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Investigating the nutritional, technological and sensory properties of compact food bar containing raw and processed quinoa

A. Norouzian[1], M. Mehraban Sangatash[2], B. Sahraiyan[2*]

1- Department of Food Science and Technology, ACECR Kashmar Higher Education Institute, Kashmar, Iran.
2- Department of Food Quality and Safety, Food Science and Technology Research Institute, ACECR Khorasan Razavi Branch, Mashhad, Iran

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*Corresponding Author E-
Baharehsahraiyan@yahoo.com

Compact food bars have become consumers' first choice as an alternative to unhealthy snacks, meal replacements or quick energy sources before exercise. Considering the increasing need of society for such products, the aim of this research is to investigate the effect of using quinoa flour in raw and processed form (flaked and roasted) and different levels of rice flour (zero, 15 and 30%) on the physicochemical (moisture, fat, protein, ash, carbohydrates, calories, specific volume, color, water activity and texture) and sensory characteristics of compact food bars. The results showed that the processing applied on quinoa, while improving the quality of the product, led to a decrease in moisture, fat and water activity, and an increase in ash and texture hardness, and the samples containing quinoa flour showed the highest amount of protein. In addition, the flaking process decreased carbohydrate and specific volume and roasting increased them and had a significant effect on the color changes of the samples. The results of the sensory analysis of the samples also showed that the processing done on quinoa and increasing the amount of rice flour in the formulation increased the overall acceptance of the product. Finally, the sample produced with quinoa flaked flour and containing 30% of rice flour (8.10% moisture, 5.90% fat, 5.74% protein, 0.78% ash, 79.47% carbohydrates and 393.97 Kcal/100g calories) was chosen as the optimal formula.

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1- Introduction

Compact Food Bars (CFBs) are products created by compressing various ingredients such as grains, dried fruits, nuts, legumes, and a binding syrup, typically made from glucose or honey. These bars help provide essential nutrients like carbohydrates, protein, and fiber that are usually obtained from main meals [1]. Chenopodium quinoa is a type of pseudo-cereal and has technological-functional properties such as solubility, water-holding capacity, gelatinization, emulsifying ability, and foaming and it is a suitable nutritional replacement for wheat, rye, and barley [2]. Quinoa's protein content (ranging from 12% to 23%) is generally higher than that of rice, corn, barley, oats, and sorghum and it is rich in essential amino acids such as lysine, methionine, and cysteine, which are limited in cereals and legumes. Additionally, quinoa contains all essential amino acids and vitamins (B6, Folate, Riboflavin, and Niacin) [3]. The phytoestrogens present in quinoa contribute to preventing cancer, cardiovascular diseases, and osteoporosis [4]. Currently, quinoa has become one of the most promising food products in the 21st century. Both the National Research Council and NASA recognize the nutritional value of quinoa by including it as part of controlled ecological life support systems (CELSS) [5]. Researchers have explored raw and processed quinoa in various studies, including forms such as flakes, extruded, steam-cooked, malted, and fermented. Processing quinoa allows for increased nutritional compounds, reduced antinutritional factors, and improved sensory properties [6]. Roasting, a common food processing operation, involves dry heating, where hot air envelops the food and cooks it evenly on all sides. Roasting softens the kernels by increasing porosity and destroying the endosperm structure. When food is exposed to warm air, low air humidity creates a moisture-vapor pressure gradient. This gradient leads to moisture evaporation from the food surface, equalizing internal moisture with the surface. The increased pressure causes expansion of internal cells, alteration of the porous nanostructure of cell walls, and facilitated gas flow. The extent of changes depends on the roasting method and considered parameters [7]. The flaking process not only improves the nutritional and functional properties but also improves the taste of the products and is used commercially to produce ready-to-eat and ready-to-cook breakfast cereals and snacks. Conventional flaking technology has been widely used to produce cereal grains including rice, wheat, barley, corn, and millet, which are popular among consumers for their crispiness, flavor, and taste [8]. This process is typically done by rolling compression of precooked or extruded grains [9]. Various studies have been done in this regard. Radhai et al. (2018) conducted a study on nutritional bar formulation containing several different seeds and evaluated the sensory acceptance, physicochemical quality, and nutrients of the bars. Grains of wheat, sorghum, millet and green mung bean flour, soybean flour, peanuts, and sesame seeds as well as yellow sugar and butter were used as binding syrups for bar formulations. The seeds were subjected to four different processes including roasting, grinding, steaming, and soaking. According to their findings, soy flour, legumes, and oilseeds used in the formulation led to an increase in the amount of protein. Also, replacing millet instead of barley in the preparation of bars improved the sensory characteristics [10]. Sharma et al. (2022) investigated the effect of different thermal processes including wet boiling and autoclave processes and dry roasting and microwave processing on total phenolic and flavonoid content, antioxidant activities, antinutrients, and functional properties of quinoa, in their study [11]. Pravalika et al. (2022) conducted a study on the production of low-cost and sustainable nutritional nutbars for overweight people. For this purpose, they produced and evaluated four different formulations containing quinoa, flax seeds, chia seeds, nuts, and dried fruits with different proportions of quinoa and flax seeds. They also examined the sensory parameters of the samples during 60 days and observed that the hardness of the bars decreased significantly during storage. On the other hand, it was found that the use of flax seeds and chia seeds is a complementary combination to improve omega-3 fatty acid as well as the quantity and quality of protein in the Nutrabar product [12].

Therefore, while studying and reviewing similar research conducted by other researchers and the growing acceptance and marketability of these products and society's need to benefit

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from high-quality products with high nutritional value and ready for consumption, the purpose of this study is to formulate a compact food bar containing raw or processed quinoa flour by the methods of flaking and roasting and replacing zero, 15 and 30% of quinoa flour with rice flour and investigate the effect of these processing methods and different ratios of quinoa flour and rice flour on the physicochemical and sensory characteristics of the samples.

2- Materials and methods

2-1- Materials

Titicaca white quinoa flour and Danima brand from Ilya Sabz Trade Development Company (moisture 36.80%, fat 3.90%, protein 11.13%, and ash 2.25%), Iranian white rice flour Abgineh brand from Gokern (moisture 16.90%, fat 2.20%, protein 8.73% and ash 0.37%), Ghancheh brand sunflower oil, maltodextrin from Behtam Powder Company, Keshav India brand soy lecithin from Pishgaman Chemi Company, glucose syrup from Zarfructose (Heshtgerd, Gold Grain Refinery), Bargah brand white sugar from Pazh Mabnatejarat Company, Golchekan Zamani brand rose water from a store in Mashhad, and all chemicals were purchased from reputable companies. The required water was also provided through purified water.

2-2- Quinoa processing

Prepared quinoa flakes were bought in ready form and converted into flour (moisture 8.06%, fat 3.67%, protein 17.10%, and ash 1.95%) using a semi-industrial mill (model PX-MFC90D made in Germany). To prepare roasted quinoa and rice flour, the purchased raw flour sample was heated at a temperature of 100 degrees Celsius for 12 minutes in a cast iron container in a laboratory oven. Roasted quinoa flour had 6.56% moisture, 3.46% fat, 6.82% protein, and 2.47% ash [13].

2-3- Sample preparation method

The dry ingredients of the formulation (control sample) including quinoa flour and binding syrup ingredients including sunflower oil, sugar, water, maltodextrin, lecithin, glucose syrup, and rose water are listed in Table 1. After weighing all the ingredients, the ingredients of the binding syrup were mixed and heated with continuous stirring until an elastic mass was obtained. In the next step, dry ingredients were added to this binding syrup at a temperature of approximately 95 degrees Celsius and mixed well until a homogeneous mass was formed. Then it was poured into a stainless steel mold with a thickness of 1 cm and placed in a digital circulation laboratory baking oven (Binder model, made in Germany) at a temperature of 100 degrees Celsius for 40 minutes. After that, the sample was cut into rectangular molds with a weight of 25 grams and a size of (9x3x1 cm). Finally, the cut samples were wrapped in a flexible polyethylene film with a zipper, packed, and kept at room temperature for physicochemical tests and sensory evaluation, as well as in a 37°C incubator (VELP model, made in Italy) to measure water activity and texture for four weeks. In this research, the type of quinoa flour (raw, flake, and roasted flour) and the ratio of quinoa flour and rice flour were varied according to Table 2. It should be noted that rice flour was subjected to dry heat treatment at 100°C for 8 to 12 minutes before preparing the samples [14].

Table 1- The percentage of compounds used in the preparation of samples (control sample).

Samples ingredients		Each one's percentage	Total percentage
Dry ingredient (%)	Quinoa flour	45	45
	Glucose syrup	26	
	Crystal sugar	14	
	Maltodextrin	5	
Agglutination syrup ingredients (%)	Sunflower oil	4	55
	Soybean lecithin	2.5	
	Water	2.5	
	Rose water	1	

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Table 2- Treatments obtained from different proportions of quinoa flour and rice flour (dry ingredients of samples)

Treatments	Type of quinoa flour	Quinoa flour (%) - Rice flour (%)
1		100-0
2	Raw	85-15
3		70-30
4		100-0
5	Flaked	85-15
6		70-30
7		100-0
8	Roasted	85-15
9		70-30

2-4- Moisture

Moisture was determined using a hygrometer scale (Sartorius model, made in Germany). For this purpose, the amount of 1 to 2 grams of the crushed and homogenized sample was weighed in the special container of the machine and placed inside the machine, and after 10 to 20 minutes, the moisture percentage of the samples was obtained [15].

2-5- Fat

The percentage of fat was measured using the standard method of 10-30, AACC (2003)-Soxhlet [16]. First, the balloons were placed in a 105°C oven for one hour, then placed in a desiccator and weighed. 2 to 3 grams of the sample were weighed and transferred to filter paper. Then they were placed in Soxhle containers. In the next step, distilled petroleum ether and extracted fat were placed in a 100°C oven for 30 minutes to evaporate the possible solvent with it. Finally, the balloons were cooled and weighed in a desiccator, and the fat percentage was calculated using Equation 1:

$$\text{Fat\%} = \frac{\text{The difference between the initial and the final weight of the balloon containing the sample}}{\text{Dry sample weight}} \times 100 \quad (1)$$

2-6- Protein

The protein evaluation of the produced samples was done using the standard method 10-46, AACC (2003)-Kjeldahl [16]. First, one gram of weighed sample was poured into the digestion container and 10 grams of catalyst was added to it. Then 25 milliliters of concentrated sulfuric acid was added to it and it was closed on the Keldal digester and heated slowly. In the distillation stage, about 30 ml of water and 125 ml of 50% soda were added and injected into the steam sample .In an Erlenmeyer flask, 50 ml of 4% boric acid and a few drops of methyl red were poured to obtain a purple-pink solution. Evaporation continued until the volume reached 200 ml. In the next step, the solution in the Erlenmeyer flask was titrated with a standardized 0.1 M hydrochloric acid solution. The percentage of protein was calculated using equation 2, where N is the specific coefficient for converting nitrogen into protein and for quinoa flour samples, it is 5.7, and for rice flour, it is 5.95:

$$\text{Protein\%} = \frac{\text{The volume of acid used for the sample} \times \text{Normality of consumed acid} \times 0/014 \times \text{N}}{\text{Sample weight}} \times 100 \quad (2)$$

2-7- Ash

Ash was measured using Iran's national standard number 13577 [17]. About 4 grams of the sample was weighed into a Chinese capsule that had already reached constant weight. The porcelain capsule was heated on the flame and burned until the sample turned into charcoal. Then, the capsule containing the burnt residue of the sample was transferred to the electric furnace (Atbin model, made in Iran), the temperature of which is set at 550 ± 5 °C, and kept in the furnace until the contents were completely whitened. Finally, the capsule was removed from the oven, placed in a desiccator, and then weighed. The amount of total ash in 100 grams of sample was obtained using Equation 3 :

$$Ash\% = \frac{\text{The difference between the initial \& final weight of the container containing the sample}}{\text{Wet sample weight}} \times 100 \quad (3)$$

2-8- Carbohydrate

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Carbohydrate content was obtained by subtracting the percentage of all compounds from 100 [18].

2-9- Calories

Calories were calculated using Atwater conversion factors according to Equation 4 [19].

(4)
(4×Carbohydrate%)+(9×Fat%)+(4×Protein%)
(Kcal/100g) Calories =

2-10- Specific volume

To obtain the specific volume of the samples, first, their volume was measured by measuring the length, width, and thickness with a caliper. Then, by dividing the volume (cubic centimeters) by the weight of the sample (grams), the specific volume was calculated [15]

2-11- Color

The color of the samples was evaluated using the HunterLab device (HUNTERLAB model of the United States) and the color indices L^*, a^*, and b^* were obtained [20]. L^* index (representing the lightness of the sample and its range varies from 0 i.e. pure black to 100 i.e. pure white), a^* (representing how close the color of the sample is to green and red and its range is from -120 i.e. pure green to +120 to The meaning of pure red is variable) and b^* (representing how close the color of the sample is to blue and yellow and its range of changes is from -120, which means pure blue, to +120, which means pure yellow). To describe the color changes during the processing of quinoa flour and the addition of rice flour to the formulation, the ΔE index (color difference of the samples compared to the control sample) was used, which is defined as Equation 5:

$$\Delta E = \sqrt{(L-L_0)^2+(a-a_0)^2+(b-b_0)^2} \quad (5)$$

In this regard, L_0, a_0, and b_0 are the color parameter values of the control sample (Treatment 1 contains raw quinoa flour and no rice flour) and L, A, and B are the color parameter values of the other samples

2-12- Water activity

Water activity was measured using a water activity measuring device for samples stored at 25°C, one day and one month after production [21].

2-13- Texture

The texture of the samples was measured using a Texture Analyzer (TA PLUS model ,USA) for the samples stored at 25°C, one day after production and one month after production. To evaluate the stiffness of the tissue samples, a cutting/shearing test was performed using a blade probe of a tissue measuring device (HDP/BSK) and a load cell specification of 100 newtons, a maximum cut of ١٠ mm and a test speed of 1 mm/s [13[٢٢ &

2-14- Sensory characteristics

To evaluate the sensory characteristics, 10 judges were selected from the Institute of Food Science and Technology, University of Mashhad. Sensory characteristics of the samples, such as form and shape, surface (burnt ,unnatural color, wrinkles, cracks, and abnormal surface), firmness and softness of the texture, chewability, smell, and taste, for all samples using the scoring method. The general ranking is the result of multiplying the points given to the sensory indicators in the coefficients of each of the characteristics (form and shape (4), surface (2), firmness and softness of the texture (2 ,(chewability (3) and smell and taste (3)) and a 5-point hedonic scale (1: very bad, 2: bad, 3: average, 4: good, 5: very good) was evaluated. Finally, with this information, the overall acceptance score was calculated using equation 6 ,where Q is the overall acceptance, P is the coefficient for each feature, and G is the score obtained from the judges for that feature:[٢١]

$$Q = \frac{\sum(P \times G)}{\sum P} \quad (6)$$

2-15- Statistical analysis

The statistical analysis of the data was done in the form of a completely random design based on the factorial of 2 factors (the first factor: is the type of quinoa flour, and the second factor: is different levels of rice flour). Analysis of the results was done using Mini-Tab version 21 software at a significance level of 5%, comparison of averages with Tukey's method and figures were drawn with MS Office Excel version 2013 software. All tests were performed in duplicate

3- Results and Discussion

3-1- Nutritional characteristics

In this section, the moisture, fat ,protein, ash, carbohydrates, and calories of the samples have been examined, and Table 3 shows the effect of the type of quinoa flour (raw, flaked, and roasted (And the different levels of rice flour (zero, 15 and 30 percent) used in the formulation show the nutritional characteristics that are discussed in the following for each of the parameters.

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Table 3- The effect of different types of quinoa flour and rice flour levels on nutritional values of produced samples

Treatments	Type of Quinoa	Rice Flour (%)	Moisture (%)	Fat (%)	Protein (%)
1	Raw	0	7.99±0.81[a]	6.18±0.04[a]	3.31±0.03[c]
2	Raw	15	8.03±0.59[a]	6.06±0.01[ab]	3.34±0.09[c]
3	Raw	30	8.55±0.35[a]	5.99±0.02[abc]	3.25±0.19[c]
4	Flaked	0	7.38±0.12[a]	6.10±0.04[ab]	7.46±0.33[a]
5	Flaked	15	7.72±0.29[a]	5.96±0.03[abc]	6.95±0.36[a]
6	Flaked	30	8.10±0.04[a]	5.90±0.02[bc]	5.74±0.23[b]
7	Roasted	0	6.30±0.38[a]	5.96±0.02[abc]	3.02±0.00[c]
8	Roasted	15	6.96±0.63[a]	5.95±0.01[bc]	3.22±0.17[c]
9	Roasted	30	7.10±1.27[a]	5.78±0.08[c]	3.08±0.12[c]
Treatments	**Type of Quinoa**	**Rice Flour (%)**	**Ash (%)**	**Carbohydrate (%)**	**Calorie (Kcal/100g)**
1	Raw	0	0.99±0.02[a]	81.50±0.75[abcd]	394.98±3.57[a]
2	Raw	15	0.89±0.00[bcde]	81.65±0.66[abc]	394.62±2.39[a]
3	Raw	30	0.81±0.00[de]	81.38±0.18[abcd]	392.51±1.30[a]
4	Flaked	0	0.96±0.00[bc]	78.08±0.49[d]	397.14±0.22[a]
5	Flaked	15	0.85±0.01[cde]	78.50±0.02[cd]	395.52±1.05[a]
6	Flaked	30	0.78±0.03[e]	79.47±0.26[bcd]	393.97±0.08[a]
7	Roasted	0	1.17±0.01[a]	83.53±0.40[a]	399.95±1.34[a]
8	Roasted	15	0.94±0.05[bcd]	82.90±0.77[ab]	398.10±2.23[a]
9	Roasted	30	0.89±0.01[bcde]	83.12±1.22[a]	396.92±4.61[a]

Different letters in each column represent significant difference from one another ($p<0.05$).

3-1-1- Moisture

According to the obtained results (Table 3), the samples produced with raw quinoa flour had the highest and the samples containing roasted quinoa flour had the lowest moisture values, but this difference was not significant (p 0.05). On the other hand, increasing the percentage of rice flour in the formulation led to an increase in moisture content, but this difference was not significant (p 0.05). The reason for the higher moisture content of samples containing raw flour can be attributed to the higher moisture content of raw flour and the effect of the thermal process on reducing the moisture content of roasted quinoa flour. Also, the reason for the increase in moisture content in samples containing a higher percentage of rice flour is the higher moisture content of this flour compared to raw and processed quinoa flour. In the research of Kaur et al. (2018) on the production of Nutrabar containing quinoa flour and rice flour, it was found that the dry heat process led to a decrease in the moisture content of quinoa, brown rice, and flax seed [13].

3-1-2- Fat

The analysis of the obtained fat amounts (Table 3) showed that the samples produced with raw quinoa flour had more fat content than the samples containing roasted quinoa flour. The lower amount of fat in samples containing processed quinoa flour compared to samples containing raw flour is due to the breakdown and oxidation of some fat during dry heat treatment, which has reduced the amount of fat in the final product. Kaur et al. (2018) also reached similar results in their research on the effect of the thermal process on Nutrabar prepared with quinoa, brown rice, and flax seed [13]. Sheikhalipoor (2016) compared the composition of raw and processed fenugreek seeds and concluded that there was a significant difference between the fat of raw fenugreek and microwaved and roasted fenugreek and the raw fenugreek had more fat. This researcher attributed the reason to the release of fat as a result of the applied heat treatment [23]. On the other hand, increasing the amount of rice flour in the formulation caused a significant decrease ($p<0.05$) in the amount of fat in the samples, which is justified considering the higher amount of fat in quinoa seeds compared to rice. The results obtained from the research of

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Javaheripour et al. (2021) also indicated an increase in the amount of sponge cake fat as a result of adding quinoa flour and sprouted wheat flour to the formulation [4]. Jancurová et al. (2009), in their research, reported the amount of fat in quinoa between 2 and 10%, which is similar to that of legumes such as soybeans and is much higher than the fat of cereals. They stated that quinoa is a rich source of fat, especially essential fatty acids [24]. Omega-6 and omega-3 fatty acids are essential fatty acids that cannot be synthesized by humans, so they must be obtained directly from food [25].

3-1-3- Protein

The evaluation of the protein content of the samples (Table 3) showed that the protein content of the samples containing flaked flour and without rice flour) treatment 4) was higher than other treatments. In addition, flaked flour had more protein than the other two types of quinoa flour (raw and roasted). Also ,the findings showed that treatments containing roasted quinoa flour had the lowest amount of protein, which is due to the loss of some non-protein content and protein denaturation due to dry heat treatment [13]. On the other hand, by increasing the substitution of quinoa flour with rice flour, the amount of protein decreased significantly (p ,(۰,۰۵>which can be attributed to the higher protein content in quinoa flour compared to rice flour. Panjeh (2019 (also achieved similar results in his research and reported that increasing the level of quinoa flour in gluten-free wafer bread formulation compared to buckwheat, amaranth, and rice flour caused a greater increase in the protein content of the samples [26]. Jaldani et al. (2017) also investigated the effect of adding whole quinoa flour and xanthan gum to Berberi bread formulation and concluded that the protein content of the samples increased significantly)p.[۲۷] (۰,۰۵>

3-1-4- Ash

The findings (Table 3) showed that the type of quinoa flour had a significant effect ($p<0.05$) on the amount of ash in the samples, so the samples containing roasted flour had the highest amount and the samples containing raw flour had the lowest amount of ash. This difference was due to more ash in roasted quinoa flour. In his research, Sheikhalipoor (2016) compared the ash of raw, roasted, flaked, and microwaved vetiver seeds and concluded that there is no significant difference between the ashes of the samples, however, based on the small changes observed, he reported that the microwaved seeds were first, then the roasted seeds, raw seeds and then flaked seeds had the highest amount of ash [23]. Increasing the replacement of rice flour with quinoa flour significantly ($p<0.05$) led to the reduction of ash in the samples. The reason for this can be attributed to the higher ash content of quinoa flour compared to rice flour. According to the results, the sample containing roasted quinoa flour in the absence of rice flour had the highest amount and the sample containing quinoa flakes flour and 30% of rice flour had the lowest amount of ash. Based on the research findings of Jaldani et al. (2019), which investigated the optimization of gluten-free cake formula containing rice flour, quinoa, and purslane leaves, it was found that the use of whole quinoa flour increases the amount of ash in the product. They attributed this to the presence of more mineral salts in bran than in other parts of the grain [28]. Haghayegh and Salehi (2017) also investigated the production of gluten-free cookies by adding different amounts of buckwheat, amaranth, and quinoa flour and obtained similar results and reported that an increase in the amount of all three pseudo-cereals caused an increase in the amount of ash in the samples [29].

3-1-5- Carbohydrate

Based on the results obtained from the carbohydrate values of the samples (Table 3), the type of flour and different levels of rice flour used in the formulation had a significant effect ($p<0.05$) on the carbohydrate content of the samples in such a way that the samples produced with roasted flour and in the absence of rice flour had the highest amount of carbohydrates and the samples produced with flaked flour had the lowest amount of carbohydrates (Table 3). The amount of carbohydrates in quinoa is comparable to rice and barley, and due to its beneficial hypoglycemic effects and reduction of free fatty acids, it is considered a useful food [25].

3-1-6- Calories

Examining the calorie values of the samples (Table 3), it was found that the sample containing roasted quinoa flour and no rice flour (Treatment 7) has the highest amount of calories and the sample containing raw quinoa flour and 30% rice flour (Treatment 3) had the lowest amount of calories (Table 3). However,

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the values obtained in this table did not show a significant difference with each other (p 0.05).

3-2- Specific volume

Table 4 shows the length, width, thickness, and weight values of each treatment and the effect of the type of quinoa flour (raw, flaked, and roasted) and different levels of rice flour (zero, 15, and 30%) used in the formulation on the specific volume obtained for each treatment. According to the results, quinoa flour processing had no significant effect (p 0.05) on the specific volume of the samples, but the samples produced with roasted flour had the highest specific volume. The denaturation of flour proteins and starch due to the thermal process causes the expansion of air bubbles due to the presence of carbon dioxide and water vapor and leads to an increase in the volume of the product [30]. Marston et al. (2016) during the investigation of the heat treatment of sorghum flour on the quality of cake and bread, found that the volume of the cake increased due to the application of heat [31]. On the other hand, the addition of rice flour did not have a significant effect (p 0.05) on the specific volume of the samples, however, the specific volume of the samples decreased with the increase of rice flour. In the research conducted by Moazeni Esfanjani (2017) which was conducted on the production of gluten-free bread based on rice and quinoa flour, similar results were obtained and the reason for the increase in volume was result of increasing the quinoa flour in the formula, creating more viscosity by quinoa flour and improving the distribution of water and gas in the dough, which trapped more gas bubbles and led to an increase in the volume of the product [2]. Panjeh (2019) attributed the increase in the specific volume of gluten-free wafer bread to the high fiber content in the structure of pseudo-cereal flour such as quinoa compared to rice flour [26]. Elgeti et al. (2014) reported that by replacing quinoa flour instead of rice and corn flour in gluten-free bread, quinoa flour improved the volume of produced bread by increasing the activity of the alpha-glucosidase enzyme [32].

Table 4- The effect of different types of quinoa flour and rice flour levels on specific volumes of produced samples

Treatments	Type of Quinoa	Rice Flour (%)	Weight (g)	Volume (cm^3)			Specific Volume (cm^3/g)
				Length (cm)	Width (cm)	Thickness (cm)	
1	Raw	0	23.12±1.61	9.11±0.32	3.10±0.02	0.79±0.08	0.84±0.12[a]
2	Raw	15	25.93±0.56	9.50±0.00	3.25±0.00	0.66±0.02	0.78±0.00[a]
3	Raw	30	23.63±0.97	9.23±0.01	3.27±0.04	0.60±0.02	0.77±0.01[a]
4	Flaked	0	21.81±2.06	9.20±0.06	3.45±0.15	0.61±0.01	0.80±0.07[a]
5	Flaked	15	25.21±0.56	9.31±0.16	3.40±0.14	0.64±0.01	0.75±0.04[a]
6	Flaked	30	23.38±1.03	9.30±0.00	3.25±0.03	0.57±0.02	0.73±0.00[a]
7	Roasted	0	26.11±0.31	9.96±0.29	3.70±0.23	0.62±0.05	0.86±0.01[a]
8	Roasted	15	21.84±3.74	9.40±0.03	3.15±0.07	0.60±0.04	0.80±0.00[a]
9	Roasted	30	25.02±0.08	9.28±0.25	3.29±0.03	0.59±0.00	0.79±0.01[a]

Different letters represent significant differences from one another ($p<0.05$).

3-3- Water activity and texture

Table 5 shows the effect of the type of quinoa flour (raw, flaked, and roasted) and different

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levels of rice flour) zero, 15, and 30%) on the amount of water activity and texture stiffness of production samples kept at 25 degrees Celsius, which was evaluated one day and one month after production.

Table 5- The effect of different types of quinoa flour and rice flour levels on water activity and texture of produced samples during storage at 25 one day and One month after production.

Treatments	Type of Quinoa	Rice Flour (%)	Water activity		Texture (N)	
			One day after production	One month after production	One day after production	One month after production
1	Raw	0	0.60±0.00[a]	0.59±0.01[a]	2.28±0.62[a]	5.05±0.58[b]
2	Raw	15	0.59±0.01[a]	0.57±0.01[a]	6.42±3.62[a]	7.55±0.59[ab]
3	Raw	30	0.59±0.02[a]	0.52±0.00[a]	9.31±2.13[a]	8.04±1.31[ab]
4	Flaked	0	0.60±0.01[a]	0.58±0.01[a]	3.77±0.61[a]	5.93±0.02[ab]
5	Flaked	15	0.57±0.00[a]	0.56±0.04[a]	7.80±0.45[a]	8.23±1.24[ab]
6	Flaked	30	0.57±0.02[a]	0.50±0.01[a]	9.67±0.84[a]	11.11±2.00[ab]
7	Roasted	0	0.54±0.02[a]	0.51±0.01[a]	9.02±0.30[a]	9.54±2.28[ab]
8	Roasted	15	0.54±0.01[a]	0.49±0.19[a]	11.11±3.08[a]	12.71±2.87[ab]
9	Roasted	30	0.53±0.01[a]	0.48±0.03[a]	11.97±1.93[a]	14.26±0.58[a]

Different letters in each column represent significant differences from one another ($p<0.05$).

3-3-1- Water activity

The results showed that the type of quinoa flour used in the formulation decreased the water activity of the samples during one month of storage in such a way that the samples produced with raw quinoa flour had the highest water activity and the samples produced with roasted quinoa flour had the lowest amount of water activity (Table 5). This difference in the amount of water activity of the samples can be related to the moisture content of quinoa flour. As the moisture content of raw flour was higher and the moisture content of flaked and roasted flour was lower due to the processing done, the water activity of the prepared treatments changed corresponding to the type of flour used. On the other hand, the results showed that the replacement of rice flour with quinoa flour reduced the water activity of the samples during both measurement periods at ambient temperature. In this way, the highest amount of water activity for treatment 1 after one day of storage at 25°C, which contains raw quinoa flour and no rice flour, and the lowest amount of water activity for treatment 9 kept at this temperature for one month, which contains roasted quinoa flour and 30% of rice flour were obtained. Sanai Fard (2009) in his research on energy-generating food rations, investigated the effect of storage time on the water activity of the samples and reached similar results. He stated the reason for the decrease in water activity over time, in addition to the moisture exchange of the sample with the environment inside the package, and the reactions related to the constituent compounds of the samples. For example, water absorption by moisture-absorbing compounds and expansion of monolayer water or change in water absorption property due to the conversion of crystal forms of constituents into each other are among the factors affecting the reduction of water activity of the samples [33].

Enzymatic and non-enzymatic browning, microbial growth, fat oxidation, and physical properties such as texture are influenced by the water activity of the food. In water activity, less than 0.6 food items are resistant to the growth of microbes [34]. Usually, the maximum browning in water activity is between 0.6 to 0.7 and the maximum oxidation of fats in water activity is 0.1 to 0.3. In addition, most enzymes are ineffective in water activity less than 0.85. If lipases can be active up to 0.3 or even 0.1 water activity [35]. The highest amount of water activity of the samples in this research was 0.6, which according to what was mentioned, enzymatic reactions, browning, and oxidation in the produced samples are the least.

3-3-2- Texture

Texture is one of the important physical characteristics of food, which plays a significant role in product acceptance. The results obtained from examining the texture of the samples show that the samples produced with raw flour had the lowest and the samples produced with roasted flour had the highest amount of texture hardness (Table 5). On the

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other hand, increasing the replacement of rice flour with quinoa flour led to an increase in the texture hardness of the samples during four weeks of storage at ambient temperature. The use of rice flour in the formulation is due to the function of its starch, which acts as a filler by gelatinization. The maximum gelatinization of rice starch occurs at a temperature of 75 degrees Celsius, which causes the consistency of the texture in the final product, and in this study, it happened at the stage of baking the samples in the oven [35]. Also, quinoa flour makes the texture soft due to its water-binding capacity. The large number of hydroxyl groups in fiber molecules increases water absorption and allows more interaction with water through hydrogen bonds [2]. Burešová et al. (2017) obtained similar results in their research. In a study on gluten-free bread based on rice flour, they found that the texture of the bread became significantly softer by increasing the amount of quinoa [37]. In the research of Miñarro et al. (2012), it was found that there is a negative relationship between the volume and the texture hardness so the texture hardness increases with the decrease of the volume [38]. This result is consistent with the results obtained from this research because adding more rice flour in the formulation has reduced the specific volume of the samples and increased their texture hardness. The hardness values of the texture samples at 25°C have increased four weeks after production, which can be attributed to enzymatic reactions, changes in the moisture content of the samples, or reactions in food polymers that cause cross-linking and hardening of the texture [34].

3-4- Color difference (ΔE)

The color differences of the samples compared to the control sample are shown in Figure 1. The obtained results indicated that the sample containing roasted quinoa flour and no rice flour (treatment 7) had the highest color difference and treatment 2, containing raw quinoa flour and 15% rice flour had the lowest color difference with the control sample (treatment 1 containing raw quinoa flour and without rice flour). The use of roasted quinoa flour has significantly ($p<0.05$) darkened the color of the samples (Table 6). Based on the results of Karimi Abdolmaleki et al. (2018) in the field of investigating the effect of using raw and heated chickpea flour on the quality characteristics of the cake, it was found that the L^* index decreased with the application of heat, and the brightness of the cake decreased with the increase of temperature and time. [39]. On the other hand, the color of the product became brighter with the increasing substitution of rice flour with quinoa flour. The darker samples with a higher percentage of quinoa flour are due to the presence of reducing sugars such as glucose and amino acids such as lysine in quinoa flour, which during the cooking process causes a non-enzymatic browning reaction and darkens the color. In addition, the presence of betalain pigment in quinoa flour causes the color of the product to darken [21]. In his research, Moazeni Esfanjani (2017) obtained similar results and attributed this darkness to the presence of fiber and bran in quinoa flour. During the investigations, the sample containing quinoa flakes and 30% rice flour had the highest brightness, and the sample containing roasted quinoa flour in the absence of rice flour had the lowest brightness [2].

The examination of color index a^* showed that the type of quinoa flour and the percentage of rice flour used in the formulation were significantly ($p<0.05$) effective on this index. The treatments prepared with roasted quinoa flour had the highest amount of a^*, and with the increase of substitution of rice flour with quinoa flour, the redness of the samples decreased. In the study conducted by Karimi Abdolmaleki et al. (2018), it was found that by applying heat treatment to chickpea flour, the ΔE index showed a significant increase compared to the untreated sample [39]. The decrease in redness in the samples with an increase in rice flour and a decrease in quinoa flour is due to the presence of betalain pigment in quinoa flour and the occurrence of the Maillard reaction [40]. The results showed that treatment 7 (containing roasted quinoa flour and no rice flour) had the most and treatment 3 (containing raw quinoa flour and 30% rice flour) had the least amount of redness among the samples.

According to the investigations, the type of quinoa flour used in the formulation had a significant effect ($p<0.05$) on the b^* index of the samples, and the treatments prepared with raw quinoa flour had the highest amount and the treatments prepared with roasted quinoa flour had the lowest amount of b^*. Also, the increase in the amount of replacing rice flour with quinoa flour caused an increase in this color index, the reason for which can be related to the yellow nature of quinoa flour compared to rice flour (which has a white color). In general, the

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highest amount of color component b* obtained was related to the sample containing raw quinoa flour and 30% rice flour, and the lowest was related to the sample containing roasted quinoa flour and no rice flour.

Table 6- The effect of different types of quinoa flour and rice flour levels on color of produced samples

Treatments	Type of Quinoa Flour	Rice Flour (%)	Color Values		
			L^*	a^*	b^*
1	Raw	0	32.99 ± 0.46^{b}	7.58 ± 0.04^{c}	27.51 ± 0.38^{ab}
2	Raw	15	34.55 ± 0.21^{ab}	7.43 ± 0.07^{c}	27.98 ± 0.87^{ab}
3	Raw	30	36.21 ± 0.55^{ab}	7.21 ± 0.02^{c}	31.54 ± 0.10^{a}
4	Flaked	0	34.09 ± 1.23^{ab}	7.87 ± 0.04^{bc}	25.51 ± 0.70^{ab}
5	Flaked	15	35.77 ± 0.06^{ab}	7.60 ± 0.32^{c}	25.54 ± 1.49^{ab}
6	Flaked	30	37.48 ± 0.13^{a}	7.30 ± 0.13^{c}	27.76 ± 0.66^{ab}
7	Roasted	0	27.60 ± 1.21^{c}	9.33 ± 0.05^{a}	22.06 ± 0.72^{b}
8	Roasted	15	32.63 ± 0.27^{b}	8.89 ± 0.025^{a}	24.11 ± 2.61b
9	Roasted	30	33.50 ± 0.61^{b}	8.73 ± 0.29^{ab}	27.35 ± 0.95^{ab}

Different letters in each column represent significant difference from one another ($p<0.05$).

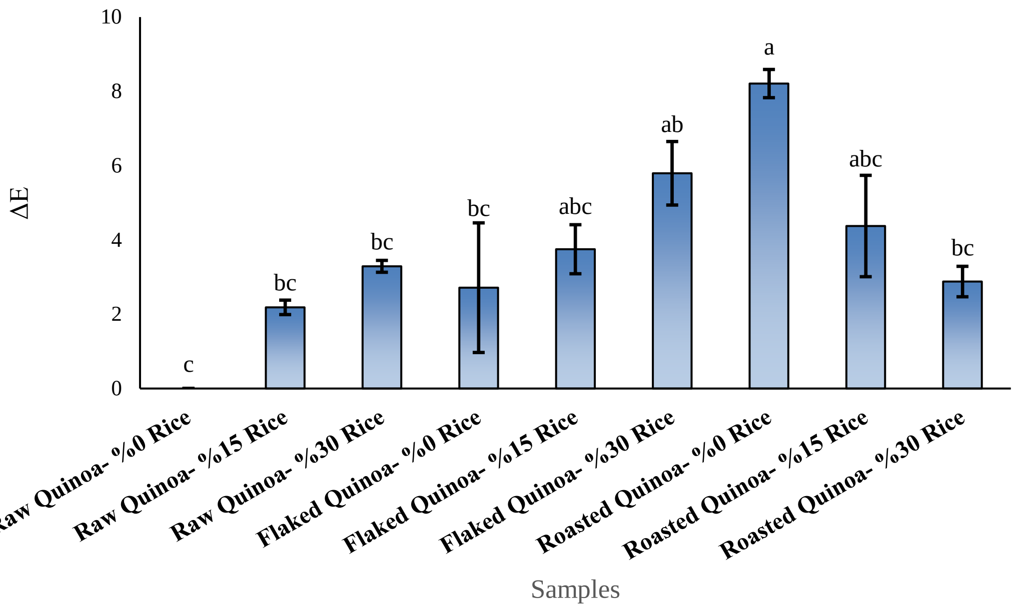

Figure 1 - The effect of different types of quinoa flour and rice flour levels on ΔE of produced samples.

3-5- Overall acceptance

The sensory characteristics of the samples produced in this research were examined from different aspects such as form and shape, surface, texture, chewability, and smell and taste by 10 judges, and their results are shown in Table 7 and the overall acceptance results obtained are also shown in Figure 2. According to these results, the processing of quinoa flour had an effective role in accepting and increasing the acceptability of the samples. The samples prepared from quinoa flour obtained a higher form and shape score than other samples in sensory evaluation, and the samples containing raw flour had the lowest acceptance rate in terms of form and shape. The shape of food is closely related to its texture. According to the results obtained from this research, the samples prepared with raw flour had a softer texture and were slightly deformed when cut compared to other treatments, which reduced their form and shape score. On the other hand, the amount of rice flour used in the formulation had no significant effect (p 0.05) on the acceptance of the samples. Examining the points obtained from the level of the samples

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showed that the treatments prepared with flaked quinoa flour got the most points and the treatments prepared with raw quinoa flour got the least points. Also, the different amounts of rice flour used in the formulation did not have a significant effect (p 0.05) on the surface of the samples, from the point of view of the judges. According to the survey conducted regarding the hardness and softness of the texture, the difference in the type of quinoa flour used in the samples had a significant effect ($p<0.05$) on their acceptance in this aspect, and the samples produced with flaked quinoa flour obtained the highest score. The different levels of rice flour used in the formula of the samples did not have a significant effect (p 0.05) on the acceptance level in terms of texture hardness and softness. According to the instrumental evaluation of the texture of the samples kept at ambient temperature (25°C) and comparing with the sensory evaluation results, it was found that the samples with medium texture hardness (containing flaked quinoa flour and 30% rice flour) scored more sensory acceptance points. The results obtained from the chewability feature indicated that the samples produced with flaked quinoa flour scored higher than the samples produced with roasted flour and they also scored higher than the samples containing raw quinoa flour. The different levels of rice flour used in the formula did not have a significant effect (p 0.05) on the acceptance of the product in terms of chewability, however, samples with 30% rice flour received the highest score. The chewability is closely related to the hardness and softness of the texture, and as the sensory evaluation results show, the treatment containing flaked quinoa flour and 30% rice flour, both in terms of texture and chewability, has received the most points from sensory evaluators. During the investigations conducted on the smell and taste scores of the samples, it was found that the type of quinoa flour used had a significant effect ($p<0.05$) on this characteristic. So that the samples prepared with raw quinoa flour scored the lowest and the samples prepared with roasted quinoa flour scored the highest. Karimi Abdolmaleki et al. (2018) also investigated the effect of using raw and heated chickpea flour on the characteristics of the cake and found that the taste score increased with the application of heat and the heat increased the aromatic compounds created during the Maillard reaction [39]. Also, the results showed that by increasing the percentage of rice flour and replacing it with quinoa flour, the smell and taste have been approved and accepted by the judges. The reason for this can be attributed to the special flavor of quinoa. Moazeni Esfanjani (2017) achieved similar results in his research on the production of gluten-free bread based on rice flour and quinoa [2].

Finally, by calculating the obtained sensory scores, the overall acceptance rate of the samples was obtained and it was found that the processing of quinoa flour increased the overall acceptance. So the samples produced with flaked quinoa flour received the highest overall acceptance score. At the same time, the different levels of rice flour used in the formulation had no significant effect (p 0.05) on overall acceptance. However, samples with 30% rice flour showed higher scores. In general, the results indicated that the treatment containing flaked quinoa flour and 30% rice flour had the highest scores, and the treatment containing raw quinoa flour and no rice flour had the lowest scores.

Table 7-The effect of different types of quinoa flour and rice flour levels on sensory properties produced samples

Treatments	Type of Quinoa	Rice Flour (%)	Form & Shape	Surface	Texture	Chewiness	Odor & Taste
1	Raw	0	3.90 ± 0.70^{a}	4.20 ± 0.60^{a}	3.70 ± 0.78^{a}	3.60 ± 0.91^{a}	2.90 ± 1.22^{b}
2	Raw	15	4.00 ± 0.63^{a}	3.90 ± 0.53^{a}	3.60 ± 0.01^{a}	3.60 ± 0.91^{a}	3.10 ± 1.13^{ab}
3	Raw	30	4.10 ± 0.70^{a}	3.90 ± 0.53^{a}	4.00 ± 0.63^{a}	3.90 ± 0.70^{a}	3.60 ± 0.80^{ab}
4	Flaked	0	4.60 ± 0.48^{a}	4.60 ± 0.48^{a}	4.40 ± 0.48^{a}	4.30 ± 0.45^{a}	3.10 ± 0.70^{ab}
5	Flaked	15	4.70 ± 0.45^{a}	4.60 ± 0.48^{a}	4.10 ± 0.70^{a}	4.20 ± 0.60^{a}	3.80 ± 0.74^{ab}
6	Flaked	30	4.60 ± 0.48^{a}	4.50 ± 0.80^{a}	4.60 ± 0.48^{a}	4.60 ± 0.48^{a}	4.30 ± 0.78^{a}
7	Roasted	0	4.50 ± 0.50^{a}	4.40 ± 0.48^{a}	4.30 ± 0.45^{a}	4.30 ± 0.45^{a}	3.70 ± 0.90^{ab}

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8	Roasted	15	4.50±0.50[a]	4.40±0.48[a]	4.20±0.74[a]	4.10±0.70[a]	3.90±1.04[ab]
9	Roasted	30	4.30±0.64[a]	4.20±0.60[a]	4.10±0.70[a]	4.00±0.77[a]	4.30±0.64[a]

Different letters in each column represent significant differences from one another (p<0.05).

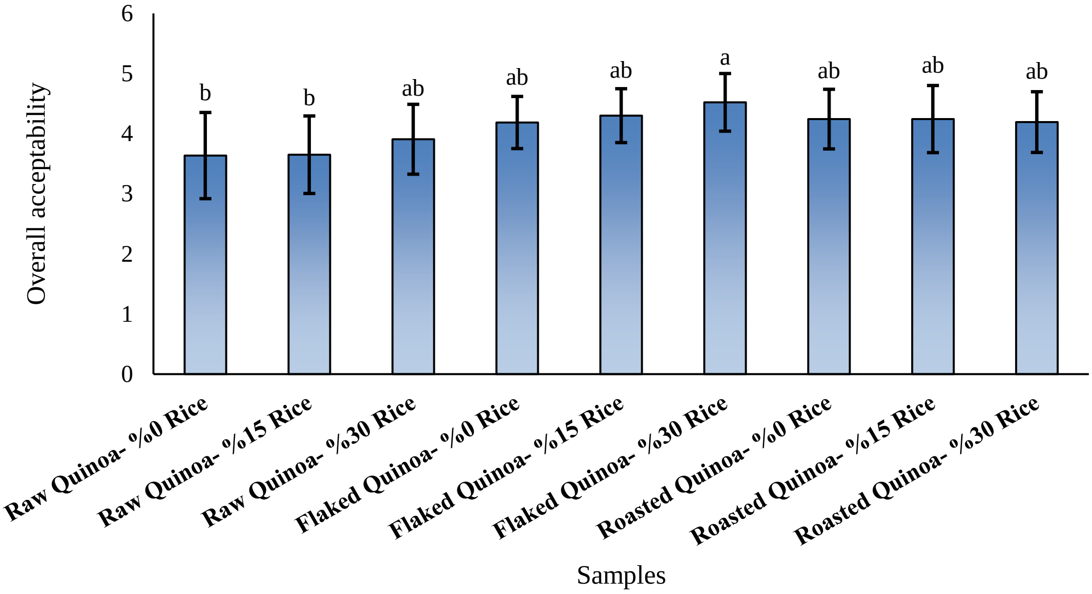

Figure 2 - The effect of different types of quinoa flour and rice flour levels on the overall acceptability of produced samples.

4- Conclusion

The results showed that the processing of quinoa flour improved the quality shelf life and nutritional properties of the food bar .Flaked and roasted quinoa flour played a role in reducing moisture and fat and increasing ash in production samples, and the samples containing flaked quinoa flour had the highest amount of protein. On the other hand, increasing the amount of replacing rice flour with quinoa flour decreased the percentage of fat, protein, and ash in the final product and increased the moisture content of the samples. In addition, roasting caused an increase, and flaking caused a decrease in the amount of carbohydrates and the specific volume of the samples.

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بررسی ویژگی‌های تغذیه‌ای، تکنولوژیکی و حسی قالب غذایی فشرده حاوی کینوای خام و فراوری شده

آتوسا نوروزیان[۱]، معصومه مهربان سنگ آتش[۲]، بهاره صحرائیان[۳]*

۱- کارشناسی ارشد، گروه علوم و صنایع غذایی، مؤسسه آموزش عالی جهاد دانشگاهی کاشمر، کاشمر، ایران.

۲- گروه پژوهشی کیفیت و ایمنی مواد غذایی، پژوهشکده علوم و فناوری مواد غذایی، جهاد دانشگاهی خراسان رضوی، مشهد، ایران.

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* مسئول مکاتبات:

Baharehsahraiyan@yahoo.com

چکیده

قالب‌های غذایی فشرده به انتخاب اول مصرف‌کنندگان به عنوان جایگزینی برای میان‌وعده‌های ناسالم یا منابع انرژی سریع قبل از تمرین تبدیل شده‌اند. با توجه به نیاز روزافزون جامعه به این قبیل فراورده‌ها، هدف از این پژوهش، بررسی تأثیر استفاده از آرد کینوا به صورت خام و فراوری شده (پرک و برشته) و سطوح متفاوت آرد برنج (صفر، ۱۵ و ۳۰ درصد) بر ویژگی‌های فیزیکوشیمیایی (رطوبت، چربی، پروتئین، خاکستر، کربوهیدرات، کالری، حجم مخصوص، رنگ، فعالیت آبی و بافت) و حسی قالب غذایی فشرده بود. نتایج نشان داد که آرد کینوای فراوری شده ضمن بهبود کیفیت فراورده تولیدی منجر به کاهش رطوبت، چربی و فعالیت آبی (بیشترین مقدار بدست آمده ۰/۶ و کمترین مقدار بدست آمده ۰/۳۶ بود) و افزایش خاکستر و سفتی بافت شد و نمونه‌های حاوی آرد پرک کینوا بیشترین مقدار پروتئین (۷/۴۶-۵/۷۴) را داشتند. به علاوه فرآیند پرک کردن موجب کاهش کربوهیدرات و حجم مخصوص و برشته کردن موجب افزایش آن‌ها شد و تأثیر قابل توجهی بر تغییرات رنگ نمونه‌ها داشت. ارزیابی حسی نمونه ها نشان داد حضور آرد کینوای فراوری شده در فرمولاسیون در مقایسه با آرد خام در افزایش پذرش کلی فراورده های تولیدی موثر بود. در نهایت نمونه‌ی تولید شده با آرد پرک کینوا و حاوی ۳۰ درصد آرد برنج با رطوبت ۸/۱۰ درصد، چربی ۵/۹۰ درصد، پروتئین ۵/۷۴ درصد، خاکستر ۰/۷۸ درصد، کربوهیدرات ۷۹/۴۷ درصد و کالری ۳۹۳/۹۷ کیلوکالری در ۱۰۰ گرم ضمن کسب بیشترین امتیاز پذیرش کلی، به عنوان بهترین فرمول انتخاب شد.

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