Original

Sensory evaluation and nutritional value of cakes prepared with whole flaxseed flour

Avaliação sensorial e valor nutricional de bolos preparados com farinha integral de linhaça

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Abstract

The objective of this study was to evaluate the nutritional value, the oxidative stabilitiy, and consumer acceptance of cakes containing four different concentrations of flaxseed flour (5, 15, 30 and 45%) as partial replacement for wheat flour. The oxidative stability of polyunsaturated fatty acids was evaluated through the lipid peroxidation test (TBARS) in the flour and cakes. Linolenic acid was determined by gas chromatography as well as contents of protein, lipid, ash, and dietary fiber. Consumer acceptance was assessed using a structured hedonic scale of nine points. The oxidative stability of lipid flaxseeds was not affected by the heat treatment during flour processing and cake baking. Cakes made with 5, 15, and 30% of flaxseed flour, the most accepted by consumers, had dietary fiber levels ranging from 3.5 to 6.2 g and linolenic acid ranging from 445 to 2,500 mg.100 g^{-1} of the product. The cakes received claims of good and excellent source of dietary fiber and linolenic acid, respectively, both are bioactive compounds. The use of up to 30% of flaxseed flour in the preparation of cakes is a useful strategy to optimize the consumption of food rich in functional ingredients.

Keywords: *flaxseed flour; cakes; lipid peroxidation; bioactive compounds; acceptance.*

Resumo

O estudo teve por objetivos elaborar bolos contendo quatro diferentes níveis de farinha de linhaça (5, 15, 30 e 45%) em substituição parcial da farinha de trigo, calcular o valor nutricional do produto e avaliar a aceitação. A estabilidade oxidativa dos ácidos graxos poli-insaturados foi avaliada por meio do teste da peroxidação de lipídios, na farinha e nos bolos. O ácido linolênico foi quantificado por cromatografia gasosa e foi determinada composição centesimal em proteína, lipídios, carboidratos, cinzas e fibras. A aceitação foi avaliada utilizando-se escala hedônica estruturada de nove pontos. A estabilidade oxidativa do lipídio da linhaça, avaliada pelo teste das substâncias reativas ao ácido tiobarbitúrico, não foi influenciada pelo tratamento térmico durante o processamento da farinha e durante o cozimento do bolo. Os bolos com 5, 15 e 30% de farinha de linhaça, os mais aceitos pelos consumidores, apresentaram teores de fibra variando de 3,5 até 6,2 g e ácido linolênico variando de 445 até 2.500 mg.100 g^{-1} de produto, constituindo boa e excelente fonte de ambos os compostos bioativos. A substituição de farinha de trigo por farinha de linhaça em até 30%, no preparo de bolos, constitui uma estratégia útil para viabilizar o consumo de preparações ricas em ingredientes funcionais.

Palavras-chave: *farinha de linhaça; bolo; peroxidação de lipídios; compostos bioativos; aceitação.*

1 Introduction

Flaxseed (*Linum usitatissimum*) has been part of the human diet for thousands of years, and more recently it has been used as a source of nutraceuticals. It has been identified as a functional food, whose benefits to health are generally attributed to high concentrations of linolenic acids (omega-3) and lignins, as well as significant quantities of dietary fiber (CONFORTI; DAVIS, 2006; HUSSAIN et al., 2006; OOMAH; DER; GODFREY, 2006; TARPILA et al., 2002).

Flaxseed contains approximately 28% fiber, of which one third is soluble and has proved to reduce cholesterol and regulate blood glucose. The remaining two thirds of insoluble dietary fiber can increase fecal mass, reducing transit time in the lumen, preventing constipation and providing protection against colon cancer (HUSSAIN et al., 2006; CUNNANE et al., 1995). Linolenic acid is the predominant fatty acid in the lipids of the flaxseed, and studies have showed its beneficial effect on the growth and development of children as well as on reducing the risk of cardiovascular disease, stroke, and inflammatory and immunological disorders (HUSSAIN et al., 2006; MARTIN et al., 2006; LUCAS et al., 2002).

Flaxseed is a food with higher contents of lignans, containing 75 to 800 times more of this substance than any other food (MOSCATTO; PRUDENCIO-FERREIRA; HAULY, 2004). Phytoestrogens, such as lignans, act on the estrogen metabolism and are purported to serve as an adjuvant in hormone replacement therapy and breast and prostate cancer prevention strategies (KNUST et al., 2006; THOMPSON et al., 2005; DEMARK-WAHNEFRIED et al., 2001).

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Flaxseed consumption is still very low in Brazil despite the growing interest of specific consumer groups encouraged to adopt healthy eating habits. The growing consumer demand for food with nutritional and sensory quality as well as functional claim (MOSCATTO; PRUDENCIO-FERREIRA; HAULY, 2004) has called for research to develop new products, which include not only the nutritional and functional characterization, but also consider consumer acceptance. Bakery products such as cakes have high consumer acceptance and are important for delivering bioactive compounds into the human diet (ALPASLAN; HAYTA, 2006; VILLARROEL; PINO; HAZBÚN, 2006). Although cakes are not considered basic food, such as bread, they are accepted and consumed by people of different ages (BORGES et al., 2006). Among bakery products, they have become increasingly important in relation to consumption and market in Brazil (MOSCATTO; PRUDENCIO-FERREIRA; HAULY, 2004).

The objectives of this work were to prepare cakes with different proportions of flaxseed and wheat flours, to characterize their nutritional value, and to evaluate the cakes acceptance by consumers and lipid peroxidation of the flour and cakes.

2 Materials and methods

2.1 Raw material

Ingredients used in the preparation of cakes included: whole flaxseed flour, wheat flour, fresh eggs, refined sugar, chemical baking powder, vegetable oil, salt, and water. All ingredients, except for the whole flaxseed, were purchased from the local market. The flaxseed was supplied by a Brazilian industry.

2.2 Preparation and selection of flaxseed flour

Seeds of flax plants were dried using three different methods (Table 1). Following natural cooling to room temperature, the seeds were ground in a blender, sieved (850 μm mesh) and the lipid peroxidation was evaluated. The flour with the lowest peroxidation rate was chosen as the selection criterion. Flour samples were taken, stored in plastic bags, and kept in a freezer at –20 °C for further chemical analyses.

2.3 Lipid peroxidation in flour formulations

Extract preparation

The total lipid extraction from the flour was carried out as described by Oomah, Mazza and Przybylski (1996). Lipids were extracted from 0.5 g flaxseed flour samples using 4 mL hexane and 20 μL BHT (0.01%). The mixture was homogenized in a shaker (180 rpm) for 20 minutes and then centrifuged for 10 minutes. The supernatant was transferred into graduated tubes and the volume completed with hexane to 5 mL. Part of the homogenized extract was used for the lipid peroxidation analysis, and the remaining hexane was evaporated under liquid nitrogen to determine the lipid concentration in the extract.

Table 1. Drying methods used for the production of flaxseed flour.

Treatment	Drying method	Binomial time × temperature
F1	Control	-
F2	Conventional oven	15 minutes, 120 °C
F3	Conventional oven	10 minutes, 150 °C
F4	Microwave oven	2 minutes, 70 W potency

Lipid peroxidationin the flour

The lipid peroxidation in the flour was evaluated by the thiobarbituric acid-reactive substances (TBARS) assay according to Buege and Aust (1978). Extract aliquots (0.5 mL) were removed and transferred to tubes containing 2.0 mL TBARS reagent [15% (w/v) trichloracetic acid, 0.375% (w/v) thiobarbituric acid, 0.25 M hydrochloric acid]. The reaction mixture was kept in a hot water bath at 100 °C for 15 minutes, cooled, and centrifuged at 3.000 rpm for 5 minutes.

Absorbance was measured at 535 nm using a spectrophotometer (Shimadzu UV-1601). Malondialdehyde (MDA) concentration was calculated using the molar absorptivity of $1.56 \times 10^5\ M^{-1}\ cm^{-1}$ (BUEGE; AUSTE, 1978). The results were expressed in MDA nanomol per milligrams of lipid. The analyses were replicated three times in duplicate.

2.4 Cake preparation

The cakes were prepared immediately after the flour preparation, following a standard formulation, with the addition of four different levels of flaxseed flour. Table 2 shows the ingredients utilized in the cake preparation.

The ingredients egg yolk, sugar, and vegetable oil were homogenized with an electric mixer at medium speed for 5 minutes; next, wheat flour, whole flaxseed flour, salt, and water were added to the mixture. The mixture was homogenized until it was uniform in consistency, and the baking powder was added. The egg whites, beaten to a stiff froth at room temperature, were manually incorporated into the cake batter. The batter was placed into aluminum pans, previously oiled and sprinkled with wheat flour, and baked in a conventional oven pre-heated to 180 °C for 25 minutes.

After cooling, the cakes were weighed and sliced in order to calculate the total cake yield and servings. The samples were taken, wrapped in plastic bags, and kept in a freezer at –20 °C for further chemical analysis.

Table 2. Composition of cake formulation with four different proportions of wheat and flaxseed flours.

Ingredients (g)[1]	Formulations[2]			
	B1	B2	B3	B4
Wheat flour	270.7	242.2	199.5	156.7
Flaxseed flour	14.2	42.7	85.5	128.2
Sugar	145.0	145.0	145.0	145.0
Baking powder	30.0	30.0	30.0	30.0
Oil	60.0	60.0	60.0	60.0
Egg	150.0	150.0	150.0	150.0
Water (mL)	60.0	60.0	60.0	60.0

[1] Quantity per recipe; [2] Considering raw batter; B1 = formulation with 5% flaxseed flour; B2 = formulation with 15% flaxseed flour; B3 = formulation with 30% flaxseed flour; B4 = formulation with 45% flaxseed flour

2.5 Yield factor

The cake yield factor was calculated from the ratio cooked/uncooked batter and the results expressed in number of servings of 80 g each.

2.6 Chemical analyses

Lipid peroxidation in cakes

The lipid peroxidation in cakes was evaluated according to Buege and Aust (1978), as described in Section 2.3, using 0.5 g cake samples, 4.0 mL hexane, and 20 μL BHT for lipid fraction extraction.

Chemical composition of cakes

The determination of dry matter, protein, ether extract, and ash contents of cakes followed the methodology recommended by AOAC (ASSOCIATION..., 1997). The carbohydrate content was calculated from difference, using the equation: 100 – (moisture + ether extract + ash + protein + fibers).

The content of Total Dietary Fiber (TDF) was determined by the enzymatic-gravimetric method recommended by AOAC (ASSOCIATION..., 2002). The caloric value was calculated using the following Atwater conversion factors: 9 $kcal.g^{-1}$ of lipid, 4 $kcal.g^{-1}$ of carbohydrate, and 4 $kcal.g^{-1}$ of protein (FRARY; JOHNSON, 2005).

Linolenic acid content

The linolenic acid content was determined by gas chromatography. The lipid fraction of cake samples (0.1 g) was obtained according to Folch, Lees and Stanley (1957). Next, saponification and esterification followed procedures described by Hartman and Lago (1973). The sample aliquots (1.0 μL) containing methyl esters were injected (in duplicate) into a gas chromatograph with a Shimadzu AOC-17 autoinjector and a Shimadzu C-R7A integrator. The Carbowax capillary column (30 × 0.25 mm) operated in the following temperature program: start 200 °C, hold for 10 minutes, ramp 6 °C/minutes to 240 °C, and hold for 16.6 minutes. The chromatographic conditions were as follows: the temperatures of the injector and detector were 240 and 260 °C respectively and the split mode at 1:20 ratio. The carrier gas (nitrogen) flow was set to 0.5 mL/minute, 100 Kpa pressure. An analytical curve of linolenic acid, ranging from 0 to 1000 ppm (R^2 = 0996) was used to quantify omega-3 fatty acids.

2.7 Nutritional value of cakes as dietary fiber and linolenic acid source

The nutritional value of servings of 80 g of the cakes as a source of fiber and linolenic acid was calculated, considering the average daily recommendation for adults of linolenic acid and dietary fiber as 1.3 and 25 g/day, respectively (INSTITUTE..., 2002). The four cake formulations were classified according to the categories proposed by Philippi (2008): food source (containing more than 5% of dietary recommended intakes – DRI in a usual serving), good food source (contains between 10 and 20% of the DRI in a usual serving), and excellent food source (contains more than 20% of the DRI in a usual serving).

2.8 Sensory analysis

The assessment of acceptability of the four formulations of the flaxseed cake was carried out at local supermarkets, on the day the cakes were prepared. The samples, labeled with three digit numerals, were presented monadically to consumers following a complete randomized block design. Consumers evaluated the overall acceptance of formulations using a hedonic structured scale of 9 points. The data obtained from the acceptance test of the four flaxseed cake samples were used for the Internal Preference Mapping analysis.

2.9 Statistical analysis

The data from lipid peroxidation analyses of the flour and cakes were examined by ANOVA, and the mean contrasts were evaluated by the Tukey test, at 5% probability level. The results obtained from the acceptance test were evaluated using the internal preference mapping analysis. To carry out the Internal Preference Mapping or Multidimensional Preference Analysis (MDPREF), the acceptance data were organized in a matrix sampling design, sample (rows) and consumer (columns), that was subjected to the Principal Component Analysis (PCA) (CARNEIRO, 2001). The results were expressed as a sample dispersion plot generated by the first two principal components and another representing the PCA loads (correlation of the data from each customer's with the first two principal components) (DANTAS et al., 2004).

Statistical analyses were performed with Statistical Analysis System Software (SAS INSTITUTE, 1994).

3 Results and discussion

3.1 Lipid peroxidation in flour formulations

There were no significant differences for the lipid peroxidation among the flours prepared with seeds submitted to three different heat treatments. The average of malondialdehyde concentration ranged from 0,164 to 0,222 nmol/of lipid. There was also no statistical difference between the lipid peroxidation in the control treatment (raw and crushed seed) and the lipid peroxidation in flours made from heat treated seeds. Therefore, heat treatment did not favor seeds lipid peroxidation.

The cakes were prepared with heat treated flour (150 °C; 10 minutes), which provided the most suitable physical characteristics for the handling of the product during ingredient homogenization.

3.2 Cake yield

The cake yield ranged from 7.4 to 8 servings of 80 g each, and the highest yield was provided by the formulation with 15% flaxseed flour (Table 3).

3.3 Lipid peroxidation in cakes

The lipid peroxidation was not significantly different among the cakes made with 5, 15, and 30% flaxseed flour (Table 4). The cake formulation with 45% flaxseed flour had significantly lower lipid peroxidation than that of the cakes prepared with lower concentrations. This was a surprising result since it was expected that the cakes containing higher levels of linolenic acid would present the highest lipid peroxidation. This result can be attributed to the protective effect of antioxidant compounds contained in the flaxseed. The antioxidant activity may have been optimized with the increase in the concentration of flaxseed in the formulation with 45% flour.

Table 3. Yield of cakes made with four different concentrations of flaxseed flour.

	Formulation			
	B1	B2	B3	B4
Raw batter	680	715	705	715
Baked cake	595	640	635	629
Yield factor	1.14	1.11	1.11	1.13
Servings* (number)	7.4	8.0	7.93	7.86

B1 = formulation with 5% flaxseed flour; B2 = formulation with 15% flaxseed flour; B3 = formulation with 30% flaxseed flour; B4 = formulation with 45% flaxseed flour; *Considering 80 g for each serving.

Table 4. Means and standard deviation of malondialdehyde concentration in cakes made with different concentrations of flaxseed flour.

Formulations	Malondialdehyde (nmol.g^{-1} lipid)*
5% flaxseed flour	26.78 ± 6.81^{a}
15% flaxseed flour	21.59 ± 2.70^{a}
30% flaxseed flour	21.60 ± 3.41^{a}
45% flaxseed flour	11.52 ± 3.12^{b}

* Mean and standard deviation of 8 repetitions, in duplicate; Means followed by different letters are significantly different by the Tukey test ($p < 0.05$).

Table 5. Chemical composition of cakes made with four concentrations of flaxseed flour.

Components (g.100 g^{-1})	Formulations			
	B1	B2	B3	B4
Moisture	17.34	18.34	19.34	20.34
Dietary fiber	3.55	5.10	6.92	8.13
Ash	2.59	2.48	2.60	2.82
Lipids	13.09	14.22	17.95	18.81
Protein	6.67	6.75	6.96	6.66
Carbohydrate	56.76	53.11	46.23	43.24
Calories	371.53	367.42	373.31	368.89
Linolenic acid (mg)	445	1240	2500	3791

B1 = 5% flaxseed flour; B2 = 15% flaxseed flour; B3 = 30% flaxseed flour; B4 = 45% flaxseed flour.

3.4 Chemical composition and nutritional value of cakes

The highest moisture content was found for the cake with 45% flaxseed flour, probably because the highest dietary fiber content can, through chemical interactions, retain water in the food matrix (Table 5). The components that showed more major quantitative variations were moisture, dietary fiber, and linolenic acid. Considering the supplying of dietary fiber and linolenic acid, one serving of flaxseed cake equivalent to 80 g can be considered an excellent source of both nutrients (Table 6).

3.5 Sensory analysis

A total of 110 consumers participated in the study including 42 men and 68 women, accounting for 38.2 and 61.8% respectively, between 16 and 82 years of ag. The internal preference mapping based on the acceptability data and carried out using PCA showed that the first two principal components accounted for,respectively, 41 and 35% of the total variation totalizing therefore, 76% of the total variance among the cake samples (Figure 1).

The spatial separation of the flaxseed cake samples suggests the existence of three groups of acceptance; one group formed by 15 and 30% of flaxseed cakes and the others formed by 5 and 45% of flaxseed cakes (Figure 1).

Figure 1 shows each point representing the correlations between the acceptance data of one or more consumers and the first two principal components. The correlation between consumers with at least one of the components indicates some difference in sample acceptance. The consumers were placed near the samples of their preference. Twenty-six percent of consumers preferred samples with 5, 15, and 30% of flaxseed flour, confirming a positive correlation ($r \geq 0.5$) with the first principal component. The second principal component also showed positive correlation ($r \geq 0.5$), 12% of the consumers preferred samples with 15 and 30%, and negative correlation ($r \geq -0.5$), 15% of consumers preferred the sample with 45% of flaxseed flour.

Excellent acceptance by consumers (94%) was observed for the formulation of flaxseed mousse in the work of Villarroel, Pino and Hazbún (2006). However, Hussain et al. (2006) found

Table 6. Nutritional value of a serving of 80 g and classification of cakes according the amount of fiber and linolenic acid provided to adults[1].

Formulation	Fiber DRI = 25 g			Linolenic acid[2] DRI = 1.3 mg		
	g/serving	% DRI	Classification	g/serving	% DRI	Classification
B1	2.84	11.36	Good source	356.00	27.38	Excellent source
B2	4.08	16.32	Good source	992.00	76.30	Excellent source
B3	5.54	22.16	Excellent source	2.000	153.85	Excellent source
B4	6.51	26.04	Excellent source	3.032	233.29	Excellent source

[1] Considering DRI (dietary recommended intakes) average for adults of both sexes (INSTITUTE..., 2002). [2] Based on AI (adequate intake). B1 = formulation with 5% flaxseed flour; B2 = Formulation with 15% flaxseed flour; B3 = formulation with 30% flaxseed flour; B4 = formulation with 45% flaxseed flour.

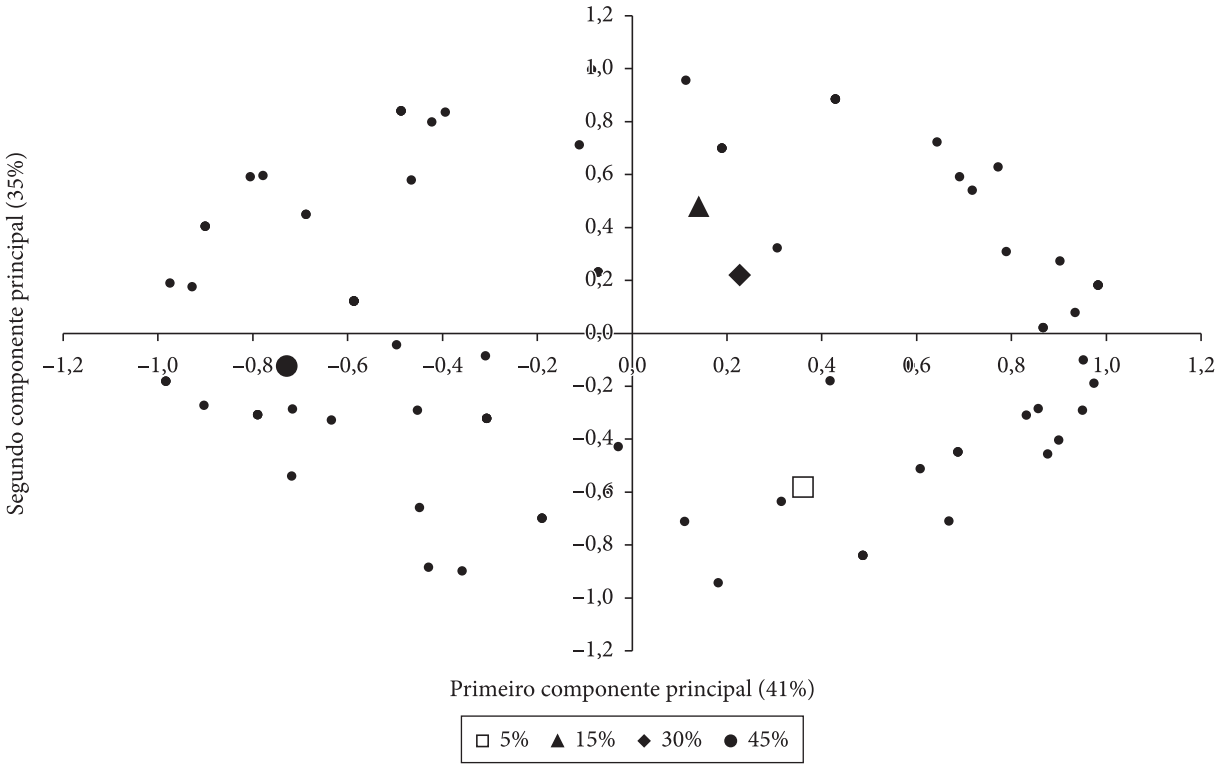

Figure 1. Dispersion of flaxseed cake samples in relation to consumer acceptance and correlations between acceptance data of each consumer and the first two principal components.

that biscuits supplemented with 25 and 30% of flaxseed flour were less accepted than those made only with wheat flour. The consumer acceptance of muffins added with flaxseeds, in the concentrations of 7.3, 11.6, and 15.5%, was also significantly lower for all examined attributes, including appearance, color, flavor, texture, and acceptability, than that of the control muffins (RAMCHARITAR et al., 2005).

Alpaslan and Hayta (2006) evaluating bakery products suggested that corn, soybean, and flaxseed flours can be added to formulations in amounts up to 10%. Cake formulations prepared with partial replacement of wheat flour for up to 30% of flaxseed flour were very well accepted.

4 Conclusion

The thermal treatment of flaxseeds aiming at flour production under the conditions used in this study did not affect lipid peroxidation.

The oven temperature (180 °C) used for baking the batter formulations did not cause significant degradation of linolenic acid in the cakes resulting in products with excellent source of omega-3 essential fatty acids.

The formulations made with up to 30% flaxseed flour as partial replacement of wheat flour had good acceptance, and the product presented nutritional and functional value classified as excellent source of dietary fiber and linolenic acid.

Adding flaxseed flour in bakery products is a useful strategy to increase the consumption of fiber and omega-3 in the human diet. New formulations could therefore be tested aiming at the development and consumption of foods fortified with higher proportions of functional and nutritious ingredients.

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