J Food Sci Technol (October 2020) 57(10):3843–3851
https://doi.org/10.1007/s13197-020-04416-3

ORIGINAL ARTICLE

Physicochemical quality and sensory acceptance of toasts with partial replacement of wheat flour by maize biomass flour

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Revised: 28 March 2020 / Accepted: 3 April 2020 / Published online: 10 April 2020

Abstract The aim of this study was to assess physicochemical and sensory viability of toasts developed from the partial replacement of wheat flour (WF) by maize biomass flour (MBF). Different levels of MBF (0, 5, 10, 15 and 20 g 100 g^{-1}) were used. Data obtained were evaluated by univariate and multivariate analyses. The level of replacement of WF by MBF influenced all physicochemical properties of the toast. Moisture (5.67–7.12 g 100 g^{-1}), hardness (56.67–131.66 N), chroma of crust and crumb (29.86–30.27 and 19.76–25.83, respectively), and hue angle of crust and crumb (60.32°–64.79° and 81.41°–82.06°, respectively) were increased; and area (2286.4–1658.1 mm^2), specific volume (3.47–1.83 mL g^{-1}) and luminosity of crust and crumb (62.39–59.67 and 65.49–62.54, respectively) were decreased as the level of substitution of WF by MBF increased. The toasts did not present microbiological risk. The formulations with higher sensory acceptance were 5 and 15 g 100 g^{-1} of MBF, being considered rich in proteins (16.25 and 15.43 g 100 g^{-1}, respectively) and rich in dietary fibers (12.10 and 16.02 g 100 g^{-1}, respectively), therefore with high nutritional and functional values. The production of toasts with partial replacement of WF by MBF is feasible in relation to physicochemical and sensory characteristics, which it may stimulate exploitation of this by-product and sustainable production of baked goods.

Keywords *Zea mays* · By-product · Bakery good · Toasted breads · Dietary fiber

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Introduction

Toasts, which are basically constituted of carbohydrates, fibers, protein, lipids, minerals and vitamins in variable proportions, are products obtained after the toasted bread. Toasts are produced with cereal flour (mainly wheat flour), water, yeast and salt, in a process that involves mixing, kneading, molding, fermentation and cooking. Bread is one of the most ancient foods in human' history and considered a basic food worldwide, in which its popularity is due to its taste, modest price and availability (Soukoulis et al. 2014; Notarnicola et al. 2017).

Nowadays, it has been seen increase in consumers' consciousness about the necessity to consume healthier baked goods, what has stimulated industries to produce food with reduced percentages of fat and caloric value, besides more quantity of minerals, vitamins and dietary fibers (Aggarwal et al. 2016).

The quantity and the type of fiber added are relevant factors in the production of baked products, because it can interfere in the final product and in its physical, chemical and sensory characteristics (Baba et al. 2015). Bread and toast can be enriched with agro-industrial by-products that contain significant concentrations of dietary fibers, which promote health benefits to consumers, since the low intake of these fibers has shown associations with gastrointestinal, cardiovascular and metabolic diseases (Almeida et al. 2013).

Many food industries have been started using the residues from the production of their products, seeking to the utilization of these materials as ingredients in formulation of different types of food sustainably produced. The maize biomass, recovered from a specific dry milling process in the "biju" maize flour processing, is predominantly constituted of maize grain pericarp. The maize biomass is rich in dietary fibers and it is considered a agro-industrial by-product or solid residue; additionally, it is utilized in animal feeding or commonly discarded improperly (Oliveira Junior et al. 2014). The "biju" maize flour is a product consumed by all social classes and, due to that, is the energy base of many typical Brazilian dishes. Moreover, for having an affordable price, this flour is consumed mainly by low-income class (Alessi et al. 2003).

In this context, the aim of this study was to assess the influence of the partial replacement of wheat flour (WF) by maize biomass flour (MBF) in the physicochemical, microbiological and sensory properties of toasts, and determine chemical characteristics of the most accepted formulations in the sensory analysis, aiming to check the viability of a new product and to stimulate exploitation of this by-product and sustainable production of baked goods.

Materials and methods

Obtaining and preparation of raw materials

Maize biomass, recovered from "biju" maize flour processing, was offered by the company Caramuru Alimentos (Itumbiara, Goiás, Brazil). The biomass was collected and immediately dried in an air circulation oven at 45 °C during 24 h, in order to avoid its fermentation. After that, it was milled in a knife mill and sieved in a sieve with 0.250 mm sized holes. The maize biomass flour (MBF) was obtained, packed in sealed bags of low-density polyethylene (LDPE), and stored at 5 °C until toasts processing.

The Vitella®'s wheat flour (WF), enriched with iron and folic acid, was donated by company Moinho Vitória (Goiânia, Goiás, Brazil). Other ingredients utilized in the formulations of the toasts were acquired in the local market (Goiânia, Goiás, Brazil).

Toasts processing

A completely randomized design was used for the formulation of toasts with five treatments [0 (T1), 5 (T2), 10 (T3), 15 (T4) and 20 (T5) g 100 g^{-1} of WF replacement by MBF] and four repetitions, totalizing 20 experimental units. The amount of the other ingredients was determined in preliminary tests and maintained fixed in all formulation: 5 g 100 g^{-1} of dry chemical yeast, 5 g 100 g^{-1} de margarine, 5 g 100 g^{-1} of white granulated sugar, 2 g 100 g^{-1} of powdered milk, 0.5 g 100 g^{-1} of salt and 32.5 g 100 g^{-1} of water.

The toasts processing was divided in two phases: firstly, the bread processing, followed by the toasting of the bread slices. In order to do that, the following steps were executed: weighing of the ingredients, homogenization and manual kneading, weighing of the dough, molding, fermentation, baking, cooling, cutting, toasting, another cooling, packaging and storage.

In order to produce the toasts, the dry ingredients were weighted and mixed altogether manually and, in sequence, the water was added. After that, the mixture was homogenized and kneaded manually during 15 min. The dough was weighted and divided in portions of 100 g and each one was put into an aluminum tray (with dimensions of 150 mm × 40 mm × 40 mm), which was greased with soy oil.

The alcoholic fermentation had duration of 45 min and the dough was baked in an industrial oven that has been pre-heated to 180 °C during 25 min. After that, the bread was cooled at room temperature and sliced in slices of a thickness of 10 mm. The slices were toasted at the temperature of 150 °C for 20 min and cooled naturally at room temperature. At last, the toasts were packed in bags of low-density polyethylene (LDPE), properly sealed, and stored at room temperature until analyses.

Physicochemical properties

Area of the toasts was determined immediately after cooling by measuring the length and the thickness using a digital caliper (Messen, 0 a 150 mm, Berlin, Germany), being performed ten determinations for each repetition. The toast mass was determined using an analytical scale. Volume was estimated with the occupied mass displacement technique using millet seeds, with 20 replicates per repetition. Specific volume (SV) was calculated by the ratio between the average volume and mass of the samples, according to the methods recommended by AOAC (2012). Moisture content was obtained in an air circulating drying oven at 105 °C until a constant weight according by AOAC (2012), in triplicate for each repetition.

Instrumental hardness was determined on the second day after toasts processing, according to the method recommended by AACC (2010), using a texturometer (Stable Micro System, TA.XT2 plus, Godalming, UK) with probe Knife Edge with Slotted Insert (HDP/BS) and HDP platform. The sample of toast was placed horizontally on the platform and cut in half. The parameters utilized on the tests were: pre-test speed = 1.0 mm s^{-1}; test speed = 2.0 mm s^{-1}; post-test speed = 10.0 mm s^{-1}. The results were expressed in Newton (N), and ten determinations for each repetition were carried out.

Instrumental color parameters (L*, a* and b*) of crust and crumb of the toast were determined in a colorimeter (Konica Minolta, Bankinh Meter, BC-10, Ramsey, USA) previously calibrated, with ten evaluations per repetition. Chroma values (color saturation) and hue angle values (chromatic tonality) were estimated based on the Eqs. 1 and 2, respectively (McGuire 1992)

$$\text{Chroma} = \sqrt{a*^2 + b*^2} \quad (1)$$

$$H^\circ = \tan^{-1}\left({}^{b*}/_{a*}\right) \quad (2)$$

Microbiological risk and sensory acceptance

The count of thermotolerant coliforms and the analysis to verify the presence of *Salmonella* sp. were carried out according to the techniques described by the Food and Drug Administration, FDA (2002).

Acceptance test of the toasts was performed by fifty untrained tasters, using a nine-points structured hedonic scale (9: like extremely; 1: dislike extremely), in which the attributes of appearance, color, aroma, texture, taste and overall acceptance were evaluated (Stone et al. 2012).

Tasters, with ages between 18 and 34, from both genders, being 56% feminine and 44% masculine, received codified samples. The samples were served in disposable plates, arranged randomly and placed one at a time as the tasters consumed the toasts. Mineral water was offered to the tasters to cleanse the palate between tastings. Sensory analysis was approved by the Ethic Committee (CAAE: 56909916.4.000.5083) of the Federal University of Goiás (Goiânia, Goiás, Brazil).

Acceptance index (AI) of the toasts was calculated (Eq. 3), considering that an acceptable product should present AI higher than 70% (Fernandes and Salas-Mellado 2017)

$$\text{AI}\ (\%) = \frac{S_1 \times 100}{S_2} \quad (3)$$

In which, S_1 refers to the average score obtained for the product, and S_2 to the maximum score given to the product.

Proximal composition and total energy value of the selected toasts

Proximal composition of the toasts selected by sensory analysis was determined according to the methods recommended by AOAC (2012). Moisture content was obtained by desiccation in an air circulating drying oven at 105 °C until constant weight; ash by incineration at 550 °C in a muffle furnace; nitrogen by the micro-Kjeldahl method with a distiller, and the factor 6.25 was used in order to quantify crude protein content; lipids by continuous extraction with petroleum ether in a Soxhlet type extractor. In order to determine the quantity of soluble and insoluble dietary fibers, the enzymatic–gravimetric method was used. Moreover, available carbohydrates and total energy value (TEV) were determined according to De Menezes et al. (2016). Available carbohydrate content was calculated by the difference [(100 − (moisture + ash + protein + lipid + dietary fibers)]. Total energy value was calculated by multiplying the lipid by 9, protein and available carbohydrate by 4, and dietary fibers by 2.

Statistical analysis

Data obtained were evaluated by variance analysis. Additionally, regression analysis was used for the data related to the physicochemical properties, and the means of the sensory attributes were compared by Tukey test ($p \leq 0.05$). In addition, principal component analysis (PCA) was performed for physicochemical and sensory parameters of the toasts.

Results and discussion

Physicochemical properties

All physicochemical properties evaluated were significant influenced ($p \leq 0.01$) by the level de substitution of WF by MBF in the toasts (Table 1). Adjusted regression models were also significant ($p \leq 0.01$) for all physicochemical properties, explaining between 75 and 99% of the responses.

Area and specific volume (SV) decreased as the level of substitution of WF by MBF increased, and a significant difference ($p \leq 0.05$) was observed among the formulations (Table 2). Area of the toasts varied from 1658.1 ± 24.45 mm^2 (T5) to 2286.4 ± 16.1 (T1) (Table 2), once the toast heights were influenced by level of replacement of WF by MBF in the formulations (Fig. 1). SV, known to influence consumer's choice strongly, is an important property of bakery goods, where a high ratio of volume per weight is desirable (Guevara-Arauza et al. 2015). SV

Table 1 Mathematical models and statistical parameters obtained in the regression analysis of the physicochemical properties of toasts developed from different levels of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing

Property	Mathematical model	R^2_{adj}	p
Area[1]	$y = 2257.397 - 30.384x$	0.95	0.00**
Specific volume[2]	$y = 5.6499 + 0.0734x$	0.96	0.00**
Moisture[3]	$y = 3.4279 - 0.1887x + 0.0117x^2 - 0.0003x^3$	0.98	0.00**
Hardness[4]	$y = 56.7792 + 3.3826x - 0.0610x^2 + 0.0040x^3$	0.99	0.00**
$Luminosity_{crust}$	$y = 62.1778 - 0.1883x + 0.0026x^2$	0.97	0.00**
$Chroma_{crust}$	$y = 29.8181 + 0.0463x - 0.0011x^2$	0.77	0.00**
Hue $angle_{crust}$[5]	$y = 60.2808 + 0.2261x$	0.98	0.00**
$Luminosity_{crumb}$	$y = 65.4953 - 0.2171x + 0.0035x^2$	0.97	0.00**
$Chroma_{crumb}$	$y = 19.8258 + 0.1139x - 0.0091x^2$	0.98	0.00**
Hue $angle_{crumb}$[5]	$y = 81.3907 + 0.0301x$	0.75	0.00**

**Significant at 1% probability

[1] mm^2

[2] $mL\ g^{-1}$

[3] $g\ 100\ g^{-1}$

[4] N

[5] Grades

Table 2 Physicochemical properties of toasts developed from different levels of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing

Property	Level of replacement of WF by MBF in toasts ($g\ 100\ g^{-1}$)				
	0 (T1)	5 (T2)	10 (T3)	15 (T4)	20 (T5)
Area[1]	2286.4 ± 16.1^a	2079.8 ± 93.99^b	1926.2 ± 32.02^c	1817.3 ± 45.77^d	1658.1 ± 24.45^e
Specific volume[2]	3.47 ± 0.14^a	2.82 ± 0.06^b	2.39 ± 0.09^c	2.24 ± 0.05^c	1.83 ± 0.05^d
Moisture[3]	5.67 ± 0.02^e	6.05 ± 0.05^d	6.27 ± 0.08^c	6.81 ± 0.18^b	7.12 ± 0.05^a
Hardness[4]	56.67 ± 0.49^e	73.09 ± 0.42^d	87.83 ± 0.67^c	107.61 ± 1.20^b	131.66 ± 0.72^a
$Luminosity_{crust}$	62.39 ± 0.33^a	61.44 ± 0.13^b	60.85 ± 0.07^c	60.07 ± 0.03^d	59.67 ± 0.20^e
$Chroma_{crust}$	29.86 ± 0.13^b	29.92 ± 0.01^b	30.22 ± 0.06^a	30.30 ± 0.06^a	30.27 ± 0.08^a
Hue $angle_{crust}$[5]	60.32 ± 0.24^e	61.21 ± 0.11^d	62.80 ± 0.27^c	63.59 ± 0.19^b	64.79 ± 0.20^a
$Luminosity_{crumb}$	65.49 ± 0.32^a	$64.53^b \pm 0.24$	63.63 ± 0.09^c	63.05 ± 0.07^d	62.54 ± 0.12^e
$Chroma_{crumb}$	19.76 ± 0.35^e	20.73 ± 0.30^d	21.96 ± 0.14^c	23.35 ± 0.04^b	25.83 ± 0.24^a
Hue $angle_{crumb}$[5]	81.41 ± 0.16^c	81.56 ± 0.07^{bc}	81.67 ± 0.16^{bc}	81.76 ± 0.13^b	82.06 ± 0.09^a

[1] mm^2

[2] $mL\ g^{-1}$

[3] $g\ 100\ g^{-1}$

[4] N

[5] Grades; means followed by the same letter in the lines do not differ statistically by the Tukey test, at 5% probability

varied among $1.83 \pm 0.05\ mL\ g^{-1}$ (T5) and $3.47 \pm 0.14\ mL\ g^{-1}$ (T1). Millar et al. (2019), who evaluating breads developed with wheat, raw yellow pea, germinated yellow pea and toasted yellow pea flours, found similar values (3.74, 3.01, 2.3 and 3.04, respectively) to those found in this research.

Reductions in the area and specific volume with the increase of the level of MBF in the toasts may be directly associated with gluten hydration and consequent weakening of its structure caused by dietary fibers present in MBF. Therefore, addition of MBF compromised the protein structure and this probably altered the viscoelastic properties of the dough once gas retention during baking has a tendency to be higher in dough without fibers (Guevara-Arauza et al. 2015). Thus, gas retention capacity during fermentation and baking were insufficient and the bread consequently had its volume reduced. This was also the conclusion of other authors who inserted materials rich

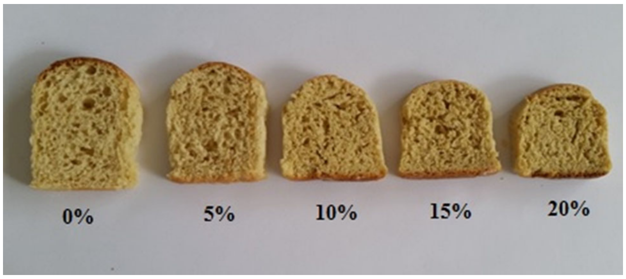

Fig. 1 Toasts made from different levels (%, g 100 g^{-1}) of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing, being T1, T2, T3, T4 and T5 toasts formulated with 0, 5, 10, 15 and 20 g 100 g^{-1} of MBF, respectively

in fibers in formulations of bread and toast (Borges et al. 2013; Hassan and Ali 2014).

Moisture content was increased as MBF was added and significant difference ($p \leq 0.05$) between all the formulations was showed, ranging from 5.67 ± 0.02 g 100 g^{-1} (T1) to 7.12 ± 0.05 g 100 g^{-1} (T5) (Table 2). Hefnawy et al. (2012) observed increased moisture of the toasts with the addition of chickpeas flour, justifying that increased amount of fibers in the dough amplified its capacity to retain moisture after baking.

Hardness of the toasts was also increased with addition of MBF in the formulations, differ statistically ($p \leq 0.05$) among all the formulations was observed, ranging from 56.67 ± 0.49 N (T1) to 131.66 ± 0.72 N (T5). The higher fiber content changed gluten structure, modifying bread structure (Eshak 2016), and consequently its texture. This is due to the insufficient gluten hydration, which causes a less gas retention capacity of the dough, since the fibers absorb more water when compared to the proteins. Therefore, all these changes result in a harder bread (Ghoshal et al. 2016). The addition of fiber can sometimes causes effects on the quality of bakery products once excess of insoluble dietary fibers impair on the formation of gluten network. The most important problems are reduction of bread volume and increase in crumb firmness (Aydogdu et al. 2018).

Luminosity (L*) of toasts decreased as level of substitution of WF by MBF increased, meanwhile chroma (saturation of color) and hue angle (tonality) were increased with MBF addition for both crust and crumb. Wherefore, instrumental color parameters of the toasts were directly affected by the original color of MBF used in the formulations, once it is darker and presents yellowish tonalities when compared to WF. Millar et al. (2019) also observed that breads with other flours added to the WF showed less L* than breads developed with WF only. Baked goods can have their color altered due to a great variety of factors, such as the intrinsic color of ingredients or resulting color from alterations caused by chemical reactions. Among them, Maillard reaction and caramelization are the most important chemical reactions occurring during baking and toasting of bakery goods (Capuano et al. 2009; Aydogdu et al. 2018).

Microbiological risk and sensory acceptance

The microbiological analyses showed that the toasts were within the limits acceptable by the Brazilian legislation (Brasil 2001), indicating good hygienic-sanitary conditions during the processing of the toasts, ensuring the food safety of the tasters. The count of thermotolerant coliforms was lower than that established by the resolution (< 10 UFC g^{-1}) and the presence of *Salmonella* sp. was not detected in the toasts in 25 g of sample.

In addition to the health benefits, dietary fiber is also an important constituent for the functional characteristics of baked goods, and it can be used to modify the physicochemical and sensory properties of the fiber supplemented food products (Aydogdu et al. 2018).

Evaluation of the sensory characteristics of food products is a widely used method to evaluate final quality of a given product. Sensory quality evaluation consists of a series of tests or tools applied in which tasters are able to investigate areas of interest (intrinsic and extrinsic attributes) of the product (Schiano et al. 2017). The sensory analysis of toasts showed a significant difference ($p \leq 0.05$) for all sensory parameters (Table 3). Therefore, the level of replacement of WF by MBF in toast formulations affected all the sensory attributes evaluated (appearance, color, aroma, texture, taste, overall acceptance).

Regarding appearance and color of the toasts no significant difference ($p \leq 0.05$) was observed between T1 and T2, and between T3 and T4 (Table 3). T5 did not differ statistically ($p \leq 0.05$) neither from T3 for appearance nor from T2 and T3 for color (Table 3). In relation to aroma no significant difference ($p \leq 0.05$) was observed amid T1, T2, T4 and T5; and T3 differed only from T1 (Table 3). Texture did not differ significantly ($p \leq 0.05$) between T1 and T2; between T2, T3 and T4; and between T3 and T5 (Table 3). With respect to taste showed no significant difference ($p \leq 0.05$) between T1, T2 and T4, between T2, T3 and T4, and between T3, T4 and T5 (Table 3). In relation to overall acceptance no significant difference ($p \leq 0.05$) was observed among T1 and T2; among T2, T3 and T4; and among T3, T4 and T5 (Table 3).

Acceptability indexes (AI) of all the formulations were higher than 70% for all the sensory attributes (Fig. 2). Among the sensory parameters evaluated, T1 presented an acceptability index ranging from 86.0 to 90.7%, while T2, T3, T4 and T5 presented AI ranging from 84.4 to 86.2%, 77.6–85.6%, 81.6–86.0% and 70.4–80.4%, respectively.

Table 3 Sensory acceptance of the attributes evaluated in toasts developed from different levels of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing

Attribute	Level of replacement of WF by MBF in toasts (g 100 g^{-1})				
	0 (T1)	5 (T2)	10 (T3)	15 (T4)	20 (T5)
Appearance	7.76 ± 1.15^{a}	7.72 ± 1.09^{a}	7.46 ± 1.23^{ab}	7.66 ± 1.04^{a}	6.94 ± 1.27^{b}
Color	7.98 ± 0.92^{a}	7.74 ± 1.14^{ab}	7.70 ± 0.93^{ab}	7.78 ± 0.91^{a}	7.24 ± 1.00^{b}
Aroma	7.74 ± 1.10^{a}	7.60 ± 1.26^{ab}	7.00 ± 1.37^{b}	7.34 ± 1.33^{ab}	7.14 ± 1.29^{ab}
Texture	8.16 ± 1.06^{a}	7.64 ± 1.26^{ab}	6.98 ± 1.13^{bc}	7.34 ± 1.10^{b}	6.34 ± 1.57^{c}
Taste	8.08 ± 1.07^{a}	7.74 ± 1.56^{ab}	7.18 ± 1.04^{bc}	7.44 ± 1.11^{abc}	6.88 ± 1.60^{c}
Overall acceptance	8.12 ± 0.96^{a}	7.76 ± 1.08^{ab}	7.42 ± 0.86^{bc}	7.44 ± 0.86^{bc}	6.96 ± 1.03^{c}

Means followed by the same letter in the lines do not differ statistically by the Tukey test, at 5% probability

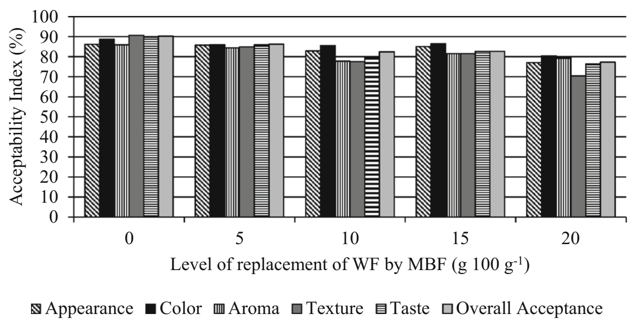

Fig. 2 Acceptability index (%) for sensory attributes evaluated in toasts according to the level of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing

Hassan and Ali (2014) observed that toast fortified with white grapefruit flour improved the sensory characteristics, and registered the highest scores for toast with 5 g 100 g^{-1} of white grapefruit flour showing acceptability indexes ranging from 70.1 to 80.3%, wherein these values are lower than those obtained in this research for toasts with 5 and 15 g 100 g^{-1} of WF substituted by MBF.

Principal component analysis and selection of the toasts

Principal components analysis (PCA) for physicochemical properties of toasts made from partial replacement of WF by MBF demonstrated that only two principal components (PC1: 96.71% and PC2: 2.34%) were required to explain 99.05% of the total variance (Fig. 3), and for sensory attributes of toasts showed that only two principal components (PC1′: 90.62% and PC2′: 7.61%) were required to explain 98.23% of the total variance (Fig. 4). PCA was used to examine the interrelations among the 11 variables considered for the physicochemical properties and six variables for the sensory attributes. The points of PC1, PC2, PC1′ and PC2′ can be obtained by Eqs. 4–7, respectively. In which variables X_1–X_{11} are level of replacement of WF by MBF, area, moisture, specific volume, hardness, luminosity of crust, chroma of crust and hue angle of crust, luminosity of crumb, chroma of crumb and hue angle of crumb, respectively. Additionally, X_{12}–X_{17} are appearance, color, aroma, texture, taste and overall acceptance, respectively

$$PC1 = -0.999X_1 + 0.997X_2 - 0.989X_3 + 0.984X_4 - 0.992X_5 + 0.993X_6 - 0.921X_7 - 0.997X_8 + 0.994X_9 - 0.978X_{10} - 0.972X_{11} \quad (4)$$

$$PC2 = -0.019X_1 - 0.011X_2 - 0.066X_3 - 0.059X_4 - 0.115X_5 - 0.059X_6 + 0.373X_7 + 0.026X_8 - 0.099X_9 - 0.187X_{10} - 0.219X_{11} \quad (5)$$

$$PC1' = -0.934X_{12} - 0.936X_{13} - 0.866X_{14} - 0.999X_{15} - 0.990X_{16} - 0.981X_{17} \quad (6)$$

$$PC2' = -0.290X_{12} + 0.339X_{13} - 0.489X_{14} - 0.011X_{15} - 0.137X_{16} - 0.019X_{17} \quad (7)$$

According to the score plot of physicochemical properties (Fig. 3a), three distinct groups (T1 and T2; T3 and T4; and T5) can be observed. In relation to the sensory attributes (Fig. 4a), four different groups (T1 and T2; T3; T4; and T5) can be noted. Thus, T1 and T2 showed similar characteristics for both physicochemical properties and sensory attributes.

According to the correlation circle of physicochemical properties (Fig. 3b), moisture, hardness, chroma of crust, hue angle of crust, chroma of crumb and hue angle of crumb presented vectors facing left and established a positive correlation with the level of substitution of WF by MBF. Though, area, specific volume, and crust and crumb luminosity presented vectors facing right (Fig. 3b), showing that these properties decreased as the level of MBF increased in the toasts. Thus, a negative correlation with the level of replacement of WF by MBF was observed, in which can be noted in the Fig. 3a (T1 and T2 are facing right side of the score plot).

Regarding to the PCA of the sensory attributes, vectors com similar measures were obtained (Fig. 4b), wherein the

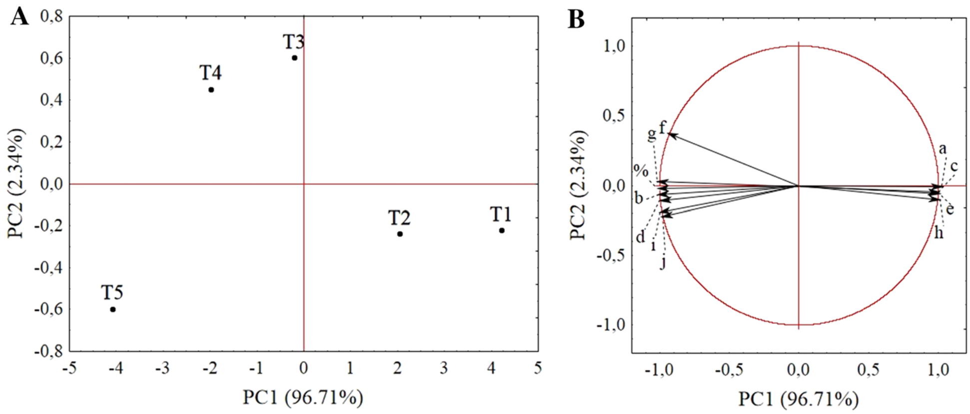

Fig. 3 Principal Component Analysis (PCA) for physicochemical properties [area (**a**), moisture (**b**), specific volume (**c**), hardness (**d**), luminosity of crust (**e**), chroma of crust (**f**), hue angle of crust (**g**), luminosity of crumb (**h**), chroma of crumb (**i**) and hue angle of crumb (**j**)] of toasts developed from different levels (%, g 100 g^{-1}) of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing, being T1, T2, T3, T4 and T5 toasts formulated with 0, 5, 10, 15 and 20 g 100 g^{-1} of MBF, respectively

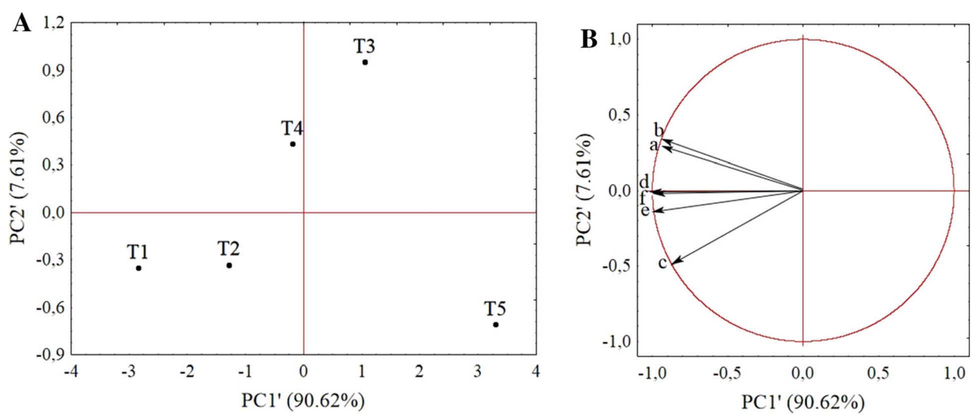

Fig. 4 Principal component analysis (PCA) for sensory attributes [appearance (**a**), color (**b**), aroma (**c**), texture (**d**), taste (**e**), overall acceptance (**f**)] of toasts developed from different levels of replacement of wheat flour (WF) by maize biomass flour (MBF) recovered from "biju" maize flour processing, being T1, T2, T3, T4 and T5 toasts formulated with 0, 5, 10, 15 and 20 g 100 g^{-1} of MBF, respectively

variables presented similar influences for both PC1′ and PC2′. T1, T2 and T4 were, respectively, the most accepted formulations by the tasters, since all the vectors related to sensory attributes are facing right (Fig. 4b) and overlapping the same quadrants that T1, T2 and T4 (Fig. 4a). Therefore, considering the interest for MBF valorization and use, T2 and T4 presented the highest commercial potential.

Proximal composition and total energy value of the selected toasts

T2 and T4 presented significant difference in relation to the moisture, dietary fibers (DF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) (Table 4). The contents of ash, protein and lipid of the selected toasts did not differ significantly between T2 and T4 (Table 4).

The low moisture contents in T2 and T4 (Table 4) were adequate for its conservation and stability during the storage, once high moisture contents can favor microbial growth in improperly sealed products (Okpala and Egwu 2015). According to the protein and dietary fibers content (Table 4), T2 and T4 can be classified as rich foods in these nutrients (Brasil 2012), therefore the toasts with MBF present high nutritional and functional value. Adequate consumption of dietary fibers helps in control of blood cholesterol levels, diabetes, cardiovascular and gastrointestinal diseases, obesity, and in prevention colon cancer (Ghoshal et al. 2016).

T2 presented SDF content superior to the quantities in T4 (Table 4). The SDF can reduce the blood cholesterol concentration by the formation of a viscous structure that decreases the absorption of lipid compounds in the small intestine (Maia et al. 2015), besides improving constipation and prevent gastrointestinal problems (Huang et al. 2015). However, T4 showed a higher IDF content in comparison to T2 (Table 4), probably due to the predominance of this dietary fiber in the MBF. IDF may stimulate satiety (Horvath et al. 2015), help in the increase of fecal volume, promote better peristaltic movements, facilitate colon emptying (Gavanski et al. 2015) and also be useful for detoxification in the digestive tract (Huang et al. 2015).

Table 4 Chemical composition and total energy value of the selected toasts in the sensory acceptance: 5 (T2) and 15 (T4) g 100 g^{-1} of wheat flour (WF) replaced by maize biomass flour (MBF) recovered from "biju" maize flour processing

Constituents	T2 Means ± SD	T4 Means ± SD
Moisture[1]	$6.05^{b} \pm 0.05$	$6.81^{a} \pm 0.18$
Ash[1]	$1.71^{ns} \pm 0.04$	$1.71^{ns} \pm 0.04$
Protein[1]	$15.26^{ns} \pm 0.52$	$14.37^{ns} \pm 0.13$
Lipid[1]	$5.43^{ns} \pm 0.07$	$5.52^{ns} \pm 0.08$
Dietary fiber[1]	$11.38^{b} \pm 0.11$	$14.92^{a} \pm 0.06$
Soluble dietary fiber[1]	$2.51^{a} \pm 0.01$	$0.39^{b} \pm 0.03$
Insoluble dietary fiber[1]	$8.87^{b} \pm 0.10$	$14.53^{a} \pm 0.03$
Available carbohydrates[1]	60.17	56.67
Total energy value[2]	373.35	363.68

SD standard deviation

[1]g 100 g^{-1}—in water wet basis

[2]kcal 100 g^{-1}—in water wet basis. Means followed by the same letter in the lines do not differ statistically by the Tukey test, at 5% probability

[ns]Not significant, at 5% probability

The importance of dietary fiber has pushed the food industries to develop a diversity of fiber-rich products and ingredients in order to improve nutritional and functional quality of foods (Dhingra et al. 2012). Thus, researches are being carried out to find new sources of dietary fibers that can be used as ingredients in the food industry, wherein addition of fiber to bakery products can decrease the fat content without loss of quality (Nyam et al. 2014).

Available carbohydrates contents of the toasts with MBF (Table 4) were superior to those found by Eshak (2016) in bread elaborated with substitution of 5 and 10 g 100 g^{-1} of WF by banana peel flour (50.5 and 44.34 g 100 g^{-1}, respectively).

TEV of T2 and T4 were relatively high (Table 4), in which may be attributed to the quantities of available carbohydrates. TEV of T4 was lower than the value of T2, probably due to the higher substitution of the fibers present in MBF by other carbohydrates of WF. Similar effect was observed by Salgado et al. (2011) in a study about bread produced with whole grain flour, which presented elevated quantities of fibers in comparison to white flour.

Alternative flour sources, as the MBF, can be added to wheat flour for harnessing a raw material that otherwise would have been wasted and modify physicochemical, sensorial and functional properties of a bakery product. Thus, product characteristics should be evaluated and can be used to compare against commercially successful products and help define the suitability of that alternative flour for use in bakery products (Longoria-García et al. 2018).

Conclusion

The replacement level of WF by MBF influenced all physicochemical and sensory properties of toasts, since promoted an increase in the moisture, hardness, chroma and hue angle, and a reduction the area and specific volume as there was an increase in MBF. Toasts presented favorable characteristics to storage at room temperature, due to low moisture. The samples did not indicate microbiological risk, ensuring the food safety of the tasters. The formulations with replacement of 5 (T2) and 15 (T4) 100 g^{-1} of WF by MBF presented a better sensory profile, indicating high commercial potential. T2 and T4 can be considered foods rich in protein and dietary fibers, mainly in insoluble dietary fiber, thus, are foods with high nutritional and functional value. Therefore, the production of toasts from the partial replacement of WF by MBF is feasible in relation to their physicochemical, microbiological and sensory properties, in which may stimulate exploitation of this by-product and sustainable production of baked goods.

Acknowledgements This work was supported by *Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG)*, *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)*, *Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)* and *Universidade Federal de Goiás (UFG)*.

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