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Quinoa and Rice Co-products Gluten Free-cereals: Physical, Chemical, Microbiological and Sensory Qualities

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Abstract Quinoa grains and rice co-products (broken grains and bran) can offer good opportunities for the production of nutritious foods without gluten. The aim of this study was to evaluate the physical, chemical, microbiological and sensory characteristics of extruded gluten-free breakfast cereals produced from quinoa and rice co-products. The cereals breakfast were submitted in three different treatments: Caramel (sweet), with addition of caramel colorant before extrusion and glucose syrup after this process; Annatto (salty), with addition of annatto colorant before extrusion and sodium chloride solution after this; and the natural, without addition of colorant and flavoring. Randomized design with the three treatments and three replicates was used to determine the physical characteristics, and randomized blocks for sensory acceptance. Attribute "crispness" was highly rated by the judges for all flavors. There were acceptance of annatto (salty) and caramel (sweet) cereals flavors, indicating the preference of consumers for more pronounced flavors. Content of protein, fiber and lipids in the natural cereal is higher corn, being a good option to meet the daily consumption values. Levels of zinc, copper and manganese supply the values for both adults and children, considering 100g of daily consumption. Obtained amino acid profile was higher than the minimum standard established by FAO/WHO for all essential amino acids except lysine. Production of breakfast cereal from quinoa grains and broken rice bran is viable considering the technological, nutritional, microbiological and sensory aspects.

Keywords: *Chenopodium quinoa Willd, Oryza sativa L., extrusion, acceptance, amino acids*

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1. Introduction

Quinoa (*Chenopodium Quinoa* Willd) is known as a pseudocereal, since it is not a member of the grass family, but from Amaranthaceae family, Chenopodioideae subfamily, which also produces seeds that can be ground and used as flour. The plant is dicotyledonous, annual, sized 0.5-2.0 m tall, with large panicles and seeds with 1.8-2.2 mm long, produced at the top of the shoot. The quinoa grain has nutritional composition with high protein, starch, dietary fiber, minerals, vitamins, essential amino acids and fatty acids content [1].

On the other hand, rice is an excellent source of energy, due to the high starch content, providing also proteins, vitamins and minerals, and has low lipid content. In developing countries, where rice is one of the main foods in diet, it is responsible for providing, on average, 715kcal per capita per day, 27% of carbohydrate, 20% of protein and 3% of lipids in the meals. In its milling process, broken grains 14% and 8% bran are produced, which have lower commercial value in relation to the main product processed rice [2]. However, those by-products can be mixed in order to replenish the nutritional properties removed in the process.

The low intake of fiber, vitamins and minerals is a constant in the population due to the low consumption of fresh vegetables. Several alternatives have been proposed to increase the consumption of these nutrients, including the production of new food items with high nutritional value, and also accessible to economically disadvantaged people. An alternative for this problem is the use of other available ingredients such as quinoa grains, which increases the nutritional value of traditional foods [3], along with low value-added co-products of the rice agro-industry. Thus, diversified products can be elaborated, meeting the specific needs of different groups of consumers. An increased prevalence of celiac disease is a major challenge for food research since it has led to an increased demand for gluten-free products, and the growing need for convenience products of gluten-free cereals such as rice, corn, quinoa and amaranth.

A good option for development of nutrient-rich foods and gluten-free are the extruded breakfast cereals. These have been widely consumed in recent decades and the main method for producing them has been the thermoplastic extrusion. Extrusion is a high temperature and short time (HTST) food and feed processing technique widely used in several industries. This process allows the manufacture of a variety of products with few modifications in the equipment and adequate control of the operational parameters [4]. In general, the extrusion results in starch gelatinization, protein denaturation, formation of complexes between starch and lipids and between and protein and lipids. [4] and [5] showed that extrusion cooking is a very complicated process that the product quality is highly variable depending on the type of extruder, screw speed and configuration, temperature profile on the barrel, die profile, feed rate and feed moisture. These researches also showed that the broken rice grains have a good potential to be used as a new source of starch in producing of high quality extruded, since the extrusion of broken rice grains resulted positive changes in the appearance, aroma, flavor and texture of the final product [4,5].

In this work, it was used broken rice grains and rice bran due to its high energetic value; as a way of appreciation and utilization of rice by-products and because the cost of broken rice grains and rice bran is lower than brown rice. The aim of this work was to evaluate the physical, chemical, microbiological and sensory characteristics of extruded gluten-free breakfast cereals produced from quinoa and co-products of rice processing. It was evaluated three treatments: Natural, Caramel (sweet) and Annatto (salty) flavors, in order to create healthier food choices for breakfast.

2. Materials and Methods

2.1. Raw Materials

Broken rice grains and bran were collected on the day of processing, and donated by the company Arroz Cristal Ltda., located in Aparecida de Goiânia, Goiás, Brazil. The quinoa grain (Chenopodium quinoa Willd.), Quinoa Real brand, originate from Salar de Uyuni, Bolivia, as well as the annatto food coloring, crystal sugar and salt were purchased at a local market in Goiânia, Goiás. The caramel coloring used was BeraColor A (Class IV INS 150d) and was donated by Beraca Company from São Paulo, São Paulo, Brazil. All ingredients were provided as free-gluten.

2.2. Formulation and Processing of Breakfast Cereals

For the production of gluten free breakfast cereal, a basic mixture of broken grains and rice bran (92:8) was used to reconstitute the percentages found in the brown rice grain. Later, from 90 parts of basic mixture and 10 parts of quinoa grain, a mixture was elaborated and extruded to obtain three breakfast cereals (treatments), distinguished by the presence and type of food dye. The breakfast cereal in which not additives were added in its formulation was named natural. The second one was added of 1.12g $100g^{-1}$ of caramel colorant prior to extrusion and 25g $100g^{-1}$of sucrose syrup after the extrusion, and the third one 1.0g $100g^{-1}$of annatto dye prior to extrusion and 10g $100g^{-1}$of NaCl solution after extrusion. A completely randomized design with three treatments and three original replicates was used. The processing conditions of the breakfast cereals were defined in preliminary tests and maintained fixed.

The extrusion was conducted in a single screw equipment (Inbramaq, PQ 30, Ribeirão Preto, Brazil), with screw compression ratio of 3:1, thread feed rate of 350g min^{-1}, opening of the circular array of 4 mm in diameter, helical shirt, temperature in the first, second and third heating zones of 50 °C, 70 °C and 120 °C, respectively, screw rotation of 250 rpm, and 12g 100 g^{-1} of moisture in the extruded mix. The treatments caramel (sweet) and annatto (salty) was flavored with glucose syrup and NaCl solution, respectively, by spraying after the extrusion in order to applicate the sensory test. For every 100g of the final product average of 24.5 mL of solution (NaCl or glucose syrup) was used.

All treatments were dried at 100 °C for 30 minutes, naturally cooled and packed in polyethylene until the analysis.

2.3. Particle Size of Raw Materials

For particle size classification of the raw materials, a shaker apparatus (Granutest, São Paulo, Brazil) was used. The sample (100g) was sieved for 5 minutes in a set of sieves with openings ranging from 0.053 mm to 4.0 mm [6].

2.4. Physical Analyzes of Breakfast Cereals

Water activity (Aw) of the experimental breakfast cereal was obtained at 25 ± 4 °C using a water activity meter (Aqua Lab CX-2, Pullman, USA); the instrumental color parameters (L*, a* and b*) in colorimeter (Color Quest II, Hunter Lab, Reston, USA), where L* (lightness or brightness) varies from black (0) to white (100), a* of green (-) to red (+) and b* from blue(-) to yellow (+). The expansion index (EI) through the quotient between the diameter of the extruded and the diameter of the extruder exit orifice; measuring the volume of millet seed displacement, the specific volume (SV) was calculated by the mass and volume ratio. To carry out the analyses of EI and SV, the breakfast cereals were cut in 30 mm length. The texture analysis of the cereals was performed by measuring friability and hardness, in a texture analyzer (Stable Micro Systems, TA.XT Express, Surrey, England). The samples were uniaxially and individually cut with a guillotine type probe, using 5 mm s^{-1}speed; 20 mm distance; and force of 20 gf. Graphs were generated by recording on line the hardness and friability, using the software Expression 2008 version 1.1.12.0, (Surrey, England). The friability corresponded to the height of the first peak of the graph, and the hardness to the maximum, both at the first cycle of compression. The analyzes of particle size and Aw were performed in triplicate for each sample, while the expansion index, specific volume, friability, hardness and instrumental color parameters were obtained in 10 breakfast cereals randomly collected per sample.

2.5. Proximate Composition of Natural Cereal and Raw Materials

The moisture content of the sample was determined by weight loss, after heated at 105 °C to constant weight; the ash content through carbonization by complete incineration in a muffle furnace at 550 °C; total nitrogen by the Kjeldahl method, multiplying by 6.25 to estimate the crude protein content; lipids, after extraction with petroleum ether in a Soxhlet extractor; and total dietary fiber by enzymatic-gravimetric method; all recommended by AOAC [6]. Carbohydrates were calculated by the difference method, subtracting the humidity, ash, protein, lipids and total dietary fiber from one hundred, and total energy intake following the Atwater conversion values. All analyzes were performed in triplicate.

2.6. Trans, Saturated and Unsaturated Fatty Acids of Natural Cereal and Quinoa Grains

Lipids were extracted by the method of Bligh and Dyer [7]; methyl esters of fatty acids determined by gas chromatography using as internal standard methyl-tridecanoate. The quantification was based on the area ratios of each fatty acid with the area of the internal standard, using the response correction factors of the flame ionization detector and conversion of methyl esters of fatty acids into fatty acid [6]. Gas chromatograph with flame ionization detector (Varian Star 3400 CX, California, USA) was used with a capillary fused silica column chromatography with stationary phase cyanopropylsiloxane, 0.25mm of internal diameter and film thickness of 0.25µm. The column temperature of 45 °C was programmed for 4min, the first slope was 13 °C min^{-1} up to 175 °C (27min), the second slope of 4 °C min^{-1} up to 215 °C (35min) using injector temperature of 220 °C, detector temperature of 220 °C, and sample splitting ratio of 1:50.

2.7. Minerals of Natural Cereal and Quinoa Grains

Minerals (Ca^{2+}, Mg^{2+}, K^{+}, Zn^{2+}, Cu^{2+}, Na^{+}, Se, Mn^{2+} and Fe^{2+}) were quantified by atomic absorption spectrometry (Varian Specter AA 50 B, Midland, Canada), and instrumental parameters (lamp, wavelength, lamp current and slit width) were specific for each nutrient. The analysis was performed according to AOAC Official Method [6] using nitric-perchloric acid digestion.

2.8. Amino Acids of Natural Cereal and Quinoa Grains

The amino acid profile was determined chromatograph (Dionex, DX 300, San Diego, USA) after acid hydrolysis. Samples containing approximately 25 mg of protein were processed following the general recommendations described by [8,9].

2.9. Microbiological Risk

The presence of coliforms at 45 °C, *Salmonella* sp., *Staphylococcus aureus*, *Bacillus cereus*, molds and yeasts was investigated following the procedures described by the Compendium of Methods for the Microbiological Examination of Foods [10]. All analyzes were performed in triplicate

2.10. Acceptance of Breakfast Cereals

The acceptance tests of the experimental breakfast cereals were carried out in laboratory for sensory analysis using individual cabins, illuminated with white light. The samples were served in a balanced way, in small disposable cups, each encoded with three-digit numbers. A panel of 60 consumers of both sexes was recruited for the sensory evaluation of the three grains. A 9-point hedonic scale was used, in which 9 represents"like extremely" and 1 "dislike extremely" score. The acceptance level was previously established as the average grade higher than or equal to six for crispness, flavor and overall rating. The purchase intention was determined with a 5-point structured scale, where 5 represented the maximum "certainly buy" and 1 the minimum score, "certainly would not buy". Random blocks design was used with three treatments (flavors) and 60 blocks (panelists). The study was approved by the UFG Ethics Committee (Protocol 364/11).

2.11. Statistical Analysis

The results were submitted to analysis of variance (ANOVA) and means compared using the Tukey test (P <0.05), using the software Statistic for Windows 7.0.

3. Results and Discussion

Table 1. Particle size of the quinoa grains, broken grains and rice bran (average mass retained on each sieve ± standard deviation)

Tyler	Opening (mm)	Quinoa grains (g $100g^{-1}$)	Broken rice grains (g $100g^{-1}$)	Rice bran (g $100g^{-1}$)
5	4.00	0.01 ± 0.01	0.00 ± 0.00	
9	2.00	0.37 ± 0.04	0.04 ± 0.05	
12	1.41	97.31 ± 0.17	81.55 ± 1.51	
16	1.00	2.26 ± 0.27	17.25 ± 1.62	
24	0.71	0.02 ± 0.03	0.82 ± 0.08	34.15 ± 14.24
Bottom		0.03 ± 0.01	0.34 ± 0.06	
32	0.50			17.48 ± 7.77
60	0.25			43.26 ± 13.15
100	0.15			4.67 ± 0.01
150	0.11			0.32 ± 2.21
270	0.05			0.08 ± 0.21
Bottom				0.04 ± 0.05

Average mass retained on each sieve ± standard deviation.

3.1. Particle Size of Raw Materials

Most quinoa grains were retained between 1.41 and 2.00mm sieve openings, and rice bran between 0.71 and 0.25 mm (Table 1). There was a difference in particle size of rice bran compared to other raw materials; rice bran was 29% lower than the quinoa and rice broken grains. The similarity between the quinoa grain and broken rice facilitated the homogenization of the mixture and the extruder feeding step. Rice bran was added as a strategy to avoid the segregation of particles of different sizes after moisture conditioning. The higher moisture of the mixture components allowed adhesion of the smaller particles of the dye and of the bran to the larger particles of the other materials.

3.2. Physical Analysis of Breakfast Cereals

It was observed that breakfast cereals of bran, and quinoa grain showed water activity values below 0.537 (Table 2) and can be considered microbiologically stable at room temperature.

Table 2. Physical characteristics (mean ± standard deviation) of the experimental breakfast cereals and rice bran with quinoa natural flavor, annatto (salty) and caramel (sweet)

Parameter[a]	Breakfast Cereal		
	Natural	Annatto (Salty)	Caramel (Sweet)
Water Activity	0.53 ± 0.03 [b]	0.50 ± 0.01[c]	0.54 ± 0.01[a]
Lightness	79.67 ± 0.00[a]	73.29 ± 0.01[b]	66.46 ± 0.02[c]
a*	2.00 ± 0.02[c]	6.11 ± 0.02[a]	4.97 ± 0.04[b]
b*	14.40 ± 0.03[b]	18.45 ± 0.02[a]	5.06 ± 0.01
Expansion Index	3.69 ± 0.11[a]	3.56 ± 0.09[b]	2.93 ± 0.15[c]
Specific Volume (mL g^{-1})	11.87 ± 1.54[a]	11.81 ± 2.61[b]	10.64 ± 4.53[c]
Fryability (gf)	2740.2 ± 0.06 [a]	2414.80 ± 0.12 [b]	2320.40 ± 0.15 [c]
Hardness (gf)	4410.7 ± 0.07 [a]	3729.80 ± 0.09 [b]	3419.90 ± 0.11 [c]

[a]Means followed by the same letter in each row did not differ by Tukey test at 5% probability.

The water activity of the cereal with annatto dye (salty) was 5.5% lower than the natural cereal, due to the presence of sodium chloride, which promotes the reduction of water activity. The lightness (L*) values were lower for breakfast cereals with caramel coloring (Table 2), indicating the expected, the caramel was darker than the natural (no colorant). The values of a* and b* were higher for breakfast cereal with annatto color, indicating that the product is redder and yellower than the natural and caramel colored cereal. In general, the color of experimental cereal was appropriate for marketing.

The cereal with no dye had greater expansion, considering EI and SV, followed by cereal with annatto dye. The expansion was lower in the cereal with caramel coloring. It is possible to infer that the caramel and annatto colors negatively interfere into the product expansion ratio. The colorant had an influence in the low extrudate expansion, due to the presence of other components than starch. Similar results with less expansion due to the use of dyes have been reported on rice and orange pulp extruded [11,12]. The experimental breakfast cereals obtained were quite light and with great expansion, desired characteristics for this type of product.

The results for friability and hardness of breakfast cereals indicated significant difference at 5% among sweet, salty and natural. The hardness is a factor that determines the acceptability of the food by the consumer as well as friability, and low values for these parameters are desirable. Despite the higher values of hardness and friability, compared to corn snack [13], yam flour [14] and potato pulp [15], extruded breakfast cereals of broken grains and rice bran with quinoa grain had good acceptance in the attribute crispness in sensory analysis. Lustosa; Leonel; Mishan [16] evaluated cassava flour snacks and casein and observed that conditions of low moisture, low protein and low extrusion temperature provided lower hardness values. The hardness of the extruded products found by these authors ranged from 4.430 gf. to 12.320 gf. The lowest value was 0.5%, 23% and 16% higher than those found in natural breakfast cereals, sweet and salty, respectively.

3.3. Proximate Composition of Raw Materials and Breakfast Cereal of Rice Bran with Quinoa Natural Flavor

The quinoa grains and rice bran are ingredients rich in protein and fiber, providing high value protein and dietary fiber to breakfast cereals (Table 3). Rice bran also contributed to increase the levels of lipids, resulting in higher caloric value. The average composition of *Chenopodium quinoa* real grain from Bolivia, used in this study, is similar to the composition found by [17] for Blanca de Juli variety, from the Andean region of Colombia, for moisture (11.39g $100g^{-1}$), protein (13.96g $100g^{-1}$) and carbohydrate (75.15g $100g^{-1}$). Moisture, protein and ash contents of quinoa grains in the present study were also similar to the values reported by [18] for quinoa flakes from Peru: 11.93g $100g^{-1}$of moisture, 11.73g $100g^{-1}$of protein, and 1.86g $100g^{-1}$ of ashes.

Table 3. Proximate analysis (mean ± standard deviation) of quinoa grains, broken grains and rice bran (dry basis) and the natural flavored experimental

Component	Quinoa grains	Broken Rice grains	Rice bran	Natural Breakfast Cereal
Moisture[a]	11.38 ± 1.34	13.67 ± 0.40	12.16 ± 1.00	10.39 ± 1.12
Ashes[a]	2.24 ± 0.16	0.39 ± 0.10	9.70 ± 0.84	1.30 ± 0.22
Proteins[a]	12.92 ± 0.13	7.90 ± 0.04	14.57 ± 0.22	8.91 ± 0.08
Lipids[a]	2.19 ± 0.03	1.18 ± 0.04	16.42 ± 0.05	2.40 ± 0.06
Total dietary fiber[a]	5.73 ± 0.13	0.66 ± 0.02	10.91±0.21	2.0 ± 0.10
Carbohydrates[a]	71.27	77.20	47.15	75.00
Total energy value[b]	356.40	349.60	394.66	354.00

[a]g $100g^{-1}$; [b]kcal $100g^{-1}$.

The proximate composition of breakfast cereals of quinoa grains and broken grains and rice bran approached basically of starchy foods such as potato flour, with low lipid content [15]. Breakfast cereals, such as rice and wheat have low fiber content (3.5g $100g^{-1}$ and 2.4 g 100 g^{-1}, respectively) [19]. The experimental cereals have higher levels of lipid and protein compared to those extruded only from rice flour of IRGA 417 variety [20], which showed lipid values of 0.24g $100g^{-1}$ and protein of 8.64 g $100g^{-1}$. [13] studying the proximate composition of the extrudate from corn obtained values 7.84g $100g^{-1}$of protein, 0.49 g $100g^{-1}$ of lipid and 0.44 g $100g^{-1}$of dietary fiber, differing from the values in this work 1.07%, 1.91% and 1.56%, respectively. It is explainable since corn *grits* have slightly lower amounts of lipids, proteins and dietary fiber.

The protein content of the experimental breakfast cereals corresponded to 12% of the recommended daily intake for an adult, the lipids to 4% and total dietary fiber to 8%, according to the Institute of Medicine [21]. The corn product obtained by [13] corresponded to 10% of protein, 1% of lipids and 2% of the required dietary fiber. Thus, it can be advantageous to consider the recommendation of the breakfast cereal from by-products of rice, when reconstituted with the composition of whole rice, enriched with quinoa grain, for a diet richer in proteins, lipids and dietary fiber in relation to corn product.

3.4. Trans, Saturated and Unsaturated Fatty Acids of Raw Materials and Natural Breakfast Cereal

There was little difference in fatty acids between the quinoa grain and natural breakfast cereal (Table 4). The trans fatty acids showed minor value for all samples.

Table 4. Total, trans and saturated fatty acids (mean ± standard deviation) of raw materials and natural breakfast cereal, compared with the recommended daily intake (RDI) for children from 4 to 6 years old and adults

	Broken Rice grains	Rice bran	Quinoa grains	Natural Cereal	IDR Children (BRASIL, 2005)	IDR Adult (BRASIL, 2005)
Total fatty acids[a]	1.16 ± 0.01	16.42 ± 0.01	2.18 ± 0.06	2.28 ± 0.01	-	-
Trans fatty acids[a]	0.02 ± 0.00	0.23 ± 0.01	0.03 ± 0.02	0.03 ± 0.05	-	-
Saturated fatty acids[a]	0.38 ± 0.01	4.74 ± 0.04	0.37 ± 0.02	0.65 ± 0.09	-	-

[a]g 100g-1.

According to the RDC 360 Resolution of the Ministry of Health of Brazil [22], the content of trans fatty acid found was not considered significant since it was lower than 0.2 g 100 g^{-1}. Total fatty acids content was also lower than those found for quinoa Blanca di Juli variety, 5.51g $100g^{-1}$, reported by [18]. The lipid content of quinoa grain can vary in the range of 2 to 10g $100g^{-1}$, depending on the cultivation methods [23]. Quinoa grains of this work showed 2.18g $100g^{-1}$of lipids, different from 4.88g $100g^{-1}$ found by [18] in quinoa flakes of the *Chenopodium* variety. These differences could be related to different cultivars, species, varieties, soil, and other factors. However, quinoa has a higher content of unsaturated than saturated fatty acids. This composition becomes important considering that saturated fatty acids raise the blood cholesterol by reducing hepatic receptors and inhibiting plasma removal of LDL, while unsaturated fatty acids exert protective effects and can reduce blood levels of LDL and triglycerides [24].

[25] analyzed commercial snacks of corn *grits* and found values ranging from 19 to 27g $100g^{-1}$of total fatty acid, whereas natural cereal of this study showed only 2.3g $100g^{-1}$of total fatty acid, difference explained by the high amount of vegetable oil or fat that are added in extruded snacks sold in the Brazilian market.

3.5. Minerals of Raw Materials and Natural Breakfast Cereal

There was little difference in minerals between the quinoa grain and natural breakfast cereal, except for potassium, which was found in lower content in the natural breakfast cereal (Table 5).

Table 5. Minerals (mean ± standard deviation) of raw materials and natural breakfast cereal, compared with the recommended daily intake (RDI) for children from 4 to 6 years old and adults

	Broken Rice grains	Rice bran	Quinoa grains	Natural Cereal	IDR Children (BRASIL, 2005)	IDR Adult (BRASIL, 2005)
Iron[a]	2.3 ± 0.0	15.0 ± 0.0	11.9 ± 0.10	7.7 ± 0.5	6.0	14.0
Zinc[a]	7.6 ± 0.0	20.3 ± 0.2	11.8 ± 0.2	13.3 ± 0.56	5.1	7.0
Sodium[a]	18.9 ± 1.0	35.6 ± 0.6	95 ± 0.5	108 ± 0.9		2400.0
Coppe[a]	0.0 ± 0.0	1.2 ± 0.0	10 ± 0.03	6 ± 0.08	440.0	900.0
Manganes[a]	1.4 ± 0.1	18.4 ± 0.2	22 ± 0.1	28 ± 0.6	1.5	2.3
Magnesium[a]	75.5 ± 2.3	570.6 ± 13.9	295 ± 0.9	252 ± 2.6	73.0	260.0
Calcium[a]	235.5 ± 2.1	45.5 ± 0.9	333 ± 2.6	287 ± 3.9	600.0	1000.0
Potassium[a]	212.2 ± 1.1	788.9 ± 3.7	781 ± 5.2	585 ± 6.2		
Selenium[b]	0.0 ± 0.0	0.0 ± 0.0	-	-	21.0	34.0

[a]mg $100g^{-1}$; [b]µg $100g^{-1}$.

Reports of [23] studying quinoa coming from Chile, presented 149mg $100g^{-1}$ of calcium, 250mg 100 $g^{-1}$of magnesium, 4.4mg 100 g^{-1} of zinc,13.2mg $100g^{-1}$of iron and 927mg $100g^{-1}$of potassium, values that differ from those found in this study in 48% lower for calcium, 68% lower for zinc, 41% higher for iron. According to the Recommended Dietary Allowance (RDA) recommended by the Institute of Medicine [21], the required amount to be consumed per day for adults is 14 mg for iron, 7mg for zinc, 900µg for copper, 2.3 mg for manganese, 260 mg for magnesium, 1000mg for calcium and 34µg for selenium. Thus, the amount of zinc, copper and manganese present in the extruded cereal supplies the value to be consumed daily for both adults and children, considering 100g of cereal daily consumption. On the other hand, the iron, sodium, magnesium, calcium and selenium contents are below the recommended RDA for adults and children (Table 5).

3.6. Amino Acid Profile of Raw Materials and Natural Breakfast Cereal

The natural cereal presented proper balance of essential amino acids, compared with the indication of FAO/ WHO [26], for adults (Table 6). Quinoa grains and rice by-products complement the amino acid profile considered as essential and of high biological value. The quinoa grains showed high levels of lysine, usually the limiting amino acid in cereals, and histidine, when compared to the results of [18], for lysine and histidine respectively in rice (0.38g $100g^{-1}$; 0.21 g $100g^{-1}$), wheat (0.26g $100g^{-1}$; 0.20g $100g^{-1}$), and oat (0.37g $100g^{-1}$; 0.21 g $100g^{-1}$). The protein from quinoa grain can be considered of high biological value, since it contained equal amounts of essential amino acids or larger than the daily needs of the individuals. Similar results in 98% were reported by [18], except for isoleucine which presented 0.41g $100g^{-1}$, while this work showed a value of 0.45 g $100g^{1}$.

Table 6. Amino acid profile of raw materials and natural breakfast cereal, compared with FAO/WHO Standard and the profile of essential fatty acids for protein of high biological value

Aminoacid	Broken Rice grains	Rice bran	Quinoa grains	Natural Breakfast Cereal	Standard FAO/WHO (1985)	High biological value protein profile
Aspartic Acid	0.69 ± 0.01	1.31 ± 0.01	1.03 ± 0.01	0.86±0.01	-	-
Glutamic Acid	1.09 ± 0.58	2.39 ± 0.01	1.85 ± 0.01	1.39±0.59	-	-
Serin	0.35 ± 0.01	0.64 ± 0.01	0.48 ± 0.01	0.46±0.01	-	-
Glycine	0.42 ± 0.01	0.90 ± 0.01	0.63 ± 0.01	0.59±0.01	-	-
Histidine	0.17 ± 0.01	0.37 ± 0.01	0.36 ± 0.01	0.25±0.01	0.19	0.17
Arginine	0.70 ± 0.01	1.37 ± 0.01	1.18 ± 0.01	0.93±0.01	-	-
Threonine1	0.33 ± 0.01	0.63 ± 0.01	0.38 ± 0.01	0.46±0.01	0.34	0.35
Alanine	0.44 ± 0.01	0.89 ± 0.01	0.52 ± 0.01	0.54±0.01	-	-
Proline	0.43 ± 0.01	0.79 ± 0.01	0.43 ± 0.01	0.57±0.01	-	-
Tyrosine	0.31 ± 0.01	0.50 ± 0.01	0.39 ± 0.01	0.38±0.01	-	-
Valine1	0.35 ± 0.01	0.62 ± 0.01	0.57 ± 0.01	0.42±0.01	0.35	0.48
Methionine1	0.21 ± 0.01	0.32 ± 0.01	0.23 ± 0.01	0.25±0.01	0.25 (met+cys)	0.26 (met+cys)
Cysteine	0.05 ± 0.01	0.03 ± 0.01	0.09 ± 0.01	0.03±0.01	-	-
Isoleucine1	0.26 ± 0.01	0.44 ± 0.01	0.45 ± 0.01	0.34±0.01	0.28	0.42
Leucine1	0.59 ± 0.01	1.00 ± 0.01	0.69 ± 0.01	0.70±0.01	0.66	0.70
Phenylalanine1	0.36 ± 0.01	0.58 ± 0.01	0.45 ± 0.01	0.43±0.01	0.63 (Phe+tyr)	0.73 (Phe+tyr)
Lysine1	0.25 ± 0.01	0.56 ± 0.01	0.56 ± 0.01	0.33±0.01	0.58	0.51

[a]Sgarbieri (1987) [28].

The natural cereal can be considered of high biological value, although the amounts were below the stipulated for isoleucine, lysine and valine (Table 6). Some amino acids had their value increased after extrusion, such as threonine, alanine and proline. The natural breakfast cereal introduced amino acid profile above the minimum standard established by FAO/WHO for most of the essential amino acids, except for lysine, which averaged 0.33 g $100g^{-1}$, under the minimum value of 0.58g $100g^{-1}$. Compared to the corn breakfast cereal of [27], five essential amino acids were below the minimum recommended by FAO for this product: isoleucine (0,23g $100g^{-1}$); lysine (0.25g $100g^{-1}$); methionine + cystine (0.22 g $100g^{-1}$) and threonine (0.30 g 100 g^{-1}). These results indicated that the natural breakfast cereal of rice with quinoa has a better profile of essential amino acids than the corn cereal. As for the non-essential amino acids, quinoa grain and natural cereal had arginine, glutamic acid, aspartic acid and alanine contents, in free form, which can play an important role in the formation of color and aroma during its roasting [28].

3.7. Microbiological Risk

Natural breakfast cereal, breakfast cereal with salty flavor and breakfast cereal with sweet flavor did not present scores above the limits of current health legislation for thermotolerant coliforms, as well as for other pathogenic microrganisms, that is *Salmonella*, *Staphylococcus aureus*, *Bacillus cereus*. It was also not identified the presence of indications of poor sanitary conditions, molds and yeasts. This result was expected once extrusion can interrupt microbial growth due to the high temperatures reached in the process. In addition, hygienic care was adopted throughout the processing of all formulations of breakfast cereals.

3.8. Acceptance of Breakfast Cereals

In relation to the acceptance, it was observed that the breakfast cereal flavor annatto (salty) reached the highest score for overall rating, flavor, crispness and purchase intent, differing from the other treatment, followed by the caramel flavor (Table 7).

In this study, natural snack obtained the lowest score, differing significantly from the others, not reaching the minimum score of 6.0, which corresponds to "like slightly", for flavor and overall evaluation. For purchase intention, natural snack obtained an average of 2.5, which corresponds to the range between "probably wouldn't buy" and "might buy", indicating that the public prefers foods with more seasoning and more pronounced flavors. In the general comments it was observed that 28% would prefer them added of more spices and aromas, emphasizing both the sweet and salty taste, with comments such as "bland" or "need more seasoning." These characteristics perceived by the panelists could be caused by processing conditions used in the production of snacks of this study, in which there was no use of various industrial condiments typically used in commercial products of maize or other cereals.

All experimental breakfast cereals have been accepted in relation to crispness. It was observed that when texture or crispness does not please the consumers even when other attributes are attractable, the rejection to the food is immediate [29]. In a product without crispness, not even the proper flavor can make it approvable. Most products with low moisture content, baked or extruded, such as breakfast cereals, wafers, cookies, and snacks have a crunchy texture. Crispy products have a low density structure, are brittle, friable and generate loud noise when broken. Thus, the crispness is associated with pleasant textural contrasts of freshness and quality, and its loss is the major cause of consumer rejection and prevent that loss is the greatest interest of the food industry.

Table 7. Scores for acceptance and purchase intention (mean ± standard deviation) of the experimental breakfast cereals of quinoa grains, broken grains and rice bran of natural flavor annatto (salty) and caramel (sweet)

Attribute[a]	Breakfast Cereal		
	Natural	Caramel (Sweet)	Annatto (Salty)
Overall rating	5.00 ±1.80[c]	6.20 ± 1.80[b]	6.50 ± 1.80[a]
Flavor	5.00 ± 2.00[c]	6.20 ± 1.80[b]	6.50 ± 1.80[a]
Crispness	6.50 ± 2.00[c]	6.90 ± 1.80[b]	7.20 ± 1.70[a]
Purchase intention	2.50 ± 1.20[c]	3.10 ± 1.20[b]	3.50 ± 1.20[a]

[a]Means followed by the same letter in each row did not differ by Tukey test at 5% probability.

For the purchase intent (scale 1-5), it was found that the natural cereal obtained the lowest average (between probably wouldn't buy and might buy) and the highest was observed for the extruded cereal of salty rice (between might buy and probably buy), both significantly different. Sweet cereal obtained average of about might buy, indicating that only the salty and sweet flavors, although different, had satisfactory scores for purchase intent and a more acceptable attitude of the judges. Based on these results, the experimental cereal of broken grain and rice bran with quinoa grain of annatto (salty), and caramel (sweet) flavors have been accepted by consumers since both reached average global acceptance, flavor and crispness between scale values "like slightly" and "like moderately", indicating its commercial potential.

4. Conclusion

The breakfast cereals of quinoa grain and rice co-products with dyes obtained less expansion than the natural ones. The content of protein, fiber and lipids in the natural cereal is slightly higher than in the corn, and it is a good option to meet the daily consumption values. The total amount of fatty acids found in raw and final product is low, indicating a good choice for calorie-restricted diets. The amount of zinc, copper and manganese present in the natural cereal supplies the value to be daily consumed for both adult and children, considering 100g of daily consumption. The amino acid profile was higher than the minimum standard established by FAO/WHO for all essential amino acids except lysine. It is feasible the production of the cereal of quinoa, broken grains and rice bran, being a consumer option for gluten intolerant consumers group. The attribute "crispness" was favorably rated by the judges, which is an important attribute for purchase and preference among breakfast cereals. However, only breakfast cereals with annatto (salty) and caramel (sweet) flavors were accepted, and the salty obtained the best score, indicating the preference of consumers for more seasoned cereals with more pronounced flavors.

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