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Assessment of nutritional and lipid quality of salted cereal bars prepared with different binding agents

Evaluación de la calidad nutricional y lipídica de barras de cereales saladas preparadas con diferentes aglutinantes

ABSTRACT

The aim of this paper was to assess the nutritional and lipid quality of salty cereal bars prepared using different binding agents. The experiment consisted of preparing four cereal formulations with four different binding agents (collagen, guar gum, xanthan gum and psyllium). The physicochemical characteristics and main minerals of the bars were assessed to determine the nutritional value, atherogenic index and thrombogenic index. The ratios between hypocholesterolemic and hypercholesterolemic fatty acids were determined to assess the lipid quality of the product. The results show that the bars have considerable lipid content, carbohydrates, protein, fiber and energetic value. The atherogenic index, thrombogenic index, and ratios between hypocholesterolemic and hypercholesterolemic fatty acids for all the formulations had good lipid quality, which indicates that the bars are a healthy food alternative.

Key words: Cereal bars; binding agent; nutritional value; lipids; quality foods.

RESUMEN

Este estudio tuvo por objetivo elaborar barras de cereales saladas, utilizando diferentes agentes de unión y evaluar su calidad nutricional y lipídica. Para ello se elaboraron cuatro formulaciones de barras de cereales alterando solamente los agentes de unión (colágeno, gomaguano, goma xantana y psyllium). En las barras de cereales desarrolladas se evaluó las características físico-químicas y principales minerales para determinar el valor nutricional y los índices de aterogenicidad (IA), trombogenicidad (IT) así como las razones entre ácidos grasos hipocolesterolémicos e hipercolesterolémicos (HH) para verificar la calidad lipídica del producto. Las barras desarrolladas presentaron considerables contenidos de lípidos, carbohidratos, proteína, fibras y valor energético. El perfil de ácidos grasos así como los índices de aterogenicidad (IA), trombogenicidad (IT) y razones entre los ácidos hipocolesterolémicos e hipercolesterolémicos (HH) mostraron para todas las formulaciones una buena calidad lipídica indicando una

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alternativa de alimento sano y diferenciado.

Palabras clave: Barras de cereal; agente de unión; valor nutricional; Lípido; comida de calidad.

INTRODUCTION

Cereal bars are quick, practical, and consumer-friendly food options¹. Preparation considers the choice of cereal, selecting the appropriate carbohydrates, enriching with nutrients and evaluating the stability in processing², with the target of obtaining good nutritional value, such as high fiber and low fat, with high energy³.

Currently the production of bars seek to meet specific segments of the consumer market, such as cereal bars with added vitamins and minerals; bars for diabetics; bars that help combat the osteoporosis, among others⁴.

The ingredients in a cereal bar must be combined to ensure taste, texture and specific physical properties⁵. These ingredients are often divided into three groups: dry ingredients, binders and coating compounds⁶.

A large variety of ingredients can be used in the elaboration of cereal bars. Often these foods are composed of a mixture of cereals, nuts and dried fruits, with oats being the most commonly used cereal^{7,8}. These ingredients must be combined appropriately so as to complement each other, obtaining desired characteristics for the final product⁸.

Cereal bars are normally prepared with syrup, usually glucose, honey or brown sugar, as a binding agent, which also provides the sweet taste and high caloric value⁹. Salty cereal bars require other binding agents that add value to the bars without the sweet taste, while maintaining a pleasant texture¹⁰. The binding ingredients that can be used to agglutinate the ingredients of salted cereal bars include guar gum, xanthan gum, hydrolyzed collagen, and psyllium.

Guar gum is a polysaccharide that is widely used as a thickening agent in the pharmaceutical industry, and as a binder, thickener, disintegrating and stabilizer in the food industry¹¹. Its main feature is the ability to hydrate quickly in cold water and reach high viscosity¹². Guar gum has wide applications in food products such as instant foods, ice cream and sauces among others¹³.

Xanthan gums are exopolysaccharides that have the ability to form gels and viscous solutions in aqueous medium. Xanthan gum is a food additive that is used as a thickener, stabilizer, emulsifier and foaming agent in the food (dry mixes, frozen foods, soups and desserts)¹⁴, pharmaceutical, chemical, and petrochemical industries^{15,16} due to its considerable rheological properties.

Collagen is a fibrous protein found in animal tissue and it contains peptide chains of the amino acids glycine, proline, lysine, hydroxylysine, hydroxyproline, and alanine. It also has unique mechanical properties, such as chemical inertness, an unusual composition of amino acids and the ability to turn into gelatine^{17,18}. In addition to use in food (additives in sausages and meats for increased shelflife¹⁹, this protein is commonly used in the pharmaceutical and biomedical industries because it is easily accessible, inexpensive, biodegradable, biocompatible, and has good plasticity and elasticity²⁰.

Psyllium is a polysaccharide extracted from the epidermis of the seeds of *Plantago ovata*. It is, along with guar gum and xanthan gum, from a species of highly soluble dietary fibers²¹. In addition to its excellent technological properties, psyllium is the only viscous fiber that resists total fermentation through bowel transit²², and is considered beneficial to health. This fiber can prevent constipation, diseases such as diabetes, hypercholesterolemia, irritable bowel syndrome, atherosclerosis, hemorrhoids, and ulcerative colitis, and helps with weight loss²³. In foods it has shown prebiotic effects and has been used in yogurts²⁴.

The ingredients used to prepare salty cereal bars also play an important role in the nutritional quality of the final

product. Cereals like oats, sesame seeds, rice flakes, chia, flax, peanuts and cashew or Brazil nuts are used for their numerous beneficial effects on consumer health. These benefits include reduced cholesterol levels^{25,26} (sesame); improved functioning of the nervous system²⁷ (sesame); controlled blood sugar and body weight²⁸ (sesame; oats; linseed); natural antioxidant properties²⁹ (chia; rice flakes; Brazil nuts); source of essential fatty acids (flaxseed and chia)^{30,31}; and protection against degenerative and cardiovascular diseases³² (linseed), and cancer³³ (linseed; cashew nuts).

In order to meet the needs of selective consumers who seek healthy, sugar-free foods, the aim of this paper was to prepare salty cereal bars with different binding agents and assess the nutritional and lipid quality of the final product.

MATERIALS AND METHODS

Raw Materials

Preparation of the salted cereal bars consisted of a fully randomized design with four treatments and three repetitions, where only the binding agents varied, namely collagen, guar gum, xanthan gum and psyllium. The binding ingredients in the form of powder of vegetable origin (guar gum and psyllium) and animal origin (xanthan gum and collagen) were purchased in local retail stores. Table 1 shows the ingredients of the four different formulations.

For each formulation, the dry ingredients were weighed and homogenized for the subsequent addition of the binding agent diluted with water. The binding agent was previously tested in formulations with different percentages to calculate the appropriate amount (4.00%) to use in this study. The obtained masses were placed in metal molds, covered with aluminum paper, pre-cut and heated in a conventional oven at 240 °C for about 45 minutes and then cooled to 20 °C. Each elaborated bar presented an approximate mass of 25 grams/unit, were 9.00 cm long, 2.00 cm wide and 1.00 cm thick. After cooking and cooling, the bars were wrapped individually in aluminum and in aluminized packages, being sealed and stored at 20 °C in a room protected from light and humidity until analyses.

Physicochemical Analysis

For the physicochemical characterization of the samples, lipids levels³⁴; moisture and total ashes³⁵; protein³⁶; crude fiber³⁷ and carbohydrates³⁸ were analyzed. The caloric value was obtained by means of mathematical calculations based on the methodology proposed by Merrill and Watt³⁹. The Atwater factors were used to calculate the percentages of proteins, lipids, carbohydrates, and total fibers: 4.0 Kcal g⁻¹; 9.0 Kcal g⁻¹; 4.0 Kcal g⁻¹, and 2.0 Kcal g⁻¹, respectively.

To determine the profile of fatty acids, lipids were extracted according to method N° 996.06 of the AOAC⁴⁰ and the fatty acid methyl esters were prepared according to AOAC⁴¹.

Fatty acid methyl esters were separated using a Varian gas chromatograph model 3900, equipped with a flame ionization detector and a workstation with STAR software,

Table 1
Formulation of the salted cereal bars

Ingredients (%)	1 Formulation	2 Formulation	3 Formulation	4 Formulation
Peanut	29.0	29.0	29.0	29.0
Rice flakes	20.0	20.0	20.0	20.0
Oat flakes	11.0	11.0	11.0	11.0
Sesame	10.0	10.0	10.0	10.0
Cashew nut	10.0	10.0	10.0	10.0
Brazil nuts	6.0	6.0	6.0	6.0
Chia	6.0	6.0	6.0	6.0
Linseed	3.0	3.0	3.0	3.0
Collagen	4.0	0.0	0.0	0.0
Guar gum	0.0	4.0	0.0	0.0
Xanthan gum	0.0	0.0	4.0	0.0
Psyllium	0.0	0.0	0.0	4.0
Sodiumchloride	1.0	1.0	1.0	1.0

a split injector and split ratio of 75:1. The adopted capillary column was ZB-WAX 60 m long with an internal diameter of 0.25 mm and a film thickness of 0.25 μ m. The chromatographic conditions were as follows: setting temperature of the column starting at 60 °C for 2 minutes, rising to 160 °C in a range of 3 °C per minute, remaining at this temperature for 20 minutes, and 240 °C from 31 to 70 minutes. Hydrogen was used as the carrier gas, at a flow rate of 2 mL/min, and nitrogen was used as the makeup gas, at 25 mL/min, with an injector temperature of 270 °C, a detector temperature of 300 °C, and an injector volume of 1 μ L.

The fatty acids were identified by comparing the retention time of the fatty acids from the samples with known standards. Thirty-seven standards of methyl esters of fatty acids were used (Supelco IM 37 Component fatty acid methyl esters Mix-Sigma-Aldrich) and quantified by normalizing the area.

To analyze the main minerals (calcium, copper, iron, phosphorus, magnesium, potassium, zinc, and sodium), the samples were incinerated⁴¹ and subsequently subjected to a flame atomic absorption spectrophotometry using a Varian Thetron AA5 spectrophotometer, with the exception of phosphorus that was calculated using a Varian DMS 100 UV-VIS spectrophotometer.

Statistical Analysis

The results of the analyses of moisture, ash, proteins, lipids, carbohydrates, fiber (triplicate analyses), minerals, and fatty acids profile (duplicate analyses) were analyzed using one-way analysis of variance (ANOVA) and the Tukey test with Statistica version 7.0⁴², after verifying the normality of data with the Shapiro-Wilk test.

RESULTS

Table 2 shows the results of the proximal composition and caloric value the cereal bars prepared with different

binding agents. Of the parameters evaluated, carbohydrate and lipids presented larger percentages, followed by the protein, reflecting a considerable amount of caloric value.

Table 3 shows composition, sum and ratios of fatty acid, as well as lipid quality indexes. The composition of fatty acids presented principally unsaturated fatty acids, reflecting in high ratio of PUFA/SFA. N-6 fatty acids also had higher percentages compared n-3, causing a high n-6/n-3 ratio and lipid quality indexes presented low values for AI and TI and high values for HH.

Table 4 shows the main minerals found in cereal bars elaborated with different binding agents. The minerals that presented higher concentrations were sodium, potassium, phosphorus, magnesium and calcium.

DISCUSSION

Table 2 shows the mean values of the respective standard deviations for the proximal composition and caloric value of the salted cereal bars made with different binding ingredients.

Moisture is one of the most important measurements used in food analysis because it is directly related to the stability, quality, and composition of food⁴³. The moisture content of the cereal bars prepared in this study showed that the percentages of the formulations F1 (collagen), F2 (guar gum), and F3 (xanthan gum) differed statistically ($p < 0.05$).

The formulations with psyllium (F4) and guar gum (F2) stored more water, a fact also reported for Zadonadi⁴⁴ for psyllium, which reports the same capacity to retain water molecules, which increases the volume and improves the binding of the ingredients.

The high moisture content verified with the use of guar gum (9.69%) may be explained by hydrocolloid characterization, which can present high ability to influence the uptake of liquids into the systems. This was described by Freitas and Cavalcanti⁴⁵, when they evaluated the hydration index of guar gum as excipient in hydrophilic matrices.

Table 2
Mean proximal composition values and caloric value of cereal bars prepared with different binding ingredients.

Constituents	Formulations			
	F1 (x ± SD)	F2 (x ± SD)	F3 (x ± SD)	F4 (x ± SD)
Moisture (%)	6.96±0.10 ^b	9.69±0.36 ^a	5.80±0.4 ^c	7.66±0.38 ^b
Ash (%)	2.93±0.04 ^a	2.92±0.02 ^a	2.90±0.01	2.92±0.04 ^a
Total Lipids (%)	32.5±0.88 ^a	29.1±0.4 ^b	29.12±0.2 ^b	31.8±0.1 ^a
Protein (%)	18.0±0.2 ^a	13.5±0.1 ^c	14.7±0.2 ^b	18.1±0.0 ^a
Carbohydrate (%)	34.6±0.8 ^c	38.0±0.4 ^b	40.9±0.3 ^a	32.8±0.8 ^d
Crude fiber (%)	4.96±0.29 ^b	5.91±0.9 ^{ab}	6.48±0.4 ^a	6.74±0.5 ^a
Caloric Value (%)*	516.3±0.4 ^a	479.2±0.6 ^d	497.6±0.7 ^c	505.2±0.3 ^b

*(kcal/100 g); F1: collagen binding agent; F2: guar gum binding agent; F3: xanthan gum binding agent; F4: psyllium binding agent. The data are averages of the triplicate tests with the respective standard deviation estimates. Values in the same row followed by the same letters do not differ ($p > 0.05$), according to the Tukey test.

The amount of total minerals did not differ statistically ($p > 0.05$) between formulations. Values lower than those found in the present study (1.45%) were reported by Tombini⁴³ in sweet cereal bars with added chia.

The variation in total mineral (ashes) content found in different studies may be related to the types of ingredients and binding agents used in each formulation. The percentages of ashes of the bars found in this study tended to be positive and may be used as a general measure of quality⁴⁶, indicating better nutritional value⁴⁷. The ashes may contain important minerals, such as calcium, magnesium, potassium among others, which are essential of functionality of the human organism^{48,49}.

The lipid content did not differ statistically ($p > 0.05$) between the formulations F1 and F4 and F2 and F3, although they all had high percentages of this component. The high percentages of lipids were related to the use of oilseeds (peanut: 47.7%; sesame: 41-65%; flaxseed: 30-40%; Brazil nut: 60%-70%; chia: 25%-35% of lipids⁵⁰⁻⁵⁴). It is a common knowledge that high levels of lipids increase the caloric value of food. According to Philippi⁵⁵ high fat content is directly related to the increased caloric value of food.

Protein content did not differ statistically ($p > 0.05$), and the highest percentages were found in formulations F1 (collagen) and F4 (psyllium). The variation of this component between the four formulations ranged from 13.50% (F2) to 18.06% (F4). Collagen (F1) may have contributed to the result since it is characterized as being a fibrous protein found in all animal tissue⁵⁶.

In accordance with resolution RDC 54/2012, the four formulations can be generally classified as functional foods with high protein content since they have more than 12 g protein/100 g of food⁵⁷. Consequently, a cereal bar (25 g) prepared with the presented ingredients (Table 1) and with the binding agents collagen, guar gum, xanthan gum,

and psyllium can provide 4.5 g; 3.4 g; 3.7 g, and 4.5 g of protein, respectively.

Carbohydrates are usually found in higher concentrations in the centesimal composition of food, especially in cereal-based products⁵⁸, as observed in the present study, where the percentages of carbohydrates varied from 32.8% (F4 - psyllium) to 40.9% (F3 - xanthan gum) with significant differences ($p < 0.05$) between the four formulations. This factor contributes to the caloric value.

The percentage of crude fiber differed significantly ($p < 0.05$) for the formulations F1 (collagen), F3 (xanthan gum), and F4 (psyllium). Values similar (6.01%) to those found by Sampaio et al.⁵⁹ in cereal bars containing rice flakes, corn flakes, oatmeal and other ingredients.

The energy value of the four formulations of the salted bars differed significantly ($p < 0.05$). Considering that a cereal bar is usually sold at a weight of 25 grams, the caloric order of the formulations was as follows: F1 - collagen binding agent (129.06 Kcal/25g); F4 - psyllium binding agent (126.3 Kcal/25g); F3 - xanthan binding agent (124.4 Kcal/25g); and F2 - guar gum binding agent (119.8 Kcal/25g). The energy value for the bar with collagen as the binding agent can be explained by the fact that this formulation had greater amounts of protein and lipids, thus resulting in higher caloric value.

Table 3 shows the fatty acid profile for total lipids, the values of the atherogenic index, thrombogenic index, ratios between hypocholesterolemic fatty acids and hypercholesterolemic and the ratio of PUFA/SFA and n-6/n-3 for the four formulations of cereal bars in the form of mean percentages of the normalized peak area with the respective standard deviations.

Of the eleven identified fatty acids, the most common were oleic acid (18:1n-9), linoleic acid (18:2n-6), and palmitic acid (16:0). Of the fatty acid profile, only three showed no significant difference ($p > 0.05$) in their percentages when

Table 3
Fatty acid composition in salty cereal bars prepared with different binding ingredients.

Fatty Acids (%)	Formulations			
	F1 (x ± SD)	F2 (x ± SD)	F3 (x ± SD)	F4 (x ± SD)
16:0	11.2±0.1 ^a	10.6±0.3 ^{ab}	10.9±0.3 ^{ab}	10.2±0.0 ^b
18:0	4.97±0.04 ^a	4.64±0.12 ^{bc}	4.84±0.07 ^{ab}	4.53±0.02 ^c
18:1n-9	46.8±0.0 ^a	45.6±1.0 ^a	46.5±0.0 ^a	47.4±0.3 ^a
18:2n-6	23.7±0.2 ^a	21.8±0.5 ^c	23.4±0.1 ^a	25.0±0.2 ^b
18:3n-3	0.82±0.01 ^a	0.94±0.17 ^a	0.78±0.01 ^a	0.75±0.04 ^a
18:3n-6	2.78±0.04 ^c	3.19±0.06 ^b	3.34±0.01 ^b	4.46±0.06 ^a
20:0	1.09±0.01 ^a	0.96±0.14 ^a	1.02±0.01 ^a	0.86±0.10 ^a
20:3n-3	0.74±0.02 ^b	1.03±0.01 ^a	0.64±0.01 ^c	Nd
20:4n-6	1.94±0.01 ^{ab}	2.28±0.01 ^a	1.78±0.09 ^{ab}	1.46±0.28 ^b
22:1n-9	3.11±0.33 ^c	5.63±0.02 ^a	4.27±0.01 ^b	3.26±0.01 ^c
22:2	2.82±0.05 ^{ab}	3.33±0.11 ^a	2.61±0.01 ^{ab}	2.01±0.46 ^b
Sum and ratio				
SFA	17.3±0.1 ^a	16.2±0.5 ^{ab}	16.7±0.3 ^{ab}	15.6±0.1 ^b
MUFA	49.9±0.3 ^a	51.3±1.0 ^a	50.8±0.0 ^a	50.7±0.3 ^a
PUFA	32.8±0.2 ^a	32.5±0.5 ^a	32.5±0.3 ^a	33.7±0.4 ^a
n-9	49.9±0.3 ^a	51.3±1.0 ^a	50.8±0.0 ^a	50.7±0.3 ^a
n-6	4.70±0.03 ^c	5.47±0.06 ^{ba}	5.12±0.09 ^{bc}	5.92±0.22 ^a
n-3	1.56±0.04 ^b	1.97±0.17 ^a	1.42±0.01 ^b	0.75±0.04 ^c
PUFA/SFA	1.90±0.02 ^b	2.01±0.03 ^b	1.94±0.05 ^b	2.16±0.04 ^a
n-6/n-3	3.00±0.01 ^{ac}	2.80±0.28 ^c	3.60±0.03 ^b	7.94±0.08 ^a
Indices of the nutritional quality				
AI	0.20	0.19	0.19	0.18
TI	0.51	0.54	0.43	0.48
HH	6.54	6.64	6.66	7.30

F1: Collagen binding agent; F2: Guar gum binding agent; F3: Xanthan gum binding agent; F4: Psyllium binding agent. The values are mean ± standard deviation of the duplicate analyses. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; n-3: Omega-3 fatty acids; n-6: Omega-6 fatty acids, n-9: Omega-9 fatty acids; n-6/n-3: ratio between Omega-6 and Omega-3; PUFA/SFA: ratio between polyunsaturated fatty acids and saturated fatty acids. (AI): Atherogenic index= [(12:0 + (4 x 14:0) + 16:0)]/(ΣAGMI + Σn-6 + Σn-3); (TI): Thrombogenic index= (14:0 + 16:0 + 18:0)/ [(0.5 x ΣAGMI) + (0.5 x Σn-6) + (3 x Σn-3) + (Σn-3/Σn-6)]; (HH): ratio between hypocholesterolemic and hypercholesterolemic fatty acids = (18:1n-9 + 18:2n-6 + C20:4n-6 + 18:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3)/(14:0 + 16:0). Values in the same row followed by the same letters do not differ, according to the Tukey test.

comparing across the four formulations, specifically oleic acid (18:1n-9), linolenic acid (18:3n-3), and arachidic acid (20:0). This behavior was also observed for the sum of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), as well as total Omega-9 (n-9). Saturated fatty acids (SFA) ranged from 15.6% to 17.3%, with no statistical difference ($p > 0.05$) between the formulations F2 and F3.

Oleic acid (18:1n-9) was the MUFA with the highest percentage in all the formulations without a significant difference ($p > 0.05$) between the values. High percentages of oleic acid are desirable and important because they reduce

the risk of heart attack and atherosclerosis⁶⁰, in addition to being sources of Omega-9 fatty acids.

Total PUFA, as in the case of MUFA, had expressive percentages, with no significant difference ($p > 0.05$) between formulations. High values of PUFA are desirable and beneficial in food. The PUFA n-3 (alpha-linolenic acid-ALA) and n-6 (linoleic acid-LA) are considered essential (AGE) in health promotion because they cannot be synthesized by the human body and must therefore be obtained through food⁶¹.

Of the polyunsaturated acids, LA (18:2n-6) and ALA (18:3n-3) are required to maintain cell membranes, brain

function and the transmission of nerve impulses under normal conditions⁶² and are the precursors of the Omega-3 (n-3) and Omega-6 (n-6) series, respectively.

Linoleic acid (18:2n-6) was the predominant PUFA, and is the precursor of arachidonic acid (AA, 20:4n-6). The percentage of this fatty acid ranged from 21.75 to 25.00%, with no significant difference ($p > 0.05$) between the formulations F1 (collagen binding agent) and F3 (xanthan gum binding agent). The high levels of linoleic acid found in the cereal bars can be justified by the presence of oilseeds in the formulations.

Although alpha-linolenic acid (ALA, 18:3n-3) was found in a small proportion (0.75% - 0.94%) in the prepared bars, it is an important source of omega-3 and its inclusion is considered critical since it is considered a precursor for the synthesis of very-long-chain polyunsaturated acids (VLCPUFA) such as eicosapentaenoic acid (20:5n-3 - EPA) and docosahexaenoic acid (22:6n-3 - DHA).

The fatty acids EPA (20:5n-3) and DHA (22:6n-3), as well as arachidonic acid (AA, 20:4 n-6), are part of numerous cellular functions such as the integrity and fluidity of membranes, membrane enzyme activity, lipid-protein interactions and the synthesis of eicosanoids such as prostaglandins, leukotrienes and thromboxanes⁶³.

The nutritional content of the oils and fats found in the cereal bars can be evaluated using the ratio n-6/n-3. In this ratio, values below 4.0 are considered desirable and suggest quantities that help prevent cardiovascular disease, according to the Department of Health and Social Security⁶⁴. The results of this study for the formulations F1, F2 and F3 were below 4.0.

However, all the formulations prepared for this study can be considered beneficial from a nutritional standpoint since the Scientific Review Committee of Canada recommends n-6/n-3 ratios between 4.0 and 10.0, and the World Health Organization recommends values of 5.0 to 10.0 for this same ratio⁶²⁻⁶⁵.

Omega-3 and Omega-6, which make up a considerable portion of the PUFA, work together to regulate various physiological processes of the human organism⁶⁶. Percentages of PUFA, especially those of the n-6 and n-3 series, are considered beneficial for consumption because these essential fatty acids can only be acquired through diet⁶⁷.

As for the content of Omega-6 fatty acid, the highest values were recorded for F4 and F2 and these formulations did not statistically differ ($p > 0.05$) from one another.

The moderate consumption of foods with MUFA and PUFA is important to reduce lipid fractions of LDL (low-density lipoprotein) and VLDL (very low-density lipoprotein)⁶⁸.

These fatty acid values were expected because the formulations contained some ingredients that have considerable levels of fatty acids from oilseeds.

Another way to assess the quality of fats and oils is through the ratio between PUFA and SFA. Levels below 0.45 are considered undesirable since they can increase blood cholesterol Department of Health and Social Security⁶⁹. In

this study, the values of the four formulations are above the limits recommended by HMSO and thus indicate the good lipid and nutritional quality of the product.

The observed fatty acid ratio can be used to assess the nutritional quality of the lipid fraction in the prepared cereal bars. For this type of assessment, it is necessary to calculate the atherogenic index and the thrombogenic index, and the ratios between hypocholesterolemic fatty acids and hypercholesterolemic.

According to Sousa Bentes et al⁷⁰, how smaller the value of atherogenic and thrombogenic index and the how more high the ratio of hypocholesterolemic fatty acids (Unsaturated fatty acids - UFA: 18:1n-9; 18:2n-6; 20:4n-6; 18:3n-3; 20:5n-3; 22:5n-3; 22:6n-3) and hypercholesterolemic (SFA: 14:0; 16:0; 12:0) more nutritionally suitable is the oil or fat⁷¹. These indices consider the functional activity of fatty acids in the metabolism of cholesterol transport lipoproteins, whose type and quantity is related to the greater or lesser risk of cardiovascular diseases⁷².

In the present study, the hypercholesterolemic values induce a food item with adequate nutritional characteristics. According to Souza Bentes et al.⁷⁰, high values for this ratio are desirable from the nutritional standpoint.

The atherogenic indices that relate the proatherogenic and antiatherogenic acids varied from 0.18 (F4) 0.20 (F1) and, unlike the hypercholesterolemic ratio, lower values for this ratio are desirable⁷³. As in the case of atherogenic indices, the values of the thrombogenic indices (TI) were lower, which also indicates good lipid quality.

According to Sousa Bentes et al⁷⁰, there is no recommended value for atherogenic and thrombogenic indices, however, the author reports that the lower the value of these indices, the more favorable the fatty acid profile to human health. Specifically, the values of the ratio of hypocholesterolemic and hypercholesterolemic fatty acids are directly related to cholesterol metabolism^{73,74}.

According to Turan et al.⁷⁵, atherogenic and thrombogenic index can potentially stimulate platelet aggregation. Lower atherogenic and thrombogenic index values relate to higher levels of antiatherogenic acids present in a given oil or fat, which is associated with prevention of coronary artery disease.

The observed fatty acid profile and lipid quality indices showed that the salty cereal bars with added chia formulated provide a good amount of fatty acids essential for human health. The formulations had good lipid quality and can be considered a healthy and nutritional food with binding ingredients that did not significantly interfere with lipid composition.

The cereal bars were assessed to determine the concentrations of key minerals, namely calcium, copper, iron, phosphorus, magnesium, potassium, sodium, and zinc (Table 4).

According to the results, copper 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. The other evaluated minerals

Table 4
Mean mineral content (mg/100 g) of salted cereal bars prepared with different binding ingredients.

Minerals (mg/100g)	Formulations				
	F1	F2 (x ± SD)	F3 (x ± SD)	F4 (x ± SD)	IDR (x ± SD)
Calcium	106.9±0.4 ^d	118.6±0.0 ^c	140.4±0.7 ^a	125.7±0.2 ^b	1,000 ²
Copper	0.81±0.04 ^a	0.81±0.02 ^a	0.78±0.08 ^a	0.87±0.01 ^a	0.9 ³
Iron	2.67±0.04 ^{ba}	2.51±0.05 ^{bc}	2.29±0.01 ^c	2.90±0.13 ^a	14.0 ²
Phosphor	345.9±0.2 ^b	367.8±0.2 ^a	333.6±0.4 ^c	324.9±0.0 ^d	700 ³
Magnesium	151.8±0.0 ^b	159.7±0.1 ^a	144.8±0.0 ^d	148.3±0.7 ^c	260 ²
Potassium	454.4±0.8 ^b	470.9±0.1 ^a	443.8±0.2 ^c	450.8±0.2 ^d	4,700 ²
Sodium	635.4±0.0 ^c	740.5±0.1 ^a	739.9±0.6 ^a	733.9±0.1 ^b	2,400 ¹
Zinc	2.53±0.01 ^a	2.54±0.01 ^a	2.29±0.01 ^b	2.31±0.03 ^b	7.0 ²

F1: Collagen binding agent; F2: Guar gum binding agent; F3: Xanthan gum binding agent; F4: Psyllium binding agent. DRI: Dietary Reference Index. 1 Diet, Nutrition and Prevention of Chronic Diseases.FAO/WHO (2003).2Human Vitamin and Mineral Requirements – FAO/WHO (2001). 3 Dietary Reference Intake, Food and Nutrition Board (2001). The results represent the mean values of the analyses in duplicate accompanied by the standard deviation. Mean values in the same row followed by the same letters do not differ ($p > 0.05$), according to the Tukey test.

differed between two or more formulations.

The highest concentration of calcium was found in the salted cereal bar formulated with the xanthan gum binding agent (F3).

Brazilian Legislation⁷⁶ recommends a daily intake of calcium of 1,000 mg for adults. Eating one 25 g salty cereal bar supplies around 3.51% (F3 – xanthan gum), 3.14% (F4 – psyllium), 2.96% (F2 – guar gum), and 2.67% (F1 – collagen) of the recommended daily calcium intake. According to França et al.⁷⁷, ingesting recommended levels of calcium ensures bone and teeth mineralization and the regulation of intracellular events in various tissues.

Copper concentration showed no significant difference ($p > 0.05$) in the four formulations and the observed values were close (0.9 mg/day) to the recommended daily intake for adults, according to legislation⁷⁶. Consequently, 25 grams of the salted cereal bar (1 unit) provide 22.5% (F1 and F2), 21.66% (F3), and 24.16% (F4) of the required daily intake of copper. Thus, according to the Brazilian Health Inspection Agency⁵⁷, the bars prepared in this study with different binding ingredients can be considered sources of copper since they provide 15% of the recommended daily intake per serving.

We observed significant differences in iron concentrations. Considering the minimum required daily intake of this mineral, 25 grams (1 unit) of the cereal bar with the binding agent psyllium (F4) provided 5.18% of the daily requirement of iron for adults. Iron is considered one of the most important minerals for the proper functioning of the human organism. According to Germano and collaborators⁷⁸, in adequate doses, iron contributes to homeostasis, cellular DNA synthesis, and energy metabolism. The minerals phosphorus, magnesium,

and potassium in the salty cereal bars all differed in relation to the binding agents. The cereal bar made with guar gum (F2) as the binding agent had the highest concentrations of phosphorus, magnesium, and potassium in comparison with the other samples. The concentrations of these minerals suggest that a single salted cereal bar (25 g) prepared with the binding agent guar gum provides 13.14% of the daily requirement of phosphorous, 15.35% of magnesium, and 2.5% of potassium.

According to Aranda et al.⁷⁹, magnesium is a mineral that is effective in foods containing cereal, which explains the high concentrations observed in the assessed products, especially in the F2 formulation that provides more than 15% of the recommended daily intake⁵⁷.

The sodium levels found in the cereal bars show no statistical differences ($p > 0.05$) between the formulations F2 and F3. Considering the maximum daily recommendation of 2,400 mg sodium/100 g⁶⁷, 25 grams (1 unit) of each cereal bar formulation provide around 6.62% (F1), 7.71% (F2), 7.70% (F3), and 7.65% (F4) of sodium.

Most of the sodium found in food comes from the added sodium chloride, which, if consumed excessively, can cause several health problems such as cardiovascular disease, osteoporosis, asthma, and obesity⁸⁰. However, sodium is also an essential and beneficial micronutrient⁸¹. Its main function is to control the volume of extracellular fluid and plasma that essentially conducts nerve impulses, allows muscle contraction, stabilizes blood pressure, and guarantees acid-base balance^{82,83}.

The percentage of zinc contribution of 1 prepared cereal bar (25 g) was approximately 9.04% (F1 and F2) and 8.21% (F3 and F4) of the daily recommended intake.

Several ingredients used in the formulation contributed to the addition of zinc in the bars. According to the Brazilian food composition chart⁸⁴, the ingredients that most contributed to zinc content were peanut (2.1 mg/100 g), sesame (5.2 mg/100 g), oats (2.6 mg/100 g), flaxseed (4.4 mg/100 g) and chia (3.66 mg/100 g)⁸⁶.

Fonseca et al.⁸⁵ prepared a cereal bar with pineapple peel and obtained the following values for a portion of 100 grams: 103 mg of magnesium, 0.31 mg of copper, 1.72 mg of zinc, 1.87 mg of iron, and 13 mg of sodium. With the exception of sodium, all the other mineral levels are below the values found in the present study.

Similarly, Freitas and Moretti⁸⁶ prepared a cereal bar with high protein and vitamin content, and obtained the following values per 100 grams of product: 77 mg of magnesium, 0.36 mg of copper, 5.10 mg of iron and 2.95 mg zinc. A comparison of the values found in the present study (Table 4) with those of the authors mentioned above revealed that the salted cereal bars of this study had higher levels of magnesium and copper and lower levels of iron and zinc.

The differences between the formulations of some parameters evaluated suggest that the binding agents increase indices of some compounds according to their composition characteristics. Collagen, having a considerable amount of proteins in its constitution, increased the protein indices in the formulation (F1). Guar gum, from seeds, besides contributing to the increase of soluble fibers, also provides elevation in the contents of minerals (F2). Xanthan gum, because it consists mainly of carbohydrates and fibers, contributed to the increase of these compounds in the formulation F3 and psyllium by its compositional characteristics had greater contribution to increase fiber content (F4).

CONCLUSIONS

The bars developed in this study presented considerable lipid, carbohydrate, protein, fiber and energy content contributing with more than 15% of the recommended daily value of minerals.

The fatty acid profile and lipid quality indexes showed that the salty cereal bars formulated with the use of different binding ingredients provide a significant amount of fatty acids and good lipid quality, offering a new product option for consumers seeking a practical and healthy food alternative.

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