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The development, the chemical composition and the sensory analysis of quinoa bars (*Chenopodium quinoa Willd.*) subjected to different thermal treatments

Desenvolvimento, composição centesimal e análise sensorial de barras à base de grãos de quinoa (*Chenopodium quinoa Willd.*) submetidos a diferentes tratamentos térmicos

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Abstract

Objective: Considering the high nutritional value of quinoa grain, with protein composed by all essential amino acids, this study aimed to develop cereal bars elaborated with this grain after two different thermal processing, to evaluate the chemical composition and to verify the preference between the bars using a sensory analysis. *Material and methods:* The bars were prepared with quinoa submitted to hydration process in water and toasting process. It was performed the chemical composition (moisture, ash, crude fiber, protein, lipids and carbohydrates) of the grains and quinoa bars. The sensory analysis for verification of preference between the bars was performed by hedonic scale of 7 points and purchase intent by 5-point scale. *Results:* The lipid, crude fiber, ash and carbohydrate contents of quinoa grains had variations after thermal processing. Between the bars, there were significant differences in protein, ash and carbohydrates amount. In the sensorial analysis, the bar containing toasted quinoa grains was preferred, with good acceptability index (85%), while the bar containing hydrated quinoa grains presented a lower rate (66.34%), not being accepted, mainly because of its softened texture. The same occurred in purchase intent, which consumers showed that would probably buy the bar elaborate with toasted grains and would maybe buy the bar containing hydrated grains. *Conclusion:* The cereal bar produced with toasted quinoa grains is

the best formulation for product development, which has viability to be commercialized, as it obtained a good acceptability index.

Keywords: Nutritive value. Snacks. Dietary proteins. Food. Chenopodium quinoa.

Resumo

Objetivos: Considerando o elevado valor nutricional dos grãos de quinoa, com proteína composta por todos os aminoácidos essenciais, objetivou-se desenvolver barras de cereais elaboradas com o grão após dois processamentos térmicos, avaliar a composição centesimal e verificar a preferência entre as barras por análise sensorial. *Material e métodos:* As barras foram elaboradas com quinoa submetidas ao processo de hidratação em água e torração. Realizou-se composição centesimal (umidade, cinzas, fibra bruta, proteína, lipídeos e carboidratos) dos grãos e barras de quinoa. Assim como análise sensorial para verificação da preferência entre as barras, por meio de escala hedônica de 7 pontos e intenção de compra por escala de 5 pontos. *Resultados:* Os teores de lipídios, fibra bruta, cinzas e carboidrato dos grãos de quinoa sofreram variações após os processamentos térmicos. Entre as barras houve diferença nos teores de proteína, cinzas e carboidratos. Na análise sensorial, a barra contendo grãos de quinoa torrados foi a preferida, obtendo bom índice de aceitabilidade (85%), enquanto a barra contendo grãos de quinoa hidratados apresentou um índice menor (66,34%), não sendo aceita, principalmente por ter apresentado textura amolecida. O mesmo ocorreu na intenção de compra, em que os consumidores demonstraram que provavelmente comprariam a barra com grãos torrados e talvez comprariam a com grãos hidratados. *Conclusão:* A barra de cereal elaborada com grãos de quinoa torrados é a melhor formulação para desenvolvimento do produto, que apresenta viabilidade para ser comercializado, pois obteve bom índice de aceitabilidade.

Palavras-chave: Valor nutritivo. Lanches. Proteínas na dieta. Alimentos. Chenopodium quinoa.

Introduction

The growing quest by individuals for a healthy lifestyle arouses interest in the development of nutritious products such as cereal bars. This food presents practicality, since it can be consumed anywhere and at any time of day. Besides it has pleasant sensory characteristics.[1] As a result, it can be used as a vehicle for inclusion of the so-called functional ingredients in the consumer market.[2]

Bars are made from a mixture of cereals, constituting some source of vitamins, minerals, fibers, proteins and carbohydrates. Various ingredients can be introduced into the bars with the aim of increasing their nutritional value and bringing greater benefits to consumers' health, with quinoa (*Chenopodium quinoa* Willd.) being one of these components.[3] Quinoa is a pseudocereal of high nutritional importance and the quality of its protein is outstanding, having all the essential amino acids, unlike traditional cereals, which are deficient in such amino acids. Another favorable and differential factor is the absence of gluten-containing proteins. Therefore it can be consumed by (autoimmune disorder) celiac disease patients and used in the production of several foods targeted to this population group.[4,5]

This grain presents in its composition vitamins C, E, B complex, minerals such as calcium, potassium, iron, magnesium, manganese and phosphorus, besides good quality (linoleic and linolenic) isoflavones and lipids, which give quinoa considerable antioxidant properties.[6] The grains also have ecdysteroids, which are the plant secondary metabolites and help in reducing glycemia and cholesterolemia. They present anabolic effects linked to the stimulation of protein synthesis in general.[7]

However, quinoa has on its outer layer glycosides called saponins, which give it a bitter taste. Saponins are easily reduced by wet (cold water washes) or dry (roasting and abrasion) methods.[8]

In Brazil the consumption of quinoa is still limited due to the high cost of the imported grain, the population's lack of knowledge, traditional habits and customs towards other cereals and low availability of cultivars adapted to local conditions.[8] Having this grain some high nutritional content, its use in various products of habitual consumption such as breads, biscuits and cereal bars becomes interesting. In this context, in order to evaluate the acceptance of incorporating some new ingredients into traditional products, it is of utmost importance to perform a sensory analysis.

Sensory analysis consists of an assessment method that can be used to verify food acceptance on the market, through which it is possible to promote the development of new products, taking into account individual consumer preferences. For this, research is conducted specifically directed to the preferences of the target audience in question.[9,10] It is based on the tasters' responses to sensations resulting from stimuli, which leads to the interpretation of the product characteristic properties.[11]

Considering the consumption of cereal bars, the product practicality and the quinoa grain high nutritional value, the objective was to develop quinoa-based cereal bars submitted to different thermal processes (hydration and roasting), its centesimal composition, evaluating changes due to such processes and the preference among cereal bars by sensory analysis.

Materials and Methods

Sample presentation and processing

Quinoa grains samples were commercially purchased in the Brazilian city of Rio Grande, RS. Grains were washed and hand rubbed under running water for 15 minutes to reduce saponins from their outer layer and then oven dried at 40 °C for 12 h.

Afterwards, grains were split into two groups. The first one was hydrated in water (1:2 ratio) at 60 °C for 30 minutes. And the second one was roasted on a heating plate at 140 °C for 7 minutes, at which point they reached a golden color.

Centesimal evaluation of quinoa grains

Analyses of centesimal composition were carried out at Post-Harvest, Industrialization and Grain Quality Laboratory at Brazilian university *Universidade Federal de Pelotas* (UFPel). Hydrated and roasted quinoa grains were evaluated for moisture, ashes, crude fiber, protein, lipids and carbohydrates according to Brazilian institute *Instituto Adolfo Lutz*,[11] presenting raw grains as control.

Development of cereal bars

Quinoa-containing cereal bars were developed in the Faculty of Nutrition Laboratory of Dietetic Technique at *UFPel*. Ingredients used in the preparation were weighed in an electronic scale and are described in Table 1.

Table 1. Cereal bar ingredients based on quinoa. Pelotas, RS, 2014.

Ingredient	Quantity %
Quinoa (hydrated/roasted)	20
Raw quinoa flour	20
Dehydrated peach	5.5
Raisin	5.5
Brazil nut (*Bertholletia excelsa*)	12
Total of dry ingredient	63
Brown sugar	7.5
Glucose syrup	26
Water	3.5
Total binding agents	37

For the development, a mixture consisting of dry ingredients (quinoa grains, quinoa flour, dehydrated peach, raisins and Brazil nuts) was prepared and syrup developed with brown sugar, glucose syrup and water was added, heated in a water bath. This mixture was placed in an aluminum foil pan and subjected to an electric oven with a temperature of 150 °C for 30 minutes. After this process, bars were covered with plastic film and stored refrigerated in the laboratory for one day for sensory analysis.

Centesimal evaluation of cereal bars

Hydrated and roasted quinoa bars were also evaluated for their centesimal composition (moisture, ash, crude fiber, protein, lipids and carbohydrates) according to *Instituto Adolfo Lutz*.[11]

Total energy value (TEV in kcal/100 g) of quinoa bars and grains was obtained by the equation TEV = (C x 4) + (A x 4) + (B x 9), where C: carbohydrates, A: total protein and B: lipids.[12]

Sensory analysis of cereal bars

Sensory analysis of quinoa-containing cereal bars was developed at *UFPel* Faculty of Nutrition Collective Feeding Laboratory by 110 untrained tasters recruited at the site (students, teachers and other employees). For the formulations sensory evaluation, the preference test was used, with a 7-point hedonic scale ranging from 7 – Like Very Much to 1 – Dislike Very Much.[13] The intention to buy the product by the consumer was also verified, using a 5-point scale ranging from 5 – I definitely would buy product to 1 – I definitely would not buy product.

The cereal bars Acceptability Index was obtained by the formula AI (%) = A x 100 / B, where A: the average score obtained for the sample and B: the maximum score given to the sample. The product presenting AI ≥ 70% is considered accepted.[13]

At the time of the test, 10 g of each cereal bar (hydrated grain and roasted grain) were disposed in disposable white plastic dishes identified by random three-digit numbers.

All participants accepted to participate in the evaluation by signing an Informed Consent Form (ICF) previously approved by the Research Ethics Committee (REC) at *UFPel* no. 452476.

Statistical analysis

Results were evaluated in STATISTICA (version 7.0) software using analysis of variance (ANOVA) with significance level of 5% followed by Tukey's test in the processed quinoa grains physicochemical analyses. For the comparison between the physical-chemical analysis means of the cereal bars and sensory evaluation, Student's t-test was used. Frequency testing was used for hedonic scales and purchase intent.

Results

Centesimal composition of grains and cereal bars

Results from the raw quinoa grains centesimal analysis and after the roasting and hydration processes showed a significant difference ($p < 0.05$) in lipid content among the three treatments. Fiber content was significantly lower for roasted grains as compared to hydrated and raw grains since the ash content was lower in the hydrated grains and the carbohydrate grains, higher in the raw grains (Table 2).

Regarding the quinoa-containing cereal bars centesimal composition, the one made with hydrated grains had a significantly higher content of protein compared to the bar made with roasted grains, whereas the ash and carbohydrate content was higher for the bar with roasted grains (Table 2).

Table 2. Centesimal composition (%) on dry basis of quinoa grains before and after processing and roasted and hydrated quinoa cereal bars. Pelotas, RS, 2014.

	Raw grain	Roasted grain	Hydrated grain	p
Protein	13.95 ± 0.55[a]	14.11 ± 0.44[a]	14.54 ± 0.34[a]	0.321
Lipids	4.84 ± 0.37[c]	6.83 ± 0.08[b]	7.57 ± 0.09[a]	< 0.0001
Crude fiber	2.70 ± 0.05[a]	2.26 ± 0.09[b]	2.61 ± 0.14[a]	0.0048
Ashes	2.01 ± 0.14[a]	2.07 ± 0.10[a]	1.68 ± 0.04[b]	0.0065
Carbohydrate	76.51 ± 0.85[a]	74.73 ± 0.66[b]	73.60 ± 0.33[b]	0.0204
Total kcal/100 g	405.34	416.80	420.66	
	Roasted grain cereal bar	Hydrated grain cereal bar		p
Protein	7.24 ± 0.28[d]	10.35 ± 0.83[e]		0.0034
Lipids	11.01 ± 0.40[d]	10.67 ± 0.25[d]		0.2732
Crude fiber	2.50 ± 0.05[d]	2.46 ± 0.16[d]		0.7006
Ashes	2.04 ± 0.02[d]	1.72 ± 0.01[e]		< 0.0001
Carbohydrate	77.20 ± 0.14[d]	74.80 ± 0.82[e]		0.0075
Total kcal/100 g	436.92	436.62		

Results expressed in dry basis (%). Raw grain humidity = 10.08 ± 0.05; roasted grain = 5.87 ± 0.26; hydrated grain = 60.53 ± 0.05; roasted grain cereal bar = 14.35 ± 0.11; hydrated grain cereal bar = 27.55 ± 0.83.

[abc]Means and standard deviation followed by different letters on the same line significantly differ according to analysis by ANOVA followed by Tukey's test ($p \leq 0.05$).

[de]Means and standard deviation followed by different letters on the same line significantly differ according to Student's t-test ($p \leq 0.05$).

Sensory analysis

Sensory analysis was performed with 110 tasters ranging in age from 18 to 57 years and mostly women (85%).

The bar containing roasted quinoa was preferred, obtaining a good Acceptability Index of 85% in relation to the hydrated one, which presented 66.3% of acceptability. This indicates that the bar containing hydrated grains was not accepted, because for this the food must present an index higher than 70%.[13] This result can be demonstrated by the frequency of scores from consumers to each attribute evaluated (color, texture and taste) presented in Figures 1, 2 and 3, respectively. It should be noted that in all attributes the highest scores were concentrated on the bar containing roasted grains, while for the bar containing hydrated grains mainly minor and intermediate scores were attributed. The greatest discrepancy was observed in the texture attribute, in which the bar containing hydrated grains obtained mainly low scores, which concentrated on 'Dislike Moderately' and 'Dislike Slightly' (Figure 2).

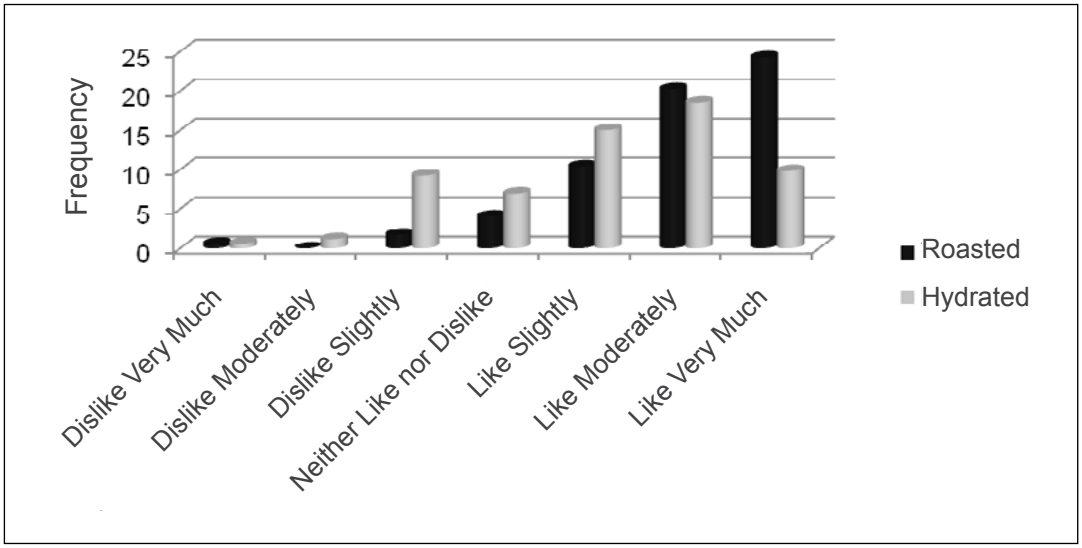

Figure 1. Hedonic values frequency distribution for the attribute cereal bar color containing roasted and hydrated quinoa grains. Pelotas, RS, 2014.

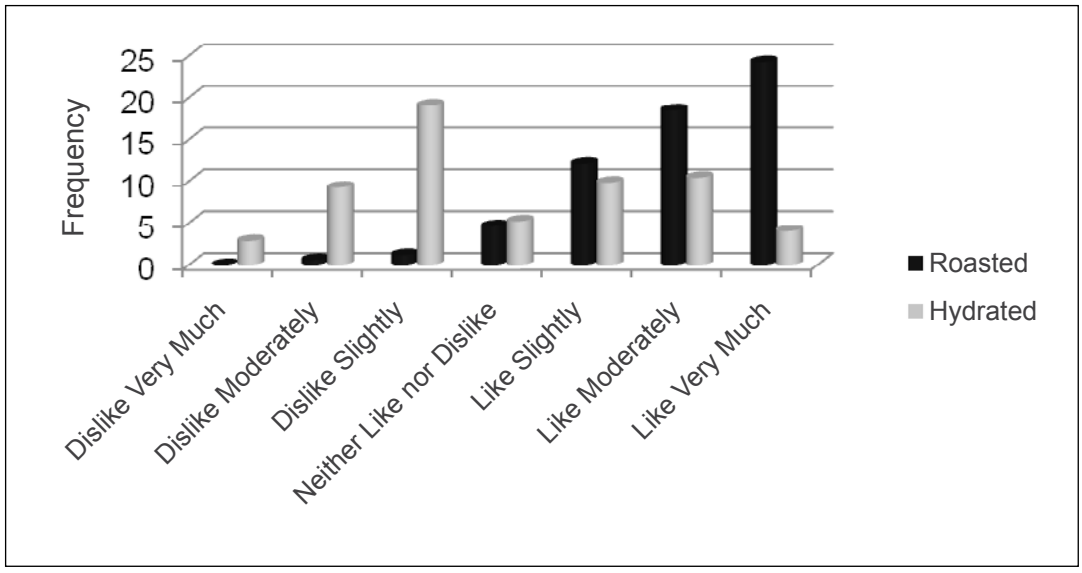

Figure 2. Hedonic values frequency distribution for the attribute cereal bar texture containing roasted and hydrated quinoa grains. Pelotas, RS, 2014.

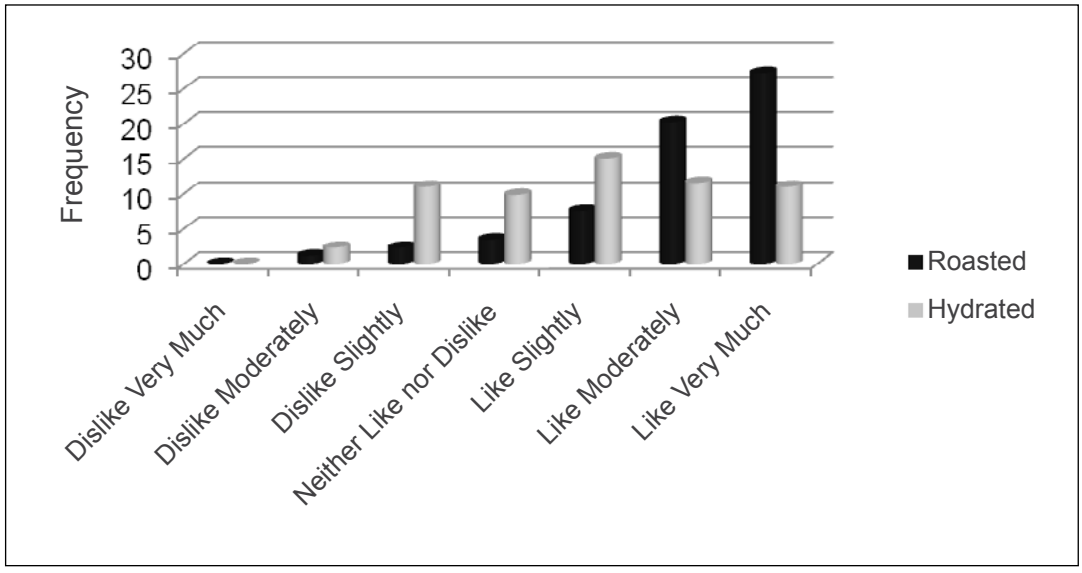

Figure 3. Hedonic values frequency distribution for the attribute cereal bar taste containing roasted and hydrated quinoa grains. Pelotas, RS, 2014.

Cereal bars containing roasted and hydrated quinoa had mean and standard deviation of 4.04 ± 0.94 and 2.83 ± 1.17, respectively, significantly differing from each other ($p < 0.05$). This result indicates that consumers would probably buy the bar made from roasted grains and perhaps buy the one made with hydrated grains, proving their preference for the first one. This can be seen in Figure 4, in which the cereal bar containing roasted quinoa grains received the highest scores, while the one containing moist grains received lower scores.

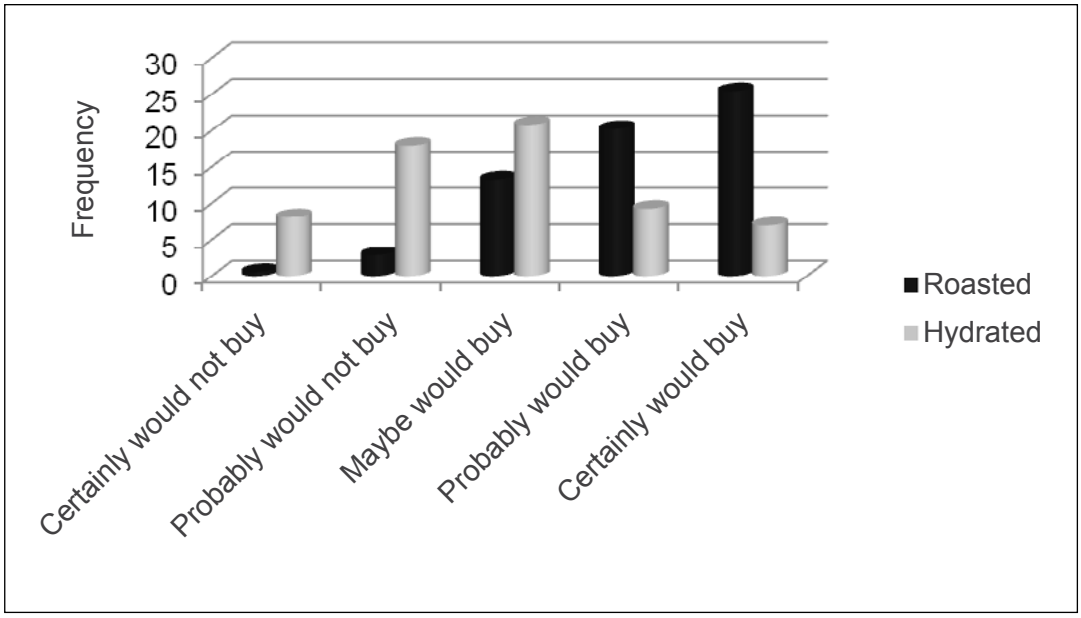

Figure 4. Frequency distribution for intention to purchase the cereal bar containing roasted and hydrated quinoa grain by consumers. Pelotas, RS, 2014.

Discussion

When evaluating the quinoa grains centesimal composition, it is observed that the protein and crude fiber content was not affected by thermal processing. As for the ashes content, it decreased in the hydrated grain, which may have occurred due to the loss of minerals in the hydration water, which was discarded. The lipid content statistically differed between treatments, being higher in the hydrated grain one. This increase in lipid content was also found by Moura et al.[14] in soybean grains subjected to different thermal treatments. It is assumed that this happens due to the change

in the chemical structure of the grain when it undergoes heating, in which the lipid component strongly binds to the starch, expressing it together in the extraction.

As for the cereal bars, the moisture value significantly differed between the bar containing roasted quinoa and the one containing hydrated quinoa. The bar formulated with roasted grains had a relatively low moisture content, being in agreement with the current legislation, which determines humidity for cereal bars lower than 15.0%, whereas the bar containing hydrated grains presented humidity above that established by the legislation.[15] High moisture contents can accelerate the deterioration of the product due to the greater availability of water for chemical and microbiological reactions.

The protein content differed between the two bars, being higher in the one developed with hydrated grains. It may be that at the time of analysis a sample with a higher content of nut was taken, influencing this result, since the processing did not affect the protein content in the grains and the bars were developed with the same ingredients, altering only the processed grain. The protein content of the two bars was higher than that found by Rodrigues et al.[16] in cereal bars marketed in the Brazilian city of Cascavel, PR, which presented on average 5.07% of this nutrient, and similar to the protein content of cereal bars developed with raw quinoa grain and quinoa flour, according to a study by Silva et al.[3] However, it was lower than the protein value found by Baú et al.[17] in cereal bars based on texturized soy protein and oats containing 15.8% protein.

Comparing the samples, the bar containing hydrated quinoa grains had a higher protein content than the bar with roasted grains and a lower ash content due to loss in hydration water. It is worth mentioning that quinoa is the only plant food capable of supplying all the essential amino acids and its protein is compared to casein, a high biological value milk protein.[18] Another positive factor is that the grain is free of gluten, as well as all other ingredients used in the formulation of the bar, and can be consumed by celiac disease patients.[19]

In our study, cereal bars had 40% of their composition based on quinoa. This adds some nutritional and beneficial value to the product, since in the study by Farinazzi-Machado et al.,[20] which used a cereal bar containing 39% of quinoa and evaluated the effect on biochemical, anthropometric and blood pressure profile in persons (parameters of risk factors for cardiovascular diseases), treated during 30 days, a significant reduction in total cholesterol values, triglycerides and LDL-c, indicating that the use of quinoa in food may be considered beneficial in the prevention of these risk factors. This may be due to its vitamin E content, polyphenols, phytosterols and flavonoids, compounds that have an antioxidant capacity and may be related to the reduction of plasma lipids found in these individuals.[21]

By means of the sensory analysis it was observed that the consumers preferred the bar with roasted quinoa, which presented higher scores than the bar with hydrated quinoa in all the

attributes, thus obtaining a good Acceptability Index (85%), while the bar containing grains was not well accepted by consumers (66.34%). In order to be considered accepted, it is necessary that the product obtain an Acceptability Index (IA) of at least 70%.[13] The determinant attribute for the low acceptance of the hydrated bar was texture. This can be proven by the low scores obtained and also by comments left by the consumers in the evaluation sheet, characterizing this bar with "softened texture" and "does not match with cereal bar texture." On the other hand, comments on the roasted bar texture were in general as having a "crunchy texture." In addition, the preference for the roasted bar is proven, which in addition to presenting higher AI, had positive comments also for other attributes such as "presenting better color" and "having a sweet taste."

Compared with other studies, the acceptance of the cereal bar with roasted grains was lower than that found by Silva et al.[3] in bars also containing quinoa (95%). However, it was higher than that verified by Rutz et al.[22] made with peanut and soybean pie, which obtained AI of 77.86%, and by Costa et al.,[23] who found AI of 81.33% for cereal bar based on cassava flour manufacture residue.

Most consumers indicated that they "certainly and probably would buy" the cereal bar developed with roasted quinoa grains but "probably would not buy" or "maybe would buy" the bar developed with hydrated grains, demonstrating that the best formulation for the quinoa bar would be with roasted grains.

Conclusion

Considering the preference and greater intention of purchase of quinoa bar with roasted grains in relation to quinoa bar containing hydrated grains, it is concluded that the formulation containing roasted grain is the most suitable for product development, which is viable for commercialization. The high nutritional content of quinoa, with an emphasis on its protein content, adds quality to this cereal bar, which represents a fast snack option for consumers.

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