Cassava derivatives in ice cream formulations: effects on physicochemical, physical and sensory properties

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Abstract In the present study, the effects of derivatives of cassava, maltodextrin and bagasse, on the physicochemical, physical and sensory properties of ice creams were investigated. The content of cassava maltodextrin increased significantly the content of carbohydrate and total soluble solids and decreased lipids content. The effect of cassava bagasse was more pronounced than the maltodextrin on physical and sensory parameters. Increased percentage of cassava bagasse in formulation led to decrease of overrun, melting and luminosity, but increased hardness and unfreezable water. Sensory attributes were mainly influenced by cassava bagasse inclusion. The results suggested the potential use of cassava derivatives in ice cream formulations. Ice creams with low percentage of cassava bagasse (1.5) and intermediate values of cassava maltodextrin (3.65%) had good nutritional, technological and sensorial acceptance.

Keywords Maltodextrin · Fiber · Fat substitute · Composition · Texture · Thermal properties

Introduction

The consumption of functional foods is increasing rapidly worldwide mainly due to consumer awareness of the importance of diet in maintaining health. This made that the food industries spend develop alternative products with modified composition, i.e. removing or limiting the presence of some compounds harmful to health (Salem et al. 2005; Crizel et al. 2014).

The development of these foods is a challenge because it must meet consumer demand for products that are both tasty and healthy and have similar characteristics to conventional food (Cruz et al. 2009).

Ice cream is a delicious and nutritious frozen dairy product widely consumed in many parts of the world. The ice cream is a frozen complex colloidal system which is composed of partially coalesced fat droplets, air cells, ice crystals and a continuous aqueous phase, wherein the polysaccharides, proteins, lactose and minerals are dispersed. A typical composition of ice cream consists of about 30% ice, 5% fat, 15% matrix and 50% air by volume.

According to Mintel (2016), a market agency, the global ice cream market continues to enjoy robust growth. The top five ice cream markets by volume globally in 2014 were China (5.9 billion litres), followed by the US (5.8 billion litres), Japan (784 million litres), Russia (668 million litres) and Germany (545 million litres).

However it is important to highlight the significant increase in ice cream market in Brazil. Ice cream trade data in Brazil showed significant increase (66.96%) of the production of ice cream in the country, from 687 (2003) to 1.14 million liters (2015), representing a growth of per capita consumption of 3.83–5.59 L year⁻¹ (ABIS 2016).

Recently, the increasing demand from consumers for healthier and functional food has led to produce ice cream

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containing special ingredients with recognized nutritional and physiological properties (Aboufazi et al. 2016).

The conventional ice cream formulations have a high content of fat, about 10–16% (Adapa et al. 2000). Ice cream manufacturers have attempted to simulate the texture and flavor of fat-containing ice cream by adding bulking agents and concentrated milk components to fat-free formulations. Carbohydrate bulking agents, such as maltodextrin and polydextrose, are currently used in low-fat formulations because they produce minimal negative effects on ice cream production, shelf-life, and price (Roland et al. 1999; Cadena and Bolini 2011).

Maltodextrin is produced as a result of starch fragmentation by enzyme and acid. Maltodextrin gel can easily combine with liquid and solid fats and form a stable emulsion gel. Since it gives the same taste as fat, it helps foods to be broken easily into pieces in mouth. It is mostly used in margarine, mayonnaise, salad sauce, pastry and dairy products (Güzeler et al. 2011).

With the knowledge that the consumption of dietary fiber has an important role in many physiological processes and in the prevention of some diseases, the use of fibers as an ingredient in food products has increased (Rodríguez et al. 2006).

In the process of cassava starch extraction is generated cassava bagasse. This solid residue is constituted by fibrous material of the root and part of the starch that has not be extracted during processing, having a high contents of total dietary fiber in dry basis (63.95 g 100 g⁻¹), with 56.84 g 100 g⁻¹ of insoluble fiber and 3.51 g 100 g⁻¹ of soluble fiber. Thus it has potential use as fiber source by food industries (Fiorda et al. 2013; Trombini et al. 2013).

Considering the growing demand for healthier products; commercial appeal and sustainability with the use of agro-industrial waste as a source of fiber in foods and the differential promoted by inclusion of derivative of cassava in ice cream formulation, this work aimed analyzing the chemical, physical and sensory characteristics of bulk ice cream, using cassava maltodextrin and cassava bagasse in formulation.

Materials and methods

Ice cream formulation

For the formulation of ice cream the following ingredients were used: crystal sugar Guarani[®] (Tereos, Severínia, São Paulo State, Brazil) (16 g 100 g⁻¹), skimmed milk powder Piracanjuba[®] (Piracanjuba, Bela Vista de Goiás, Goiás State, Brazil) (70 g 100 g⁻¹), vanilla Dr. Oetker[®] (Dr. Oetker Brasil, São Paulo, São Paulo State, Brazil) (0.2 g 100 g⁻¹), vegetable fat Primor[®] (Bunge Brasil, São Paulo,

São Paulo State, Brazil) (1.46–5.18 g 100 g⁻¹), Emulsifier Emustab Selecta[®] (Duas Rodas Industrial Ltda, Jaguará do Sul, Santa Catarina State, Brazil) (1.0 g 100 g⁻¹), League Neutral Selecta[®] (Duas Rodas Industrial Ltda, Jaguará do Sul, Santa Catarina State, Brazil) (0.5 g 100 g⁻¹), Maltodextrin Neomalt 5010B[®] (Indústria Agro Comercial Cassava S.A., Rio do Sul, Santa Catarina State, Brazil) and cassava bagasse (donated by Lotus Comércio e Indústria de Produtos de Mandioca Ltda, Cândido Mota, São Paulo State, Brazil) were added in accordance with the experimental design.

The cassava bagasse was dried in an oven (± 50 °C), crushed, sieved (180 Mesh, 0.09 mm) and characterized as the physicochemical composition, presenting in its composition: 6.24% of moisture, 1.50% of ash, 1.80% of protein, 1.23% of fat, 0.39% of total sugars, 67.68% of total dietary fiber and 21.16% of starch, with pH 4.89 and titratable acidity of 11.69 mL NaOH g⁻¹.

Experimental design

A Central Composite Rotational Design (CCRD) was employed to assess the experimental data. Experimental design included four factorial points, four axial points and three replicates of the central point. The maltodextrin content ranges from 1.46 to 5.84 g 100 g⁻¹ and cassava bagasse from 0 to 10%. Thus, according to the cassava bagasse composition the content of total fiber in the ice cream formulations ranged from 0 to 6.77 g 100 g⁻¹.

The response functions (Y) were physic-chemical parameters, physical characteristics and sensory attributes. These values were related to the coded variables by a second order polynomial using Equation:

$$Y_1 = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_{11}X_1^2 + \beta_{22}X_2^2 + \beta_{12}X_1X_2 + \varepsilon \quad (1)$$

where Y₁, Dependent variable or response function; X₁, X₂, Values of the independent variables; β_0 , Coefficient relative to the line interception with the response axis; β_1 , β_2 , Linear coefficients assessed through least square method; β_{11} , β_{22} , Coefficients of quadratic variables; β_{12} , Coefficient of interaction between independent variables; ε , Experimental error.

Ice cream manufacture and analysis

The manufacture of ice creams consisted of weighing and mixing the ingredients until the syrup becomes homogeneous. The slurry was pasteurized (70 °C 30 min⁻¹) and aged overnight at 4 °C. After this period the slurry was subjected to partial freezing with incorporation of air in a

discontinuous production line of ice cream (Refrigria, Comércio e Refrigeração Refrigria Ltda-ME, Amparo, São Paulo State, Brazil) at $-18\text{ }^{\circ}\text{C}$ 30 min^{-1} . The ice creams formulations were packed in plastic containers ($V = 2\text{ L}$) and stored at $-18\text{ }^{\circ}\text{C}$.

Standard methods of AOAC (2005) were used to determine moisture (AOAC—925.10), fat (AOAC—2003.05) by soxhlet extraction, ash (AOAC—923.03) by combustion, protein (AOAC—960.52) by micro Kjeldahl method ($N \times 6.25$) in triplicate. The Nifext fraction (carbohydrates) was obtained by the calculation of the difference in other analyzed fractions.

Textural characteristics of the ice cream was carried out in a Stable Micro Systems Texture Analyser TAXT Plus (Texture Technologies Corp, England), in triplicate. Testing characteristics were: Accessory: Probe p/2 N; Mode: strength measured in compression; Pre-test speed: 2.0 mm s^{-1} ; Test speed: 3.0 mm s^{-1} ; post-test speed: 7.0 mm s^{-1} ; Penetration distance: 25 mm.

Overrun was determined according to the method described by Marshall (2003). A known volume of ice cream mix and frozen ice cream were weight and overrun was calculated according to the equation:

$$\text{Overrun}\% = \frac{\text{weight of the ice cream mix} - \text{weight of the ice cream}}{\text{weight of the ice cream mix}} \times 100 \quad (2)$$

The melting test was conducted according to the procedure described by Granger et al. (2005) with modifications. Samples of 100 g of each ice cream were stored in cylindrical pots of 250 mL for standardization of the sample and stored in a freezer until analysis. Each cream sample was placed on a mesh grid (5.6 mm) supported in a funnel coupled through a support on a beaker (250 mL of capacity). The beaker was kept on an analytical balance for weighing the molten mass. The ambient temperature was maintained at $26 \pm 1\text{ }^{\circ}\text{C}$. The weight of the material passed through the screen was recorded at 5-min time intervals for 60 min duration. The melting rate was determined as the slope of the graphs of the dripped portion as function of the time, and expressed in g min^{-1} .

The color of the ice cream was evaluated in a Minolta CR-400 colorimeter (Konica Minolta Sensing). The samples were placed in Petri dishes and stored in a freezer until the time of analysis. The results were expressed in L^* , a^* and b^* , where L^* values (brightness) ranging from black (0) to white (100), the chroma values a^* ranging from green (-60) to red ($+60$), values of chroma b^* ranging from blue (-60) to yellow (60).

Thermograms of ice cream were obtained with a Perkin-Elmer calorimeter (DSC 8500) and Pyris Software for Windows Version 11.0.0.0449 following methodology

adapted from Soukoulis et al. (2008). The DSC instrument was calibrated with pure indium standard before analysis. Aliquots (15 mg) of each sample of ice cream were sealed into aluminium pans (50 ll, Perkin-Elmer) and placed into the DSC. A protocol was implemented including the following steps: (a) cooling to $-70\text{ }^{\circ}\text{C}$ at $10\text{ }^{\circ}\text{C min}^{-1}$, (b) heating from $-70\text{ }^{\circ}\text{C}$ to $-40\text{ }^{\circ}\text{C}$ and annealing at the same temperature for 30 min to promote maximal ice formation, (c) cooling to $-70\text{ }^{\circ}\text{C}$ at $10\text{ }^{\circ}\text{C min}^{-1}$ and isothermal holding for 5 min and (d) heating from -70 to $20\text{ }^{\circ}\text{C}$ at $5\text{ }^{\circ}\text{C min}^{-1}$. Freezing points of the formulations were calculated from the DSC melting curves by determining the temperature at which the steepest slope was observed. The amount of ice formed per gram of sample (IC) was determined by integrating the melting curves and dividing the melting enthalpy with the pure ice fusion latent heat ($DY = 334\text{ J g}^{-1}$). The percentage of unfreezable (bound) water (UFW) was calculated using the Eq. 3 (Alvarez et al. 2005):

$$\text{UFW}(\%) = \text{moisture content}(\%) - \text{IC}(\%) \quad (3)$$

The glass transition temperatures were calculated by constructing the tangents to the DSC curve baselines before and after the glass transition. The intersection of these tangents to the tangent of inflection point gives the extrapolated onset, midpoint and end point temperatures.

Consumer acceptance test

Consumer acceptance test of the ice cream was performed by 60 untrained consumers. Each consumer was also provided with room temperature water and plain crackers to cleanse their palate in between each sample. Each consumer evaluated each sample for acceptability of appearance, color, texture, flavor, taste using the 9-point hedonic scale (1 = dislike extremely, 5 = neither dislike nor like, 9 = like extremely). The intent to purchase was evaluated by five-point scale with extremes 1—“Certainly not buy” and 5—“definitely buy” (Meilgaard et al. 1999). It was approved the implementation of sensory analysis by the Ethics Committee of the Medical School of the São Paulo State University, under protocol number 51005415.4.0000.5411.

Statistical analysis

The significant terms in the model were found by analysis of variance (ANOVA) for each response. The model was fitted by the stepwise selection of the SAS program the model obtained was validated by the F test using the pure error mean square as denominator.

The melting data of ice cream as a function of time were subjected to analysis of variance and subsequent regression analysis, adopting as a criterion for choosing the model the magnitude of the significant regression coefficients at 5% of significance by *F* test using the statistical program SISVAR.

Results and discussion

Physicochemical analysis of ice creams

The second-order polynomial response surface model was fitted to each of the response variables (*Y*). Table 1 presents the regression coefficients, calculated *F* values and determination coefficients for the variables parameters.

Moisture content of the ice cream varied from 63.57 to 69.84% with incorporated of bagasse in the formulation (Table 1). Ice cream has water content of about 60–72 wt% and the majority of water was converted to ice crystals during ice cream production.

The response surface drawn from the adjusted model showed that bagasse at lower level and cassava maltodextrins at medium levels produced ice cream with lower moisture content (Fig. 1a).

This result may be related to different water retention capacity of the two ingredients. Boff et al. (2013) using orange fiber as a fat substitute in ice cream observed moisture ranging from 63 to 70% with lower levels in the no fiber ice cream (control).

The reduction of fat using maltodextrin may have facilitate the retention of water in ice cream, since fat prevents the binding of water molecules (Pinheiro and Penna 2004).

The ash content in ice cream ranged from 0.60 to 0.72% and significant effects of bagasse and maltodextrin was not observed (Table 1). The low effect of the inclusion of functional ingredients on the ash content in ice cream was also observed earlier (Rossa et al. 2012; Boff et al. 2013). Variation in the percentage of these in the formulation often did not result in significant change in the final product levels.

The proteins are important for the production of ice cream structure, contributing to emulsification, aeration, water retention capacity, reduce ice formation and increase melting time. It was observed that protein content in ice cream ranged from 2.62 to 3.64%, with the significant effect of maltodextrin in formulation (Table 1) with the maximum values of protein using intermediate percentage of maltodextrin was observed.

Table 1 Regression coefficients of physicochemical and physical analysis of the ice creams

	Moisture	Ash	Protein	Lipids	Total carbohydrate	Solubles solids
Physicochemical analysis						
Intercept	65.50	0.65	3.46	1.35	29.25	32.54
MD	−0.13	−0.001	0.136	−1.25***	1.24**	1.16*
B	1.86**	0.001	0.085	−0.007	−1.95**	−1.81*
MD*MD	1.09*	0.002	−0.23*	0.57*	−1.55**	−1.42
B*B	−0.16	0.005	−0.109	0.32	−0.17	−0.26
MD*B	−0.20	0.027	−0.220	0.08	0.32	−0.06
Pr > f	0.0400	0.8851	0.084	0.010	0.009	0.039
R ²	0.8499	0.239	0.792	0.915	0.917	0.850
	<i>Overrun</i>		Hardness	L*	a*	b*
Physical analysis						
Intercept	23.38		12.1	74.45	4.675	13.194
MD	−0.66		−1.28	0.064	0.191	0.301
B	−2.95**		5.66**	−6.786***	1.798***	1.757***
MD*MD	−0.92		3.58*	−0.367	−0.043	0.448
B*B	−0.69		3.56*	2.889**	−0.528	−0.759
MD*B	−6.0***		0.37	0.012	−0.036	0.512
Pr > f	0.0217		0.0026	0.004	0.0011	0.0122
R ²	0.8844		0.9521	0.9765	0.9661	0.909

MD, linear effect of maltodextrin; B, linear effect of bagasse; MD*MD, quadratic effect of maltodextrin; B*B, quadratic effect of bagasse; R², determinant coefficient

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fig. 1 Effect of maltodextrin and bagasse on the physico-chemical characteristics of ice creams. **a** Moisture (%), **b** total carbohydrates (%), **c** soluble solids (%) and **d** hardness (%)

The lipid content ranged from 1.26 to 4.20% with negative linear effect (Table 1), i.e. lower levels were observed in higher concentrations of maltodextrin. Fats have a critical role in stabilizing air bubbles in ice cream, contributing to the creamy texture and flavor, as well as slowing down the melting rate of ice cream. Considering that typical commercial ice cream has a fat content of about 8–10%, the ice cream showed significant reduction of this component.

The total carbohydrate content varied from 22.89 to 31.11%. The response surface drawn from the adjusted model showed higher levels of total carbohydrates in ice cream which included the highest levels of maltodextrin and lower percentage of bagasse (Fig. 1b). This is mainly due to the high maltodextrin carbohydrate content.

The soluble solids content ranged from 27.4 to 32.83%. The response surface showed that in the conditions of higher maltodextrin content and low percentage of bagasse were observed higher soluble solids (Fig. 1c). These results show that the inclusion of the cassava bagasse led to a lower sugar content and the increased content of

maltodextrin, product with 99% soluble solids, led to changes in the characteristics of the final product.

Air is an important component in ice cream affecting the physical and sensory properties as well as the storage stability. Ice cream normally has around 100% overrun meaning that the air makes up 50% of the ice cream volume. The amount of air incorporated into the mix influences the sensory attributes of the ice cream (Ludvigsen 2012).

The overrun ranged from 14.44 to 30.94%. The volume of air incorporated in the ice cream production may be more than 50% to a minimum of 10–15% (Goff 2002). So, the ice creams obtained in this study showed higher percentages of the same.

Data analysis showed negative linear effect of bagasse on overrun, i.e. the increase in cassava bagasse content in the formulation promoted decreased the overrun, possibly due to increased viscosity of the mix, decreasing the molecular mobility, which made the incorporation and uniform distribution of the air cells difficult. A more

Fig. 2 Melting curves of ice creams in function of time

uniform air cell distribution in the ice cream results in a creamier and slower melting ice cream.

The effect of the inclusion of fibers on the overrun of ice cream has been observed in other studies. Dervisoglu and Yazici (2006) using citrus fibers obtained overrun between 39 and 22% with the lowest values in ice cream with higher fiber content. Crizel et al. (2014) observed that the ice cream with fibers used as a substitute for fat had lower overrun values (17.3%) compared to control ice cream (54.5%).

Ice cream acceptability by the consumers is mainly perceived by means of texture and flavor. Hardness, as a physical property of ice cream, measures the resistance of the sample to deformation when an external force is applied. Additionally, hardness is an indirect measure of the ice crystal size.

The hardness of the ice cream ranges from 10.13 to 29.83 N. The data analysis showed that ice creams produced with low bagasse content and average contents of maltodextrin had lower hardness (Fig. 1d).

As noted in overrun results, higher fiber contents led to less air entrainment, thereby influencing the formation of large ice crystals. Therefore, hardness of the ice cream was also influenced. If a lower amount of air is applied, the

resulting ice cream is dense, heavy and colder eating. If a higher amount is used, the texture is lighter, creamier and warmer eating.

Moreover, the use of maltodextrin caused a significant decrease in fat content of ice creams and El-Nagar et al. (2002) and Akalin et al. (2008) showed the inverse relationship of hardness fat content in ice cream.

The results of color analysis in ice creams showed that the luminosity (L*) varied 69.9–91.6, chroma a* from 1.47 to 6.03 and the chroma b* from 8.5 to 14.18. The analysis of the data showed a significant effect of bagasse on color of the ice cream, promoting a decrease in luminosity and an increase in chroma a* and b* with levels formulation.

In general, bagasse from the processing of fruit and other plant is brownish and when used as ingredient in a product formulation promotes color changes. Similar changes in color parameters were reported by Dervisoglu and Yazici (2006) and Crizel et al. (2014) using citrus fiber as an ingredient in ice cream.

Desirable quality of ice cream are a slow melting rate, good shape retention and slower foam collapse. Melting involves both heating and the mass transfer phenomenon. The gradual warming occurred from the outer region into the cream causing the melting of the ice crystals (Muse and

Table 2 Regression coefficients of thermal parameters

	Heat of ice melting (ΔH)	Ice content (IC)	Unfreezable water(UFW)	Freezing point (FP)
Intercept	168.20	54.42	16.4	−1.42
MD	−0.016	−0.005	−0.12	−0.05
B	−1.38	−0.41	2.27*	0.19**
MD*MD	−0.87	−2.3**	0.72	0.09*
B*B	−3.1*	−2.97***	0.13	−0.08
MD*B	5.9**	1.79*	1.99	0.15*
Pr > f	0.0153	0.0041	0.0987	0.0101
R ²	0.9001	0.9423	0.7767	0.9160

MD, linear effect of maltodextrin; B, linear effect of bagasse; MD*MD, quadratic effect of maltodextrin; B*B, quadratic effect of bagasse; R², determinant coefficient

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Hartel 2004; Soukoulis et al. 2008). Figure 2 shows the melting curves of the ice creams.

The melt-down rate of ice cream is affected by many factors, including the amount of air incorporated, the nature of the ice crystals and the network of fat globules formed during freezing (Muse and Hartel 2004).

Creaminess as well as melting resistance is related to the distribution of air cells in the product. A more uniform air cell distribution in the ice cream results in a creamier and slower melting ice cream.

Ice creams with higher percentages of bagasse maintained structure and shape for longer time as compared with ice cream with lower bagasse content (Fig. 2). This reduction probably occurred due to the water absorption capacity of the cassava residue and increase in viscosity which reduced the molecular mobility and the time for water transfer from inner to outer, delaying the melting.

Decrease in melting of ice cream using different types of fibers in the formulation have been reported by other researchers. El-Nagar et al. (2002) found that the addition of inulin in the ice cream formulation reduced the melting speed. This result was also obtained by Soukoulis et al. (2008) who reported that increased hydrocolloid content in ice cream led to decreased melt rate.

Ice cream containing higher fat content should melts more slowly than the ice cream with a low fat, as the fat slows the heat transfer rate (Akalin et al. 2008). This observation was confirmed by melting curve of the treatments 5 and 6, formulations where we evaluated opposite maltodextrin extreme values in the formulation (Fig. 2).

Calorimetric analysis

The knowledge of the thermal properties of the ice cream is essential to estimate the time of freezing and also to simulate the variations in temperature during the storage period. This information is critical to control the quality and

stability of frozen foods in general, and particularly for ice cream, which require a strict temperature control to maintain quality (Cogné et al. 2003).

In addition, simulation of the freezing process has great significance for the efficient design of the industrial freezing equipment and to control their operating costs.

The regression coefficients of heat of ice melting (ΔH), ice content per gram of sample (IC), unfrozen water content (UFW) and freezing point (FP) are shown in Table 2.

The ΔH values of the ice creams ranged from 155.51 to 173.61 J g^{−1}. In the opposite extreme conditions of bagasse inclusion in the ice cream formulations the enthalpy range is smaller, indicating is, less energy requirement (Fig. 3a).

Hwang et al. (2009) observed decrease in enthalpy value, the decrease in moisture content and the presence of least amount of freezable water in the sample.

The ice content of the ice cream ranged from 46.56 to 55.49%. The response surface drawn from the adjusted model shows that in the central conditions of percentage of bagasse and maltodextrin in the formulation showed the highest ice contents (Fig. 3b). Under these conditions the ice formation was more intense due to their lower solids content as well as their intermediate maltodextrin content, which tend to hydrate and bind water.

In ice cream matrix the water may be in the free state or bound water to the hydrophilic sites of the various components (carbohydrates, protein, fiber, etc.), but only free water can undergo crystallization. The unfreezable water content in the samples ranged from 15.21 to 23.27% with an increase of this percentage in conditions of higher bagasse content in the formulation (Fig. 3c).

The freezing point temperature of the ice cream ranges from −1.16 to −1.78 °C. Under conditions of high concentration of maltodextrin and low percentage of bagasse the ice cream freezing point occurred at lower temperatures (Fig. 3d). Generally, the freezing point is depressed as the

Fig. 3 Effect of maltodextrin and/or bagasse on thermal properties. **a** Enthalpy (ΔH , J g^{-1}), **b** ice content (% IC), **c** unfreezable water (% UFW) and **d** freezing point (FP, $^{\circ}\text{C}$)

serum phase concentration is increased or as the solutes molecular weight is decreased.

Sensorial analysis

The ice cream is a product that appeals to the most varied tastes of all age groups and every social class. Understanding the nuances of ice cream is possible with the use of sensory product testing.

The regression coefficients of the parameters of the sensory evaluation of ice creams are shown in Table 3. The addition of cassava bagasse influenced all sensory parameters analyzed. As shown in Fig. 4a, larger percentage of bagasse in the formulation of ice cream led to a reduction in sensory acceptability. The scores for aroma, appearance, color and texture of the ice cream ranged from 4 to 7 i.e. “dislike somewhat” and “liked moderately” on a hedonic

scale. Ice cream with lower fat content and the presence of insoluble fibers in the formulation have obtained lower scores on the evaluation scale. Karaca et al. (2009) found that the reduction of fat in ice cream with the addition of carbohydrate-based fat substitutes obtained lower score for flavor than the control sample.

Sensory evaluation of taste of ice creams showed range from 4.4 to 7.5 equaling the hedonic scale “slightly disliked” and “liked moderately”. The percentages of bagasse and maltodextrin had significant effect.

The response surface drawn from the adjusted model showed that the ice cream produced with low bagasse content and intermediate maltodextrin percentage had higher scores for taste (Fig. 4b). Similar results were related by Crizel et al. (2014) who found that the taste of ice creams were adversely affected by the reduction of fat content and adding orange fiber.

Table 3 Regression coefficients of sensorial parameters

	Flavor	Appearance	Color	Texture	Taste	Intent to purchase
Intercept	5.44	5.60	5.57	5.25	5.39	3.1328
MD	0.10	0.005	0.12	−0.06	0.17*	0.032
B	−0.64**	−0.63**	−0.64**	−0.64**	−1.41***	−0.638***
MD*MD	−0.05	−0.002	0.01	0.10	−0.31*	−0.252*
B*B	0.17	0.19	0.28	0.19	0.06	0.025
MD*B	0.08	0.10	0.01	−0.06	−0.13	−0.037
Pr > f	0.2029	0.1782	0.0541	0.0347	<0.0001	0.0070
R ²	0.7880	0.8068	0.8290	0.8588	0.9876	0.9281

MD, linear effect of maltodextrin; B, linear effect of bagasse; MD*MD, quadratic effect of maltodextrin; B*B, quadratic effect of bagasse; R², determinant coefficient

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fig. 4 Effect of maltodextrin and/or bagasse on sensory attributes. **a** Flavor, appearance, color and texture, **b** taste and **c** intent to purchase

The effect of maltodextrin on sensory parameters also was observed. Sonwane and Hembade (2014) evaluated the influence of maltodextrin as a milk fat substitute in ice cream on sensory parameters (color, texture, taste and overall acceptance) and concluded that treatment with 30% maltodextrin replacing the milk fat had the highest scores compared to treatment with 0, 10, 20 and 40% maltodextrin.

Consumers' perception of health in relation to products, processes and enrichments involved in the production of

functional foods is crucial in determining consumer acceptance of these products (Bech-Larsen and Grunert 2003).

Score for intention to purchase of the ice cream ranged from 2 to 4.05, with equivalent in hedonic scale "probably would not purchase" and "probably would purchase". The response surface drawn from the results of the ice cream intention to purchase shows that the inclusion of 3.65% of maltodextrin and 1.5% bagasse had positive intention (might buy) (Fig. 4c).

Silva et al. (2014) studying the perception of 224 Brazilian consumers in relation to different ice cream concepts (Traditional, Light, Zero Sugar, Zero Fat, Fiber Enriched, Enriched with Bioactive Proteins and Enriched with Omega 3) observed that independent of consumer interest in relation to health, the addition of fiber to ice cream made it as attractive to the consumer as traditional ice cream. The authors also cited that concern for the health of consumers is reflected in the intent to purchase of enriched ice cream, statistically equal to that obtained for traditional ice cream, showing that the enrichment would be an important motivator for the consumption of ice cream, enhanced by specific benefits related to each nutrient added.

Conclusion

The use of cassava derivatives as fat replacer and source of fiber in ice creams is an effective way to enhance nutritional aspects of this product. But their inclusion influences the nutritional, rheological and thermal properties of the final product.

The ice creams with a high content bagasse showed some undesirable effects such as reduction in overrun and sensory acceptance, however, these effects are less pronounced in smaller percentages. On the other hand, the addition of lower percentage of cassava bagasse improved some quality parameters, such as the prolongation of the melting time, decrease in the frozen water and increase in nutritional value due its high content of fiber. The use of cassava maltodextrin as fat substitute was efficient and its inclusion did not showed any negative effect on physical and sensory parameters of ice cream.

Further research is needed to optimize sensory properties of ice cream containing cassava bagasse. However, the addition of food coloring in formulation can be an option to improve the acceptability.

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