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# A low calorie and nutritive sorghum powdered drink mix: Influence of tannin on the sensorial and functional properties

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ABSTRACT

Sorghum tannins are excellent antioxidants and may contribute to the health although their astringency is believed to be objectionable. This work aims to develop a low calorie and nutritive powdered drink mix with tannin-sorghum (PDT-3670) and tannin-free sorghum (PDTF-7064) extruded flours and to evaluate their sensorial, nutritional and functional properties. Both products were accepted on all attributes with acceptance from 70.9 to 93.2%. PDT-3670 had greater purchase intention than PDTF-7064 and better acceptability for flavor and overall acceptability. There was no difference in the aroma, texture and color acceptability between the two products. The antioxidant activity, phenols, tannins and anthocyanin contents were higher in the PDT-3670 powdered drink, having potential functional properties. Chemical analyzes indicated that both powdered formulates may be potential sources of fiber (7.9–9.1 g/100 g) and proteins (18.5 g/100 g). The serving size dissolved in water had 126.5–128.3 kcal and dissolved in milk 214–215.18 kcal. The tannin did not negatively influence the acceptance of drinks, and improved their functional properties. This nutritive and low calorie sorghum powdered drink mix has potential to be introduced, especially, into the gluten-free food market and can bring health benefits to the consumers.



## 1. Introduction

In the last decades, there has been an increasing demand for products that are more nutritious and with functional appeal, which have bioactive compounds capable of promoting health and improving the life expectancy and quality of life of the population (Chen, 2011). On the other hand, due to the modern lifestyle and high overweight and obesity rates, consumers have also been looking for foods of low caloric value which are easy to prepare, aiming to lose weight. Thus, practical, low-calorie and healthier products have been a trend and a challenge for the food industry.

In this context, sorghum may be an excellent choice for these products. This grain has significant concentrations of dietary fiber (Queiroz et al., 2015) and some genotypes are sources of minerals (Paiva et al., 2017) and bioactive compounds, such as the condensed tannins, which are present only in varieties with pigmented testa (Dykes and Rooney, 2006).

The presence of tannins in sorghum grains has advantages and disadvantages. The high-tannin sorghums play important agronomic roles by reducing bird predation and grain damage in the pre and post-harvest. The tannins are also associated with several health benefits such as antioxidant and radical scavenging

*Abbreviations:* PDT-3670, tannin-sorghum; PDTF-7064, tannin-free sorghum; CNS, Conselho Nacional de Saúde (Brazilian National Health Council); NDF, Neutral Detergent Fiber.

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functions; immunomodulatory and anticancer activity and anti-inflammatory, cardioprotective, vasodilating and antithrombotic effects (Wu et al., 2012). On the other hand, tannins are known to bind to proteins and carbohydrates, reducing caloric availability and may bring health benefits for special human diets aimed at weight loss (Awika and Rooney, 2004), but, this property may cause a decrease in the feed efficiency (Dykes and Rooney, 2006). Another disadvantage is related to the predominantly bitter and astringent taste that polyphenols of high molecular weight, such as condensed tannins have which may compromise the palatability of the products and elicit negative consumer response (Lesschaeve and Noble, 2005). According to some authors the main cause of condensed tannins in sorghum being objectionable is its bitterness and astringency (Awika and Rooney, 2004).

In Brazil, the consumption of sorghum for human food is still insipient, although some products, such as cereal bars, cookies, pasta and breakfast cereals have already been developed with whole sorghum and showed good acceptance, revealing great potential for the local market (Anunciação et al., 2017; Queiroz et al., 2012). However, it is not yet known how the presence of tannin may influence, or not, the palatability and the sensorial acceptance of new products developed with tannin-sorghum.

In view of the foregoing, the objective of this work was to develop a practical, low calorie and nutritive powdered drink mix with extruded tannin-sorghum flour and extruded tannin-free sorghum flours, carry out their sensorial, nutritional and functional characterization and to evaluate the effect of the tannin presence on these variables.

## 2. Material and methods

### 2.1. Development of the sorghum powdered drinks mix

Two powdered drink mixes were developed with extruded sorghum flours and flavored with cocoa powder. The flours were from the experimental tannin-sorghum hybrid 3670 (PDT-3670) and from the experimental tannin-free sorghum hybrid 7064, (PDTF-7064), both with brown pericarp. The presence of tannins in the hybrid 3670 was confirmed by the Bleach test (Taylor and Taylor, 2008) which identified the presence of pigmented testa in this sorghum genotype. The sorghum hybrids were cultivated and harvested under the same field conditions, at the experimental fields of Embrapa Milho e Sorgo, in Sete Lagoas - MG, Brazil, in the 2014/15 crop season.

After harvesting, sorghum grains were sent to the Embrapa Agroindústria de Alimentos, Rio de Janeiro, RJ, Brazil, where they were processed to produce the extruded flours of both sorghum genotypes in a co-rotating twin-screw model Evolum HT 25 (Clextral, Firminy, France), according to procedures described by Vargas-Solórzano et al. (2014). The sorghum extrudate flours were sent to Embrapa Milho e Sorgo and stored in polyethylene bags at $10 \pm 2$ °C until use.

The other ingredients of the formulations (skimmed milk powder, cocoa powder and xanthan gum) were purchased from the local market of Sete Lagoas, MG, Brazil. The powdered drinks mixes were manufactured by weighing the ingredients on an analytical balance (OHAUS, model AR3130) and blending them (Table 1). The formulation was based on the Brazilian legislation for products for weight maintenance or reduction and on the taste and chemical composition of similar products available on the Brazilian market.

*Serving size definition*: It was defined, in preliminary tests, that 35 g is the ideal amount of the product to be dissolved in 250 mL of water or skimmed milk to prepare a serving-size cup. This amount corresponds to 7 tablespoons of the powder.

Immediately before the sensory test, a total of 6 L of each formulation were prepared by mixing, in a domestic blender, 5 L of skim milk with 615 g of the sorghums powdered mixes, which were formulated according to the proportion described in the Table 1.

**Table 1**
Formulation of the powdered drink mixes using extruded sorghum flours (%).

| Ingredients | % |
|---|---|
| Extruded sorghum flour | 56.7 |
| Skimmed milk powder | 20.0 |
| Cocoa powder | 23.2 |
| Xanthan gum | 0.3 |

### 2.2. Sensory acceptance

The sensory tests to evaluate the acceptance of the powdered drink mixes prepared with extruded tannin-sorghum flour (PDT-3670) and extruded tannin-free sorghum flour (PDTF-7064) were carried out in the Sensory Analysis Laboratory of the Centro Universitário de Sete Lagoas (UNIFEMM), Sete Lagoas, Minas Gerais, Brazil. Teachers, workers and students were recruited and invited to participate in the study. A total of 103 non-trained consumers (65 women and 38 men) with ages between 18 and 55 years, evaluated the sensory acceptability of the products. Most of the panelist (83.5%) was still undergraduates.

Consumers were accommodated in individual tasting booths, where they received instructions about the test. They were requested to sign an Informed Consent Form, according to the Guidelines and Norms for Research with Humans, Resolution 466/2012 of the Brazilian National Health Council (CNS) (Conselho Nacional de Saúde, 2012). The Human Ethics Research Committee at Federal University of Minas Gerais, Brazil, approved this study (N°. 03591312.0.0000.5149).

Samples were randomly served under white light, in disposable 50 mL white plastic cups coded with three-digit random numbers. Water was provided for mouth rinsing between samples.

Consumers were requested to taste the product and evaluate the acceptability of each sample as to color, aroma, texture, flavor and overall acceptability, using a 10-cm hybrid hedonic scale (Villanueva et al., 2005) ranging from 0 (dislike extremely) to 10 (like extremely). They were also asked to evaluate their purchase intention for the tested products, using a 5 points scale (1 = I would certainly not buy, 5 = I would certainly buy). A positive purchase intention was calculated according to the percentage of panelists who attributed scores from 4 to 5 (Luna Pizarro et al., 2015).

For the five sensorial attributes evaluated, the scores attributed to the two formulations were divided into three groups: (1) rejection: percentage of individuals that attributed scores $< 5.0$; (2) indifference: percentage of individuals that attributed scores between 5.0 and 5.9; (3) acceptance: percentage of individuals that attributed scores $\geq 6.0$. Gularte (2009) consider a formulation as accepted when this percentage of acceptance is equal to or greater than 70%.

### 2.3. Chemical composition

The chemical composition of the two sorghum formulations was determined in the Centesimal Composition Laboratory of Embrapa Milho e Sorgo.

#### 2.3.1. Determination of protein, lipid, ash, fiber and carbohydrate

The moisture, protein, lipid, ash, fiber, carbohydrate and energy of the two sorghum formulations were determined according to the methodologies described below.

Samples were ground for 2 min in a Marconi (TE 020) mill prior to analysis and were maintained in closed glass containers, under refrigeration (10 ± 2 °C) until use. Neutral Detergent Fiber (NDF) was analyzed in 0.5 g of sample with a Tecnal EQ LCC 08 fiber analyzer using the Ankom system with filter bags (ANKOM, 2006). The lipids were determined in 1 g of sample using an XT10 Ankom Fat extractor, following the AOCS protocol (AOCS, 2004). The protein content was determined by the Dumas method (Wiles et al., 1998) in 0.25 g of sample using an FP-528 Leco Nitrogen Analyzer and the results were multiplied by the factor 6.25. The ash content was determined in 2 g sample, according to the AOAC method (AOAC, 2000) with calcination of the organic matter in a Q 318 D 24 Quimis muffle at 600 °C for 2 h. The moisture was determined by the gravimetric method in a 2 g sample, using a forced-air oven at 105 °C for 6 h. The carbohydrate content was calculated by difference using the equation: 100 - (moisture + protein + lipid + ash + fiber). The caloric value (energy) of the flour was calculated using the Atwater conversion factors: 9 kcal per gram of lipid, 4 kcal per gram of carbohydrate and 4 calories per gram of protein. All results were expressed on a dry matter basis.

The energy (kcal), protein, carbohydrate, lipid, ash and fiber contents were calculated in 100 g of the dry products (powdered mixes) and in the serving size of 35 g diluted in 250 ml of water or skim milk. The skimmed milk composition was obtained on the product label.

*2.3.2. Phenolic compounds extraction*

For total phenolic and antioxidant activity determination, 0.25 g of the two sorghum powdered mixes (PDT-3670, PDTF-7064) was extracted in 25 mL 1% HCl/methanol (v/v) for two hours in a shaker (Nova Ética, 109). All extracts were then centrifuged at 2012*g* for 10 min in a centrifuge (Hettich, EBA 200), decanted and immediately analyzed.

*2.3.3. Determination of antioxidant activity*

The antioxidant activity was determined in triplicate in the two sorghum powdered mixes (PDT-3670, PDTF-7064), by spectrophotometry (Instrutherm, UV 2000A spectrophotometer), using the 2,2 - azinobis (3-ethylbenzothiazoline-6-sulfonate) radical cation (ABTS +) assay described by Awika et al. (2003). Trolox was used as a standard. Results were expressed as μmol Trolox Equivalent (TE) $g^{-1}$ of fresh matter.

*2.3.4. Determination of total phenols*

Total phenols of the acidified methanol extracts of the two sorghum powdered mixes (PDT-3670, PDTF-7064) were measured using the modified Folin-Ciocalteu method of Kaluza et al. (1980). One aliquot of the extract (0.1 mL) was dissolved in 1.1 mL of water and reacted with 0.4 mL of Folin reagent and 0.9 mL of 0.5 M ethanolamine. The reaction was allowed to stand for 20 min at room temperature and the absorbance was read at 600 nm. The absorbance reading was performed in a spectrophotometer (Instrutherm, UV 2000A) at 765 nm. The analytical curve of gallic acid (0.005–0.10 mg/ml) was used to quantify the phenolic compounds. The results were expressed in mg of gallic acid equivalents/g of sample (mg GAE/g).

*2.3.5. Determination of total anthocyanins*

The total anthocyanins of the two sorghum powdered mixes (PDT-3670, PDTF-7064) were determined by the method described by Awika et al. (2004). The absorbance of sorghum extract samples were read at 480 nm in a spectrophotometer (Hitachi UV–Visible 1100). The concentrations of 3-deoxyanthocyanins were calculated based on the absorbance of luteolinidin at 480 nm using the Lambert-Beer's Law: $A = \varepsilon CL$, where A is the absorbance at 480 nm, $\varepsilon$ is the molar extinction coefficient ($\varepsilon$) of luteolinidin, C is sample concentration, L is the pathlength, which is 1 cm. The total anthocyanins content was calculated based on the formula C (mol/L) = $A/\varepsilon$. The mg luteolinidin equivalent (LE) of a sample = $A/\varepsilon \times 103 \times 270 \times$ dilution factor, where 270 is the molecular weight of luteolinidin and molar extinction coefficient ($\varepsilon$) of luteolinidin used was 29,157. Results were expressed as mg luteolinidin equivalents (LE)/g sample, on dry basis (db).

*2.3.6. Determination of condensed tannins*

The condensed tannin content was determined in the two powdered mixes (PDT-3670, PDTF-7064), by the vanillin-HCl method described by Price et al. (1978). For the extraction, 0.15 g of sorghum flour was mixed with 8 mL of 1% HCl in methanol. The tubes remained in a water bath (30 °C) and were agitated in a vortex 3 times at an interval of 20 min. The extracts were centrifuged for 15 min and then one aliquot (1 mL) of the supernatant was added to 5 mL vanillin reagent (0.01 g/mL vanillin in methanol mixed with equal volume 8% HCl in methanol) and allowed to react for 20 min at 30 °C. A blank was prepared under the same reaction condition by reacting 1 mL the same aqueous sample with 5 mL 4% HCl in methanol. Absorbance was read at 500 nm in a spectrophotometer (Hitachi UV–Visible 1100) and blank for each sample was subtracted. Serial concentrations of catechin (0, 0.2, 0.4, 0.6, 0.8, and 1.0 mg/mL in methanol) were used as standards. Results were calculated and expressed as mg catechin equivalent (CE)/g sample, in dry basis.

*2.4. Experimental design and statistical analysis*

A completely randomized design was used, with 103 replications for sensorial analysis, represented by the tasters, and with 3 replications for nutritional and sensorial analysis.

Data were submitted to the analyses of variance (ANOVA) and the means were compared by the Tukey test at 5% probability, using the SISVAR statistical program (Ferreira, 2010).

A Histogram with the frequency distribution of the acceptance and the purchase intention data were created by the Excel 2010 program.

## 3. Results and discussion

*3.1. Sensory acceptance*

The frequency of the score of the products formulated with extruded tannin-sorghum flour (PDT-3670) and extruded tannin-free sorghum flour (PDTF-7064) are shown in Fig. 1. The highest number of individuals was concentrated in the highest scores for all attributes evaluated (color, texture, flavor, aroma and overall acceptability) in both products. It is important to note that, compared to the product formulated with tannin-free sorghum, there was a higher frequency of scores between 9.1 and 10 (for all attributes) and 8.1 and 9.0 (except for color) for the product with tannin-sorghum flour.

The mean score and the percentage of rejection (<4.0), indifference (5.0–5.9) and acceptance (≥6.0) of the products are presented in Table 2. The scores attributed to the PDTF ranged from 7.16 to 7.86 and to the PDT ranged from 7.51 to 8.21. There was no significant difference in the color, aroma and texture acceptability of the two products. However, for the flavor and overall acceptability attributes, the powdered drink mix formulated with tannin-sorghum was more accepted ($p < 0.05$) than the tannin-free powder drink.

According to Gularte (2009), the products are considered

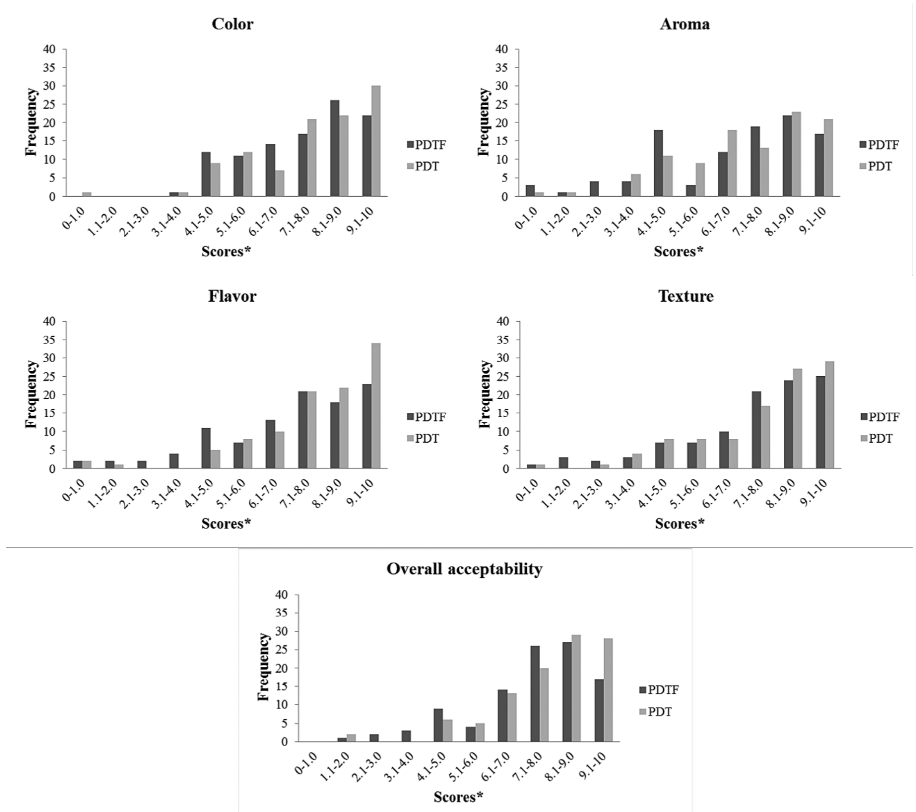


**Fig. 1.** Frequency of individuals that attributed sensory scores of the Powdered Drinks Mixes with tannin-sorghum (PDT) and tannin-free sorghum (PDTF).
*Scores attributed by the panelists to the color, aroma, flavor, textures and overall acceptability attributes based in a10-cm hybrid hedonic scale ranging from 0 (dislike extremely) to 10 (like extremely).

accepted, in terms of their sensorial properties, when they have an index of acceptance above 70%. Thus, it was verified that both products were very well accepted in all attributes evaluated, since they obtained acceptance ranging from 70.9 to 93.2% (Table 2). Although the products were flavored with chocolate powder, which has a pleasant aroma, this attribute had the highest percentages of rejection. On the other hand, the flavor and overall acceptability of the PDT obtained the highest acceptance percentages. This result may be due to genetic factors intrinsic to each hybrid used in this study, because the only difference between the drinks formulations was the sorghum genotype. However, to better understand why the flavor and overall acceptability of the drink with tannin sorghum was higher than that with tannin-free sorghum we need to perform a sensory test with a trained panel capable of identifying and describing differences between the formulations.

The results presented in the Fig. 1 and in the Table 2 showed that the bitter and astringent flavor of the tannins (Lesschaeve and Noble, 2005) did not negatively influence the acceptance of the drink. Probably, the tannin taste was not perceived or may not have been objectionable by the panelists because the tannin content of the genotype 3670 was not high enough to cause a product rejection. Collaborating with this hypothesis, Kobue-Lekalake et al. (2007) demonstrated that the bitterness and astringency, as well as other sensory attributes of a tannin sorghum (NS 5511), were perceived as similar to a tannin-free sorghum (PAN 8564) even though NS 5511 had more than twice the total phenol content of

**Table 2**
Acceptability of Powdered Drinks Mixes with extruded tannin-sorghum flour (PDT-3670) and extruded tannin-free sorghum flour (PDTF-7064).

| Sensory attributes | Formulations | Score (Mean ± SD)[1] | Rejection (%) | Indifference (%) | Acceptance (%) |
|---|---|---|---|---|---|
| | | | <5.0 | 5.0–5.9 | ≥6.0 |
| Color | PDTF | 7.83 ± 1.75 | 9.7 | 2.9 | 87.4 |
| | PDT | 8.04 ± 1.85 | 10.7 | 1.9 | 87.4 |
| Aroma | PDTF | 7.16 ± 2.34 | 15.5 | 13.6 | 70.9 |
| | PDT | 7.51 ± 2.04 | 11.7 | 8.7 | 79.6 |
| Flavor | PDTF | 7.41 ± 2.27 | 10.7 | 10.7 | 78.6 |
| | PDT | 8.19* ± 1.92 | 4.9 | 1.9 | 93.2 |
| Texture | PDTF | 7.72 ± 2.18 | 5.8 | 8.7 | 85.4 |
| | PDT | 8.00 ± 1.98 | 5.8 | 8.7 | 85.4 |
| Overall Acceptability | PDTF | 7.73 ± 1.85 | 8.7 | 5.8 | 85.4 |
| | PDT | 8.21* ± 1.70 | 4.9 | 3.9 | 91.3 |

[1]Mean of 103 scores, SD: standard deviation.
*Means between formulations (PDTF and PDT) differ statistically at 5% probability by Tukey Test.

PAN 8564. The authors concluded that not all condensed-tannin from sorghums have objectionable sensory attributes.

Another hypothesis for the good acceptance of the drink with tannin-sorghum is that the xanthan gum, an ingredient added in the both formulations, may have complexed with tannin, reducing its astringency sensation. According to Carvalho et al. (2006), the astringency is due to interactions between polyphenols and salivary proteins, resulting in insoluble aggregates that precipitate, obstructing the lubrication of the palatine and causing a sensation of dryness and constriction. The authors reported that polysaccharides, such as pectin, xanthan, gum arabic and gellan are effective inhibitors of protein precipitation by polyphenols (condensed tannins).

The reduction of the polymerization degree of proanthocyanidin (condensed tannins), which occurs in extrusion process, may also increase the acceptability of the tannin-sorghum (Cardoso et al., 2015). Corroborating this result, González (2005) also demonstrated that extrudates of excellent flavor, appearance and texture were obtained from both, whole and decorticated white tannin free sorghum and brown tannin-sorghums, can be an excellent choice for food processors. Sorghum with tannin also produced good extrudates, making it possible to add value to the product, for its nutraceutical properties. Moreover, its reddish-brown appearance can be an advantage in special products. Anunciação et al. (2017) compared the sensory acceptance of breakfast cereals made with extruded whole-wheat and with extruded whole-sorghum of genotype SC319 (with tannins). Although the use of sorghum as human food is little known in Brazil, the authors found that only the breakfast cereal made with sorghum was considered acceptable by presenting an acceptance index greater than 70%.

So, in view of this work results, it is suggested a further study to evaluate by trained panelists, the acceptance of beverages formulated with extruded flours of sorghum genotypes with different levels of tannin and different types of polysaccharides (pectin, xanthan, gum arabic and gellan).

In relation to the Purchase Intention, about 77% of the panelists (scores 4 and 5) would buy the sorghum product with tannin (PDT-3670) and only 9% would not buy (scores 1 and 2) (Fig. 2), so, there was a positive purchase intention for this product (Luna Pizarro et al., 2015). On the other hand, for the product formulated with tannin-free sorghum (PDTF-7064) only 53% would buy and 23% would not buy. Thus, the product formulated with extruded tannin-sorghum was rated better evaluated than the tannin-free sorghum. Similar to what happened in the acceptability test, other factors, intrinsic to the hybrids 3670 and 7064, may have contributed to this result.

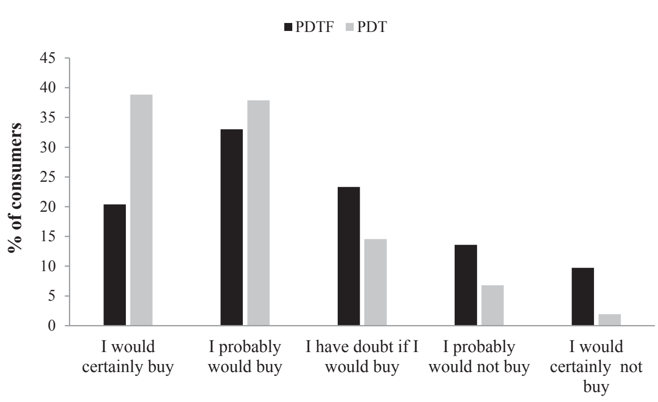


**Fig. 2.** Purchase intention of the Powdered Drinks Mixes with extruded tannin-sorghum flour (PDT) and extruded tannin-free sorghum flour (PDTF).

## 3.2. Chemical composition

### 3.2.1. Protein, lipid, water, ash, fiber and carbohydrate

The results of the samples are shown in Table 3. The 35 g value refers to the amount of product to be dissolved in 250 ml of water or skimmed milk to obtain a cup of the serving size. The fiber content was significantly higher ($p < 0.05$) in the tannin-sorghum powder drink than in the tannin-free sorghum. However, this result is probably not related to the tannin content of the grains, but to the genetic differences between the hybrids 3670 and 7064. The other nutrients did not present significant differences between the two products.

A food to be considered a fiber source should contain at least 3 g of fiber per 100 g or at least 2.5 g of fiber per serving (Brasil, 2012). Thus, both sorghum powder formulations are good sources of fiber, since the fiber content of this nutrient is between 9.1 and 7.9 g per 100 g and 3.2 and 2.8 g per 35 g (serving size) in the PDT-3670 and PDTF-7064, respectively. These values correspond to 12.8 and 11.2% of the daily reference value, in the PDT and PDTF, respectively. This high amount of fiber in the formulation is a consequence of the use of whole-grain sorghum in the production of the extruded flour, the base of the instant powder. This result is relevant especially for celiac disease patients, since gluten-free products, usually found on the market, have low fiber content because they come from refined flour or starch (Gallagher et al., 2004). Thus, the powdered form of whole sorghum may contribute to the achievement of the fiber daily recommendation for these individuals.

These products can also be considered good protein sources, since they contain a minimum of 6.5 g of protein in the serving size (8.7% DV), a value above the minimum established (6 g) per portion (Brasil, 2012). Both products presented from 0.8 to 1.7 g of lipids in the 35 g portion, which classifies them as low fat products, since, to be included in this group the food should contain a maximum of 3 g of total fat per serving (Brasil, 2012).

The serving size (35 g) dissolved in water had ranged from 126.5 (PDT) to 128.3 (PDTF) kcal and when dissolved in milk, had from 214 (PDT) to 215.18 (PDTF) kcal. According to Brazilian legislation (Brasil, 1998), foods formulated for the purpose of maintaining or losing body weight are those specially formulated in order to present a defined composition, adequate to partially meet the nutritional needs of the individual and may replace, respectively, up to one or two meals of the daily diet. The energy that this food provides should neither be less than 200 kcal (840 kJ) nor exceed 400 kcal (1680 kJ) per serving size and the protein amount must be at least 25% and must not exceed 50% of the total energy value of the diet (Brasil, 1998). Thus, the new formulations, based on extruded sorghum flours, can be used for this purpose when added with skimmed milk (35 g in 250 ml), as they have approximately 215 kcal and about 27% of these calories in the form of proteins per portion.

Sorghum products diluted in water do not fit this profile, since they present caloric values and energy in the form of proteins below those recommended in the legislation (Brasil, 1998). However, similar products sold in Brazil (Herbalife®, Linea, BioSlim, Diet Way and Diet Shake) also have energy values lower than 200 kcal per serving (between 90 and 124 kcal) and, with the exception of Herbalife and Linea, they also have between 12 and 13.5% of energy in the form of proteins.

### 3.2.2. Phenolic compounds and antioxidant activity

The results of total phenols, condensed tannins, anthocyanins contents and the antioxidant activity were shown in the Table 4. Although it was not showed in this Table, the cocoa powder contributed between 46 and 54% of the total phenols (5.2 mg GAE/g of the powdered mix), between 54 and 67% of the tannins contents

**Table 3**
Protein, lipid, ash, fiber and carbohydrate contents (dry basis), energy and % of daily value of the Powdered Drinks Mixes with extruded tannin-sorghum flour (PDT-3670) and extruded tannin-free sorghum flour (PDTF-7064) in 100 g of powder and in the serving size (35 g) diluted in 250 ml of water or skimmed milk.

| Composition | In 100 g of powder | | In 35 g of powder diluted in 250 mL of water | | | | In 35 g of powder diluted in 250 mL of skimmed milk | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PDT | PDTF | PDT | %DV[1] | PDTF | %DV[1] | PDT | %DV[1] | PDTF | %DV[1] |
| Protein (g) | 18.5 | 18.5 | 6.5 | **8.7** | 6.5 | **8.7** | 14.7 | **19.6** | 14.7 | **19.6** |
| Lipid (g) | 2.4 | 2.3 | 0.8 | **1.5** | 0.8 | **1.5** | 1.7 | **3.1** | 1.7 | **3.1** |
| Fiber (g) | 9.1* | 7.9 | 3.2 | **12.8** | 2.8 | **11.2** | 2.8 | **11.2** | 2.8 | **11.2** |
| Ash (g) | 3.4 | 3.4 | 1.2 | | 1.2 | | 3.2 | | 3.2 | |
| Carbohydrate (g) | 66.6 | 67.9 | 23.3 | **7.8** | 23.7 | **7.9** | 35.1 | **11.7** | 35.5 | **11.8** |
| Energy (kcal) | 361.6 | 366.6 | 126.5 | **6.3** | 128.3 | **6.4** | 214 | **10.7** | 215.8 | **10.8** |
| Energy (%) from Protein | | | 20.5 | | 20.3 | | 27.5 | | 27.2 | |

*Means between formulations (PDT and PDTF) differ statistically at 5% probability by Tukey test.
(1)Based in daily values (DV) proposed by ANVISA for a diet of 2000 kcal (Rotulagem, 2005).

(6.75 mg CE/g of the powdered mix) and between 63.3 and 83.8% of the antioxidant activity (79.1 μmol TE/g of the powdered mix), respectively, in the formulations containing sorghum with (PDT-3670) and without tannins (PDTF-7064). Thus, cocoa is a good flavor for this kind of product because it has the same color of the sorghum used (brown pericarp) and contributed with functional properties of the formulates.

The estimated total phenols content (6.05 mg GAE/g) and antioxidant activity (45.75 μmol TE/g) of the extruded sorghum flour of the PDT (PDT minus cocoa powder) were higher than those found by Cardoso et al. (2015) in the extruded SC319 tannin-sorghum (4.8 mg GAE/g and 28.5 μmol TE/g). The variations found in the two studies may be due to the intrinsic differences to the genotypes used in each one.

On the other hand, the estimated total phenol contents (4.4 GAE/g) and antioxidant activity (15.2 μmol TE/g) of the extruded sorghum flour of the PDTF (PDTF minus cocoa powder) were similar to those found in the extruded B.DLO357 tannin-free sorghum (3.0 mg GAE/g and 15.6 μmol TE/g) in the Cardoso et al. (2015) study. The methodology of tannin analysis used by these authors (high performance liquid chromatography) was very different from the one used in the present study, so the results could not be compared.

The total phenols, condensed tannins, anthocyanins contents and the antioxidant activity were significantly higher ($p < 0.05$) in powdered drink formulated with tannin-sorghum than in tannin-free (Table 4). Although the bleach test confirmed that before the extrusion process only the sorghum hybrid 3670 had pigmented testa (tannins), the absolute values of the PDT-3670 and PDTF-7064 formulations were not so high (Table 4). This fact may be because, during the extrusion process, the condensed tannins may have interacted with carbohydrates and proteins, forming insoluble and less extractable complexes, reducing this compound in the PDT-3670, taking it to levels closer to those of the tannin-free sorghum. This hypothesis is corroborated by Cardoso et al. (2015) that found an reduction of around 52% in condensed tannins after the extrusion in the sorghum genotype SC319 (with pigmented testa).

**Table 4**
Total phenols, condensed tannins, anthocyanins contents (dry basis) and antioxidant activity of Powdered Drinks Mixes with extruded tannin-sorghum flour (PDT-3670) and extruded tannin-free sorghum flour (PDTF-7064).

| Compound | Unit | PDTF | PDT |
|---|---|---|---|
| | | Mean ± SD | Mean ± SD |
| Total phenols | mg GAE[a]/g | 9.58 ± 0.7 | 11.26* ± 0.5 |
| Condensed tannins | mg CE[b]/g | 10.28 ± 0.3 | 12.76* ± 1.15 |
| Anthocyanins | mg LE[c]/g | 0.23 ± 0.02 | 0.27* ± 0.0 |
| Antioxidant activity | μmol TE[d]/g | 94.30 ± 2.0 | 124.82* ± 5.4 |

*Means between formulations (PDT and PDTF) differ statistically at 5% probability by Tukey test.
[a] GAE: gallic acid equivalents (FolinCiocalteu method).
[b] CE: catechin equivalents (Vanillin-HCl method).
[c] LE: luteolinidin equivalents.
[d] TE: trolox equivalents (ABTS method). Values ± SD (Standard deviation) reported for three separate replicates.

In recent years there has been an increase in the interest for new functional foods, which have bioactive compounds, such as the phenolic compounds, including the condensed tannins that are capable of delaying the appearance of disease.

The condensed tannins are associated with several health benefits such as antioxidant and radical scavenging functions; immunomodulatory and anticancer activity and anti-inflammatory, cardioprotective, vasodilating and antithrombotic effects (Wu et al., 2012). On the other hand, according to Awika and Rooney (2004), when compared to other types of grains, the starch of the sorghum with tannins is more slowly digested which may help the gastric fullness and ensures satiety for a longer period. Thus, the tannin-sorghum formulation has potential for use in diets of obese and/or diabetic individuals, since it can delay gastric emptying, allowing slower absorption of glucose and promoting satiety for longer.

## 4. Conclusions

The powdered drink mixes formulated with extruded tannin-sorghum flour and extruded tannin-free sorghum flour were accepted by consumers in relation to color, flavor, texture, aroma and overall acceptability, although the tannin-sorghum product has shown a little higher flavor and overall acceptance.

Both products had low lipid and high fiber and protein content, having potential to be sources of these two nutrients.

The tannin presence did not negatively influence the acceptance of the drinks, and improved their functional properties.

Studies using sorghum genotypes with different levels of tannin should be conducted to confirm the results found in this study.

The good acceptance of sorghum powdered drink mixes demonstrates that sorghum has potential to be inserted as an ingredient, more frequently, into human food and can provide health benefits to future consumers.

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