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Resource recovery in the food industry: use in the development of cakes

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Abstract

This study aimed to evaluate the technological potential of using fruit residues and beer residue in the preparation of cakes, as well as the effects of their incorporation on the nutritional and sensory qualities of the cakes. Four cakes were developed: one with fruit residues (control) and 3 with fruit residues and also 10, 30 and 50% of malt bagasse flour (MBF). Analyses were performed of chemical composition, color and texture, as well as sensory evaluation of the cakes. The cakes with 30 and 50% MBF had higher levels of moisture, ash, protein and dietary fiber. The higher levels of MBF (30 and 50%) influenced the color parameters of the crust and the crumbs; the cakes also showed higher levels of hardness, gumminess, elasticity and cohesiveness. All the cakes were well accepted sensorially, except for the cake with 50% MBF. These results demonstrate the potential use of these waste products by the food industry in the development of functional foods and in the recovery of nutrients that are currently discarded. This would protect the environment and also provide social and economic benefits through the recovery of these resources.

Introduction

The cleaner production in foods include changes in product design, which incorporate a reduction in the use of hazardous materials, reduced waste, and reduced energy consumption in the production process and use of the relevant product (Rosa *et al*., 2015). The evolution of agribusiness and the development of food processing processes has led to the generation of large quantities of waste, which is a major environmental problem worldwide (Giordano, 2000). Brazil is an agro-industrial country and, as a consequence, produces various types of waste that could potentially be reused, such as corn husks; the husks of coffee seeds, peanuts and coconut; cassava stalks; and sugarcane bagasse, among others (Mendes *et al*., 2010; Scatolino *et al*., 2013).

The growing market for natural products, coupled with consumer interest in disease prevention, has prompted the food industry to search for healthier products, and consequently there has been much research in this area. The idea of traditional foods with added nutrients in their formulation is a practice that provides access to nutrients for consumers, without requiring the need to change eating habits (Anjo, 2004). Changes in processing, and growing consumer demand for foods with sensory and nutritional quality that bring health benefits, have encouraged the study of new ingredients for the food industry (Moscatto *et al*., 2004).

A large proportion of fruit production is currently directed to meet the demand for fresh fruit; however, there is also a global trend for processed products such as preserves, juices, jellies and candies. The manufacture of fruit juice generates large amounts of industrial waste, which is mainly discarded (85%) or used for animal feed in the form of a component in mixed feed or green manure (about 15%), procedures that lead to economic and biotechnological losses for the food industry (Corrêa *et al*., 2001).

Malt bagasse is the residue from the initial process of manufacturing beer. This residue comes from the process of obtaining the wort by boiling ground malt and additional ingredients, which, after filtering, results in a residue that is currently discarded or used for animal feed (Aquarone, 2001). Malt bagasse is the main by-product of the brewing process; 14-20 kg is generated per 100 liters of beer that are produced. The large annual production of beer in Brazil (an average of 8.5 billion liters) gives an idea of the amount of this by-product that is generated. Because this waste is generated in large quantities during beer production, and it is also rich in fiber and protein, other forms of usage than in animal feed have been studied, such as use in food for human consumption (Santos and Ribeiro, 2005). The development of new products by the food industry not only requires the use of new ingredients, but also that those products should be environmentally, socially and economically sustainable in order to develop products which are

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acceptable to consumers (Bertoluci *et al*., 2014).

One of the products in which the waste generated in agro-industrial processes could be used is in the manufacture of cakes. The latter have been acquiring increasing importance in Brazil in terms of consumption and, especially, in the industrialized production of cakes. Data from the Brazilian Association of Industrialized Pasta, Bread and Cakes (ABIMAPI, 2014) reveals that in 2010 the per capita consumption of industrially produced cake amounted to 1.3 kg, the highest level in the last five years. Although it is not a staple food such as bread, cake is consumed by people of all different age groups (Borges *et al.*, 2006). The aim of this study was to develop cakes containing fruit residues and malt bagasse flour, and to and evaluate their chemical, physical and sensory qualities.

Materials and Methods

The experiment was conducted at the Integrated Center for the Development of Laboratory Analysis (NIDAL) at the Food Technology Center (NTA), and at the laboratories of the Department of Food Science and Technology at the Federal University of Santa Maria (UFSM). The malt bagasse was obtained after the mashing of Château Pilsen malt (2 RS), which was of German origin and came from the first stage of the brewing process. The fruit residue, which consisted of pineapple (cv. pérola) and banana (cv. prata) in a 2:1 ratio, was obtained after the preparation of a mixed juice on the laboratory scale.

Chemical composition

For characterization, the Château Pilsen malt (2RS) was triturated in a specific rolling mill designed to break it up, followed by drying in an oven with forced-air circulation at 50°C for 48 hours. The malt bagasse was dried in an oven with forced-air circulation at 50°C for 48 hours. The malt bagasse was subsequently triturated in a Marconi® MA-630 micro-mill (<1 mm). The determination of the chemical composition of the malt and the malt bagasse were performed according to the techniques described by the Association of Official Analytical Chemistry (AOAC, 2005). The moisture analyses were performed at 105°C to constant weight. The analysis of ash was performed by incineration in an oven at 550°C/5h and the analysis of crude protein was performed by the determination of nitrogen using the Kjeldahl method; a factor of 6.25 was used for the conversion of the total nitrogen into total protein. The crude fiber content was determined using a fiber digester apparatus (Ankom® 220 Fiber Analyzer), which was corrected for mineral matter in accordance with the manufacturer's recommendations. The lipids were quantified gravimetrically following extraction with chloroform and methanol (Bligh and Dyer, 1959).

Water activity (A_w)

The Aw was measured directly using a AquaLab®, model 4TEV, water activity analyzer (Braseq, Brazil) at constant temperature (25 ± 0.2°C), according to the manufacturer's specifications.

Color analysis

The color was assessed objectively by reflectance in the CIELab color space, using a Konica Minolta® CR-300 colorimeter with standard D65 illuminant and 2° viewing angle. The color parameters which were evaluated were brightness (L^*) and the a^* and b^* color coordinates. The samples were homogenized and placed in 40 mL Petri dishes (0.1 cm thick) on a standard white background, on which six sequential readings were performed.

Formulation of the cakes

Four cake formulations were developed; a control (BC) without malt bagasse flour (MBF) and three experimental cakes B10, B30 and B50, containing 10, 30 and 50% of MBF respectively. The remaining ingredients, except for the MBF and the fruit residues, were purchased in shops in the city of Santa Maria, RS. The ingredients of the cakes are described in Table 1.

Firstly, the MBF was obtained from the malt bagasse, which was crushed in a domestic blender for 5 minutes at high speed. Then, all the ingredients were weighed according to the preset formulations (Table 1) and the fruit residue was homogenized with the milk in a domestic blender. Half of the quantities of sugar, margarine and egg yolk were mixed for 10 minutes in a planetary mixer (Arno Deluxe) to obtain a homogeneous and light cream. Then the previously sifted wheat flour, MBF, cinnamon powder and egg white (beaten in a mixer for 5 minutes at medium speed along with the remaining sugar) were added. After homogenization, the baking powder was added and mixed by hand. The dough was distributed in a rectangular aluminum baking dish, which was greased with margarine, and baked in a conventional oven at 200°C for 30 minutes. The cake was removed and divided into individual portions (3 cm x 3 cm) after cooling for 1 hour at room temperature. The samples were then analyzed.

Table 1. Formulations of the developed cakes

Ingredients	Formulations*			
	BC	B10	B30	B50
Wheat flour (g)	100	90	70	50
Malt bagasse flour (g)	-	10	30	50
Pineapple/banana residue (2:1) (g)	40	40	40	40
Refined sugar (g)	45	45	45	45
UHT whole milk (mL)	85	80	85	90
Margarine (g)	20	20	20	20
Egg (one)	1	1	1	1
Baking powder (g)	5	5	5	5
Cinnamon powder (g)	2	2	2	2

*BC: control cake; B10: cake with 10% MBF; B30: cake with 30% MBF; B50: cake with 50% MBF.

Chemical composition of the cakes

To determine the chemical composition of the cakes, the analyses of moisture, ash, protein, lipids, water activity, and calculation of the energy value (Kcal g^{-1}) were performed according to the procedures described in section 2.2.1.1 (AOAC, 2005). The analysis of total dietary fiber was carried out according to the 991.43 (AOAC, 2005) enzymatic-gravimetric method. The enzymes used in the method were α-amylase (Termamyl® 2X), protease (Alcalase® 2.4 L FG) and amyloglucosidase (AMG® 300L), all of which were obtained from Novozymes Latin American Ltda. The carbohydrates were calculated by difference from the other fractions.

Color analysis

The color of the crust and the crumbs of the cakes were determined using a CM-700d/600d Minolta® colorimeter (Konica Minolta Sensing Americas Inc., Ramsey, New Jersey, USA) using the CIELab system. Six sequential measurements were performed directly on the crust and the crumb samples. The presented results are the means of the values obtained for the L^*, a^* and b^* parameters.

Sensory analysis

The sensory test was performed in the Sensory Analysis Laboratory of the Department of Food Science and Technology at UFSM. The cakes were subjected to acceptance testing by 60 untrained male and female testers, aged between 18 and 55. Each tester received a sample of each formulation, which was coded with random three-digit numbers; the samples were served in a monadic and randomized manner. The testers were instructed to evaluate each sample with respect to the attributes of color, aroma, taste, texture and overall acceptability using a verbally-structured seven-point hedonic scale (1 = disliked very much, 2 = disliked a lot, 3 = disliked, 4 = indifferent 5 = liked, 6 = liked a lot and 7 = liked very much). All the testers were offered a glass of water at room temperature to clean the taste buds between each sample (Ferreira, 2000).

Statistical analysis

The experiment was completely randomized, with four treatments, three replicates and readings in triplicate. The data are presented as mean ± standard deviation and underwent analysis of variance (ANOVA) and Tukey's test ($p \leq 0.05$) using Statistica software, version 7.0 (StatSoft Inc., 1984-2004, Tulsa, USA).

Results and Discussion

Characterization of malt and malt bagasse

The moisture (Table 2) content recorded in the malt was similar to values reported by Sleiman and Venturini (2004) in Cristal type malt (8.2 g 100 g^{-1}) and Curi *et al.* (2009) for malt used in the manufacture of beer (9.0 g 100 g^{-1}). According to the technical details of the product, Château Pilsen malt has a maximum moisture content of 4.5 g 100 g^{-1}. According to Curi *et al.* (2008) the values found this paper are high when compared to the recommendations in the literature, but so as not to from suffer microbial decay or insect attack, the malt used in the present study was stored frozen, where it acquired humidity, thereby explaining these results.

The moisture content of the malt bagasse was high, which was in agreement with the results obtained by Cordeiro *et al.* (2012), who reported an average moisture content of 75.45 g 100 g^{-1} in humid malt bagasse. Vieira and Braz (2009) confirmed that malt bagasse is a by-product that has high moisture content (70-75%). Chaves *et al*. (2004) also emphasize that humidity is an important factor to be considered because it directly affects the maintenance of the quality of the raw material, thus, reducing the moisture content contributes to greater conservation

Table 2. Water activity (a_w), color, composition of malt and malt bagasse.

Physicochemical analysis		Malt	Malt bagasse
Aw		0.15±0.00	0.26±0.00
	L*	78.81±1.37	55.03±0.71
Color	a*	+2.98±0.03	+5.41±0.07
	b*	+14.75±0.04	+19.72±0.28
Moisture (g 100 g^{-1})		8.84±0.12	77.88±0.00
Ash (g 100 g^{-1})		1.68±0.03	0.51±0.00
Crude protein (g 100 g^{-1})		8.54±0.30	3.38±0.07
Lipids (g 100 g^{-1})		2.00±0.03	1.24±0.02
Crude fiber (g 100 g^{-1})		3.62±0.24	2.65±0.11
Nitrogen-free extract (g 100 g^{-1})		75.33±1.30	14.34±0.08
Energetic value (kcal 100 g^{-1})		353.41±1.18	82.03±0.39

The results, on a wet basis, were expressed as mean ± standard deviation. L^*: lightness, a^* and b^*: color coordinates.

of the product and increases its length of use because it reduces the water available for the growth of micro-organisms and chemical reactions.

According to Pinto (2009), water activity is a more important variable than water content in the characterization of foods because it determines absolute values for the growth of fungi and bacteria, and for the development of biochemical reactions. The water activity found for the malt bagasse in the present study was low and did not cause any problems related to fungi and bacteria.

Regarding the content of ash, crude protein, lipids, crude fiber and energetic value, the results for the malt bagasse were lower than the values found by Cordeiro *et al.* (2012). The differences observed between the values found in the present study and those found in the literature are due to the composition of the residue, which can undergo variations in the concentration of nutrients, and can be related to the quality of raw material and/or the type of malt used to prepare the beer. According to Santos *et al.* (2003) the chemical composition of malt bagasse can vary according to the variety and the time of harvest of the barley, the grinding conditions for the malt, and the type of additional ingredients (maize, rice, wheat and sorghum) which are added to the fermentation process.

Chemical composition and water activity

The inclusion of malt bagasse flour significantly increased the moisture content and level of dietary fiber (Table 3) compared to the control cake made with fruit residues. The presence of higher levels of dietary fiber in the cakes increased the water retention in the product after cooking, which may have been related to the hydration capacity of the fiber, which is a property that profoundly influences the final texture of products (Elleuch *et al*., 2011).

Other studies have also noted the large hydrophilic ability of dietary fiber when added to food products (Perez and Germani, 2007; Mauro, Silva and Freitas, 2010). The cakes with 30 and 50% MBF did not differ from each other but they differed significantly from the other formulations, presenting higher levels of protein, ash and lipids. Similar results were found by Guimaraes *et al.* (2010) in formulations of cakes with the addition of 30% of flour made from the inner skin of watermelon.

In relation to the total dietary fiber content, it was observed that the use of MBF as a partial replacement for wheat flour caused a significant increase ($p \leq 0.05$) in total dietary fiber content. The addition of MBF contributed to an increase of 50.57; 127.59 and 154.25% of dietary fiber in the cakes with 10, 30 and 50% MBF, respectively. Moreover, the high content of dietary fiber contributed to a reduction in carbohydrate content and energetic value (Table 3). Under current Brazilian legislation, Resolution No. 360 of 23 December 2003 (Brasil, 2003) and Decree No. 27 of 13 January 1998 (Brasil, 2012), it can be said that the three formulations with MBF could be classified as foods that were with a high fiber content, or that they were rich in fiber, because they had an average value of 10 g/100 g. For a product to be legally considered to have high fiber content it must contain at least 6 g/100 g.

The cakes with 10 and 30% MBF differed statistically from the other formulations in terms of having lower levels of A_w. Water activity indicates the amount of water that is available to perform molecular movement and transformations, and also to promote microbial growth in a product. Similar results to those that were obtained in the present study were observed by Panzarini *et al*. (2014) in honey cake enriched with fiber; the cakes with 7 and 10.5% of malt bagasse had Aw of 0.9066 and 0.8952, respectively.

Color

Regarding the L^* parameter (Table 4), it was

Table 3. Water activity and chemical composition of the cakes.

Constituents (g 100 g^{-1})	Formulations*			
	BC	B10	B30	B50
Water activity (Aw)	0.952±0.001a	0.950±0.002ab	0.946±0.003b	0.953±0.002a
Moisture	38.26±0.02c	38.37±0.01c	38.53±0.04b	41.80±0.10a
Protein	7.94±0.15b	7.88±0.22b	8.62±0.07a	8.57±0.20a
Mineral material	1.60±0.01b	1.62±0.04b	1.77±0.02a	1.78±0.01a
Lipids	7.38±0.31bc	7.22±0.20c	7.92±0.23ab	8.10±0.02a
Total dietary fiber	4.35±0.46d	6.55±0.33c	9.90±0.24b	11.06±0.11a
Non-fibrous carbohydrates**	16.22±1.78a	12.63±1.97ab	8.65±3.07b	8.98±2.68b
Energetic value (kcal 100g^{-1})	163.02±4.26a	147.01±7.62ab	131.30±13.19b	143.07±11.31ab

Means with the same letters in the same line indicate that the samples did not differ (p> 0.05) by Tukey's test. Results expressed on a wet basis. *BC: control cake; B10: cake with 10% MBF; B30: cake with 30% MBF; B50: cake with 50% MBF. ** Calculated by difference in relation to the other components.

Table 4. Instrumental color parameters (L^*, a^*, b^*) of the cakes.

Formulations[1]	Color of crust			Color of crumbs		
	L^*	a^*	b^*	L^*	a^*	b^*
BC	60.58±3.6a	12.91±2.03[a]	35.78±1.27a	64.14±5.33a	2.85±0.28d	16.49±0.44b
B10	57.47±2.53a	12.85±2.27[a]	33.41±1.98a	61.13±4.14a	4.40±0.22c	18.53±0.67a
B30	50.41±1.05b	10.17±1.12b	26.13±1.83b	50.39±3.54b	6.17±0.27b	19.97±0.94a
B50	45.41±1.01c	9.25±0.41b	22.08±0.96c	44.13±4.48b	6.98±0.55a	20.30±1.80a

Means in the same column with the same letter did not differ significantly by Tukey's test (p> 0.05).
1BC: control cake; B10: cake with 10% MBF; B30: cake with 30% MBF; B50: cake with 50% MBF

observed that the higher the content of MBF in the formulation, the lower the levels of brightness of the crust and crumbs in the cakes, indicating lower light reflectance. This was due to the addition of malt bagasse replacing wheat flour, which gave a darker color to the final product. The brightness of the crust and the crumbs in the cakes with 10% MBF and the control did not differ; however, they differed from the other formulations (p> 0.05). Lower L^* values were also observed in a study by Padilla et al. (2010) in relation to cake formulations with higher percentages of yacon flour; however, Panzarini *et al.* (2014) found no significant difference in the L^*, a^* and b^* parameters in honey cakes enriched with malt bagasse when the variation of malt bagasse was small in the formulations.

Regarding the a^* and b^* color parameters, all the portions of the crust and crumbs in the samples showed readings in the regions of red and yellow, and positive values for these coordinates were obtained (Table 4). It was also observed that the cakes with 30 and 50% MBF had lower a^* and b^* values in the crust ($p \leq 0.05$) compared to the control cake. In relation to the crumbs, it was observed that a^* and b^* values increased in line with increased concentrations of MBF.

According to Silva (2007), positive a^* and b^* values result in a brown color, which is characteristic of products made with chocolate. A tendency towards brown coloring was found in the cakes with added MBF. Regarding the results of the color of the crumbs, the a^* and b^* values increased with the addition of MBF, i.e. the malt bagasse increased the tendency to yellow and red in the crumbs compared with the control formulation. Furthermore, the other formulations with added malt bagasse differed between themselves in terms of a^* values, while there was no difference between the formulations with malt bagasse in relation to b^* values.

Sensory evaluation

Sixty untrained testers participated in the

Table 5. Means scores for sensory attributes in the acceptance test for the cakes.

Sensory Attributes	Formulations*			
	BC	B10	B30	B50
Color	5.07±1.06a	4.65±1.15ab	4.85±1.05ab	4.33±1.43b
Aroma	5.51±0.84a	5.27±1.10a	5.15±1.09a	4.40±1.30b
Taste	5.56±1.00a	5.32±1.08ab	4.95±1.23b	4.30±1.33c
Texture	5.73±1.06a	5.05±1.11b	4.22±1.35c	3.62±1.32d
Overall Acceptance	5.49±0.82a	5.12±1.04ab	4.78±1.14b	4.08±1.21c

Means on the same line with the same letter did not differ significantly by Tukey's test ($p > 0.05$). *BC: control cake; B10: cake with 10% MBF; B30: cake with 30% MBF; B50: cake with 50% MBF. Scores: 7 - liked very much; 6 - liked a lot; 5 - liked; 4 - indifferent; 3 - disliked; 2 - disliked a lot; 1 - disliked very much.

sensorial analysis. They were aged 18-25 (63%) or 26-35 (25%) and were predominantly female (83%). The average acceptance scores for the attributes of color and aroma (Table 5) showed that the cakes with 10 and 30% MBF were not statistically different from the control cake. The cake with 50% MBF was the least accepted of the formulations with added MBF. No significant differences were found for the color attribute; however, in terms of aroma the means scores for the cakes with 10 and 30% MBF were higher and differed statistically from the cake with 50% MBF.

For the attributes of taste and overall acceptance, the means scores for the cakes with 30 and 50% added MBF corresponded to the term "indifferent" (4) on the hedonic scale when compared to the control cake. The cake with 10% MBF received scores for the attributes of taste and overall acceptance which were statistically equivalent to those for the control cake and also received higher values than the control, corresponding to the evaluation of "liked" on the hedonic scale. In terms of texture, the cakes with added MBF differed from the control, having a less firm texture. The cake with 50% MBF corresponded to the hedonic term "disliked", demonstrating rejection regarding this attribute.

Conclusion

The malt and malt bagasse had high nutritional value and can be used as a source of nutrients in foodstuffs, in particular in cakes. The formulations of the cakes with fruit residues and malt bagasse flour showed high levels of protein, ash and total dietary fiber, with reduced levels of carbohydrates. The sensory analysis showed that the control cake and the cakes with 10% malt bagasse flour received excellent acceptability. Among the formulations it was possible to produce cakes with fruit residues and cakes with 10% malt bagasse flour without changing the chemical, physical and sensory characteristics, as well as the purchase intent and acceptability of the cakes. The results of this study show the potential use of these by-products from the food industry to develop new products, to recover nutrients that are currently discarded, to protect the environment, and to provide economic and social benefits related to the recovery of these by-products.

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