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Physical and sensory characteristics of salty cereal bar with different binding agents

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Abstract

The purpose of this study was to evaluate different binding agents for the preparation of salty cereal bars and to characterize them regarding their physical and sensory parameters. Four formulations of cereal bars were developed using collagen, guar gum, xanthan gum and psyllium as binders, which were evaluated for instrumental color and texture. The results of the instrumental analysis revealed that the cereal bars presented characteristic color and crispness for this type of product and the microbiological analyzes ensured food safety. Sensorially, the cereal bars showed good acceptability, especially the bars made with psyllium and xanthan gum binders in the parameters of appearance, texture, flavor and color. The different binders showed technological efficiency in the elaboration of salty cereal bars, but xanthan gum and psyllium were the ones that best corresponded to the expected attributes.

Keywords: cereal bar; binding agents; physical characteristics; sensory characteristics.

Practical Application: Influence of different binding agents in salty cereal bar.

1 Introduction

Cereal bars are a differentiated category of food products and meet various segments of consumers seeking a healthy diet (Carvalho et al., 2011). Cereal bars not only promote health benefits but are palatable and this has favored the development of cereal bars with new ingredients and flavors, including salty taste (Sampaio et al., 2009).

In order to obtain a compact and textured cereal bar, choosing the binder is a major challenge for the industry (Haddad, 2013). The technological characteristics of this food depends on the binder because, besides having nutritional and functional characteristics, they should contribute to the bars have a pleasant texture and no odor and taste, (Fonseca & Srebernich, 2010) in addition to help in the stability and conservation of cereal bars (Leite, 2014).

In the preparation of salty cereal bars, the challenge becomes even greater, since being salty, the sweet taste should be absent. Thus, binding agents such as guar gum, xanthan gum, collagen and psyllium were tested in this study, aiming at meeting all the technological and sensory characteristics of the product.

2 Materials and methods

2.1 Formulation and ingredients

Four salty cereal bar formulations were prepared by applying a completely randomized design (CRD) in three repetitions, in which only the binding agent varied: collagen, guar gum, xanthan gum and psyllium. Binding agents were purchased in powder form from local businesses. The ingredients used as well as their proportions are presented in Table 1.

Salty cereal bars were formulated at the Bakery Laboratory of the Federal Technology University of Paraná, Francisco Beltrão Campus. The dried ingredients were weighed and homogenized for further addition of the binder diluted with water. The masses were arranged in baking sheets lined with aluminum foil, pre-cut and subjected to the cooking process (240 °C for 45 minutes). They were then packaged in aluminum containers and kept in a dry place and free from lighting.

2.2 Physical characteristics (texture and color)

The instrumental texture was performed in TA – XT2I Stable Microsystems Texturometer, where hardness, fracturability and shear were evaluated. For fracturability and hardness, a P/2 cylindrical probe was used and the samples were evaluated as 2-cm cubes, compressing twice to 50.00% of their size, with a compression speed of 4mm/s and a force of 0.1 N. For shear force using the Warner Bratzler blade (HDP/BSW).

Instrumental color analysis was performed via CIELAB system (L*, a*, b*) by colorimeter reading (MOD CR-400/410 Konica Minolta), with illuminant D65 and 10° observation angle. The values of L* (Brightness), a* (Intensity of red color) and b* (Intensity of yellow color) were determined. Saturation Indices (C*) and Tint Angle (h*) were calculated by Equations 1 and 2, respectively:

$$C^* = \left(a^{*2} + b^{*2}\right)^{1/2} \quad (1)$$

$$h^* = \tan^{-1}\left(b^* / a^*\right) \quad (2)$$

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Table 1. Ingredients and percentages (%) used in formulations of salty cereal bars.

Ingredients	F1 (%)	F2 (%)	F3 (%)	F4 (%)
Peanut	29.00	29.00	29.00	29.00
Rice flakes	20.00	20.00	20.00	20.00
Oats	11.00	11.00	11.00	11.00
Sesame	10.00	10.00	10.00	10.00
Cashew nut	10.00	10.00	10.00	10.00
Brazil nuts	6.00	6.00	6.00	6.00
Chia	6.00	6.00	6.00	6.00
Flax Seed	3.00	3.00	3.00	3.00
Collagen	4.00	0.00	0.00	0.00
Guar Gum	0.00	4.00	0.00	0.00
Xanthan Gum	0.00	0.00	4.00	0.00
Psyllium	0.00	0.00	0.00	4.00
Salt	1.00	1.00	1.00	1.00

F1: collagen binding agent; F2: guar gum binding agent; F3: xanthan gum binding agent; F4: psyllium binding agent.

2.3 Microbiological analyses

Total coliforms (at 35 °C), thermotolerant coliforms (at 45 °C), positive Staphylococcus coagulase, presence of Salmonella sp. and Bacillus cereus (Brasil, 2003).

2.4 Sensory analysis

Sensory analysis was performed after project approval, protocol nº 35570314.7.0000.5547 and joint opinion no. 953.480, by the Research Ethics Committee (REC) of the Federal Technology University of Paraná (UTFPR).

The acceptance test (9-point hedonic scale) to evaluate the attributes of overall appearance, color, taste and texture was performed at the UTFPR Sensory Analysis Laboratory, Francisco Beltrão campus, with the participation of 109 untrained tasters (Instituto Adolfo Lutz, 2008).

2.5 Statistical analysis

Color and texture analysis data were analyzed by Anova Analysis of Variance and Tukey Range Test, using Statistica software, version 7.0. (Statsoft Inc., 2005). Sensory analysis data were evaluated by the Shapiro-Wilk Normality Test, followed by the Kruskal Wallis Test at a 5.00% significance level. Principal Component Analysis (PCA) was also performed using Statistic for Windows software (XLSTAT, 2015) and "Action" software (Estatcamp, 2015).

3 Results and discussion

Table 2 presents the results of the instrumental texture profile analysis of salty cereal bars in relation to the parameters of hardness (firmness), fracturability (breaking) and shear (cutting).

In the instrumental texture analysis, the hardness presented values that differed ($p<0.05$) between the formulations and supported the shear force, i.e., the formulation that presented the highest hardness value also presented the highest cut strength, being that the lowest values of these parameters were for the cereal bar added with collagen as a binding agent, the softest among the prepared cereal bars, while the highest values were observed for the formulation with guar gum, the hardest among them.

Table 2. Average values of the texture parameters of salty cereal bars made with different binding agents.

Formulations	Texture parameters		
	Hardness (N)	Fracturability (N)	Shear (N)
F1	11.19 ± 0.60^{d}	2.49 ± 0.38^{b}	19.60 ± 0.31^{d}
F2	55.81 ± 0.45^{a}	3.71 ± 0.11^{a}	47.49 ± 0.71^{a}
F3	21.91 ± 0.21^{c}	3.80 ± 0.46^{a}	27.03 ± 1.00^{c}
F4	35.35 ± 0.54^{b}	2.75 ± 0.08^{b}	38.76 ± 0.75^{b}

N: Newton. The results are average representations of triplicates with the respective estimates of the standard deviation. Values in the same column followed by the same letters do not differ ($p \geq 0.05$). [ANOVA and Tukey's Test]. F1: collagen binding agent; F2: guar gum binding agent; F3: xanthan gum binding agent; F4: psyllium binding agent.

The binders used in formulations F2, F3 and F4 can be classified as polysaccharides, which differs in chemical structure from the binders used in F1 (collagen), and may have implied the lower hardness and shear strength observed for these formulations. This is because, according to what was reported by Dikeman et al. (2006), psyllium and guar and xanthan gums are made up of a highly soluble dietary fiber and may therefore have contributed to the hardness of cereal bars made from such binding agents as compared to F1, for which collagen was used as a binding agent. Following the logic of what Neklyudov (2003) explained, because it is highly soluble in water these polysaccharides are easily solidified with the high temperature used during the cereal bars milling.

Hardness values similar to those found in this study were noted by Sun-Waterhouse et al. (2010) in cereal bars with high levels of dietary fiber (44.05 N to 64.40 N), as well as corroborated the results obtained by Paiva (2008) which produced cereal bars containing rice flour and soy extract residue (11.42 N to 28.53 N).

For shear force, values higher (61.29 N to 62.76 N) than those presented in this research were reported by Sun-Waterhouse et al. (2010) in fiber bars enriched with fiber and phenolic compounds (44.05 N to 60.00 N).

The formulations made with guar gum and xanthan gum accounted for the highest ($p<0.05$) values of fracturability without statistical difference ($p>0.05$). According to Damasceno (2016), hardness is defined as the force required for the compression of food by teeth and is directly related to the property of fracturability, so that the harder the food, the lower the compression force required to break it (fracture). Therefore, the results found in this study do not corroborate the explanation given by the authors mentioned, since the values of fracturability tended to follow the behavior obtained for the hardness of samples, i.e., the higher the hardness, the higher the fracture of sample, and this observation is evidenced mainly in F2 and F4, when these formulations should have the lowest and second lowest fracture values, since they were responsible for the first and second highest hardness values, respectively.

Proportionally, there is a tendency for the sample with higher hardness and lower fracture results to have lower chewability results. This means that, although the food is firm, it does not require much time to disintegrate during its chewing, a characteristic that is essential for cereal bars, since it is sensorially desirable that the product has a rigid texture, but breakable when compressed between the teeth.

Following this line of reasoning, a hard texture and intermediate values for fracturability would be sensorially more interesting for the products elaborated in this study. Thus, there is a need to reformulate the cereal bars to present such characteristics in the final product.

Table 3 provides the color analysis results evaluated for L*, a*, b*, C* and h* of salty cereal bars.

As for the results obtained for parameters that refer to the color of products, it was found that for the coordinate L* formulations F1 and F3 did not have statistical difference ($p>0.05$) between them. The psyllium binder formulation (F4) has been shown to have a darker color (lower lightness) assuming the characteristic of the binder itself.

In studies performed by Paiva (2008) and Silva et al. (2009) the values for L* coordinate were similar to those noted in this study, which varied from 43.93 to 56.3 and 46.4 to 65.0, respectively.

Haddad (2013) who tested starch, gum acacia and collagen on cereal bars found L * values from 25.25 to 28.57, characterizing a darker shade product than the bars developed in this study.

The a* coordinate values (green/red variation) showed no significant difference ($p>0.05$) as a function of the binder used, indicating a tendency to reddish color in all formulations. The values of a* corroborated the values found by Paiva (2008) (5.53 to 6.94) in cereal bars made with agro-industrial by-products. However, Haddad (2013) and Silva et al. (2009) obtained lower values (3.05 to 4.85) and (3.4 to 7.9), respectively, when processing oat-based cereal bars. What differentiates a* values are the ingredients used in each formulation, which tend to be characteristic of the cereals used.

The values of b* did not differ ($p>0.05$) between formulations F3 and F4 and showed a tendency of yellow coloration, which was also observed by Silva et al. (2009) in oat-based cereal bars when b* coordinate values ranged from 18.0 to 22.4.

The saturation index (C*) represents the color purity, where the value is equal to zero (0) in the center of the circle, and increases as it moves away from the center (Konica Minolta, 1998). In the present study, C* values did not differ ($p>0.05$) for F3 and F4 formulations. The values found for C* indicate expressive characteristics in terms of purity and color, since the higher its value the higher the purity or intensity of the color.

The h* values, which indicate the color tone itself, were between 71.44 and 77.50 without significant difference ($p>0.05$) between F1, F2 and F3 formulations. According to Araújo (2013) the h* value is associated with the saturation index (C*) and results in a vector that directs the determination and intensity of the product color.

The National Health Surveillance Agency (Anvisa) recommends for cereal bars the evaluation for the presence of Bacillus cereus, Thermotolerant Coliforms and Salmonella sp. However, for greater safety of the judges were also performed analyzes of total coliforms and positive coagulase Staphylococcus, which results are presented in Table 4.

The microbiological evaluations showed that the four formulations of cereal bars elaborated in this research fit for human consumption and according to the resolution RDC nº. 12/2001 (Brasil, 2001), reason why they could be sent to the sensory analysis. The results of microbiological analyzes of the different elaborated cereal bars are show in Table 4.

Table 5 shows the average scores for taste, color, texture and overall appearance attributes of salty cereal bar formulations through the 109-judge acceptance test.

Sensory analysis corresponds to the product feasibility in relation to the attributes considered determining in the consumer's choice. For the sensory attributes evaluated, the flavor attribute presented the lowest score ($p<0.05$) for the F1 formulation. The presence of polysaccharides as binding agents in F2 and F3

Table 3. Average values of brightness (L*), intensity of red color (a*), intensity of yellow color (b*), saturation index (C*) and shade angle (h*) of salty cereal bars.

Formulations	Color parameters				
	L*	a*	b*	C*	*h
F1	58.29 ± 0.50ᵃ	7.35 ± 0.77ᵃ	27.15 ± 0.56ᵃ	28.09 ± 0.31ᶜ	76.13 ± 0.01ᵃ
F2	56.17 ± 0.48ᵇ	6.13 ± 0.62ᵃ	25.44 ± 0.02ᵇ	26.17 ± 0.12ᵇ	75.90 ± 0.73ᵃ
F3	59.51 ± 0.49ᵃ	5.47 ± 0.88ᵃ	23.01 ± 0.49ᶜ	23.67 ± 0.68ᵃ	77.50 ± 0.93ᵃ
F4	47.61 ± 0.56ᶜ	7.87 ± 0.94ᵃ	22.61 ± 0.45ᶜ	23.96 ± 0.59ᵃ	71.44 ± 0.56ᵇ

The results are average representations of triplicates with the respective estimates of the standard deviation. Values in the same column followed by the same letters do not differ ($p>0.05$). [ANOVA and Tukey's Test]. F1: collagen binding agent; F2: guar gum binding agent; F3: xanthan gum binding agent; F4: psyllium binding agent.

Table 4. Results of microbiological analysis of salty cereal bars.

Microbial groups	ANVISA Specification UFC/g	Formulations			
		F1 UFC/g	F2 UFC/g	F3 UFC/g	F4 UFC/g
Total coliforms	$5.0x10^1$	< 1.0	< 1.0	< 1.0	< 1.0
Thermotolerant coliforms	S.E	< 1.0	< 1.0	< 1.0	< 1.0
Salmonella sp.	-	-	-	-	-
Bacillus cereus	$5.0x10^2$	< 1.0	< 1.0	< 1.0	< 1.0
Staphylococcus*	S.E	< 1.0	< 1.0	< 1.0	< 1.0

ANVISA: National Health Surveillance Agency; UFC/g: Colony forming unit/gram of sample; S.E: No specification; *Positive Staphylococcus coagulase; F1: collagen binding agent; F2: guar gum binding agent; F3: xanthan gum binding agent; F4: psyllium binding agent.

Table 5. Acceptance test results for the attributes evaluated in salty cereal bars.

Formulations	Atributos Sensoriais			
	Taste	Color	Texture	Overall appearance
F1	6.62 ± 1.18[b]	7.32 ± 1.15[ab]	6.18 ± 1.39[b]	7.00 ± 1.44[b]
F2	6.84 ± 1.30[a]	6.75 ± 1.48[b]	6.19 ± 1.67[b]	6.83 ± 1.25[b]
F3	7.23 ± 1.41[a]	6.70 ± 1.66[b]	7.50 ± 1.34[a]	7.22 ± 1.26[ab]
F4	7.14 ± 1.43[a]	7.53 ± 1.08[a]	7.21 ± 1.42[a]	7.50 ± 1.20[a]

The results represent averages of the scores of 109 untrained judges, followed by the standard deviation. Means with the same letters, in the same column, do not show significant difference (p>0.05) by the Kruskal Wallis test. F1: Formulation with collagen binding agent; F2: Formulation with binding agent Goma Guar; F3: Formulation with binding agent Goma Xantana; F4: Formulation with Psyllium binding agent.

formulations may have triggered Maillard reactions, contributing to flavor enhancement of these samples and thus intensifying their flavor compared to F1 (Nunes & Baptista, 2001). Similar scores (6.10 to 7.31) for this attribute were found by Haddad (2013) also in salted cereal bar.

Regarding color, the scores of all formulations were desired. By relating the color analysis instrumentally with the results presented in the acceptance test via analysis by judges, a tendency of the product to be more attractive when cereals have lower L* value pointing to darker and larger a* coordinate values (green/red) pointing to red is noted. Lower scores (5.26 to 6.62) for this attribute were reported by Freitas & Moretti (2006) in high protein and vitamin cereal bars. In turn, Arévalo-Pinedo et al. (2013) obtained higher scores (8.2 to 8.4) when developing and evaluating babassu almond flour-based cereal bars.

For the texture attribute, the highest scores were revealed for formulations F3 and F4 differing ($p<0.05$) from F1 and F2, which presented statistically equal average scores ($p>0.05$).

The formulations that accumulated higher scores for this attribute were made with xanthan gum and psyllium as binder agents, i.e., one with polysaccharides and one with considerable fiber content which may have contributed to the higher CRA and thus implicated in softer and more homogeneous texture (Toneli et al., 2005). This information can be explained by what was said by Fonseca & Srebernich (2010), when they justified that the gums, derived from polysaccharides, promote a short texture without elasticity that remains during storage through water activity control.

Lower values (4.08 to 5.29) of texture were reported by Freitas & Moretti (2006) in functional bars and similar scores

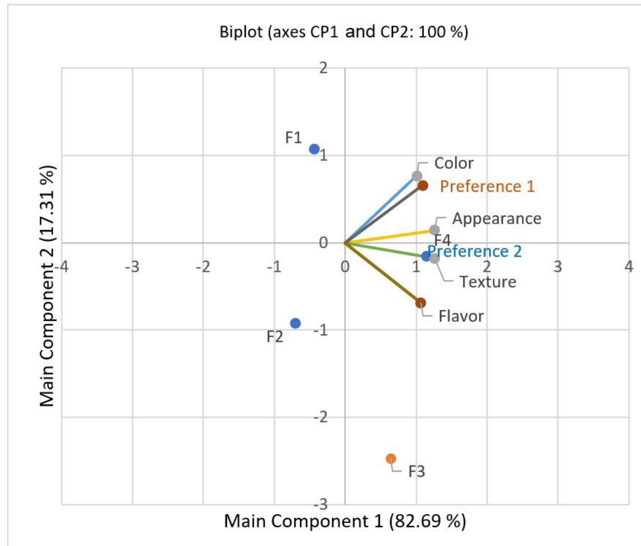

Figure 1. Two-dimensional projection of the Principal Component Analysis (PCA), of the descriptive terms of the samples of salted cereal bars added with chia. F1: Binding agent - collagen; F2: Binding agent - guar gum; F3: Binding agent - xanthan gum; F4: Binding agent – psyllium; CP1: Main Component 1; CP2: Main Component 2.

(6.6 to 7.3) were found by Carvalho (2008) in bars prepared with sapucaia almonds and pineapple peel.

The overall appearance scores corroborate the flavor, color and texture attributes and indicated good acceptance of the salty cereal bars developed in this study. Other research with cereal bars showed similar values, including: Carvalho (2008) with an overall appearance score of 6.2 to 7.1; Haddad (2013), who scored 6.45 and Colussi et al. (2013) with a score of 6.25 to 6.80.

Figure 1 shows the result of Principal Component Analysis (PCA) for the descriptive terms (color, appearance, texture, flavor) of salty cereal bar samples.

In the Principal Component Analysis (PCA), the first component (CP1) preferably contributed with 82.69% of total variance and the second (CP2) with 17.31%, representing the first two factor axes (100.00%) in the total variance.

According to Sodré et al. (2008) if the first two or three components accumulate a relatively high percentage of the total variation, usually above 70.00%, these components satisfactorily explain the variability manifested between the samples evaluated.

In the graphic representation (Figure 1), it is evident that F4 formulation was preferred considering all attributes (taste, color, texture and overall appearance). For the other formulations, preference was given to only one or two of the evaluated attributes, and for formulation F3, texture and flavor appear as a preference trend, while for F1 and F2 formulations, taste and color attributes, respectively, contributed modestly to the preference of tasters.

The results shown by PCA confirm the mean scores obtained for the attributes evaluated individually in each formulation (Table 5), i.e., for the texture attribute, the cereal bars that obtained the highest score were F3 and F4 formulations.

4 Conclusion

Color evaluation by L*, a*, b*, C* and *h coordinates revealed that the use of psyllium as a binder resulted in a color close to traditional cereal bars. The acceptance test results showed that the added formulation of psyllium as a binder had better taste, color, texture and overall appearance characteristics compared to the added formulations of xanthan gum, guar gum and collagen, which took the second, third and fourth place among the best accepted formulations, respectively.

Although the added formulation of psyllium as a binding agent has stood out in this study in most of the analyzes performed, it is suggested to continue the research with reformulation of samples by changing the binding agent percentages to achieve all the expected physical and sensory characteristics for the cereal bar product.

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