

Full Length Research Paper

Inclusion of sweet sorghum flour in bread formulations

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Sweet sorghum (*Sorghum bicolor* L. Moench) has been studied as an additional source of raw material for production or partial replacement of foods due to its high fiber concentration. Its consumption is associated with the prevention of some diseases and nutritional benefits. The aim of this study was to evaluate the partial replacement of wheat flour by sweet sorghum flour in bread formulations in order to characterize the nutritional and physical profile of the flour. Four bread formulations were prepared and evaluated for sensory and textural profile. The composition of sweet sorghum flour showed high fiber content and relative protein value, and moisture showed average value, in accordance with limits established by legislation. The addition of 3% sweet sorghum flour to bread was shown to be technically feasible, with great acceptance by consumers, being a nutritious and tasty option.

Key words: Functional food, fiber, baking, texture.

INTRODUCTION

Bread, one of the most consumed foods worldwide, has high energy value and low cost. It is used as food for different social classes. In addition to its good flavor, bread has important nutritional value, being also a source of protein, fiber and minerals (Almeida et al., 2008). Bread is one of the main foods consumed daily in all parts of the world, although there is a wide variety of different types, the term generally refers to fermented products containing wheat (Hager et al., 2012). According to Santos et al. (2012), the use of mixed flour is aimed at

the partial replacement of the raw material used in order to introduce fibers and increase the nutritional value of the product. Ingredients for baking are best used for the inclusion of fibers, due to the large consumption in the habitual diet of the population. Thus, bread enriched with fibers can be of great significance for those who need a higher intake of this food due to its protective effect against cardiovascular diseases (Justo et al., 2007). The replacement of wheat flour by gluten free flour are used because increasingly these substitutions can provide

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Abbreviations: SRW, Solubility rate in water; SRM, solubility rate in milk; ARO, absorption rate in oil; FSS, flour of sweet sorghum.

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breads with different grain characteristics technologically feasible and acceptable with higher nutritional value compared to the wheat flour (Collar et al., 2014). Thus, functional foods not only satisfy hunger but provide the necessary nutrients, prevent diseases and increase physical and mental well-being of consumers (Wansink et al., 2005).

Sweet sorghum is an excellent ingredient of renewable, the foods contains high amount of soluble and insoluble carbohydrates, that presents fast growth and has high resistance to harsh climate conditions (like drought) and requires low fertilization and irrigation (Matsakas and Christakopoulos, 2013). Souza et al. (2005) evaluated the quality of sweet sorghum products formulated alone or combined with sugarcane juice and reported that the flour obtained from three types of sorghum grains showed significant contents of ash and total sugars, and can be used as additional raw material in the production of brown sugar and grains in the preparation of flour, featuring sweet sorghum as a valid alternative for use as food. However, studies involving sweet sorghum (bagasse) in food formulations aiming at increasing the nutritional properties have not yet been carried out. Sweet sorghum is a high biomass- and sugar-yielding gramineous crop whose origin is in Africa (Chohnan et al., 2011), is a C4 crop possessing high photosynthetic efficiency and can grow in geographical areas with a temperate climate, it is the only crop that provides grain and stem that can be used for sugar, alcohol, syrup, jaggery, fodder, fuel, bedding, roofing, fencing, for industry of paper or simply to chew because is sweet, having so great versatility (Ratnavathi et al., 2011).

This study aimed the partial replacement of wheat flour by sweet sorghum flour in the preparation of bread in order to assess and physical of the flour, as well as the sensory characteristics of bread enriched with sweet sorghum flour. The inclusion of sweet sorghum fiber might be used to develop new types of bread.

MATERIALS AND METHODS

Sweet sorghum

Sweet sorghum was obtained from the Experimental Farm at the Federal Institute of Goiás - Rio Verde Campus, Rio Verde - GO, Brazil, where the weather was classified as Tropical wet (UR). Sowing was held on January 20, 2013 and manual harvested on May 20, 2013. Sweet sorghum flour was processed at the Laboratory of Fruits and Vegetables - Federal Institute of Goiás. Initially, the sweet sorghum flour were cleaned to remove sheaths and sanitized with chlorinated water (10 ml water sanitary / liter of water), and then with the help of sugarcane grinder, juice was extracted. Bagasse was stored in plastic bags and frozen at -18°C until time of drying. Drying was performed in a forced air circulation oven at 75°C up to constant weight. Then, the dried were submitted to milling in Willey type mill, aseptically packed in polyethylene bags and stored at room temperature until time of analysis and processing of breads. Physicochemical analyses were performed at

the Laboratory of Food Sciences, Food Engineering Unit - Federal Institute of Goiás. Crude protein, ash, ether extract and crude fiber values were expressed on a dry basis with an average of five replicates and solubility rate in water (SRW), solubility rate in milk (SRM) and absorption rate in oil (ARO) results with average of six replicates.

Crude fiber

For analysis of crude fiber, 200 ml of sulfuric acid and sodium hydroxide solution and 1.0 g of Celite were used, according to Silva and Queiroz (2002).

Ash

The ash content was calculated from the ratio between the amount of incinerated ash and the sample mass (AOAC, 1995) (AOAC, 1995), being expressed as percentage (%) using the following equation:

$$\text{Ash (\%)} = \frac{\text{g of ash}}{\text{g of sample}} \times 100$$

Ether extract

Ether extract was determined by extraction of oils and greases (Marconi, MA 044/8/50) using petroleum ether as solvent according to official method No. 032 / IV (IAL, 2005). Lipid content (%) was obtained using the following formula:

$$100 \times \frac{N}{P}$$

Where, N = grams of lipids, P = grams of sample.

Moisture

The moisture content was determined using a forced air drying oven for 24 h at 105°C according to methodology proposed by AOAC (1995).

Protein

Protein was determined with the aid of a Kjeldahl digester at temperature of 400°C. The results were expressed in percentage (AOAC, 1995).

Solubility rate in water, milk and absorption rate in oil

The absorption rate in oil (ARO) was determined with the aid of a centrifuge. ARO calculation used the following equation:

$$\text{ARO} = \frac{mh}{md}$$

Where, mh = mass of hydrated sample, md = mass of dried sample.

Solubility rate in water (SRW) and solubility rate in milk (SRM) were obtained by the same methodology used to obtain absorption rate

Table 1. Ingredients used in the formulations of breads fortified with sweet sorghum flour (FSS).

Ingredients	Formulation (g)			
	1	2	3	4
Wheat flour	515	510	505	500
FSS	0	5	10	15
Yeast	60	60	60	60
Water	85	85	85	85
Milk	85	85	85	85
Sugar	70	70	70	70
Fat	65	65	65	65
Egg	50	50	50	50

in oil. Results are expressed by the following equation:

$$\text{SRW and SRM} = \frac{\text{msd}}{\text{ma}} \times 100$$

Where, msd is the mass of dehydrated solid and m is the mass of sample.

Scanning electron microscopy

Flour of sweet sorghum (FSS) microscopy was performed at the High-Resolution Microscopy Multiuser Laboratory at the Institute of Physics, Federal University of Goiás. Scanning Electron Microscope, Jeol, JSM - 6610, equipped with EDS, thermoscientific NSS spectral imaging was used.

Breads enriched with sweet sorghum flour

Four bread formulations were processed (treatments) with addition of 0% (control), 1, 2 and 3% sweet sorghum flour. Breads were produced using bread molder G. PANIZ, cabinets for the storage of dough during fermentation, cylinder and Tedesco kiln. The amount of ingredients to be used in formulations was also calculated (Table 1). Solid and liquid ingredients were mixed in the container, placed in the bread molder where they were mixed and homogenized, and after forming the dough, it was divided and rounded. Then, the dough was placed in appropriate storage facilities for growth and fermentation room temperature, and finally placed in 180°C industrial kiln for 8 min.

Physical and sensory analysis of breads enriched with sweet sorghum flour

Texture

Bread firmness was determined at the Laboratory of Post-Harvest Vegetable Products Federal Institute of Goiás, Rio Verde Campus, using the Brookfield LFRA texturometer applying loads between 4500-0 g and 100-0 g, used to compress 30 mm of bread thickness.

Weight and length

The length of breads was evaluated before and after baking

through DIGIMESS caliper with results expressed in mm. Weight was assessed by analytical scales, with results in grams.

Color

Instrumental color parameters (L *, a * b *) of breads were determined in Color Flex EZ colorimeter at the Laboratory of Post-Harvest Vegetable Products, Federal Institute of Goiás, Rio Verde Campus. Sensory and visual characteristics were determined in order to quantify the consumer preference for different types of bread with addition of FSS and purchase intent. Instrumental color parameters (L *, a * b *) of breads were determined in Color Flex EZ colorimeter at the Laboratory of Post-Harvest Vegetable Products, Federal Institute of Goiás, Rio Verde Campus (Minolta, 1994).

Sensory analysis

Sensory and visual characteristics were determined in order to quantify the consumer preference for different types of bread with addition of FSS and purchase intent. Sensory analysis was performed at the Laboratory of Sensory Analysis, Federal Institute of Goiás, Rio Verde Campus. Analyses were performed with 50 untrained panelists in individual booth (IAL, 2005). Sensory analysis was performed in four formulations: 0% (control), 1, 2 and 3% sweet sorghum flour. Breads were served in white plastic cups (50 mL capacity), accompanied with a glass of mineral water at room temperature (to be drunk between samples). Regarding the purchase intent, questions were asked where panelists chose to buy or not to buy.

Statistical analyses

The results obtained were analyzed in a completely randomized design with the use of the SISVAR software (Ferreira, 2003). Physicochemical analyzes was done with three replicates per treatment using the Tukey test (0.05) to compare means.

RESULTS AND DISCUSSION

Chemical composition, solubility rate in water and milk and absorption rate in oil of sweet sorghum flour are

Table 2. Moisture, protein, ash, ether extract, crude fiber and SRW, SRM and ARO values of sweet sorghum flour (FSS).

Parameter	Mean value
Moisture (%)	4.95 ± 1.18
Crude protein (%)	3.24 ± 0.78
Ash (%)	6.33 ± 1.14
Ether extract (%)	3.77 ± 1.77
Crude fiber (%)	78.62 ± 28.40
SRW (%)	17.99 ± 0.51
SRM (%)	9.64 ± 2.87
ARO (g of oil/g of FSS)	3.48 ± 0.15

Chemical composition, moisture, crude protein, ash, ether extract, crude fiber, SRW, SRM and ARO values followed by standard deviation. The physical-chemical parameters were expressed on a wet basis.

shown in Table 2. The high fiber, ash and ether extract contents of sweet sorghum flour may be related characteristics intrinsic in plants monocots, because, Oliveira et al. (2012) characterize chemically elephant grass and reported similar values to the sorghum saccharine flour. This vicinity of values may be related because both species belong to the family *Poaceae*. The moisture content of flour of 4.95% was in accordance with limits established by Brazilian legislation (maximum 14%). The moisture 4.95% content of flour of sweet sorghum was in accordance with limits established by Brazilian legislation (Brazil, 1978). The low moisture content reduces probability of microbial growth in the product due to the low water activity.

The protein value of FSS of this study was higher than the protein content (2.32%) reported by Freitas et al. (2008) for hydrolyzed sugarcane bagasse. The high ash content of sweet sorghum flour may be related to intrinsic plant characteristics. However, the ash content (6.33%) was higher than the limit set by law (maximum of 2.0%) (Brazil, 1978). Martino et al. (2012) to evaluate in eight sorghum genotypes for human consumption had relatively higher protein values than those found in sweet sorghum flour of the present study. This reduction may have occurred during processing of sorghum flour. Processes involving heat as drying may cause loss of nutritional value and protein denaturation (Fellows, 2006). The effect of fiber on digestion is based on physical properties such as water absorption, gel filtration, ion exchange and organic absorption. SRW, SRM and ARO resulted in average values of 17.99%; 9.64% to 3.48 g oil / g FSS, respectively. According to Fernandes et al. (2002), increased solubility rate in water is probably due to starch fragmentation, increasing the amount of soluble solids. The determination of solubility and absorption rates aims to determine the hygroscopic properties of flour. These analyses reveal the technological quality of

flour to be incorporated into food products. Scanning electron microscopy images (Figure 1) show the external morphology of sweet sorghum flour. The figure with 30 times magnification shows an overview of FSS with uneven surface and heterogeneous constitution full of multiform structures. SEM showed that sweet sorghum flour is a rich source of fibers, and its inclusion together with wheat flour is an alternative to the addition of fibers to bakery products. Images with 3000 and 10,000 times magnification show the presence of starch granules adhered to the fibrous structures.

Fiber as seen in the image above magnified 200 times comprises the cell wall components of plants that are not digested by the human body but play a vital role in stimulating peristalsis, bowel movements that determine higher or lower rate of passage of food through the gastrointestinal tract, the effect of fiber on digestion is based on physical properties such as water absorption, gel filtration, ion exchange and organic absorption (Derivi et al., 2002). Individuals with low daily intake of dietary fiber are prone to a number of problems ranging from discomfort caused by intestinal gases, intestinal cancer and cardiovascular problems (BOAS, 2001). Figure 2 shows the texture of bread, according to the load required for compressing 30 mm of bread. The graph simulates the load in grams required to compress the thickness of 30 mm of bread enriched with FSS. It was observed that for compressing 30 mm of thickness among different treatments, breads with the addition of FSS required larger load because the texture of bread with higher FSS content is more consistent for not forming the gluten network required for expansion. Formulation containing 3% FSS required greater compressive load compared to control formulation. However, there was no interference in the texture analysis. The curves were ascending for all treatments. The addition of fiber increases firmness, the amylopectin

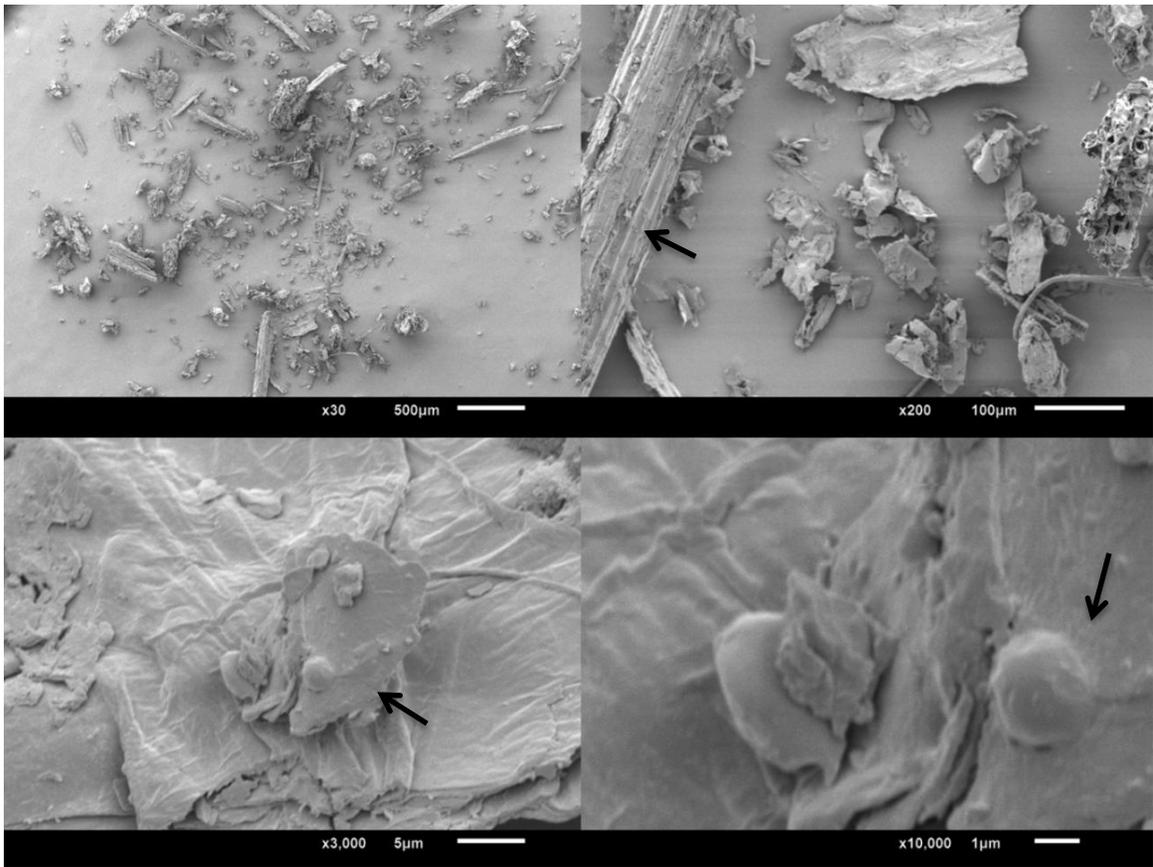


Figure 1. Scanning electron microscopy of sweet sorghum flour.

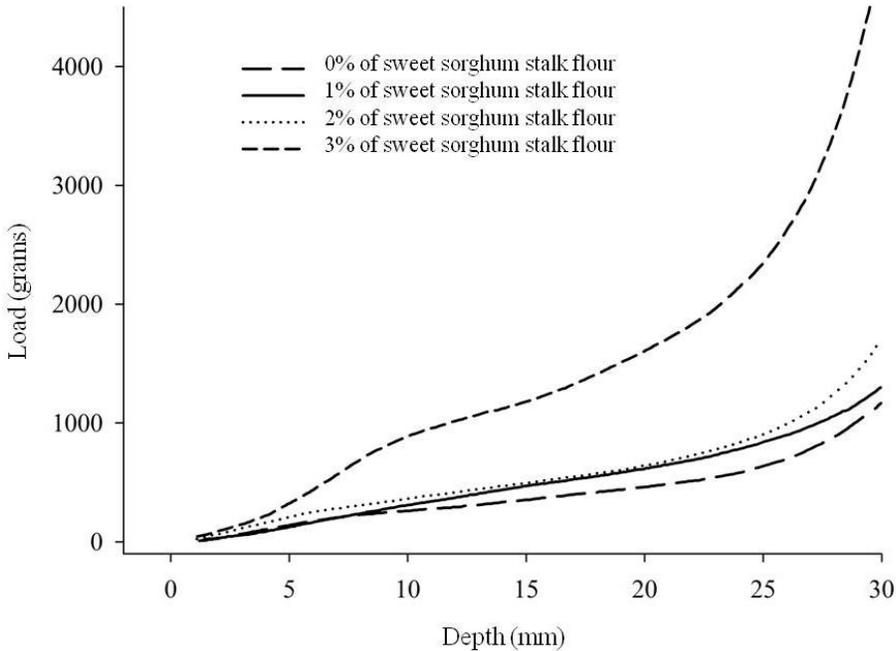


Figure 2. Texture of breads fortified with sweet sorghum flour.

Table 3. Average values for parameters weight loss, length and standard deviation of breads fortified with sweet sorghum flour (FSS).

FSS (%)	Weight loss (%)	Length (mm)
0	7.12 ± 2.99 ^a	24.62 ± 3.93 ^a
1	8.73 ± 3.43 ^a	15.25 ± 3.56 ^b
2	6.56 ± 3.94 ^a	24.20 ± 7.37 ^a
3	8.24 ± 4.28 ^a	18.34 ± 7.29 ^b
VC (%)	48.26	28.28

Different letters in the column significantly differ at 5% probability.

Table 4. Mean values for instrumental color parameters (L *, a * and b *) and standard deviation of breads fortified with sweet sorghum flour (FSS).

FSS (%)	Parameter		
	L*	a*	b*
0	44.81 ± 3.92 ^c	13.28 ± 2.58 ^a	29.53 ± 2.26 ^c
1	45.90 ± 5.25 ^c	16.93 ± 0.72 ^a	30.13 ± 2.41 ^c
2	49.07 ± 5.27 ^b	18.18 ± 2.74 ^a	32.79 ± 2.40 ^b
3	58.47 ± 5.11 ^a	60.31 ± 3.14 ^a	34.79 ± 1.24 ^a
VC (%)	9.82	15.60	6.73

L * ranging from 0 (black) to 100 (white); a * ranging from red (+ a *) to green (-a *); and b * ranging from yellow (+ b *) to blue (-b *). Different letters in the column significantly differ at 5% probability.

downgrading, and increase the bread moisture content (Skendi et al., 2010).

Table 3 shows the weight loss values, and when the dough is baked, the measure shows the loss of moisture that causes weight loss and values did not differ significantly from each other, with mean value of 7.66%. Table 3 shows the weight loss values, and when the dough is roast occurs the loss of moisture consequently weight loss and values did the breads fortified with sweet sorghum flour (FSS) not differ significantly from each other ($p < 0.05$). Table 4 presents the average values of lightness parameters (L *), a * and b * chromaticity determined in the four types of breads fortified with sweet sorghum flour, where L * ranges from 0 (black) to 100 (white), a * from red (+ a *) to green (-a *); and b * from yellow (+ b *) to blue (-b *). The addition of 3% FSS to the dough resulted in greater lightness value (L *), with significant difference ($p < 0.05$) from the others, and breads containing 1 and 0% showed no significant difference from each other ($p > 0.05$). In assessing the chromaticity coordinate (a *), it was observed that there was no significant difference ($p < 0.05$); in treatments 0, 1, 2, 3, respectively, the average results were: 13.28; 16.93; 18.18 and 60.31. However, there is an increase in red intensity in breads enriched with sweet sorghum flour. Observing values of chromaticity coordinate (b *), the control treatment (0% FSS) showed the lowest value (±

2.26) along with treatment with addition of 1% FSS, which showed value equal to 30.13, giving less tendency to yellow, with no significant difference ($p < 0.05$) between each other. Bread with the highest FSS percentage (3%) showed the highest b * value (more yellow), 34.79, significantly deferring ($p < 0.05$) from each other.

According to results obtained, it could be inferred that the addition of FSS to bread formulations can contribute to better acceptability by consumers due to significant variations in instrumental color parameters, L * and b *. At the time of purchase, consumers can be influenced by the bread color due to attractive characteristics related to senses. At the time of purchase, consumers can be influenced by the bread color due to attractive characteristics related to senses the red and yellow colors attract the attention of consumers (Toledo et al., 2014). Sensory parameters such as color, aroma, flavor, texture and appearance did not differ significantly ($p > 0.05$) by comparing with the Tukey test at 5% probability (Table 5), but when observing the average note is the preference of the panelists for the product obtained starting from the formulation containing 1% of sorghum flour. Regarding the purchase intent, 96% of panelists would buy the product if they were for sale and 4% of them would not. Of the 50 panelists, 64% consumed bread every day; 4.16% every 15 days; 27.08% once a week and 6.25% once a month. These

Table 5. Average values and standard deviation of the sensory analysis of breads fortified with sweet sorghum flour (FSS).

FSS (%)	Sensory parameter				
	Color	Aroma	Flavor	Texture	Appearance
0	7.58 ± 1.44 ^a	7.40 ± 1.41 ^a	7.24 ± 1.55 ^a	7.52 ± 1.52 ^a	7.66 ± 1.55 ^a
1	7.72 ± 1.70 ^a	7.18 ± 1.68 ^a	7.36 ± 1.45 ^a	7.60 ± 1.60 ^a	7.72 ± 1.53 ^a
2	7.64 ± 1.80 ^a	7.08 ± 1.71 ^a	7.02 ± 1.74 ^a	7.08 ± 1.96 ^a	7.60 ± 1.67 ^a
3	7.28 ± 2.05 ^a	6.78 ± 1.83 ^a	6.74 ± 1.83 ^a	6.74 ± 1.71 ^a	7.22 ± 1.60 ^a
VC (%)	23.35	23.47	23.35	23.65	21.15

Different letters in column differ by the Tukey test at 5% probability.

results indicate that bread is part of the diet of consumers and studies aiming to improve formulations by enriching with alternative sources of flour can contribute to increase bread consumption.

Conclusion

The chemical composition of sweet sorghum flour showed high fiber content and relative protein content. The 5% moisture content provides a long-term storage, provided that flour is kept at appropriate places.

Conflict of interests

The authors did not declare any conflict of interest.

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