Research, Society and Development, v. 9, n. 11, e8269119958, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i11.9958

Technological and nutritional aspects of salted food bars manufactured with different binding agents

Aspectos tecnológicos e nutricionais de barras alimentícias salgadas desenvolvidas com diferentes agentes ligantes

Aspectos tecnológicos y nutricionales de las barras alimenticias saladas desarrolladas con diferentes aglutinantes

Received: 11/05/2020 | Reviewed: 11/09/2020 | Accept: 12/01/2020 | Published: 12/05/2020

Felipe Furtini Haddad
ORCID: https://orcid.org/0000-0001-8134-8305
Federal University of Lavras, Brazil
E-mail: felipe.haddad@ufla.br
Ana Paula Lima Ribeiro
ORCID: https://orcid.org/0000-0002-9368-264X
Federal University of Lavras, Brazil
E-mail: anaplima.com@gmail.com
Camila Teodoro Rezende Picinin
ORCID: https://orcid.org/0000-0002-0621-9770
Federal University of Lavras, Brazil
E-mail: camilatrezende@gmail.com
Maria da Penha Píccolo
ORCID: https://orcid.org/0000-0001-8550-1661
Federal University of Espírito Santo, Brazil
E-mail: penhapiccolo@gmail.com
Maria de Fátima Píccolo Barcelos
ORCID: https://orcid.org/0000-0003-0691-5626
Federal University of Lavras, Brazil
E-mail: piccolob@gmail.com

Abstract

Salted food bars are an alternative in order to reach sugar reduction consumption. The challenge to create this type of bar is to substitute sweet binding agents. This study intended to evaluate the technological and nutritional aspects of salted food bars elaborated with

different concentrations of binding agents (modified starch, hydrolyzed collagen and acacia gum) with low caloric value. The basic ingredients (oats, linseed, soybean, sesame, quinoa, dehydrated tomato, seasonings such as garlic, onion and dehydrated parsley and NaCl) were added to the binding agent solutions. The food bars were analyzed chemically, physically and physicochemically. The results demonstrated that the three binding agents tested presented technical viability of agglutination of the ingredients. The food bars presented high content of dietary fiber, low caloric value, and high mineral (Fe, Zn, Mn and Mg) contents. Cereal bars produced with acacia gum presented higher texture values related to the chewability parameter, which had a positive influence.
Keywords: Acacia gum; Cereal bar; Dietary fiber; Hydrolyzed collagen; Modified starch.

Resumo

As barras alimentícias salgadas são uma alternativa para se atingir a redução do consumo de açúcar. O desafio de criar esse tipo de barra é substituir os agentes ligantes de sabor doce. Este estudo teve como objetivo avaliar os aspectos tecnológicos e nutricionais de barras alimentícias salgadas elaboradas com diferentes concentrações de agentes ligantes (amido modificado, colágeno hidrolisado e goma acácia) de baixo valor calórico. Os ingredientes básicos (aveia, linhaça, soja, gergelim, quinoa, tomate desidratado, temperos como alho, cebola e salsa desidratada e NaCl) foram adicionados às soluções dos agentes ligantes. As barras alimentares foram analisadas química, física e físico-quimicamente. Os resultados demonstraram que os três agentes ligantes testados apresentaram viabilidade técnica de aglutinação dos ingredientes. As barras alimentares apresentaram alto teor de fibra alimentar, baixo valor calórico e alto teor de minerais (Fe, Zn, Mn e Mg). As barras de cereais produzidas com goma arábica apresentaram maiores valores de textura em relação ao parâmetro mastigabilidade, o que teve uma influência positiva.
Palavras-chave: Goma acácia; Barra de cereal; Fibra alimentar; Colágeno hidrolisado; Amido modificado.

Resumen

Las barras alimenticias saladas son una alternativa para conseguir reducir el consumo de azúcar. El desafío de crear este tipo de barra es reemplazar los aglutinantes de sabor dulce. Este estudio tuvo como objetivo evaluar los aspectos tecnológicos y nutricionales de las barras alimenticias saladas elaboradas con diferentes concentraciones de aglutinantes com bajas calorías (almidón modificado, colágeno hidrolizado y goma de acacia). Los ingredientes básicos (avena, linaza, soja, sésamo, quinua, tomate deshidratado, especias como ajo, cebolla y perejil deshidratado y NaCl) se agregaron a las soluciones de los aglutinantes. Las barras alimenticias fueron analizadas con respecto a las propriedades química, física y físico-química. Los resultados mostraron que los tres aglutinantes probados mostraron viabilidad técnica de aglutinación de los ingredientes. Las barras alimenticias mostraron alto contenido de fibra dietética, bajo valor calórico y alto contenido de minerales (Fe, Zn, Mn y Mg). Las barras de cereales producidas con goma arábiga mostraron valores de textura más altos en relación al parámetro de masticabilidad, lo que tuvo una influencia positiva.

Palabras clave: Goma de acácia; Barra de cereales; Fibra dietética; Colágeno hidrolizado; Almidón modificado.

1. Introduction

Cereal bars have gained much popularity in the market. They are widely consumed as a source of protein and bioactive compounds, providing energy in a practical and healthy way for every day (Kaur, Ahluwalia, Sachdev & Kaur, 2018). Commercialization of sweet food bars is common, since sugars act as binder and sweetener. In cereal bars sugar has technological function. The glucose syrup, honey, molasses and brown sugar act as binding agents. These binding agents promote the aggregation of the dry ingredients, help shape the dough and confer high caloric value (Pallavi, Chetana, Ravi & Reddy, 2015).

Despite the technological and sensory functions of sugar in cereal bars, consumers have become more aware of the problems caused by excessive sugar consumption (Pallavi et al., 2015). The high consumption of sugar causes dental cavities, diabetes mellitus, cardiovascular diseases, obesity and hypertension (Manickavasagan, Mathew, Al-Attabi & Al-Zakwan, 2013). Therefore, the demand for reduced sugar supply or sugar free products have increased (Pallavi et al., 2015). Sugar substitutes in cereal bars may have low sensory acceptance and lower shelf life (Su-Ah, Ahmed & Eun, 2017), making the development of these products a challenge for the food industry. Thus, research on new binding agents is important to reduce the caloric content of cereal bars, making these snacks healthier with higher sensorial acceptance.

Salted food bars are an alternative in order to reach sugar reduction goals. The challenge to create this type of bar is to substitute sweet binding agents. These agents aggregate or agglutinate all the basic or dry ingredients, and may be replaced by other agents that provide compact and cohesive dough with lower caloric value (Srebernich, Gonçalves, Ormenese & Ruffi, 2016). To produce salted food bars it is necessary to find ingredients that have the same technological properties as sugar and can interfere positively on the flavor and texture, while having good sensory acceptance by the consumer. An alternative is the use of hydrocolloids, which are extensively applied to restructure foods with low sugar content (Saha & Bhattacharya, 2010).

Hydrocolloids are used in the food industry because they have properties of thickening and gelling agents and low caloric value (Mikuš, Valík & Dodok, 2011). They are able to modify the rheology of food because of their ability to bind with water. This unique property of water uptake is able to eliminate free water, providing unique texture and consistency according to the concentration utilized, stabilizing the shelf life of the food (Saha & Bhattacharya, 2010).

The starch properties of gelling, thickening and aqueous solubility are the preferable characteristics for food processing (Mahmood et al., 2017). The use of modified starch by the food industries is an alternative which has been applied for some time with the purpose of overcoming one or more limitations of common starch (Zhu, 2018) in order to obtain food products with several texture sensations.

Acacia gum (gum arabic) is characterized as soluble fiber that provides adhesive properties, in addition to good stability during storage, decreasing the hygroscopicity in cereal bars (Ali, Maqbool, Ramachandran & Alderson, 2010). Solutions of gum arabic are very low in viscosity, forming solutions with high viscosity at concentrations above 30% (p/p) (Goff & Guo, 2019). It is an almost odorless, tasteless, water-soluble gum, forming a limpid and non-toxic solution. Thus, it can be utilized in food bars, reducing their caloric value (Calame, Thomassen, Hull, Viebke & Siemensma, 2011).

Collagen is a substance in the family of proteins, found in animals, especially in the flesh and connective tissues of mammals (Mohammad, Suhimi, Aziz & Md Jahim, 2014). Since it easily dissolves in water, partially hydrolyzed collagen is very useful in the food industry as it acts as an emulsifier, foaming agent and colloid stabilizer (Gómez-Guillén et al., 2011).

Few studies show the possibility of other non-sugar derivative binders. Tramujas, de Carli, do Prado, Lucchetta and Tonial (2017) showed that the use of collagen, guar gum and xanthan gum in salted cereal bars is an alternative to replace sugar as a binding agent. Srebernich et al. (2016) used acacia gum in cereal bars with the addition of inulin and sorbitol, obtaining the desirable texture and good sensory acceptance.

The food industry faces challenges to design healthier products that resemble the

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i11.9958

conventional concerning physical, physicochemical and sensory characteristics (Simoncello et al., 2020). Thus, the objective of this work was to manufacture salted cereal bars with different concentrations of the binding agents modified starch, hydrolyzed collagen and acacia gum to evaluate 1) the effect of different concentrations of binding agents in the cereal bar through physical, chemical, physicochemical analyzes and 2) consumer acceptance of the salted taste cereal bars with different binding agents.

2. Methodology

The salted food bars were developed and analyzed quantitatively according Pereira, Shitsuka, Parreira and Shitsuka (2018) in relation to the centesimal composition, caloric value, soluble and insoluble dietary fiber, minerals, antioxidant activity, pH, water activity, color and texture profile. The methodologies for each analysis are described below.

2.1 Material

The raw materials utilized in the developing of the food bars were: salted granola containing 50% oats, 25% linseed, 10% soybean, 10% sesame seed and 5% quinoa; partially dehydrated tomato; seasoning (dehydrated garlic, onion and salsa; salt (NaCl)). The.binding agents were: a) acetylation-modified starch (85% carbohydrate fraction, 13% moisture and 2% ash), b) hydrolyzed collagen (93% protein and 7% moisture) and c) acacia gum (86% fiber, 13% moisture and 1% insoluble solids).

2.2 Preparation of cereal bars

Considering the difficulty of finding research on salted cereal bars, the formulations were developed according to pre-tests to stipulate the minimum necessary amounts of binding agents and basic ingredients to obtain a salted cereal bar with a texture similar to sweet cereal bars, however, with low caloric value. The food bars were manufactured by weighing the ingredients, which were: a) basic ingredients (salted granola, partially dehydrated tomato, seasonings and salt) and b) binding agents (modified starch or hydrolyzed collagen or acacia gum) at three different proportions (4.5%, 6.5% and 8.5%) for each agent, aiming to prepare binding solutions, amounting to nine solutions, that is, nine distinct food bars (Table 1).

Table 1. Amounts of the basic ingredients and of the agents utilized in the manufacture of the food bars.

Cereal bars	Binding agente	Concentration (%)	Solution (% in the bar)	Granola** (%)	Dehydrated tomato (%)	Seasoning*** (%)
A	Modified	4.5	70	21	7	0.3
B	Starch	6.5	70	21	7	0.3
C	(MS)	8.5	70	21	7	0.3
D	Hydrolyze	4.5	70	21	7	0.3
E	d Collagen	6.5	70	21	7	0.3
F	(HC)	8.5	70	21	7	0.3
G	Acacia	4.5	70	21	7	0.3
H	Gum	6.5	70	21	7	0.3
I	(AG)	8.5	70	21	7	0.3

* The indicated amount of binding agent was mixed into heated distilled water (95°C/1.5 minutes);
** Granola composed of oats, soybean, quinoa, linseed and sesame seed
*** Seasoning consisting of dehydrated garlic, onion and salsa.
Source: Author (2020).

In Table 1, it is important to observe the variation in the concentrations of binding agents used in the preparation of food bars.

The basic ingredients, previously weighted, were added to the binding solution, for the complete agglutination and homogenization of the dough, under heating, for 1.5 minutes. The dough obtained was cooled at room temperature for 25 minutes and then shaped in rectangular pieces of 10 cm x 3 cm x 15cm, approximately. The bars were placed in a forced ventilation oven for drying at 65°C for 20 hours. The moisture loss of the bars was taken into consideration during the drying period, obtaining the final product with around 25 grams of moisture. After that period, the food bars obtained were packed in transparent plastic polyvinyl chloride (PVC), as the primary package, in addition to aluminum foil (secondary package) and glass containers (tertiary package).

2.3 Physical, chemical and physicochemical analysis

Analyses of centesimal composition (moisture, ether extract, protein, ash and carbohydrates) were carried out in the food bars, according to the AOAC (2005) methods.

Soluble and insoluble dietary fiber according to the AOAC (2005) enzyme gravimetric method. Caloric value, utilizing Atwater conversion factors of 4kcal/g (proteins), 4kcal/g (carbohydrates) and 9kcal/g (lipids), according to Osborne and Voogt (1978) and mineral contents (magnesium, copper, manganese, zinc, iron and sodium), according to methodology described by Malavolta, Vitti and Oliveira (1997).

The analyses of pH was performed utilizing a Schott Handylab digital potentiometer, according to the AOAC (2005), water activity, with use of an Aqua Lab® apparatus, with determination of the dew point on encapsulated mirror (AOAC, 1997). Color was determined by a Minolta colorimeter, Chroma Meter CR-3000 model under the L*a*b* Cielab system, according to the methodology of Bible and Singha (1997).

2.4 Total antioxidant activity

The total antioxidant activity was determined through the DPPH method (Rufino et al., 2007), with adaptations, the results being expressed in Effective Concentration 50% (EC_{50}).

2.5 Texture profile

Texture profile analysis (TPA) was conducted in a texturometer (Stable Micro Systems Model TA-XT2i; Goldaming, England) under the following conditions: pre-test velocity of 1.0 mm/s, test velocity of 1.0 mm/s, post-test velocity of 1.0 mm/s, compression distance of 20.0 mm and with an aluminum cylindrical probe of 6.0 mm diameter (Szczesniak, 1963). The studied parameters were hardness, fracturability and chewability.

2.6 Statistical analysis

The effect of treatment was evaluated by variance analysis, followed by Scott-Knott test, at 5% of significance to identify the differences in significant cases. The variance analyses and the means test were conducted on Sisvar 5.1 Build 72 software (Ferreira, 2011).

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i11.9958

3. Results and discussion

3.1 Centesimal composition, caloric value and soluble and insoluble dietary fiber

Table 2 presents the values of the centesimal composition, caloric value and soluble and insoluble dietary fiber of salted food bars developed with different binding agents at different concentrations.

Table 2. Average values of the centesimal composition, caloric value and dietary fiber of the food bars manufactured with different binding agents (modified starch, MS; hydrolyzed collagen, HC; acacia gum, AG) at different concentrations and respective coefficients of variation.

Cereal bars	Centesimal Composition						Caloric Value (kcal/ 100g)	Dietary Fiber	
	Moisture (%)	Protein (%)*	Lipid (%)	Total Fiber (%)	Ash (%)	NFE (%)**		Sol. (%)	Ins. (%)
4.5% MS (A)	2.82[a]	18.25[b]	12.30[a]	23.72[b]	4.51[a]	38.40[a]	337.37[a]	5.15[b]	18.57[b]
6.5% MS (B)	2.64[b]	17.80[b]	11.32[a]	21.65[b]	4.54[a]	42.05[a]	341.32[a]	4.01[b]	17.64[b]
8.5% MS (C)	2.49[b]	16.64[b]	12.87[a]	19.79[b]	4.56[a]	43.65[a]	357.04[a]	5.02[b]	14.77[b]
4.5% HC (D)	2.60[b]	27.44[a]	13.95[a]	25.17[b]	4.26[a]	26.58[b]	341.69[a]	5.36[b]	19.81[b]
6.5% HC (E)	2.59[b]	29.81[a]	13.14[a]	24.46[b]	4.24[a]	25.76[b]	340.58[a]	3.67[b]	20.79[b]
8.5% HC (F)	3.12[a]	32.59[a]	11.81[a]	23.70[b]	4.22[a]	24.56[b]	334.94[a]	4.02[b]	19.68[b]
4.5% AG (G)	2.45[b]	19.09[b]	11.14[a]	35.07[a]	5.02[a]	27.23[b]	285.62[b]	9.92[a]	25.15[a]
6.5% AG (H)	2.45[b]	17.39[b]	11.93[a]	37.05[a]	4.95[a]	26.23[b]	281.85[b]	12.75[a]	24.30[a]
8.5% AG (I)	2.91[a]	17.28[b]	11.19[a]	39.59[a]	4.80[a]	24.23[b]	270.12[b]	14.37[a]	25.22[a]
CV (%)	5.33	4.48	4.17	8.18	8.19	7.06	3.93	9.31	9.50

Means in the columns followed by equal letters are not significantly different according to Scott-Knott test (p>0.05). (CV% = coefficient of variation).
*% Protein = (%N x 6,25). **Nitrogen free extract (calculated by difference). Source: Author (2020).

According to the previous table, it is observed that the chemical characteristic of each binding agent interfered in the centesimal composition of the cereal bars. A higher amount of protein was found in bars D (27.44%), E (29.81%) and F (32.59%). Bars G, H and I presented higher amounts of total fiber (35.07%, 37.05, and 39.59, respectively), soluble fiber (9.92%, 12.75%, and 14.37% respectively) and insoluble fiber (25.15%, 24.30%, and 25.22, respectively) and lower caloric value, presenting significant difference ($p<0.05$) from the other samples. The nine samples of salted cereal bars presented no significant difference ($p<0.05$) as to lipid content. Regarding calorific value, the food bars containing modified starch (A, B and C) and hydrolyzed collagen (D, E and F) in their compositions showed values between 334.94 and 357.04 kcal /100g of product. The food bars developed with acacia gum presented caloric values between 270.12 and 285.62 kcal/100g of product.

Several food bars have been developed in studies which seek to create or improve ideas which join together practical and nutritive feeding. Studies conducted by Nadeem Rehman, Anjum, Murtaza and Din (2012) and Padmashree, Sharma, Srihari and Bawa (2011), aiming to develop a food bar based on protein concentrates, showed protein contents of the bars between 7.41 and 18.8%. These values are below those found in the food bars developed in the current study, including the bars which do not contain hydrolyzed collagen in their compositions.

Cereal bars with collagen showed high amounts of protein. This result was expected considering that it is the most abundant and ubiquitous protein of animal origin, which comprises approximately 30% of total protein (Hashim, Ridzwan, Bakar & Hashim, 2015). Goméz-Guillén, Giménez, López-Caballero and Montero (2011) stated that, when applied to food, collagen provides characteristics of water binding capacity and gelling behavior, being applied as texturizers. The findings are in accordance with Tramujas et al. (2017), who showed that cereal bars produced with collagen have higher amounts of protein than cereal bars produced with other types of hydrocolloids, such as guar gum and xanthan gum, used as binding agent.

Regarding to fiber, according to the U.S. Dietary Guidelines (2015) the adequate intake for males between 19 and 50 years varies from 25 to 38g of fiber/day. Cruz-Requena et al. (2015) point out that the importance of dietary fiber consumption is related to the proper functioning of the intestinal microbiota, prevention and treatment of body weight control and obesity, like all secondary diseases derived from this condition. However, its intake has been much less than the recommended (King et al., 2012; Fernstrand, Bury, Garssen & Verster, 2017), which increases the importance for providing food products with higher levels of dietary fibers. The fiber content presented by the food bars G, H and I showed that the intake of 25g of this product contributes with 35.04%, 37.04% and 39.56% of the adequate daily fiber intake, respectively, for females between 19 and 50 years old.

Taking into consideration the classification of dietary fiber into soluble and insoluble fiber, it is estimated that for a daily intake of 25g of total dietary fiber, 18.75g should be insoluble fiber and 6.25g soluble fiber. Thus, the same food bars G, H and I contributed with 33.50%, 32.37% and 33.60%, respectively, of the recommended daily intake of insoluble fiber, and with 39.68%, 50.88% and 57.44%, respectively, of the recommended daily intake of soluble fiber.

In studies conducted by Sampaio, Ferreira and Brazaca (2010) with food bars containing rice flakes, flaked oats, corn flakes, dehydrated apple, chocolate, corn syrup, and brown sugar, contents of 6.01% total fiber were found, 2.93% of which being soluble fiber and 3.08% insoluble fiber. These values are much lower than those found in this study, in which the high fiber content of the salted food bars standing out.

Considering a food bar containing 25g, a value usually used by companies producing this kind of food, the bar G (4.5% GA) presents 71.04 kcal, the bar H (6.5% GA) around 70.46 kcal and the bar I (8.5% GA), 67.53 kcal.

Bampi et al. (2016) also developed salted cereal bars containing 340kcal per 25g, a value higher than that in samples of this present study. The values in the findings are well below the caloric values found in sweet food bars developed by other authors. Waterhouse, Teoh, Massarotto, Wibisono and Wadhwa (2010) and Norajit, Gu and Ryu (2011) developed bars with calorific value close to 99 kcal for 25 g of product; Nadeem et al. (2012) 103.66 kcal for 25g of product; Wang, Zhang and Mujumdar (2012) 145.91 kcal to 25g of product; Sung et al. (2014) 119.75 kcal to 25g of product and Timm et al. (2020) developed a high-functional cereal bar with 134.20 kcal to 22g.

Tramujas et al. (2017) concluded that the differences found in the centesimal composition, caloric value and soluble and insoluble dietary fiber suggest that the binding agents influence the composition of the cereal bars. Thus, collagen increased the protein indices in the formulation and hidrocoloids tend to increase total dietary fiber.

3.2 Minerals

The content of copper, manganese, zinc, iron and sodium showed significant differences ($p<0.05$) among the treatments. According to the results, magnesium was the only assessed mineral that revealed no significant difference (p> 0.05) in all four formulations of salted cereal bars prepared with different binding ingredients (Table 3).

Table 3. Average contents of minerals of the salty-tasted food bars manufactured with different binding agents (modified starch, MS; hydrolyzed collagen, HC; acacia gum, AG) and respective coefficients of variation and values of the *Dietary Reference Intake* (DRI) of each mineral for males between 19 and 30 years. DRI= Dietary Reference Intake – Estimated Average Requirement (EAR) *(20)* and Adequate Intake (AI) for males between 19 and 30 years *(21).*

Cereal bars	Minerals (mg mineral / 100g food bar)					
	Mg	Cu	Mn	Zn	Fe	Na
4.5% MS (A)	180[a]	1.23[a]	1.41[b]	3.21[c]	11.45[d]	360[c]
6.5% MS (B)	140[a]	0.91[c]	1.25[c]	3.25[c]	11.85[c]	410[b]
8.5% MS (C)	170[a]	0.71[d]	0.90[e]	3.14[d]	12.06[c]	420[b]
4.5% HC (D)	180[a]	0.63[e]	1.06[d]	3.78[a]	10.58[f]	340[c]
6.5% HC (E)	160[a]	0.46[g]	1.21[c]	2.72[e]	9.92[g]	400[b]
8.5% HC (F)	180[a]	0.32[h]	1.38[b]	3.29[c]	11.12[e]	360[c]
4.5% AG (G)	200[a]	0.57[f]	1.60[a]	3.12[d]	12.41[b]	530[a]
6.5% AG (H)	190[a]	0.71[d]	1.45[b]	3.08[d]	13.37[a]	535[a]
8.5% AG (I)	210[a]	0.97[b]	1.66[a]	3.52[b]	12.50[b]	550[a]
CV (%)	12.91	4.12	2.68	1.43	1.11	5.41
DRI	330[1]	0.70[1]	2.30[2]	9.4[1]	6[1]	1500[2]

Means in the columns followed by equal letters are not significantly different according to Scott-Knott test (p>0.05). (CV% = coefficient of variation). DRI= Dietary Reference Intake – Estimated Average Requirement (EAR) *(20)* and Adequate Intake (AI) for males between 19 and 30 years *(21)*.
Source: Author (2020).

Observing the previous table, it is emphasized that the cereal bar I, containing 8.5% acacia gum, showed the highest mineral levels analyzed. A portion 25g of the this food bar showed 52.5mg of magnesium, 0.24 mg of copper, 0.41 mg of manganese, 0.88 mg of zinc, 3.12 mg of iron and 137.5 mg of sodium. Based on the DRI's, these mineral contents represent 15.9% of the magnesium, 34.3% of the copper, 18% of the manganese, 9.4% of the zinc, 52%

of the iron and 9.2% of the sodium, estimated or appropriate, in the daily intake of males between 19 and 30 years.

The finding regarding sample I may be explained since acacia gum is rich in minerals. Ali, Elkarim, Fageer and Nour (2012) showed that Na, K, Ca, Mg, Mn, Fe, Cu, Zn, Br, Rb, Sr and Zr were presented in 10 types of acacia gum. Lopez-Torrez, Nigen, Williams, Doco and Sanchez (2015) found that the mineral content, on dry basis, of A. *Senegal* is 33.0 and *A. seyal* 40.0 (mg/g).

The food bar I also presented the highest amount of sodium among all the bars developed. However, a food bar of 25g presents 137.5 mg of sodium, which represents 9.2% of the appropriate sodium content in the daily intake of males between 19 and 30 years, showing that this value, associated with a wholesome diet, proves feasible.

3.3 Total antioxidant activity, pH and water activity

The values for total antioxidant activity, pH and water activity of the salted food bars developed are presented in Table 4.

Table 4. Total antioxidant activity (TAA) expressed at EC_{50} (g food bar/g DPPH); pH and water activity of the food bars manufactured with different binding agents (modified starch, MS; hydrolyzed collagen, HC; acacia gum AG) and their coefficients of variation.

Cereal bars	AAT EC_{50} (mg/L)	pH	Water activity
4.5% MS (A)	188.00^{a}	4.75^{c}	0.366^{a}
6.5% MS (B)	186.16^{a}	4.93^{b}	0.373^{a}
8.5% MS (C)	188.66^{a}	4.90^{b}	0.360^{a}
4.5% HC (D)	187.33^{a}	4.90^{b}	0.343^{b}
6.5% HC (E)	185.83^{a}	4.94^{b}	0.336^{b}
8.5% HC (F)	187.33^{a}	5.01^{a}	0.360^{a}
4.5% AG (G)	184.50^{b}	4.83^{c}	0.340^{b}
6.5% AG (H)	184.16^{b}	4.83^{c}	0.346^{a}
8.5% AG (I)	182.16^{b}	4.90^{b}	0.326^{b}
CV (%)	0.57	0.97	4.09

Means in the columns followed by equal letters are not significantly different according to Scott-Knott test ($p>0.05$). (CV% = coefficient of variation).
Source: Author (2020).

According to the Table 4, it is emphasized that the food bars containing acacia gum in their compositions (G, H and I) presented the lowest EC_{50} values, these being of 184.50mg/L for treatment G, 184.16mg/L for treatment H and 182.16mg/L for treatment I. The highest EC_{50} values were presented by samples A, B, C, D, E, F and G, ranging from 184.5 to 188 mg/L, without significant difference ($p<0.05$) between samples.

The ingredients utilized in the manufacture of the food bars, mainly the basic ingredients such as oats, quinoa, soybean, linseed, sesame and dehydrated tomato, are foods which present high antioxidant activity, thus contributing towards the low EC_{50} values in the product. However, binding agents also contribute to product antioxidant activity. Mirghani et al. (2018) showed high antioxidant activity of acacia gum using the methods 2,2-diphenyl-1-picrylhydrazyl (DPPH), Folin-Ciocalteu indexes (FCI), which indicate total phenolic compounds (TPC), oxygen radical absorbance capacity (ORAC), ferric reducing antioxidant power (FRAP), and cupric reducing antioxidant capacity (CUPRAC). Ayaz, Ramadan, Farid and Alnahdi (2017) and Ahmed, Fedail, Musa, Musa and Sifaldin (2016) concluded that acacia gum presents antioxidante activity and may be useful in oxidative stress reduction.

Regarding pH, the highest values were found in the food bars containing hydrolyzed collagen. Some of these values did not present significant difference when compared with the other bars. Possibly, the low amount of binding agent added to the food bars or the closeness of the pH value of each binding agent was not enough of a decisive factor to alter their pH values.

The water activity of bars A, B and C, which contain modified starch and F (8.5% of hydrolyzed collagen) and H (6.5% acaia gum) presented the highest water activity, with no significance difference ($p>0,05$). Aigster, Duncan, Conforti and Barbeau (2011) explained that the increase in water activity in cereal bars containing starch in the formulation is due to the retrogradation of starch molecules resulting in water release.

Water activity measurements help to predict food mechanical properties, stability and shelf life (Rawat and Darappa, 2015).The values of water activity found in the present study (under 0.4) suggests safe food in relation to the growth of microorganisms, considering the ideal Aw for the growth of most microorganisms is above 0.9. Therefore, this is an important parameter which indicates the conditions for the growth of microorganism and the safety of the food for consumer health (Damasceno et al., 2016).

3.4 Color

Table 5 presents the results of the analysis of the color of the food bars. According to the analyses carried out, the manufactured food bars showed no significant difference (p> 0.05) among them in relation to the color parameters L*, a* and b* analyzed.

Table 5. Average values of the color parameters of the salted food bars manufactured with different binding agents (modified starch, MS; hydrolyzed collagen, HC; acacia gum, AG) and respective coefficients of variation.

Cereal bars	Color parameters		
	L*	a*	b*
4.5% MS (A)	28.57[a]	4.63[a]	6.42[a]
6.5% MS (B)	26.74[a]	4.14[a]	6.72[a]
8.5% MS (C)	27.40[a]	3.05[a]	6.92[a]
4.5% HC (D)	27.19[a]	3.18[a]	7.46[a]
6.5% HC (E)	27.02[a]	3.46[a]	7.31[a]
8.5% HC (F)	27,06[a]	3,36[a]	7,18[a]
4.5% AG (G)	26.72[a]	4.85[a]	6.95[a]
6.5% AG (H)	26.53[a]	3.40[a]	7.09[a]
8.5% AG (I)	25.25[a]	3.92[a]	6.70[a]
CV(%)	11.47	14.44	18.34

Means in the columns followed by equal letters are not significantly different according to Scott-Knott test (p>0.05). (CV% = coefficient of variation).
Source: Author (2020).

According to the Table 5, in general, it is important that the salted food bars developed in the current study presented low L* values, which means that they are darker products, closer to black than white. The drying process of the salted bars possibly resulted in products with low luminosity indices, whereas sweet bars developed in several studies, with high L* values, were not subject to the drying process after being manufactured. Studies showed that the value of L* is also affected by level of sweetener in the cereal bar (Sharma & Mridula, 2015), or by ingredients such as pear and wheat bran that may decrease the values of L* (Bchir, Jean-François, Rabetafika & Blecker**,** 2017).

Regarding the parameter a* (green to red), the salted food bars and the bars developed in other studies showed close values and parameter b* (blue to yellow) presented lower values. Waterhouse et al. (2010) found values close to 60.0 for L*, near 5.0 for a* and near 20 for b* in their developed food bars.

3.5 Texture profile analysis

The parameter hardness ranged from 101.76 to 158.03 N and fracturability from 15.19 to 40.70 N. Those parameters presented no significant difference (p>0.05) among the treatments of food bars. Regarding the parameter chewiness, the food bars G, H and I ranged from 10.94 to 12.55 N, and showed significant difference (p <0.05) in relation to the other bars (Table 6).

Table 6. Mean values of the texture profile analysis (TPA) for the parameters of hardness fracturability and chewability performed in the salty-tasted food bars prepared with different binding agents (modified starch, MS; hydrolyzed collagen, HC; acacia gum, AG) and respective coefficients of variation.

Cereal bars	TPA		
	Hardness (N)	Fracturability (N)	Chewability (N)
4.5% MS (A)	154.38^{a}	28.22^{a}	4.48^{b}
6.5% MS (B)	109.20^{a}	40.70^{a}	2.68^{b}
8.5% MS (C)	158.03^{a}	16.46^{a}	4.54^{b}
4.5% HC (D)	132.13^{a}	35.14^{a}	5.95^{b}
6.5% HC (E)	101.76^{a}	15.19^{a}	1.87^{b}
8.5% HC (F)	153.07^{a}	36.30^{a}	4.10^{b}
4.5% AG (G)	144.19^{a}	19.17^{a}	10.94^{a}
6.5% AG (H)	111.92^{a}	29.31^{a}	11.34^{a}
8.5% AG (I)	105.54^{a}	33.88^{a}	12.55^{a}
CV (%)	31.73	59.13	56.17

Means in the columns followed by equal letters are not significantly different according to Scott-Knott test (p>0.05). (CV% = coefficient of variation).
Source: Author (2020).

Texture is an important parameter to be studied since it may influence sensory analyses. Pallavi et al. (2015) showed that cereal bars with low sugar also presented lower overall quality score because of harder texture and reduced chewiness. However, the findings are in accordance with Damasceno et al. (2016), who found that hardness of cereal bars with pineapple peel flour range from 99.60 - 157.95N, and the higher hardness values were related for the cereal bar with higher amount of flour.

Concerning the parameter chewability and according to the results showed in Table 6, the food bars containing acacia gum presented the highest chewability values implying that these bars demand an increased energy potential to be chewed until the point of being swallowed. This result is due to the high amount of fiber presented by the samples G, H and I. Marques et al. (2015) showed that the increase in the amount of total fiber causes an increase in the firmness of cereal bars. This result is related to an increase in the cheweness of the product. Rawat and Darappa (2015) showed that cereal bars with high fiber values have higher chewiness values. On the other hand, the same study showed that the addition of protein decreases the chewiness value, as can be seen in samples D, E and F.

4. Conclusions

The three binding agents tested in this study (modified starch, hydrolyzed collagen and acacia gum) presented technical viability of agglutination of the ingredients. Related to the texture properties, cereal bars produced with acacia gum presented higher chewability values. Also, food bars containing acacia gum presented low caloric value, high content of dietary fiber and minerals such as magnesium, manganese and greater antioxidant power regardless of the concentrations of this binder, increasing the possibility of their use for the same technological purpose in several types of food products. Gum acacia, as a binding agent, stood out in some parameters compared to the other two binding agents of this study.

Further studies should be done to improve the texture of these bars, as well as the addition of flavorings to evaluate sensory acceptance and purchase intent of the product.

Acknowledgments

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) (Finance Code 001) and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG).

References

Ahmed A., Fedail, J. S., Musa, H. H., Musa, T. H. & Sifaldin, A. Z. (2016). Gum Arabic supplementation improved antioxidant status and alters expression of oxidative stress gene in ovary of mice fed high fat diet. *Middle East Fertil. Soc. J*. 21(2), 101-108.

Aigster A., Duncan S. E., Conforti, F. D. & Barbeau, W. E. (2011). Physicochemical properties and sensory attributes of resistant starch-supplemented granola bars and cereals. *LWT-Food Sci Technol*. 44, 2159-2165.

Ali A., Maqbool, M., Ramachandran, S. & Alderson, P. G. (2010). Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (Solanum lycopersicum L.) fruit. *Postharvest Biol Tec*. 58, 42–47.

Ali, N. E. S., Elkarim, A. M. A., Fageer, A. S. H. M. & Nour, A. A. M. (2012). Physicochemical Characteristics of Some Acacia Gums. *Int. J. Agric. Res*. 7(8), 406-413.

Ayaz, N. O., Ramadan, K. S., Farid, H. E. A. & Alnahdi, H. S. (2017). Protective role and antioxidant activity of arabic gum against trichloroacetate-induced toxicity in liver of male rats. *Indian J. Anim. Res*. 51(2), 303-309.

AOAC - Association of Official Analytical Chemists (1997). *Official methods of analysis of the Association of Official Analytical Chemist*. (16a ed.), Washington.

AOAC - Association of Official Analytical Chemists (2005). *Official methods of analysis of the Association of Official Analytical Chemist*. (18a ed.), Washington.

Bampi, G., Backes, G. T., Cansian, R. L., Matos, F. E., Ansolin, I. M. A., Poleto, B. C., Corezzolla, L. R. & Favaro-Trindade, C. S. (2016). Spray Chilling microencapsulation of Lactobacillus acidophilus and Bifidobacterium animalis subsp. lactis and its use in the preparation of savory probiotic cereal bars. *Food and Bioprocess Technology*, 9(8), 1422-1428.

Bchir, B, Jean-François, T., Rabetafika, H. N. & Blecker, C. (2017). Effect of pear apple and date fibres incorporation on the physico-chemical, sensory, nutritional characteristics and the acceptability of cereal bars. *Food sci technol int*. 24(3), 198–208.

Bible, B. B. & Singha, S. (1997). Canopy position influences cielab coordinates of peach color. *Hortscience*. 28, 992-993.

Calame W., Thomassen, F., Hull, S., Viebke, C. & Siemensma, A. D. (2011). Evaluation of satiety enhancement, including compensation, by blends of gum arabic. A methodological approach. *Appetite*. 57:358–364.

Cruz-Requena, M., Aguilar-González, C. N., Prado-Barragan, L. A., da Cunha, M. G. C., Correia, M. T. S., Contreras-Esquivel, J. C. & Rodríguez-Herrera, R. (2016). Dietary fiber: An ingredient against obesity. *Emir J Food Agr*. 28(8), 522-530.

Damasceno, K. A., Gonçalves, C. A. A., Pereira, G. S., Costa, L. L., Campagnol, P. C. B., de Almeida, P. L. & Arantes-Pereira, L. (2016). Development of Cereal Bars Containing Pineapple Peel Flour (Ananas comosus L. Merril). *J. Food Qual*. 39(5), 417-424.

Fernstrand, A. M., Bury, D., Garssen, J. & Verster, J. C. (2017). Dietary intake of fibers: differential effects in men and women on perceivedgeneral health and immune functioning. *J.* Food *Nutr. Res*. 61(1), 1- 7.

Ferreira, D. F. (2011). Sisvar: a computer statistical analysis system. *Ciênc Agrotec*. 35(6), 1039-1042.

Goff, H. D. & Guo, Q. (2019). The Role of Hydrocolloids in the Development of Food Structure, in *Handbook of Food Structure Development*, 1-28.

Gómez-Guillén, M. C., Giménez, B., López-Caballero, M. E. & Montero, M. P. (2011). Functional and bioactive properties of collagen and gelatin from alternative sources: A review. *Food Hydrocoll*. 25, 1813-1827.

Hashim, P., Ridzwan, M., Bakar, J. & Hashim, D. (2015). Collagen in food and beverage industries. *Int. Food Res. J*. 22(1), 1 - 8.

IOM – Institute of Medicine (2005). Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein anda mino acids. Washington (DC): National Academic Press.

Kaur, R., Ahluwalia, P., Sachdev, P. A. & Kaur, A. (2018). Development of gluten-free cereal bar for gluten intolerant population by using quinoa as major ingrediente. *Journal of Food Science and Technology*. 55, 3584-3591.

King, D. E., Mainous, A. G. & Lambourne, C. A. (2012). Trends in diet-ary fiber intake in the United States, 1999-2008. *J Acad Nutr Diet.* 112(5), 642–648.

Lopez-Torrez, L, Nigen, M., Williams, P., Doco, T. & Sanchez, C. (2015). Acacia senegal vs. Acacia seyal gums e Part 1: Composition and structure of hyperbranched plant exudates. *Food Hydrocoll*. 51, 41-53.

Mahmood, K., Kamilah, H., Shang, P. L., Sulaiman, S., Ariffin, F. & Alias, A. K. (2017). A review: Interaction of starch/non-starch hydrocolloid blending and the recent food applications. *Food Biosc*. 19, 110–120.

Malavolta, E., Vitti, G. C. & Oliveira, S. A. (1997). *Assessment of the nutritional status of plants - Principles and applications*. (2a ed.),, Brazilian Potash and Phosphate Research Association.

Manickavasagan, A., Mathew, T. A., Al-Attabi, Z. H. & Al-Zakwan, A. M. (2013). Dates as a substitute for added sugar in traditional foods – A case study with idli. *Emir. J. Food Agric*. 25(11), 899-906.

Mikuš, L., Valík, L. & Dodok, L. (2011). Usage of Hydrocolloids in Cereal Technology. *Acta Univ. Agric. et Silvic. Mendel. Brun*. 35(5), 325-334.

Mohammad, A. W., Suhimi, N. M., Aziz, A. G. K. A. & Md Jahim, J. (2014). Process for Production of Hydrolysed Collagen from Agriculture Resources: Potential for Further Development. *Res. J. Appl. Sci*. 14(12), 1319-1323.

Nadeem, M, Rehman, S. U., Anjum, F. M., Murtaza, M. A. & Din, G. M. U. (2012). Development, Characterization, and Optimization of Protein Level in Date Bars Using Response Surface Methodology. Sci. *World J*. 1, 1-10.

Norajit, K., Gu, B. J. & Ryu, G. H. (2011). Effects of the addition of hemp powder on the physicochemical properties and energy bar qualities of extruded rice. *Food Chem*. 129:1919–1925.

Osborne, D. R. & Voogt. P. (1978). *The analysis of nutrient in foods*. London: Academic, 47, 156-158.

Padmashree, A., Sharma, G. K., Srihari, K. A. & Bawa, A. S. (2011). Development of shelf stable protein rich composite cereal bar. *J Food Sci Technol*. 49(3), 335–341.

Pallavi, B. V., Chetana, R., Ravi, R. & Reddy, S. Y. (2015). Moisture sorption curves of fruit and nut cereal bar prepared with sugar and sugar substitutes. *Journal of Food Science and Technology*, 52(3), 1663-1669.

Pereira A. S., Shitsuka, D. M, Parreira, F. J. & Shitsuka, R. (2018). *Metodologia da pesquisa científica*. [e-book]. Santa Maria. Ed. UAB / NTE / UFSM. Recuperado de https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_Computacao_Metodologia-Pesquisa-Cientifica.pdf?sequence=1.

Rawat, N. & Darappa, I. (2015). Effect of ingredients on rheological, nutritional and quality characteristics of fibre and protein enriched baked energy bars. *J Food Sci Technol*. 52(5), 3006–3013.

Rufino, M. S. M., Alves, R. E., Brito, E. S., de Morais, S. M., Sampaio, C. G., Pérez-Jiménez, J. & Saura-Calixto, F. D. (2007). Scientific methodology: determination of the total antioxidant activity in fruits by capturing the free radical DPPH. Brasília: *EMBRAPA. Technical Communication*, 128, 12.

Saha, D. & Bhattacharya, S. (2010). Hydrocolloids as thickening and gelling agents in food: a critical review. *J Food Sci Technol* . 47(6), 587–597.

Sampaio, C. R. P., Ferreira, S. M. R. & Brazaca, S. G. C. (2010). Physico-chemical characterization and composition of iron-fortified cereal bars. *Alim. Nutr*. 21, 607-616.

Sharma, M. & Mridula, D. (2015). Development and quality evaluation of maize-based fortified nutritious bar. *Agric res*. 4(1), 93–101.

Simoncello, B. A., Maia, C. J. S., Monteiro, R. S., Santos, O. D. H., Gandra, K. M. B. & Pereira, P. A. P. (2020). Evaluations of the Physical and Physicochemical Properties and Perception of Liking of Conventional and Low-Calorie Orange Jellies. *JBFS*. 7(3), 1-12.

Srebernich, S. M., Gonçalves, G. M. S., Ormenese, R. C. S. C. & Ruffi, C. R. G. (2016). Physico-chemical, sensory and nutritional characteristics of cereal bars with addition of acacia gum, inulin and sorbitol. *Food Sci. Technol*. 36 (3).

Su-Ah, J., Ahmed, M. & Eun, J. B. (2017). Physicochemical characteristics, textural properties, and sensory attributes of low-calorie cereal bar enhanced with different levels of saccharin during storage. *Journal of Food Processing and Preservation*. 42 (2), e13486.

Sung, Y. Y., Kimb, S. H., Kima, D. S., Parka, S. H., Yooc, B. W. & Kim, H. K. (2014). Nutritional composition and anti-obesity effects of cereal bar containing Allium fistulosum (welsh onion) extract. *J. Funct. Foods*. 6, 428 – 437.

Szczesniak, A. S. (1963). Objective measurement of food texture. *Food Sci*. 28, 410–420.

Timm, T. G., de Lima, G. G., Matos, M., Magalhães, W. L. E., Tavares, L. B. B. & Helm, C. V. (2020). Nanosuspension of pinhão seed coat development for a new high-functional cereal bar. *J Food Process Pres*. e14464.

Tramujas, J. M., de Carli, C. G., do Prado, N. V., Lucchetta, L. & Tonial, I. B. (2017). Assessment of nutritional and lipid quality of salted cereal bars prepared with different binding agents. *Rev. Chil. Nutr*. 44(4), 350–359.

U.S. Department of Agriculture (2010). Dietary Reference Intake. Food and Nutrition Information Center.

U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015). *2015 – 2020 Dietary Guidelines for Americans*. (8a ed.),. Recuperado de https://health.gov/our-work/food-and-nutrition/2015-2020-dietary-guidelines/.

Wang, Y., Zhang, M. & Mujumdar, A. (2012). Mujumdar. Influence of green banana flour substitution for cassava starch on the nutrition, color, texture and sensory quality in two types of snacks. LWT. *Food Sci Technol*. 47:175-182.

Waterhouse, D. S., Teoh, A., Massarotto, C., Wibisono, R. & Wadhwa, S. (2010). Comparative analysis of fruit-based functional snack bars. *Food Chem*.119:1369–1379.

Zhu, F. (2018). Modifications of starch by electric field based techniques. *Trends in Food Science and Technology*. 75, 158-169.

Percentage contribution of each autor in the manuscript

Felipe Furtini Haddad – 40%

Ana Paula Lima Ribeiro – 15%

Camila Teodoro Rezende Picinin – 15%

Maria da Penha Píccolo – 15%

Maria de Fátima Píccolo Barcelos – 15%