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Manufacturing cereal bars with high nutritional value through experimental design

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ABSTRACT. Organizations responsible for public health throughout the world have been increasingly concerned with the feeding of the populations, by encouraging a nutritious and balanced diet in order to decrease the occurrence of chronic diseases, which are constantly related to an inadequate diet. Still, consumers are increasingly seeking convenient products due to the modern lifestyle. This being so, cereal bars have been an option when the issue is low calorie fast food and source of fiber. This study aimed at developing a cereal bar with high dietary fiber, iron, vitamins A and E, in order to easily enable adult population to achieve the daily recommendation for such nutrients. Eight formulations plus the focal point were prepared through experimental planning; sensory analysis was conducted with 110 tasters for each block and texture. Afterwards, we performed proximate analysis for all three formulations presenting the best sensory results. After statistical analysis and comparison with the means of products available in the market, it was possible to conclude that the product developed had great acceptance and fiber level more than double of mean values for commercial products.

Keywords: cereal bars, functional food, dietary fiber.

Desenvolvimento de barra de cereais com alto valor nutricional por planejamento experimental

RESUMO. Organizações responsáveis pela saúde pública ao redor do mundo vêm se preocupando cada vez mais com a alimentação das populações incentivando a procura por alimentos nutritivos e balanceados, com o objetivo de diminuir os índices de doenças crônicas cada vez mais relacionadas à alimentação incorreta. Entretanto, os consumidores, em função do estilo de vida moderno, buscam cada vez mais a conveniência nos produtos. Neste contexto, as barras de cereais têm sido uma opção para o alimento rápido, com baixo valor calórico e como fonte de fibras. O objetivo deste estudo foi desenvolver uma barra de cereais com alto teor de fibra alimentar, ferro, vitaminas A e vitamina E, para que se atinja a recomendação diária desses nutrientes para a população adulta de maneira viável no dia a dia. Foram realizadas oito formulações mais o ponto central por meio de planejamento experimental, realizaram-se análises sensoriais com 110 provadores em cada bloco e de textura. Posteriormente, foi feita a análise centesimal das três formulações que apresentaram melhores resultados sensoriais. Após análise estatística dos resultados e comparação com as médias dos produtos disponíveis no mercado foi possível concluir que o produto desenvolvido apresentou elevada aceitação e teor de fibras de mais que o dobro da média dos produtos comerciais.

Palavras-chave: barra de cereais, alimento funcional, fibra alimentar.

Introduction

There are many evidences on the relationship between dietary factors and primary and secondary prevention of chronic diseases such as heart diseases, diabetes and some types of cancer, as well as better muscle functioning or immune responses (WELCH et al., 2011).

Cereal bars became a practical food, can be easily consumed, do not require any preparation and are a source of essential nutrients (GUTKOSKI et al., 2007).

According to Freitas and Moretti (2006), the tendency to associate cereal bars with healthy food has already been remarked in food industry. Nevertheless, such food is not always beneficial once the amount of some essential nutrients therein it is not as significant as recommended.

Iron deficiency is a matter of public health and this is why food supplemented with iron is a measure to remedy and prevent iron-deficiency anemia. (NABESHIMA et al., 2005; CARVALHO et al., 2010).

The use of NAFeEDTA has shown several advantages compared with other iron compounds such as ferrous sulfate, ferrous fumarate and others once it does not lead to lipid oxidation and is stable when processing food (HURRELL, 2002).

Both vitamins A and E are important nutrients in daily diets, and at insufficient amounts there is risk of coronary heart disease, night-blindness and low immunity (FREITAS; MORETTI, 2006; MARIATH et al., 2010).

Dietary fibers are not regarded as essential nutrients, however much interest is placed on them. Such nutrients are associated to the balance of intestinal system, glucose plasma, cholesterol and triglyceride levels (SLAVIN, 2004).

Resistant starch is the portion of starch resistant to digestion when passing through gastrointestinal tract, being classified as dietary food (SHARMA et al., 2008; FUENTES-ZARAGOZA et al., 2010). There are many advantages when used in industry, with an improvement in appearance, texture and taste compared with other sources of fiber (CHARALAMPOPOULOS et al., 2002; PÉREZ-ALVARES, 2008; FUENTES-ZARAGOZA et al., 2010).

In order to provide food with important nutrients in a practical way, this study aimed at developing a cereal bar with high levels of dietary fiber, iron and vitamins A and E.

Material and methods

Raw material

Oat fiber (SL Alimentos - Brazil), resistant starch (CornProducts - Brazil) and NAFeEDTA (Synth® - Brazil) were used in this study. Oat flakes, rice flakes, soy lecithin, invert sugar, glucose, vegetable fat, Brazil nut, golden flaxseed, sodium chloride and vitamins A and E were purchased at local shops in Maringa.

Cereal bars production

Cereal bars were produced according to the methodology employed by Freitas and Moretti, (2006) with some modifications once we used polyethylene packaging.

An experimental planning was set in order to identify a better combination of fiber sources.

Cereal bars formulations were composed of 40% (mass) of fixed components and 60% of variable components defined through the experimental planning.

The fixed components received the components responsible for sensory characteristics typically found in cereals and iron and vitamins, with the proportion of 20% the daily recommended in order to obtain an enhanced product, according to Huma et al. (2007).

For daily values needed we used the recommended average for adult population between 19 and 50 years old with National Research Council (NRC, 2005).

Vitamins A and E were added in their pure form while iron was added as NaFeEDTA, with insignificant amount concerning final weigth of cereal bars produced.

Table 1 lists the fixed components added to the cereal bars.

Table 1. Fixed ingredients in the cereal bars.

Ingredients	% (mass)
Brazil nut	20.0
Flaxseed	2.5
Rice flakes	10.0
Salt	1.0
Soy lecithin	2.5
Vegetable fat	4.0
Invert sugar	10.0
Glucose	50.0
Vitamins and iron	< 0.001*

*Quantities of vitamins A, vitamin E and iron were added to 20% of Dietary reference intakes National Research Council (NRC, 2005) .

Experimental Design

A 2^3 factorial design was employed where each factor varied for both highest and lowest quantities and the three factors corresponded to the sources of fiber (resistant starch, oatmeal fiber and coarse oatmeal).

The experimental design, according to Barros Neto et al. (2010) allows all effect combinations to be simultaneously tested.

Table 2 presents all three blocks where each had its center point repeated as set by the experimental design.

Table 2. Experimental design (2^3) of cereal bars.

Ingredient Variable	Block 1			Block 2				Block 3			
Formulation	1	2	3	4	5	6	7	8	9	10	11
Resistant starch	0	-	-	0	-	-	+	0	+	+	+
Oatmeal fiber	0	-	-	0	+	+	-	0	+	-	+
Coarse oatmeal	0	-	+	0	+	-	+	0	-	-	+

The resistant starch varied from 86 g (-) to 171 g (+), the oatmeal fiber varied from 78 g (-) to 180 g (+), the coarse oatmeal varied from 107 g (-) to 200 g (+). The center point for all repetitions represents the simple arithmetic mean between the highest and the lowest values.

Sensory analysis

All formulations had their sensory analysis performed in three blocks where each block received a formulation in the center point. The tests

were carried out through a nine-point hedonic scale for overall assessment with 110 non-trained tasters for each block.

The volunteers signed an Informed Consent Form, approved by the Research Ethics Committee of the University (CAAE 18718013.3.0000.0104).

Texture

The texture analysis was carried out using a Stable Micro Systems Texture Analyzer TAXT2i (Texture Technologies Corp, England), following the methodology by Oliveira et al. (2013). The parameters employed were (i) pre-test rate = 2.0 m s^{-1}; (ii) test rate = 2.0 m s^{-1}; (iii) post-test rate = 2.0 m s^{-1}.

Proximate composition

The proximate composition was evaluated in triplicate for products with better sensory acceptance. The Kjeldahl method was employed to determine total protein, for fat we used Soxhlet extractor as described by the AOAC, (1997).

Moisture was determined according to Instituto Adolfo Lutz (IAL, 2008). Through data obtained from the proximate composition the energy value in the samples was estimated considering factors of Atwater conversion of 4, 4 and 9 Kcal g^{-1} for protein, carbohydrate and lipid, respectively (MERRIL; WATT, 1973).

The values found were compared with average values for cereal bars from five major manufacturers in Brazil (considering sales volume).

Determination of iron levels

Iron levels were quantified through mineral determination method using atomic absorption spectrometry Instituto Adolfo Lutz (IAL, 2008).

Determination of vitamins levels

Levels for both vitamins A and E were quantified, respectively, through methods for determining Vitamins A and E (total tocopherols) in food according to Instituto Adolfo Lutz (IAL, 2008).

Statistical analysis

The statistical analysis for the results was carried out through Two-Way Analysis of Variance without replication (ANOVA) and mean values were compared by Tukey's test ($p < 0.05$) using the Statistica StatSoft (2008) 6.0 software.

Results and discussion

Sensory analysis

Based on the results in Table 3 it was possible to observe that formulations with better sensory acceptance were F3, F7 and F10.

Table 3. Results from overall sensory analysis for all 11 cereal bars[1].

Formulation	Mean ± SD
F1	5.48 ±1.74 [c]
F2	5.87 ±1.63 [b]
F3	6.45 ±1.50 [a]
F4	5.74 ±1.84 [bc]
F5	5.93 ±1.70 [b]
F6	6.07 ±1.76 [b]
F7	6.60 ±1.63 [a]
F8	5.51 ±1.77 [c]
F9	6.17 ±1.45 [b]
F10	6.63 ±1.57 [a]
F11	6.04 ±1.55 [b]

[1]Equal lower-case letters in the column indicate non-significant differences according to Tukey's test ($p < 0.05$).

The data obtained indicated that the highest sensory acceptance was obtained with lower levels of oatmeal fiber. Such result may be due to the great amount of silicon in this ingredient, which provided a gritty sensation to the product.

Gutkoski et al. (2007) revealed a good acceptance for products manufactured using oat with high level of dietary fiber. Similarly to that verified in this study, the formulations with oat were well-rated by the tasters.

Texture analysis

The texturometer is an instrument to establish the softness of a food by simulating human chewing, evaluating a relevant sensory attribute (SILVA et al., 2003). All 11 formulations passed through texture analysis, whose results are given in Table 4. It was possible to notice that different formulations did not alter the texture characteristics of the cereal bars.

Table 4. Results from texture analysis[1].

Formulation	Force (kgf) ± SD
F1	5.05 ±0.76 [a]
F2	5.46 ±1.17 [aa]
F3	5.13 ±0.98 [a]
F4	5.96 ±1.02 [a]
F5	5.45 ±0.84 [a]
F6	5.07 ±0.59 [a]
F7	5.21 ±0.85 [a]
F8	5.19 ±0.77 [a]
F9	5.09 ±1.09 [a]
F10	4.97 ±0.93 [a]
F11	5.36 ±1.01

[1]Equal lower-case letters in the column indicate non-significant differences according to Tukey's test ($p < 0.05$).

Proximate composition

Table 5 presents results obtained from the composition analysis of cereal bars F3, F7 and F10.

The cereal bars presented relatively low moisture content; the formulation F3 had the highest moisture level, however it is in accordance with the law that establishes that cereal bars moisture must be below 15.0%, Regulation RDC number 263, September 22nd, 2005 (BRASIL, 2005a).

Table 5. Proximate composition of cereal bars (composition in 100 g).

Component	Formulation F3 ± SD	Formulation F7 ± SD	Formulation F10 ± SD
Moisture (g)	10.43 ± 2.34	8.98 ± 1.97	8.76 ± 1.76
Ash (g)	1.71 ± 1.02	1.55 ± 1.21	1.57 ± 0.99
Protein (g)	6.41 ± 1.23	6.61 ± 1.73	6.05 ± 1.45
Lipid (g)	9.03 ± 2.08	9.07 ± 1.99	8.75 ± 1.67
Carbohydrate (g) Nifext*	51.07 ± 3.97	55.05 ± 4.71	55.59 ± 3.40
Total Fiber (g)	21.35 ± 2.19	18.74 ± 2.56	19.28 ± 2.33
Vitamin A (μg)	673.5 ± 12.4	635.2 ± 10.7	658 ± 13.4
Vitamin E (mg)	9.58 ± 0.98	10.30 ± 1.26	10.41 ± 1.27
Iron (mg)	15.76 ± 1.76	14.64 ± 2.76	15.12 ± 2.64
VCT (TCC) (kcal)**	311.19	328.27	325.31

*Estimated by difference; **Total Caloric Content

Water is the component that influences the stability, and physic-chemical analysis of food. The texture characteristics of processed cereal-based foods contribute to their popularity and are closely related to low moisture levels (GATES et al., 2008; SUN-WATERHOUSE et al., 2010). Baú et al. (2010) found moisture level of 12.5% when analyzed cereal bars with high protein values, similarly to that found by Lima et al. (2010): values from 9 to 13% in cereal bars formulated with Baru pulp and almond.

The cereal bars presented ash levels similar to reported by Lima et al. (2010) ranging from 1.33 g 100 g^{-1} to 1.44 g 100 g^{-1}.

Protein levels were similar to those found in commercial cereal bars (around 6.5 g 100 g^{-1}) and cereal bars with dried bananas and dried *murici* standardized by Guimarães and Silva (2009) varying from 6.9 g 100 g^{-1} to 7.7 g 100 g^{-1}.

Lipid levels for all three formulations were slightly lower compared with commercial cereal bars that on average present 11 g 100 g^{-1} of such nutrient. The lipid content in cereal bars in this study was associated with the addition of Brazil nut and linseed, oilseeds that present high amount of monounsaturated and polyunsaturated fatty acids, highlighting omega 3 and omega 6, both responsible for several benefits for human health such as decreasing in cholesterol and cardiovascular diseases rate and others (FREITAS; NAVES, 2010; DE AGUIAR et al. 2011).

Carbohydrate levels were high in all cereal bars, similarly to commercial cereal bars, due to high concentration of cereals and both glucose and invert sugar, which is the nutrient with greatest contribution to the energy value.

Fiber values were higher than in both commercial and homemade cereal bars (BRITO et al., 2004), which on average presented 3.44 g 100 g^{-1}. Dietary fibers form a set of plant-derived substances non-hydrolyzed by the endogenous enzymes in the digestive tract (SLAVIN, 2004), its low ingestion has been associated to several diseases such as colon, rectal and breast cancer, diabetes, atherosclerosis, appendicitis, Crohn's disease and others (GUTKOSKI et al., 2007). The high levels of dietary fibers allow stating that the cereal bars in this study can be categorized as functional food, once their formulations achieved values higher than established by law (BRASIL, 2005b), which is at least 3 g fibers per 100 g of product, and are able to be classified in high level attribute.

Both vitamins A and E were well preserved after processing the cereal bars. The values found were higher than in commercial cereal bars (90 mcg and 1 mg, respectively). Freitas and Moretti (2006) also reported a good preservation of vitamin E after processing the cereal bars, added to the formulation with 300 mg 100 g^{-1}.

The iron level was higher than found by Freitas and Moretti (2006), who reported values similar to the ones in foods such as chestnut (5.5 mg 100 g^{-1}) and wheat (5.0 mg 100 g^{-1}) as well as in commercial cereal bars (2.1 mg). According to Sampaio et al. (2009), the iron level in the NaFeEDTA compound is 14%. Thus, the value registered in the present study is due to the sum of iron levels present in ingredients with great iron content, such as chestnut and the ingredient added in the form of NaFeEDTA.

The energy values estimated for the cereal bars were close to 337 Kcal 100 g^{-1} and 349 Kcal 100 g^{-1}, found by Lima et al. (2010) in cereal bars formulated with baru pulp and almond. The total caloric value of cereal bars decreases as increases the fiber level; and similar results were obtained in the study described by Gutkoski et al. (2007).

Conclusion

The cereal bars supplemented with fibers, iron and vitamins A and E were well rated.

The F3 formulation presented the highest level of fiber and the lowest energy value among the best accepted formulations. The use of resistant starch as a source of dietary fiber did not affect the product acceptance, once F10 was the formulation with the highest concentration for such ingredient and was classified within the three best accepted ones.

Therefore, it was possible to achieve a product regarded as a source of fibers, iron and vitamins A and E and with double the fiber levels in formulations available in the market, besides the presence of resistant starch and good sensory acceptance.

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