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Functional aspects of *Xanthosoma violaceum* flour: proximate composition and antioxidant activity

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Abstract:

Xanthosoma violaceum is an unconventional plant known in Brazil as "taioba roxa". It is easily available in Northern Brazil and has high nutritional values and low cost, however, it has a short shelf life. Therefore, the utilization of raw materials, such as flour, emerges as a preparation alternative. In this sense, the objective of this work was to evaluate the raw X. violaceum and flour from different parts of the plant. The composition of the flour from the leaves showed levels of proteins (8.88%), carbohydrates (61.29%), and high fiber content (11.31%), but low lipid levels (0.87%) and 291.73 kcal of energy per 100 g. Mineral content was expressive in the macrominerals as mg% of sodium (94.72), potassium (272.99), calcium (180.10), and magnesium (61.59) and the microminerals as µg% of copper (105.0), selenium (15.03), manganese (299.0) and cobalt (21.29). Low antioxidant activity was observed despite the good amount of total phenols found. The X. violaceum flour may be used in the preparation of food for the vegan public and diets of people allergic to cereal proteins or in composition with other flours to produce by-products.

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1. INTRODUCTION

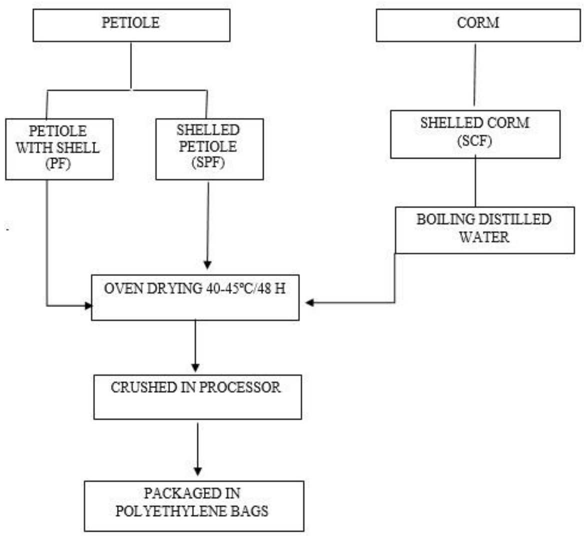
In the past, plants were domesticated in and around the Amazon region. However, most plants grown in the Amazon today are not domesticated, and this can be understood to convey substantial genetic and phenotypic divergence from nature, varieties, or species (Neves & Heckenberg, 2019). In this context, it is important to understand the nutritional composition of uncommonly used plants. Many of these food sources are little known or have fallen into disuse due to the current globalized food standards imposed by agriculture and industrialization, nevertheless, they can still be alternative natural sources of diversification in the human diet (Silva et al., 2018). There is a worldwide need to review eating habits and act against malnutrition, which is responsible for problems including obesity and its comorbidities. Thus, improving food, nutritional status, and reducing excessive consumption of fatty and processed foods is a way to improve population health, since a poor diet is directly linked to increased rates of chronic diseases (Oliveira et al., 2019; Pedraza et al., 2017). Moreover, this also adds to the need to consume products from natural sources, guarantee health, and promote respect for the environment (Frison & Clément, 2020). One way to tackle such problems is by inserting new foods that present low costs to the consumer and have significant nutritional values, thus increasing the options available in the market. Therefore, unconventional edible plants are promising alternatives, as they are spontaneous, native, or exotic plants that are not included in our daily menu and end up being excluded due to the way they develop. This is because people see these plants as "weeds," which may play a role as functional foods in our body (microsystem) by means of nutrients that are not always found in other foods or even in greater quantities than in domestic plants (Kinupp & Barros, 2007). One example is the taiobas (*Xanthosoma* sp.), which likely originates from Central and South America and has a wide geographical distribution in the tropical and subtropical areas of the planet (Boakye et al., 2018). In Brazil, specifically in the Southeastern region, it is customary to use sauteed and steamed leaves in food. Exceptionally in the Amazon region, the leaves are discarded, with the potato being the most used part. Plants of this genus are innovative alternatives for improving food, since *Xanthosoma sagittifolium* has significant amounts of proteins, fibers, magnesium, and calcium in the leaves, in addition to antioxidant activity (Araújo et al., 2019), resistant starch in *Xanthosoma mafafa* (Eleazu et al., 2018), and antioxidant properties in the leaves of *Xathosoma violaceum* (Picerno et al., 2003). Species such as *Xanthosoma sagittifolium* (Taioba) and *Colocasia esculenta* (Taro) have similar phenotypic characteristics, (shape and color of the leaves and petioles). The main characteristics that separate the Taioba from Taro are the basal petiole insertion of Taoiba and the petiole insertion near the center of the blade of the latter (Sepulveda-Nieto et al., 2017). The genus itself produces tuber species whose nutritional properties and food applications are rarely studied, with no processed products on the market as in other tubers. In addition, due to the amount of moisture found in this plant variety being over 80% (Araújo et al., 2019), the shelf life of the plant becomes short and susceptible to immediate damage after harvest. Therefore, considering the physicochemical properties of the plant, which has a nutritional content and that the species of the genus *Xanthosoma* continues to be used in some cultures to meet basic dietary needs, it is important to characterize its by-products, such as flour. There is lack of information on this species and the possible products for food supplementation, both human and animal, which can be a low-cost nutritional alternative. In this way, the objective of this study was to analyze the proximate composition of the meals of *X. violaceum* based on the need to validate the importance of these unconventional foods that can become efficient food alternatives for the population.

2. MATERIAL AND METHODS

2.1 Sampling and treatment

The samples of *X. violaceum* were provided by the Federal Institute of Amazonas (IFAM) and are cataloged in the institution's herbarium. The samples were anlyzed in triplicate. Immediately after collection, the parts to be used in the study were previously selected based on their external characteristics such as color and physical damage caused during transport, rot, injuries by pathogens, state of maturity, smell, peel condition, and size. The samples were washed, immersed in 2.5% NaClO solution for 20 min, and washed a second time with running water to remove the chemical, which is important for decontamination and removal of dirt. The production flowchart is shown in Figure 1 with the samples obtained: (a) SHELLED PETIOLE FLOUR (PF), (b) SHELL-LESS PETIOLE FLOUR (SPF), and (c) SHELLED CORN FLOUR (SCF).

Figure 1. Flowchart of *Xanthosoma violaceum* flours.



2.2 Centesimal composition and Water activity

The methods described in AOAC (2016) were used to analyze moisture content (*mc*), lipids, proteins, ash, and crude fiber. Carbohydrate content was determined by the difference calculation. Water activity (*Aw*) was determined using the AquaLab 4TE dew point water activity meter (AOAC International, 2016).

2.3 Minerals

The samples were dry digested according to AOAC (2016), with calcination in a muffle at 550 °C/6 h and recovery with a 5% (v/v) nitric acid solution. The minerals Calcium (Ca), Sodium (Na), Potassium (K), and Magnesium (Mg) were quantified in an atomic absorption spectrometer AA240FS (Varian, USA) and expressed in mg of the mineral per 100 g of product. The minerals Selenium (Se), Cobalt (Co), Manganese (Mn), and Copper (Cu) also followed the same methodology; however, its expression was in µg/100g.

2.4 Antioxidant activity

Since it is not an extract, the flours were immersed in 96ºGL alcohol and placed in an ultrasonic water bath for about 15 min before analysis. Extraction and solution were obtained in the concentration of 1mg/mL. The tests were: (1) DPPH (1,1-diphenyl-2-picryl-) antioxidant activity: carried out according to a modified version of Burits & Bucar (2000), with a test carried out on 96-well microplates. (2) Sequestering activity of the ABTS radical: 30 µL of freshly prepared flour extracts were placed in microplate wells along with 270 µL of ABTS and incubated for 15 min in the absence of light at room temperature. The reading was made on the microplate reader at 620 nm. (3) Total phenols (TPC): total phenols were quantified by the method described by Kim et al., (2003).

2.5 Statistical analysis

The Kruskal-Wallis non-parametric test was used to verify if there was any statistically significant difference between the flours, their compositions, and the minerals. The p-value is less than 0.05. When there was a statistically significant difference in the Kruskal-Wallis test, the Post-Hoc test was used to locate them.

3. RESULTS AND DISCUSSION

3.1 Centesimal composition

The raw material was previously weighed to determine the flour yield, as its calculation is based on the difference between the initial weight and the final drying weight. Yield ranged from 6.24 (PF) to 8.26% (SCF). Given that the yield is affected by the mc of the raw material, the *X. violaceum* has a high level of mc: 81.69 ± 0.32 in the rhizome, 93.51 ± 1.34 in the petiole with bark, being very similar to the values found in *X. sagittifolium* (Araújo et al., 2019), which was 88.58% in the leaves and 93.86% in the petioles. The results referring to the physical and chemical properties of the *X. violaceum* flours are shown in Table 1.

Table 1. Physical and chemical properties of *Xanthosoma violaceum* flours

Components (%)	PF	Flours[1] SPF	SCF	*P*
mc	7.44 ± 0.19	7.69 ± 0.56	12.1 ± 0.32	0.061
A_w	0.35 ± 0.00	0.30 ± 0.01	0.44 ± 0.00	0.022
Protein	8.38 ± 0.17	6.67 ± 0.11	8.88±0.08	0.034
Lipids	2.09 ± 0.09	1.55 ± 0.03	0.87±0.07	0.061
Ash	12.32 ± 0.02	11.09 ± 0.21	5.64±0.07	0.021
Fiber	13.20 ± 0.24	8.17 ± 0.11	11.31 ± 0.82	0.022
Carbohydrate	56.59 ± 0.48	64.89 ± 0.58	61.29 ± 1.03	0.022
Calorific value (Kcal)	278.70 ± 1.54	299.66 ± 2.68	291.73 ± 0.44	0.022

[1] SHELLED PETIOLE FLOUR (PF), SHELL-LESS PETIOLE FLOUR (SPF), and (c) SHELLED CORN FLOUR (SCF).

The *mc* of the flours varied from 7.44 ± 0.19 (PF) to 12.1 ± 0.32 (SCF). As there is no specific legislation for this product in Brazil, we consider that the values obtained are below the maximum allowed value for wheat flour, which is 15% (BRASIL, 2005). *Aw* is related as a source for microbial growth and chemical reactions. Among the possible reactions of food spoilage is mycotoxin production, which are fungal cancer metabolites present in food. In the analyzed samples, the water activity values ranged from 0.30 ± 0.01 (SPF) to 0.44 ± 0.00 (SCF), demonstrating that the applied dehydration process was efficient, guaranteeing water activity <0.70, which is considered safe against toxigenic fungi. As for the protein content, the lowest value (6.67 ± 0.11) was recorded in shelled petiole flour and the highest (8.88 ± 0.08) in shelled corn flour, with a statistically significant difference between them. A similar result (8.76%) was registered for *X. violaceum* corn and a less significant one (9.68%) for *X. sagittifolium* (Tresina et al., 2020). However, our flour was superior to the *X. sagittifolium* (6.37%) and *Colocasia esculenta* (6.18%) flours studied by Pérez et al. (2007), yam (3.3 - 5.9%) by Asiyanbi-Hammed & Simsek (2018), cassava (1.2%), and corn (7.2%) (TACO, 2011). Although the flours produced here do not have a higher protein values than wheat flour (9.8%) (TACO, 2011) for example, and in comparison with other rhizomes and tubers (Tresina et al., 2020), there is a significant protein quantification, which can be used in the production of compounds or improved flours, thus adding other sources of protein. Several plants have low lipid content in vegetative organs, including leaves (Araújo et al., 2019) and lipids, as these constituents are the most susceptible to chemical degradation and influenced by drying temperatures (Sebben et al., 2017). The lipid content of the flours varied from 0.87 ± 0.07 (SCF) to 2.09 ± 0.09 (PF) and should not be considered a source of lipids, as they present low levels of ether extract compared to the *Xanthosoma spp*. flour (2.4%) carried out by Coronell-Tovar et al., (2019). This enables the use of this product in the formulation of foods for people who need to restrict this component in their diet. In wheat flour, despite lipids being present at lower levels than starch or protein, they exhibit important functional properties. The ash usually represents the inorganic part of the plant. Its quantity and remaining composition, after combustion of plant material, varies considerably according to the part of the plant, age, and treatment, in addition to being an important quality attribute for some food ingredients. The ash content varied from 5.64 ± 0.07 (SCF) to 12.32 ± 0.02 (PF), with statistically significant differences between them. These values are higher than the ones reported by Pérez et al., (2007) for *X. sagittifolium* (4.25%) and *C. esculenta* (2.61%) flours and Asiyanbi-Hammed & Simsek (2018) for yams (2.21%). Such variations are normal, as the mineral content depends on the amount of botanical source, soil conditions, and the minerals that can be distributed in different forms throughout the plant. Based on Table 1, we can consider that *X. violaceum* flours are sources of fiber and important in the current diet, which ranged from 8.17 ± 0.11 (SPF) to 13.20 ± 0.24 (PF), with statistical significance. Moreover, the stem bark directly influenced fiber values by increasing it. These values are higher than other types of flours, including breadcrumbs (4.8%), wheat (2.3%), corn (5.5%) (TACO, 2011), yams (3.7%; Asiyanbi-Hammed & Simsek (2018)), and *X. sagittifolium* (5.19%) and similar to *C. esculenta* (8.24%) (Pérez et al., 2007). The importance of dietary fibers lies in the fact that they are considered prebiotics, as they are not digested by the enzymes of the gastrointestinal tract of humans, passing through the large intestine intact or even undergoing fermentation by the colonic microbiota. Thus, they are healthy as they may cause positive physiological effects such as reduced blood glucose and cholesterol, modulate the intestinal microbiota, and even decrease the chances of cancer (Kim & Je, 2016; McRae, 2018). The carbohydrate content of the flours varied from 56.59 ± 0.48 (PF) to 64.89 ± 0.58 (SPF), with statistically significant differences between them. The same occurred for the caloriies, renagung from 278.70 ± 1.54 to 299.66 ± 2.68. These results lead to the highest calorific values for the largest amounts of carbohydrates present in shelled petiole flour. The results of carbohydrates obtained here were lower than the values reported in *X. violaceum* flour (77.21%) (Coronell-Tovar et al., 2019); Nevertheless, the flours seem to be good sources of calories and carbohydrates and within the range of flours in the Brazilian Standards (TACO 2011).

3.2 Minerals

The mineral composition of the *X. violaceum* flours are in Table 2. The Na, K, Ca, and Mg values ranged from 94.72 ± 0.01 (SCF) to 117.05 ± 0.06 (SPF), 272.99 ± 0.20 (SCF) at 317.09 ± 1.60 (PF), 180.10 ± 4.30 (SCF) at 248.23 ± 4.30 (SPF), and 58.49 ± 0.01 (SPF) at 61.59 ± 0.00 (SCF) mg/100g, respectively. For Cu (105.0 ± 1.10 to 182.48 ± 0.50), Se (4.78 ± 0.14 to 15.03 ± 1.26), Mn (201.17 ± 0.35 to 299.0 ± 0.23), and Co (19.10 ± 0.21 to 21.29 ± 0.43), the values are expressed in μg/100g, with shellless corn flour showing the lowest values for the first element and, for the last three, the most expressive values. There was a statistically significant difference between the flours produced for the mineral's Na, K, Cu, and Mn. The values obtained for the different minerals are higher than those obtained for *X. sagittifolium* and *C. esculenta* flours, as reported by Pérez et al., (2007) and lower for *Xanthosoma spp*. flour (Coronell-Tovar et al., 2019), which makes it relevant as many metals are used as enzymatic cofactors. The intake of 100 g of *X. violaceum* flour can provide 22.0% of the recommended daily intake (RDI) of calcium and magnesium for adults (ANVISA, 2005). Although sodium is shown at levels above the comparative literature, it is important to note that its maximum daily intake recommended by the WHO is 2,000 mg (WHO, 2013). The flours were considered good source of potassium, since the WHO recommends the RDI of this mineral should be at least 3,500 mg. According to ANVISA (2005), the RDI of selenium for an adult is only 34 μg. This mineral participates in enzymatic and metabolic reactions, functioning as an indirect antioxidant by participating in the oxidation process of glutathione (D'Amato et al., 2020).

Table 2. Mineral composition in *X. violaceum* flours

	Flours[1]			
Components (%)	**PF**	**SPF**	**SCF**	***P***
Sodium (mg)	104.90 ± 0.05	117.05 ± 0.06	94.72 ± 0.01	0.022
Potassium (mg)	317.09 ± 1.60	301.08 ± 0.90	272.99 ± 0.20	0.034
Calcium (mg)	235.02 ± 1.52	248.23 ± 4.30	180.10 ± 4.30	0.051
Magnesium (mg)	58.53 ± 0.00	58.49 ± 0.01	61.59 ± 0.00	0.666
Copper (µg)	125.80 ± 0.83	182.48 ± 0.50	105.0 ± 1.10	0.034
Selenium (µg)	7.34 ± 0.39	4.78 ± 0.14	15.03 ± 1.26	0.561
Manganese (µg)	245.40 ± 0.45	201.17 ± 0.35	299.0 ± 0.23	0.022
Cobalt (µg)	20.55 ± 0.33	19.10 ± 0.21	21.29 ± 0.43	0.528

[1] SHELLED PETIOLE FLOUR (PF), SHELL-LESS PETIOLE FLOUR (SPF), and (c) SHELLED CORN FLOUR (SCF).

3.3 Antioxidant activity

Antioxidants are substances that effectively delay or inhibit the rate of oxidation through one or more mechanisms, such as inhibition of free radicals and metal complexation of oxidizable substrates, even when in low concentrations compared to the substrate (Laguerre et al., 2010). Due to the radical reducing ability of polyphenols and phenolic compounds, many therapeutic properties are attributed to them and, thus, the use or ingestion of the synthetic form or food in the human diet may combat oxidative stress. Therefore, in theory, the plant species under study has great chances of having antioxidant activity because its corn and petiole have a pink-violet color. This activity is caused by anthocyanins, which are responsible for the pink, scarlet, red, violet, and blue colorations of the petals of flowers and fruits of superior vegetables. Picerno et al., (2003) reported the presence of polyphenols and significant oxidative activity in *X. violaceum* leaves. In addition, antioxidant activity in *X. sagittifolium*, which is a species like the one in our study, was reported by Nishanthini & Mohan (2012) and Araújo et al., (2019). The values recorded for DPPH and ABTS were low for *X. xantosoma* flours, where the highest value found was 6.23% (SCF) and 0.77% (PF), respectively. Nevertheless, the values found for total phenols ranged from 121.47 (SPF) to 149.70 mg (PF) EAG/100g. These values are higher than the different types of flour studied by Camatari et al. (2016) and like black rice flour (Thanuja & Parimalavalli, 2020). According to the latter, phenolic compounds tend to decompose into smaller and more stable forms when exposed to heat or high temperatures, which may or may not show antioxidant activity.

Such results may have occurred due to several factors, mainly edaphoclimatic ones, that is, the time of collection, soil conditions, rain, and the amount of sunlight. These circumstances influence greatly as these compounds are the result of the secondary metabolism of the plant, which is essential for growth and reproduction and found in different proportions in the body of the plant. Picerno et al., (2003) reported antioxidant activity and high presence of phenolic content in *X. violaceum* leaf extracts that were collected in Ecuador, being the main constituents a series of flavones C- glycosyl. Another reason is that the injuries done to the tissues during the transport and manufacturing process of the flour may have contributed to the reduced phenol content due to enzymes called polyphenoloxidases (PPO). In this sense, Efrain et al., (2011) attributed to the drastic reduction in the polyphenol content during the fermentation of cocoa seeds to the enzymatic browning caused by polyphenoloxidase, followed by non-enzymatic browning induced by the polymerization of the resulting quinones and the accumulation of insoluble compounds, steps that involve the occurrence of complex biochemical reactions or a significant variation in pH. Parameters such as increased temperatures and pH and the proportion of ethanol in water influenced the extraction of phenolic compounds from the aerial parts of sugarcanes, slightly influencing the total antioxidant capacity of this species (Souza-Sartori et al., 2013).

4. CONCLUSION

The flours obtained showed potential due to their stability, which fulfills one of the problems of rapid food spoilage. From a nutritional point of view, they are good sources of calories, proteins, and metals important for the human metabolism. In addition, flours can act as a prebiotic due to their significant fiber content that assist the intestinal microbiota and prevent colon cancer. Despite the signficant amount of total phenols found, low antioxidant activity was recorded by the DPPH and ABTS methods. Thus, phytochemical prospecting is suggested to better understand the phenolic compounds contained and assess their compatibility with the methodologies of the antioxidant activity tests. Flours can be used in the preparation of foods for vegans and diets of people allergic to cereal proteins or in composition with other flours and in the production of various food products, contributing in a technological and socio-biodiversity context in a sustainable system that promotes safety food and nutrition.

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