for 30 minutes at ambient temperature. Then the absorbance of the sample was recorded at a wavelength of 517 nm. The following formula was used to calculate the DPPH radical inhibitory activity of the samples. The results of this test were reported in terms of IC50, a concentration extracted from the extract that inhibits 50% of the radical.

= DPPH inhibitory activity (percentage)
100 * (A witness A/ sample A - witness)

2-10- Plan of experiments and statistical analysis

In this research, the rotatable central composite design was used to investigate the effect of humidity treatments and the mixing ratio of whole Jodo head: almond flour on the physicochemical and functional characteristics of the extruded product. With the help of this statistical plan, the final number of treatments was 20, and all the coefficients of the regression and quadratic models and the mutual effect of the factors could be estimated. Optimal operating conditions were also searched using numerical optimization technique [13].

3- Results and discussion

3-1- Chemical compositions of raw materials

The chemical compositions of the raw materials used in the formulation of instant puree based on dry weight are given in table (1).

Table 1 Nutritional composition of ingredient

Almond	Whole oat meal	
1± 20.29	0.21± 14.7	Protein
0.5± 0.74	0.3±2.07	Ash
0.25±49.25	0.59± 8.57	Fat
0.31±11.05	0.14± 6.07	Total fiber
0.44± 0.65	1.2±7.25	Soluble fiber
0.26± 1.62	0.36± 5.72	Insoluble fiber
0.11± 6.69	0.68± 7.41	Moisture

* Data are reported in two replications in terms of (Mean ± SD value).

2-3- The effect of formulation variables on bulk density

Bulk density indicates the increase in volume in all dimensions of the extruded product, low density is one of the desired and expected features in extruded snacks [7]. Based on the results of variance analysis, the quadratic model for the formulation variable was significant and the significant terms of the model included the amount of almond powder, the moisture level of the primary feed (P<0.05). According to Figure 1, the mutual effect of the amount of almond powder and humidity is shown. Based on this, reducing the amount of almond powder and moisture had a significant effect on reducing the density of the bulk product. Almonds are a rich source of oil and fiber. Because insoluble fibers absorb a lot of water due to their hydrophilic properties, they reduce the elasticity and viscosity of the dough, and the presence of fat also prevents the movement of water absorbed by the fiber in the carbohydrate matrix due to its hydrophobic structure as an insulator [14]. At the same time, the fibers cause the cell walls of the bubbles to break, and they disrupt the bubble formation system [15]. As a result, the structure of the product became denser and had a higher density. The results of other researchers in the field of other nut kernels are also logical to these findings. For example, by adding levels of defatted peanut flour, they saw an increase in the density of extruded food products [16]. Another report on the production of special dietary snacks for children with dried fruit powder confirms this case [17].

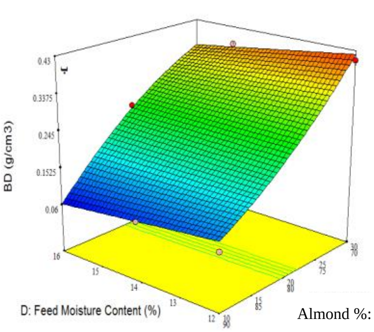

Fig 1 Interaction of Almond: Oat meal ratio, feed moisture on the final bulk density of the extruded product at 150 RPM screw speed

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3-3- The effect of formulation variables on porosity index

One of the methods of monitoring the spongy structure of bulk products is measuring the porosity of these products [8]. Porosity actually describes the solid spongy structure in the product, when the lava is becoming voluminous and the temperature starts to drop at once, the texture of the product is affected by the amount of available gas. The air cells formed during the extrusion process cause the production of voids with different sizes and numbers in the bulk product. The formation of spongy and porous tissue in the bulked product is the result of the production of small steam bubbles due to the rapid exit of steam and the sudden decrease in pressure when exiting the die [16].

According to the results of the analysis of variance, the significant terms of the model included the amount of almonds, moisture and also the interaction effect of the amount of almonds - moisture ($p < 0.05$). The range of porosity changes produced in this research is 0.0606 and 0.912 based on statistical data. Figure 2 shows the independent and simultaneous effect of the input feed moisture and the amount of almond powder on the porosity of the given texture.

Considering the form of moisture increase from 14 to 16%, it has a significant positive effect on the porosity of the extruded product. The increase in the porosity of the extruded samples with the increase of the moisture content above 14% is due to the presence of more available water, which leads to the production of more nucleation centers; In this case, smaller and more bubbles are formed and the resulting tissue becomes spongy [18, 19]. The increase in porosity with increasing humidity has been reported by other researchers [15, 18 and 19].

As seen in Figure 2, increasing the amount of almonds has a negative effect on the porosity of the extruded samples. Thus, at high levels of almond powder (30%), we saw the lowest porosity. The reasons for observing this phenomenon are: 1) that because starch is responsible for creating tissue with a spongy structure, by reducing its concentration, tissue structure with less porosity is produced [15]. Also, increasing the amount of fiber, which, with its strong hydrophobic properties, prevents the gelatinization of starch, as well as the formation of a suitable wall for air cells and the expansion of air cells [20, 5]. These findings are consistent with the results of extruded samples containing peanut powder and apple puree [15, 16 and 21].

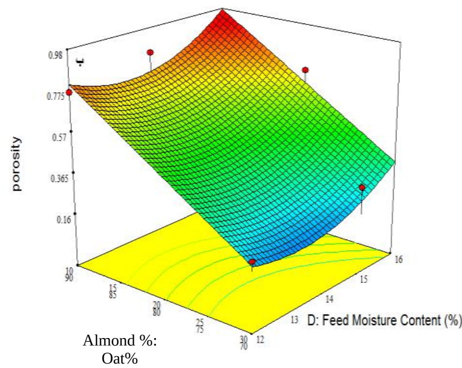

Fig 2 Interaction of Almond: Oat meal ratio, feed moisture on the porosity of the extruded product

4-3- The effect of formulation variables on the amount of water absorption index

The water absorption index indicates the amount of water absorbed by starch after swelling in the presence of a lot of water, which is equal to the weight of the formed gel [6]. This factor is an indicator of starch gelatinization and shows the proportion of intact molecules that have retained their ability to absorb water during extrusion [8]. The amount of WAI water absorption index depends on the available hydrophilic groups and the capacity of gel formation by macromolecules [4]. According to the results of the analysis of variance, the significant terms of the model included the amount of almond powder, the moisture content of the primary feed ($p<0.05$). The range of water absorption index for the produced samples was between 5.49 and 7.89.

Gelatination is one of the most important changes created during the extrusion process on starch

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components [22]. Due to the fact that the amount of humidity and the speed of rotation of the mill have an effect on the amount of gelatinization of starch, these two variables are also effective on the amount of water absorption index. The healthier the chain of starch polymers, the more hydrophilic groups are available, the possibility of creating more connections with water, and as a result, the values of the water absorption index are higher [22, 23]. Extrusion process with high spiral rotation speed also creates cracks and destruction in the starch chain, which leads to the production of dextrin. It may cause molecular interactions between degraded starch, protein and fat, which will reduce the solubility and then the water absorption index [17 and 22]. As it can be seen in this figure, the increase in humidity up to 14% increases the water absorption index, and after that, probably due to the cooling and decrease in the temperature of the molten dough, it causes the water absorption index to decrease. The amount of water during the extrusion process has an important effect on starch conversion (dextrinization). The most transformations of starch occur at low water content and high temperature [8].

In Figure 3, the simultaneous effect of two variables, the amount of almond powder and the amount of moisture, at the level of constant rotation rate of 150 rpm on the water absorption index is shown. With increasing humidity, we see an increase in starch gelatinization and an increase in water absorption. When starch is processed at a higher moisture level, it is less damaged and the possibility of protein denaturation is also reduced [22]. Because water acts as a plasticizer, preventing the decomposition of starch, it helps to maintain the water absorption capacity of starch [22, 23]. These results are in accordance with the reports of extruded food products such as soy protein-based meat substitute product [24], potato-based extruded product [22].

The water absorption index decreases with increasing the amount of almond powder in high humidity (16%), so that the minimum amount of this index was observed in the samples containing 30% almond powder and 12% humidity. This phenomenon is due to the low amount of starch in the sample of 30% and as a result of reducing the concentration of starch, although the proteins contain hydrophilic groups such as -OH, -NH2, -COOH, -SH, but compared to the amylose and amylopectin groups of starch, they tend to They have less water absorption [5]. The index of water absorption depends on the behavior of the material used in the formulation and the purpose of using this material (emulsifier, stabilizer and protein source) as well as material changes such as protein denaturation during extrusion [10]. In snack samples with low levels of defatted almond powder, due to the fact that hydrophilic groups are not covered and the availability of these groups, the possibility of water penetration and water absorption increases [5].

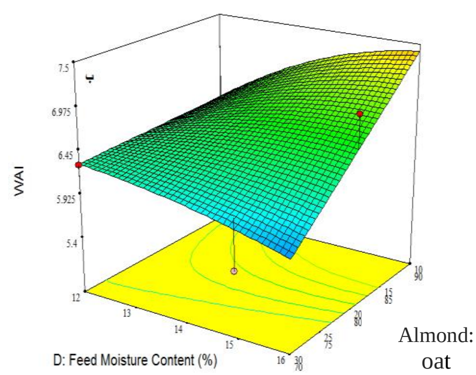

Fig 3 Interaction of Almond: Oat meal ratio, feed moisture on the WAI of the extruded product.

In a research, water absorption was reduced by increasing the amount of defatted peanut powder due to the decrease in Andis starch content [15]. In the research of Fernández et al. (2019), the reason for the decrease in the water absorption index in the casein-starch content sample was the denaturation of the protein during extrusion.

5-3- The effect of formulation variables on antioxidant activity

The term antioxidant refers to free radical receptors, lipid peroxidation inhibitors and chelating agents.[1] It is attributed. Due to the property of antioxidants in preventing the effects of free radicals in causing diseases (such as

[1] Chelating agent

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cancer, heart diseases) and spoilage of food, antioxidant capacity evaluation studies are one of the most common topics studied in food products [12]. Different reports of increasing Or the reduction of the amount of total phenolic compounds and as a result the amount of antioxidant activity during extrusion cooking has been presented. In addition to measuring the total phenolic compounds, the antioxidant power of the extract extracted from the bulk product was evaluated by DPPH-reviving antioxidant power methods[18]. The results of changes in total phenolic compounds and antioxidant power for raw materials and extruded products are summarized in Table 2 for three levels of ratio of almond powder to oat flour (90:10, 80:20 and 70:30). Based on these results, a significant decrease in total phenolic compounds and antioxidant activity is observed.

In short, the difference in antioxidant activity of raw materials and extruded products includes the polymerization of phenols and the reduction of free radical scavenging activity by them, the reaction between phenols and proteins under thermal conditions and the formation of products resulting from Maillard reactions or participation in Maillard reactions that cause the reduction of their antioxidant activity [12, 18] On the other hand, there have been reports on the increase of antioxidant activity in extruded products, which are attributed to the breaking of the cell wall and the release of phenolic compounds. And they have also related the breaking of polyphenol compounds due to high pressure and the formation of phenol molecules with lower weight [26]. From a biochemical point of view, the increase in antioxidant activity can be attributed to the induction of the production of enzymes responsible for increasing the amount of phenols under conditions of pressure and high temperature and stress caused by water vapor. The range of changes in the amount of antioxidant activity in this product sample was measured from 12.1 to 29.3%. In studying the functional properties of grain-based foods, only measuring the amount of total phenolic compounds is not enough because the bioavailability of phenolic compounds in foods limits their antioxidant activity [12]. According to Figure 4, the negative effect of the moisture level of the primary feed on the level of antioxidant activity of the product, such as the amount of total phenolic compounds, is observed. Due to the polymerization of total phenolic compounds due to the increase in humidity, a decrease in antioxidant activity was expected [26]. At high levels of almond powder, the amount of antioxidant activity is at its maximum. This finding is consistent with the results of the high amount of phenolic compounds and the reason is the high amount of phenolic compounds. In another research, by adding the amount of peanut powder, it has been stated that the amount of phenolic compounds and high antioxidant activity increased due to the presence of DPPH-receiving phenols [21]. During the extrusion processes, due to the hydrolysis of the cell wall and the release of insoluble fibers and protein, the possibility of forming a bond between phenolic compounds and insoluble fibers or proteins is intensified, and as a result, a complex is formed between these compounds, which reduces the bioavailability of phenols due to The lack of effect of digestive enzymes on the phenol-insoluble fiber or phenol-protein complex [16, 5].

Table 2 The total phenolic content and antioxidant activity in unprocessed and extruded products

Almond: Oat meal ratio	Total phenolic content (mg/100g)		Antioxidant activity (%)	
	unprocessed	extruded products	unprocessed	extruded products
90:10	252	198-238	16.2	12.5-14.9
80:20	289	241-269	25.1	15.2-19.8
70:30	356	282-327	32.9	25.3-29.3

According to the results obtained from the study of the amount of total phenolic compounds and antioxidant activity of the product, a high correlation was observed between the amount of total phenolic compounds and antioxidant activity, and while reducing the antioxidant activity, the product still contains significant amounts of phenolic compounds and antioxidant activity. is [18].

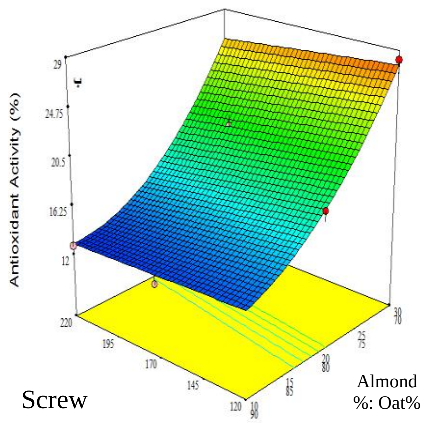

Fig4 Interaction of Almond: Oat meal ratio, Screw speed (RPM) on the Antioxidant activity (%) of the extruded product.

According to Figure 5, with the increase of humidity from 12% to 16%, a significant decrease in the amount of phenolic compounds was observed. By increasing the feed moisture, the polymerization of phenolic compounds is done and as a result the antioxidant activity decreases, the results were in line with other reports [16].

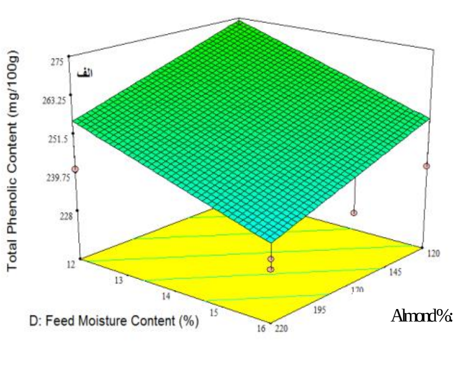

Fig 5 Interaction of Almond: Oat meal ratio, feed moisture on the Total phenolic content (mg/100g) of the extruded product.

6-3- Scanning electron microscope images

Based on the results of the research, there is a significant relationship between the investigated parameters in microscopic measurement‘ The bulked tissue, such as the size, number and wall thickness of the air cells, has the physical

characteristics of the tissue (porosity and density). There is also a relationship between the models presented to change the shape of the tissue with the size of the air cells and their wall thickness [11].

Figure 6 shows the effect of the ratio of almond powder to oat flour and Figure 7 shows the effect of the moisture level of the initial feed. In the mentioned figures, the cross-sectional images of the inflated product are shown with a magnification of 80 showing the diameter of the air cells and a magnification of 500 showing the thickness of the wall of the air cells. In all the pictures, a porous structure with non-uniform texture and holes can be seen.

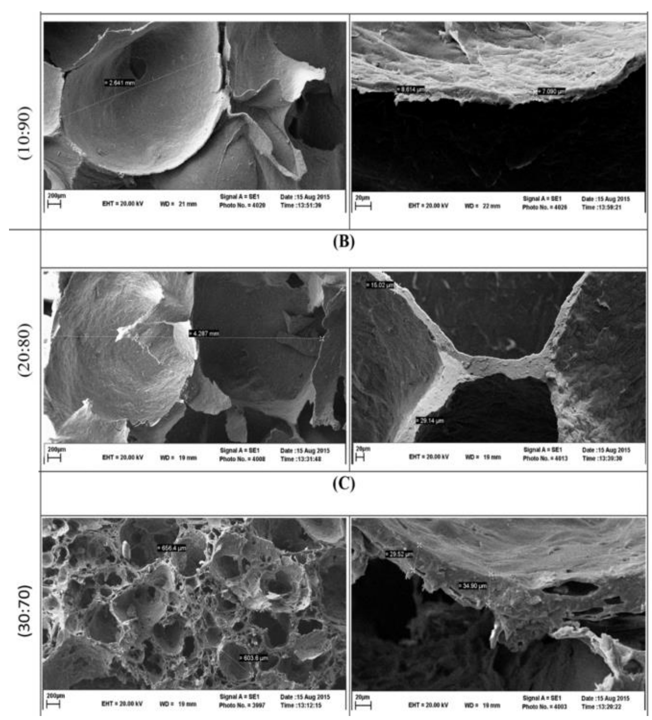

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Fig 6 Investigating the microstructure of the textured product based on almond: oat powder using a scanning electron microscope.

By increasing the level of almond powder in constant process conditions (150 rpm = spiral rotation speed and 16% = moisture content of the primary feed)

The number of air cells is more with thicker cell wall and smaller diameter. Due to the increase in the amount of fat and fiber in samples containing 30% almond powder, the number of nucleation points increases and as a result the number of air bubbles increases; But bubbles do not have the ability to expand and increase in volume. Therefore, the diameter of the bubbles decreases and the cell wall increases. These results are consistent with the interpretations obtained from the density test. In another research, the increase of cell walls and the decrease of their diameter with the increase in the surface of peanuts in the extruded product have also been stated [21].

As a result of changing the amount of moisture in the primary feed, the microscopic structure of the product undergoes many changes. By increasing the amount of moisture (16%) due to the dilution and lowering of the temperature of the dough, its viscosity is reduced, gelatinization is better, and larger air bubbles with thinner cell walls are created.

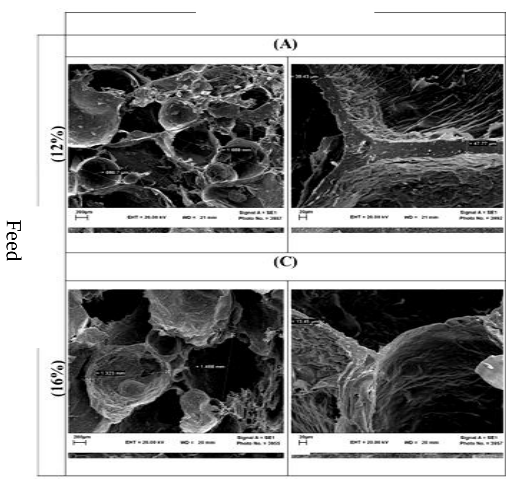

Fig 7 Investigating the microstructure of the textured product at different feed moisture content

According to Figure 7-c, the product produced with a spiral rotation speed of 150 rpm and 16% humidity has fully grown and large air cells with a thin cell wall. These conditions are favorable for the production of products with suitable texture, low density and high expansion coefficient. The results of the microscopic examination of the sample confirm the results of the macrostructure tests, including density and porosity [13 and 23].

4- Conclusion

Rice bran together with almond kernels are recommended as a traditional and beneficial food with high nutritional value for most age groups of the society. The need to produce useful food products that can be prepared quickly is one of the most important concerns of producers. In this project, the production of super-beneficial instant powder based on almond-oats was pursued as a new product. The results of this research showed that with the help of extrusion technology to process almond-oat flour, instant silk powder with desirable properties can be produced. so that; According to the results of the numerical optimization of the software, in order to have a product with the highest porosity, antioxidant capacity and water absorption with the lowest density, the optimal treatment includes feed moisture of 13%, rotation speed of 150 revolutions per minute and the ratio of whole almond flour to oats. 24.5% was determined. This production product, in addition to having suitable microstructure features, also has a desirable functional feature.

5- Thanks and appreciation:

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6- Resources

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مقاله علمی_پژوهشی

ارزیابی ویژگی های کیفی پودر فوری حریره بادام- جودوسر تولید شده توسط فناوری اکستروژن

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چکیده

احیاء غذای بومی، ورود آن به چرخه صنعتی متناسب با سبک زندگی مدرن کنونی و تمایل به مصرف غذاهای آماده، نقش موثری در حفظ الگوی غذایی صحیح، افزایش سلامت عمومی و معرفی آن در سطح بین المللی خواهد داشت. از میان غذاهای بومی، حریره غلات به همراه دانه بادام به عنوان غذای سنتی فراسودمند دارای ارزش غذایی بالا برای اکثر رده‌های سنی جامعه توصیه می شود. تولید این فراورده با محدودیت هایی نظیر عدم اماده سازی سریع، بافت غیریکنواخت و ماندگاری کوتاه همراه است. از این رو اصلاح فرمولاسیون و روش فرایند برای عرضه غذای بومی به بازار امری مهم به شمار می آید. در این پژوهش از فناوری اکستروژن به منظور تولید گرانول فوری حریره حاصل از آرد مرکب بادام- جودوسر استفاده شد. بدین منظور بر پایه طرح مرکب مرکزی چرخش پذیر اثر تیمارهای رطوبت (۱۲ تا ۱۶ درصد) و نسبت اختلاط آرد کامل جودو سر: بادام (۹۰:۱۰تا۷۰:۳۰)، بر ویژگی های فیزیکوشیمیایی و عملگرای فراورده ارزیابی گردید. نتایج نشان داد، افزایش همزمان رطوبت و سطح آرد کامل بادام بدلیل افزایش بخش های فیبری و چربی سبب افزایش دانسیته گردید. همچنین شاخص تخلخل در سطوح بیشینه بادام و رطوبت بیشترین بود. در سطح ۳۰ درصد پودر بادام میزان فعالیت آنتی اکسیدانی در حداکثر میزان ۲۹/۳ درصد بود. مطابق نتایج بهینه سازی؛ برای داشتن فراورده ای با بیشترین تخلخل، ظرفیت آنتی اکسیدانی و جذب آب همراه کمترین دانسیته تیمار بهینه شامل رطوبت خوراک ۱۳ درصد، سرعت چرخش ۱۵۰ دور بر دقیقه و آرد بادام کامل ۲۲/۳ درصد تعیین گردید. این فراورده تولیدی، ضمن داشتن ویژگی‌های میکروساختار مناسب دارای ویژگی عملگرای مطلوبی نیز می‌باشد.

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