Production and characterization of tannia rhizome flour

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Abstract: Tannia is an unconventional vegetable of high nutritional value. In Brazil, only its leaves are used, and the use of its rhizome is advantageous to avoid post-harvest losses and to reduce waste. Thus, the objective of this work is to produce and characterize the tannia rhizome flour in terms of its physical-chemical characteristics, centesimal composition, and technological properties. The flour was obtained by drying the rhizome slices at 65 °C in a drying oven and subsequent grinding. The fineness modulus was 3.10, with a classification between fine and medium, with a yield of 14.36%. With a pH of 5.43, and a titratable acidity of 4.09%, it was classified as low acid. As it presents water activity equal to 0.23% and moisture content of 6.07%, it is a product without risk of microbial development. The water solubility (16%), milk solubility (11.44%), WAI (8.08 $g.g^{-1}$), MAI (6.52 $g.g^{-1}$) and OAI (3.68 $g.g^{-1}$) obtained, show an excellent application of the flour in meat products, instantaneous and milk-based, proving its viability in the use of the tannia rhizome flour as a nutritional source for the population and a possible ingredient in formulations of food products.
Keywords: Centesimal composition, Vegetable, *Xanthosoma sagittifolium* Schott.

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Introduction

Tannia (*Xanthosoma sagittifolium* Schott) is a vegetable originating in the Antilles belonging to the family of Araceae**.** Its physical characteristics are the presence of tuberous rhizomes and a height of up to 1.7 meters. It is classified as an unconventional vegetable. Its rhizome has high energy value and presence of carotenoids. This plant is also often mistaken for bush by the Brazilian population, thus wasting its potential as a source of nutrients. (KELEN, 2015; QUINTAS JUNIOR et al., 2018).

Despite being considered a backyard plant in Brazil, tannia is the main source of food for about 500 million people in Asia, Africa, Central America and the Pacific Islands. It is the third most important tuber, second only to yams and cassava in Nigeria. Usually its leaves, stems and rhizomes are used in the preparation of stews, roasts, pasta and flour. The states of Bahia, Minas Gerais, Rio de Janeiro and Espírito Santo are the ones who consume the most tannia leaves in Brazil (SEGANFREDO et al., 2001; SOUZA, 2018).

According to RDC Resolution No. 263 of 22 September of 2005 (BRASIL, 2005), flour is the product obtained from edible parts of one or more species of cereals, fruits, legumes, seeds, tubers and rhizomes, through grinding and/or other technological processes considered safe for the manufacture of food, and must be designated through of the term "flour" followed by the common name of the vegetable species used in its manufacture.

The use of the rhizome of tannia for the preparation of flour will provide a better destination for this part of the plant, besides to increasing the nutritional value of products that use it as an ingredient. This use meets the growing worldwide concern for the consumption of healthier, more nutritious, and natural foods (ORTIZ, 2016) and, also, for the reduction of food residues that affect the environment.

Given the above, the work aimed to produce and characterize tannia rhizome flour in terms of its physical-chemical characteristics, chemical composition, and technological properties.

Methods

The tannia rhizomes were collected in the germplasm bank of the Escola de Agronomia (EA) of Universidade Federal de Goiás (UFG), in the early hours of the morning and transported to the Vegetable Processing Laboratory of the Food Engineering Sector of EA/UFG. This harvesting procedure was carried out on three different days to obtain three samples of flour.

The flour was processed according to the flowchart shown in Figure 1.

The analyzes were carried out in the Physical Chemistry Laboratory of EA/UFG, except for the determination of total and mineral proteins, made in the Laboratory of Foliar Analysis and Fertilizers (LAFF) of EA.
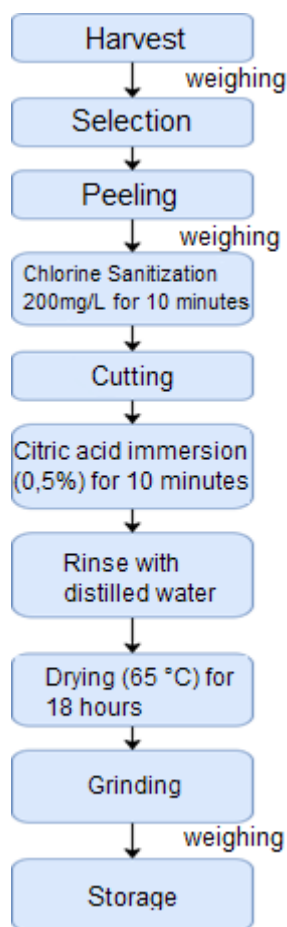

Figure 1. Flowchart of production of the tannia rhizome flour.

The granulometry was obtained by sifting 50 grams of flour in 16, 24, 32, 60, 100 and 150 mesh sieves with collector bottom, for about 10 minutes (ZANOTTO; BELLAVER, 1996).

The percentage of the flour considered coarse (C) was determined by the fraction of flour retained in sieves of mesh≤16, medium (M) by the product retained between 24 and 60 mesh and fine (F) for flour retained in sieves of mesh ≥ 60.

Titratable acidity and pH were obtained according to the methodologies of Adolfo Lutz Institute (2008).

The analysis of water activity (Aw) was performed in a portable water activity analyzer AquaLAB CX-2, at room temperature.

The content of soluble solids was obtained in a digital refractometer (RTD-95), according to the method proposed by AOAC (2012).

The moisture content was determined by reading Infrared 220 V Q533M2 QUIMIS.

The determinations of total proteins and minerals were performed by the analysis of organic residues, finding the content of nitrogen and other minerals in the product. The methodology used was the one recommended by EMBRAPA (1997). The factor 6.25 was used to convert the total nitrogen into protein content, according to Equation 1, with N being the amount of nitrogen found in the sample.

Equation 1   % proteins = 6.25 x N

The methodology used to determine the total lipid content of the sample was from Bligh and Dyer (1959).

The total carbohydrate content was calculated by difference, subtracting from one hundred the values obtained for moisture, ashes, proteins and lipids, as proposed by AOAC (2012).

The ash content was determined by incinerating 2 g of the sample in a muffle furnace at 550 °C, according to the methodology of the Adolfo Lutz Institute (2008).

The solubility of flour in water was obtained according to the methodology adapted from Okezie and Bello (1988) and the solubility in milk by the methodology adapted from Anderson et al. (1969).

The water absorption index (WAI), milk (MAI) and oil (OAI) were obtained according to the modified methodology of Okezie and Bello (1988).

The results were expressed by the mean and standard deviation of six measurements of one flour sample and analyzed by descriptive statistics. The experiment was carried out with three replications.

Results and discussion

From 6.846 kg of peeled tannia rhizomes, 1.065 kg of flour were produced, with a yield of 14.36%.

Temperature is a determining factor of yield, as well as drying time and handling of the product. Losses occurred during the processing of the tannia rhizome, being the main one during slicing of the rhizome, with the loss of non-uniform pieces, and in the grinding, with loss of the flour in the mill. Therefore, improvements in processing are needed to reduce losses and increase yield.

Dunck et al. (2013) found higher yield values when producing tannia rhizome flour, being 23.65%. Araújo et al. (2015) obtained yields between 18.43 to 25.25% during the production of sweet potato flour under different temperatures.

The results of the physical and chemical analyses of the rhizome tannia flour are shown in Table 1.

Table 1. Physical and chemical parameters of tannia rhizome flour.

Parameters	Measures
Fineness module (FM)	3.10 ± 0.03
Average size (mm)	0.305 ± 0.03
F* (%)	65.65 ± 0.56
M* (%)	29.24 ± 0.96
C* (%)	6.08 ± 0.65
pH	5.43 ± 0.13
Titratable acidity (%)	4.09 ± 0.59
Water activity	0.23 ± 0.001
Soluble solids (%)	2.50 ± 0.50

* Fine (F), medium (M) and coarse(C) particles.

It can be seen that 65.65 % of the flour was retained in the sieves of mesh ≥ 60, 29.24% between the sieves of 24 and 60 mesh and 6.08% in sieves of mesh ≤ 16, thus demonstrating the predominance of fine particles.

As the FM was 3.10, it can be said that the flour had a classification between fine and medium, considering that the wheat flour is classified as coarse if its FM = 4.10; medium if FM = 3.20, fine if FM = 2.30 and very fine if FM = 1.50 (BAIOCCHI, 2011).

Dunck et al. (2013) working with tannia flour, found 51.45% and 48.87% of fine and medium particles, respectively. There was also a predominance of fines, however, with a higher percentage of medium particles than that found in this work.

Greater uniformity of the flour can be acquired by adjustments in the grinding stage; however, the mixture of medium and fine granules can positively affect the development and stability of pasta (BAIOCCHI, 2011).

Granulometry standards are only required by legislation for wheat flour. According to Decree No. 763 of December 28, 2004, about 95% of the wheat flour must pass through 250 mesh sieves (BRASIL, 2004).

Finer flours are desirable due to their better digestion and absorption of nutrients by the body. These characteristics are due to the ability of the finer particles to absorb water faster than coarse particles, thus influencing the cooking time and the homogenization of the elaborated pasta. The particle size also negatively affects the flow, cohesiveness, and characteristics of the final product (AMORIM et al., 2016).

The tannia rizhome flour had a pH of 5.43. Dunck et al. (2013), when analyzing the same type of flour, found a pH equal to 5.0. Leonel et al. (2005), studying starchy tubers, observed that the fresh tannia had a pH of 5.61.

Small differences in values for the same type of flour can be induced by several factors such as: storage of the raw material, place and time of planting and degree of maturity of the raw material (COSTA et al., 2017).

For Souza et al. (2008), pH is an important factor in limiting the proliferation of microorganisms in food, with the majority of fungi, bacteria and yeasts growing at a pH higher than 4.5. Thus, for the flour of the rhizome of tannia, greater care must be taken when producing and storing the product.

The titratable acidity of the flour was 4.09%. According to Araújo et al. (2015), this parameter can indicate the type of fermentation process the product was submitted, since the lower the acidity, the lower the fermentation or processing time of the product.

Dunck et al. (2013) found a value close to that for tannia rizhome flour, of 3.37%. Castro et al. (2017) obtained values ranging from 0.72% to 0.92%, when characterizing yam flours produced at different drying temperatures. They observed that, with an increase in the drying temperature, the titratable acidity decreases, as there is an increase in the evaporation of free water and organic acids oxidize. The amount of organic acids in foods will influence their odor and taste (ARAÚJO et al., 2015).

The tannia rizhome flour showed water activity of 0.230. According to Garcia (2004), in foods with water activity below 0.6, it is unlikely that bacteria will grow. With water activity from 0.65 there will be growth of specific microorganisms, and up to 0.75 only some yeasts, halophytes bacteria and xerophilic fungi will be able to develop. Thus, foods such as flours, which have water activity below this range, can be considered stable, since there is hardly any microbiological development.

Castro et al. (2017) found values between 0.100 and 0.160 for yam flours produced under different temperatures. Araújo et al. (2015) obtained higher values, between 0.412 and 0.551, for sweet potato flours. Water activity of 0.320 was obtained for tannia rizhome flour (DUNCK et al., 2013). These variations are because the samples have different water contents. In addition, during the process, the higher the temperature used, the lower the water activity of the final product (ARAÚJO et al., 2015).

The measurement of water activity within the food allows the determination of the amount of free water necessary for reactions to occur, being, then, one of the main elements that can favor the deterioration of food. Thus, it is one of the most important factors for conservation, as it is related to the stability of the food and allows an assessment of the growth of microorganisms, indicating under which conditions the food should be kept during storage (GARCIA, 2004).

The soluble solids content of the flour was 2.50%. Souza (2018) found a value of 1.39% in the tannia rizhome. The increase of this content in the flour is expected since the drying of the product increases the concentration of soluble solids.

Pagani and Santos (2017) found values of 1.7% and 2.2% for white sweet potato and purple sweet potato flours, respectively. This variation can be explained by the type of processing, by climatic factors, by the tuber variety and by the soil types (PITA, 2012).

Higher contents of solids are desirable for the agribusiness, since products with high concentrations imply less sugar added and greater savings in ingredients (ARAUJO et al., 2017).

Table 2 shows the results of the centesimal composition of the tannia rizhome flour.

The moisture content obtained for the flour was 6.07%, close to found by Dunck et al. (2013), 6.6%, for tannia rhizome flour. However, Pérez et al. (2007) obtained a value of 11.04% for tannia rhizome flour. All values found are in accordance with the Brazilian legislation for flour, which establishes the maximum moisture content limit of 15% (BRASIL, 2005).

According to Melo Filho and Vasconcelos (2011), foods can be classified as low, high, and intermediate moisture, when they have values less than 20%, greater than 40% and between 20% and 40%, respectively.

Table 2. Centesimal composition of the flour of the rhizome of tannia.

Parameters	Measures
Moisture Content (%)	6.07 ± 0.51
Proteins (%)	12.69 ± 2.23
Lipids (%)	1.01 ± 0.14
Carbohydrates (%)	74.18 ± 2.86
Ashes (%)	6.05 ± 0.79
Phosphorus (%)	0.34 ± 0.51
Potassium (%)	1.26 ± 0.49
Calcium (%)	0.03 ± 0.01
Magnesium (%)	0.23 ± 0.05
Copper (mg/dm^{-3})	4.57 ± 1.30
Iron (mg/dm^{-3})	13.00 ± 1.50
Manganese (mg/dm^{-3})	6.00 ± 0.01
Zinc (mg/dm^{-3})	28.58 ± 3.12

Foods that have moisture content higher than 13% tend to favor microbial growth, increasing deterioration and decreasing shelf life. Therefore, it is important to determine the moisture content of foods, since products with less moisture are more microbiologically stable (SOUZA et al., 2008).

The tannia rhizome flour is considered a low moisture food, allowing a longer shelf life. However, it must be stored in conditions that prevent the absorption of humidity and in temperatures that prevent the development of microorganisms, since foods with moisture lower than the environment tend to absorb humidity from the air, which may favor microbial growth and the appearance of lumps (DUNCK et al., 2013)

The protein content found in the flour was 12.69%, higher than obtained by Pérez et al. (2007) and Dunck et al. (2013), of 6.37% and 6.28%, respectively, in tannia rhizome flours. Souza et al. (2008) found lower values for cassava flour samples, between 0.85% and 2.58%.

The tannia rhizome flour can be used as a supplement in bread and cake formulations, increasing its protein content.

The result of the lipid content for the flour under study was 1.01%, higher than found by Perez et al. (2007), 0.88%, for tannia rhizome flour. It was also shown to be superior to the levels found by VIEIRA et al. (2015), LEONEL et al. (2006) and FREITAS et al. (2005), in cassava (0.46%), yams (0.39%) and potatoes (0.2%) flours, respectively. In wheat flour, the lipid content found by VIEIRA et al. (2015) was 1.25%, being the most used in the world.

The presence of lipids in flour is desirable due to its ability to modify the structure of gluten in the mixing stage, polymerize proteins, improve gas retention by sealing cells, in addition to having a lubricating action, and delay the aging of bread. Therefore, the use of flours with higher contents of lipids or increasing this concentration with mixed flours is interesting, to improve the processing of some bakery products (BORGES et al., 2011).

The carbohydrate content found in the tannia rhizome flour was 74.18%, higher than obtained by Pérez et al. (2007), 68.50%, when evaluating tannia rhizome flour. Souza et al. (2008) found higher values for cassava flour, ranging from 83.34 to 88.36%.

According to Pacheco (2006), when consuming carbohydrates, energy reserve, in considerable quantities, proteins are maintained in their constructive functions in the tissue. In this way, the tannia rhizome flour can be considered an energy source if consumed in satisfactory quantities.

The 6.05% ash content obtained in this work was higher than the one found by Dunck et al. (2013) and Pérez et al. (2007), of 5.79% and 4.25%, respectively, in tannia rhizome flours.

There is no specific legislation for tannia flour, as it is a new product. Thus, the current legislation for wheat flour is used as a basis. According to normative instruction n° 8 of June 2, 2005, the maximum allowed ash content for whole wheat flour, type 1 and type 2 is 2.5%; 0.8% and 1.45%, respectively (BRASIL, 2005).

High ash contents may be related to the presence of minerals such as calcium, phosphorus, iron and magnesium, or to contamination during processing, caused by errors in washing or peeling (ÁLVARES et al., 2013).

Ash contents reflect the amount of minerals present in food. In the tannia rhizome flour were found phosphorus, potassium, calcium, magnesium, copper, iron and zinc (Table 2).

Pérez et al. (2007) obtained values for iron and calcium of 0.05 mg/dm^{-3} and 0.0052%, respectively, for tannia rhizome flour, thus showing lower contents than those found in this work.

Andrade et al. (2015), characterizing the demucilated taro flour (*Colocasia esculenta*), found values of 0.93% for potassium, 0.05% magnesium, 0.12% phosphorus, 22.4 mg/dm^{-3} manganese, 3.0 mg/dm^{-3} copper and 48.3 mg/dm^{-3} zinc. The tannia rhizome flour showed higher values of phosphorus, potassium, magnesium and copper, and lower contents of zinc and manganese.

Minerals are of great importance in health, balancing basic acid metabolism, muscle stress and osmotic pressure, however, they are not produced by the body, but are obtained through food. Thus, their intake is of great importance for health maintenance (GUIMARAES, 2018).

According to Pinheiro et al. (2005), the recommended daily intake for potassium, magnesium and phosphorus is 2000 mg, 280 to 350 mg, 800 mg, respectively. Ingestion of these minerals can prevent muscle fatigue, weakness, heart and blood problems, irritation, kidney manifestations, among others. The consumption of tannia rhizome flour can help supply this need in minerals.

The results obtained for the technological properties of tannia rhizome flour are shown in Table 3.

The water solubility of dry samples is related to the physical composition of the flours, that is, the amount of hydrophilic and hydrophobic groups, the content of soluble solids and the interactions of molecules with water. These characteristics allow verifying properties such as starch degradation, gelatinization, dextrinization and solubilization, as well as the degree of severity of the treatment applied (BORBA et al., 2005; ORTIZ, 2016).

Table 3. Technological properties of tannia rhizome flour

Parameters	Measures
Solubility in water (%)	16.00 ± 2.83
Solubility in milk (%)	11.44 ± 5.53
Water absorption index (g.g^{-1})	8.08 ± 2.27
Milk absorption index (g.g^{-1})	6.52 ± 1.19
Oil absorption index (g.g^{-1})	3.68 ± 0.23

The tannia rhizome flour showed solubility in water of 16%. Smaller solubilities were found by Santana et al. (2017) in oat, white and whole wheat flours, with values of 4.5; 5.5 and 4.5%, respectively.

Higher solubility rates are desirable to produce soups, porridges, instant products, and sauces. Also, for products that need hydration and humidity retention in their structure, such as meat and bakery products, since they improve the yield of the final product, alter the structure and decrease the preparation time (LEAL et al., 2013; ORTIZ, 2016).

The solubility index in milk was 11.44%, higher than those found by Ortiz (2016) in flours of papaya peel (5.72%), pineapple peel (5.68%) and banana peel (6.61%). Becker et al. (2014) also found lower values for rice flour (5.46%).

Tannia rhizome flour has the potential to be used in milk-based food formulations, since high solubility rates decrease the risks of syneresis and improve the mixing of ingredients (ORTIZ, 2016).

The water absorption index (WAI) of the flour was 8.08 g.g^{-1}, higher than that found by Santana et al. (2017) in oat and white wheat flours, with values of 1.20 g.g^{-1} and 1.15 g.g^{-1}, respectively. The low WAI of wheat is probably due to the higher starch content in its composition and its low solubility in cold temperatures.

According to Santana et al. (2017), the knowledge of the WAI of flours is important to evaluate the effect of the addition of water in meat products, breads and cakes, thus allowing greater control in the addition of water, in order to avoid dryness of pasta during storage.

The tannia rhizome flour showed an milk absorption index (MAI) of 6.52 g.g^{-1}, higher than that found by Becker et al.(2014) for rice flour (3.26 g.g^{-1}) and close to obtained by Ortiz (2016) for pineapple peel, banana peel and papaya peel flours, with values of 5.68 g.g^{-1}; 6.61 g.g^{-1} and 5.72 g.g^{-1}, respectively.

According to Ortiz (2016), the study of MAI in flours is of vital importance when it is intended to produce products such as dairy desserts, children's snapshots or some based on milk, as a high MAI improves homogenization and avoids the syneresis of these products.

Low MAIs are interesting in the preparation of breakfast cereals, since these products need to have a crunchy texture even when soaked with milk (BECKER et al., 2014).

The oil absorption index (OAI) found in the flour was 3.68 g.g^{-1}, which was higher than obtained by Santana et al. (2017) for oatmeal flour (2.75 g.g^{-1}) and wheat flour (2.0 g.g^{-1}).

The ability of products to absorb oil is related to the binding of proteins of the product to the oil. Factors such as the number of hydrophilic groups exposed to the protein and their interaction with the hydrophobic part of the fat are structural characteristics that can modify this absorption content (SANTANA et al., 2017).

High levels of oil absorption are, therefore, desirable for the preparation of meat products, cakes, mayonnaise, sauces, soups, cheeses, and other emulsified products. This characteristic of flour helps in palatability, viscosity, and adhesion, in addition to improving the consistency, texture and the process of substitution of ingredients (SANTANA et al., 2017).

Conclusion

The yield obtained from the product was 14.36%. The flour showed fine and medium particles, low acid character, stability to microbiological activity, high contents of proteins, lipids, carbohydrates, and minerals. Its technological properties are favorable to the production of milk products, meat products, soups, porridges, instant products, and sauces.

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