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Development of peach palm fibrous flour from the waste generated by the heart of palm agribusiness

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ABSTRACT. The consumption of fibrous foods has been stimulated in recent years. While wheat and oat brans are still the conventional sources of fiber for human consumption, other new fibrous products have been developed – at research level – from waste or by-products generated by food industries. This research aimed to develop a new dehydrated food product - peach palm fibrous flour - from the waste generated during the processing of the heart-of-peach palm. The average yield in dry weight from this waste into farinaceous products was 129.8 g kg^{-1}. The flours showed high values for the total dietary fiber, 59.1 to 65.5 g 100 g^{-1}, almost entirely represented by the insoluble fiber, as well as a low proportion of calories - 96.1 to 101.1 kcal or 408.2-429.5 kJ per 100 g of product - when compared to wheat bran. These results highlighted the peach palm flour as a potential source of fiber for human nutrition, particularly as fibrous ingredient of formulated food and functional supplements. Also, it contributes to minimizing waste disposal and to the agribusiness of peach palm grown for heart-of-palm production.

Keywords: *Bactris gasipaes*, fibrous food, dietary fiber, nutrition, drying.

Desenvolvimento de farinha fibrosa de pupunheira a partir do resíduo gerado pela agroindústria do palmito

RESUMO. O consumo de alimentos fibrosos tem sido estimulado em anos recentes. Enquanto os farelos de trigo e aveia continuam sendo fontes convencionais de fibra para a alimentação humana, novos produtos fibrosos são desenvolvidos e sugeridos, nas pesquisas, a partir de resíduos gerados pelas agroindústrias alimentícias. A pesquisa teve por proposta desenvolver um novo produto alimentício – farinha fibrosa de pupunheira – a partir de resíduo do talo dessa palmeira gerado pela agroindústria do palmito. O rendimento médio (massa seca) dos resíduos de talos em produtos farináceos foi de 129,8 g kg^{-1}. As farinhas apresentaram valores altos para o nutriente fibra alimentar, 59,1 a 65,5 g 100 g^{-1}, o qual foi representado quase na sua totalidade pela fibra insolúvel; também apresentaram baixa proporção de calorias (96,1-101,1 ou 408,2-429,5 kJ 100 g^{-1}), comparado ao farelo de trigo. Estes resultados destacaram a farinha de pupunheira como uma fonte fibrosa potencial para a nutrição humana, em particular para ingrediente de alimentos formulados funcionais e suplemento alimentar; também, fizeram contribuição para minimizar o descarte de resíduos ao meio ambiente e contribuiram para o agronegócio da pupunheira cultivada tendo por finalidade o aproveitamento de palmito.

Palavras-chave: *Bactris gasipaes*, alimento fibroso, fibra alimentar, nutrição, secagem.

Introduction

The bud of the peach palm that contains the heart-of-peach palm consists of three parts (CHAIMSOHN, 2000): the apical leaf, the leaf center (providing the stem's prime portion) and the stem located at bottom of the palm's stalk, also known as basal. The stem portion of the heart-of-palm has the largest diameter and has low commercial value as pickles.

Cruz (1990) relates the preservation of a dehydrated product with its moisture content, correlating this to longer or shorter shelf-life of dried products, and defines the residual moisture as the minimum desirable percentage that remains in the product.

Dietary fibers are carbohydrates not digested by the digestive juices of the human body, some of which are hydrolyzed or degraded by the microflora naturally present in the large intestine. These fibers contribute to the digestive function by stimulating the gastrointestinal peristalsis, making it easier for the fecal excretion of harmful substances from the body, and are thus considered to have protective functions (RAUPP et al., 2000, 2004a; SCHWEIZER; EDWARDS, 1992). In this way fiber plays an important role in controlling and/or preventing illnesses such as constipation, diverticulitis, digestive cancer, lipids, high cholesterol and blood glucose (KRITCHEVSKY, 1998; SCHWEIZER; EDWARDS, 1992).

Wheat and oat brans are considered conventional sources of dietary fiber and, therefore, are marketed on a large scale, contributing to the healthy diet of a significant portion of the population. New farinaceous products and dehydrated fruits with high dietary fiber content have been developed in recent research to also become part of the healthy diet of many Brazilians. Many studies used by-products or wastes generated by agricultural industries, including from processing cassava starch (RAUPP et al., 2002, 2004a), corn (ALESSI et al., 2003), apple (RAUPP et al., 2000), and, more recently, from the heart-of-peach palm agribusiness. In other studies were developed dehydrated fruit and vegetables that do not meet standards for marketing as fresh products (ARAÚJO FILHO et al., 2011; PORFÍRIO-DA-SILVA et al., 2011; RAUPP et al., 2007, 2008b, 2009). Those studies determined the nutritional composition of farinaceous products obtained and compared them with wheat bran. Some also determined the digestive properties of functional and nutritional products in rat models (RAUPP et al., 2000, 2002, 2004a), comparing with those of wheat bran (conventional source of fiber). Such food products have been suggested, in research, as an ingredient for the formulation of alternative fibrous functional digestive foods for human.

This research aimed to develop a new fibrous dehydrated food product for human consumption - the peach palm fibrous flour - from the waste of the stem of this palm generated by the industry during the processing of the canned heart-of-peach palm. It was focused on the specifications of processing and the characterization of the product obtained. Also, the research aimed to contribute to minimizing waste disposal, in an effort to search for environmentally friendly processes and, thus, provide scientific support for the development of cultivated peach palm agribusiness for the use of heart-of-peach palm.

Material and methods

The heart-of-palm (*Bactris gasipaes* Kunth. Var. Gasipaes Henderson) was grown at the Sítio Vovô Miguel, owned by Dr. Deodato Miguel de Paula Souza, in Morretes, Paraná State. At this site, besides the cultivation of peach palm, there is also a unit for agribusiness, canned and minimally processed products.

The canned heart-of-palm – the main product at the site – is prepared from the edible part of the palm stem, healthy and fit for human consumption. All the external parts of the palm are removed by peeling and cutting. The heart-of-peach palm is obtained, then sliced, sanitized and immersed in acidified brine (liquid medium), with or without spices and other condiments. The packed product is subjected to heat treatment under appropriate conditions of temperature and time, being generally heated in boiling water for 40 minutes for the leaf portion (thole) or up to 50 minutes for the stem (basal) (RAUPP et al., 2008a). The apical part is understood as the edible portion of the palm, along with the regions above and below this, corresponding to the soft leaves on growth (characterized by heterogeneous structure) and soft tissues of the stem (characterized by homogeneous structure).

The waste generated by the Sítio Vovô Miguel agribusiness during the processing of canned peach palm was used for the production of a fibrous flour - ‘peach palm fibrous flour’. This waste was separated into four parts: (W1) waste from inside the covers of the talus, removed just before slicing the stem and leaf of the heart-of-palm; (W2) waste from the base of the stem; (W3) waste from the base portion in the outmost layers of the stalk (the first sheath to be removed); and (W4) waste from the apex portion in the outer layers of the stalk (the first sheath to be removed). Each waste was processed according to the flowchart in Figure 1 to obtain the farinaceous product, the 'peach palm fibrous flour', specified by F1, F2, F3 or F4, respectively.

Waste material (W1, W2, W3, W4)
generated during the processing of heart-of-peach palm
⇓
Slicing
⇓
Washing with potable water
⇓
Sanitizing solution
⇓
Rinsing with clean water
⇓
Weighing
⇓
Drying
⇓
Cooling
⇓
Weighing
⇓
Grinding in knife mill
⇓
Final product: Flour 1; 2; 3; 4
‘Peach palm fibrous flours’

Figure 1. Flowchart of processing the farinaceous product from the waste of hearts-of-palm agribusiness.

After being weighed and sliced into 1cm cubes, the waste - now raw materials named W1, W2, W3 or W4 (Figure 1) – were immersed in potable water with agitation to remove surface dirt, and were placed for 15 minutes in a aqueous solution containing 1 Ml l^{-1} of sodium hypochlorite, with a concentration of active chlorine in the commercial product from 2 to 2.5 g 100 g^{-1}. Finally, the waste was rinsed again with potable water.

After the sanitization process, the waste was weighed and transferred to a forced air circulation oven (90 x 80 x 80 cm) with renewable circulating air at a temperature of 90°C for two hours, followed by 80°C for two hours and by 60°C for 17 hours and also 60°C by the end of the drying, completing a total time of 85 hours. After drying, the waste material was cooled to room temperature and weighed, and was then ground in a knife mill to obtain a farinaceous product called 'fibrous stalk peach flour'. The drying curve was determined for the four wastes (W1, W2, W3, W4) and the moisture of their dried products were below 5 g 100 g^{-1}. The yield of flour obtained from the residues was also determined.

Flours 1, 2, 3 and 4 were characterized for color, granulometry, and nutritional properties. The color was evaluated visually and in an environment of normal artificial light. The particle size of the flour – granulometry - was determined according to Raupp et al. (2004b), i.e., the flour is screened in a series of sieves at regular and continuous stirring for 30 minutes.

Except for the analysis of dietary fiber and carbohydrates, the nutritional composition was performed in triplicate and according to the official method of the Institute Adolfo Lutz (IAL, 2008). Moisture was determined on a sample of approximately 5g that remained in an oven at 105°C for 12 hours. The ash, representing the total of minerals, was determined by calcining approximately 2 g of the sample in triplicate in a muffle furnace set at 550°C for three hours. Lipids (ether extract) were determined in the sample through the analysis of moisture and using ethyl ether as a solvent extractor for six hours. The ether extract obtained was placed in an oven at 70°C for one hour to remove residual solvent, followed by cooling in a dry area and weighing. The total protein was determined in a sample of 0.5 g by using the micro-Kjeldahl method, which quantifies the nitrogen content. The protein concentration was calculated by multiplying the percentage of total nitrogen by the conversion factor 6.25.

As for the digestive carbohydrate, were determined the soluble reducing sugars before and after the amylolitic enzymes hydrolysis procedures (IAL, 2008). The non-reducing soluble sugars were obtained by difference.

The insoluble and soluble fractions and total dietary fibers were determined through the official enzymatic method from Prosky et al. (1992) and used about 1g of the sample, in quadruplicate. The method consists in hydrolyzing protein using a protease, followed by hydrolysis of starch with thermal stable alpha-amylase and amyloglucosidase (glucoamylase) enzymes. The products obtained from hydrolysis that are the soluble and insoluble fibers were removed from the hydrolyzate and constituted the residual fibrous mass. The residue (insoluble, soluble and total) obtained from the hydrolyzate was oven dried at 70°C, cooled in desiccators to room temperature and weighed. The percentage of fibers can be calculated by subtracting the protein and minerals masses.

The caloric value, kcal and kJ, was determined considering the conversion factor for kcal of 4.0 for protein and carbohydrate and 9.0 for lipids.

Results and discussion

Samples of the products 'peach palm fibrous flour' (PPFF) obtained from wastes generated at the Sítio Vovô Miguel are shown in Figure 2. The average yield (dry weight) of peach palm stem waste in farinaceous products was 129.8 g kg^{-1}.

Flour 1 Flour 2 Flour 3 Flour 4

Figure 2. Peach palm fibrous flour: Flour 1, obtained from the waste on the sheath discarded during the processing; Flour 2, obtained from the waste on the base of the stem; Flour 3, obtained from the waste on the bottom of the outer sheath discarded before processing; Flour 4, obtained from the waste on the top of the outer sheath, discarded before the palm processing.

As expected, PPFF products became darker during the drying process, and the flour F4 was the darkest, followed by the flours 1, 2 and 3. The darkening can be explained by the occurrence of caramelization and Maillard browning reactions. The caramelization reaction is due to the transformation of sugars at high temperature and results in the formation of compounds that darken the food product. The Maillard reaction also occurs in heated food that contains sugars, proteins and/or amino acids resulting in the formation of dark compounds containing nitrogen. Both sugars and protein are abundant in the residues used as raw material for the production of the flours (Table 1).

Table 1. Nutritional composition (g 100 g^{-1}, m m^{-1}) and calorific value (kcal 100 g^{-1} and kJ 100 g^{-1}) of peach palm fibrous flours.

Component	Flour 1	Flour 2	Flour 3	Flour 4
Water (as damp)	2.9 (0.16)	3.4 (0.07)	3.9 (0.25)	3.1 (0.19)
Mineral (ash)	5.8 (0.16)	5.1 (0.01)	3.2 (0.05)	2.6 (0.02)
Protein	6.3 (0.10)	6.3 (0.09)	4.4 (0.03)	1.9 (0.08)
Total nitrogen	1.5 (nd)	1.9 (nd)	2.1 (nd)	0.5 (nd)
Non-protein nitrogen	0.5 (nd)	0.9 (nd)	1.4 (nd)	0.2 (nd)
Lipid	1.0 (0.01)	1.0 (0.01)	0.9 (0.02)	0.6 (0.01)
Total dietary fiber	63.0 (0.4)	59.1 (0.2)	65.5 (1.0)	65.2 (2.2)
Insoluble dietary fiber	59.3 (0.4)	55.4 (0.8)	60.8 (1.0)	60.6 (1.6)
Soluble dietary fiber	3.7 (0.8)	3.7 (1.1)	4.7 (2.0)	4.6 (3.7)
Total carbohydrate	17.1 (0.4)	23.0 (0.5)	21.1 (0.6)	27.8 (0.8)
Reducing sugar	5.6 (0.5)	9.5 (0.1)	13.0 (0.3)	13.5 (0.7)
Non-reducing sugar	7.3 (0.3)	7.6 (0.4)	4.5 (0.2)	5.8 (0.2)
Starch	4.2 (0.3)	5.9 (0.5)	3.6 (0.6)	8.5 (0.3)
Total sum	96.1	97.9	99.0	101.1
Total calories				
(kcal 100 g^{-1})	106.6	131.1	114.4	129.3
(kJ 100 g^{-1})	452.8	556.9	486.0	549.3

nd = non-determined

Moreover, with the exception of the waste 2 (W2), the others showed typical natural color along the sheath layers or predominantly a greenish color, which was the more intensely colored waste that resulted in flour 1; followed by W4 and W3 from which the flours 4 and 3 were produced, respectively. This may also have contributed to the coloring of the flour. The greatest darkening of the flour 4 can have been also accented by the darker natural pigment of the waste W4.

The content of total dietary fiber (TDF) in the flour was high, ranging from 59.1 to 65.5 g 100 g^{-1} (Table 1), almost entirely represented by the insoluble fraction (IDF). The SDF was only 3.7 to 4.7 g 100 g^{-1} of total dietary fiber.

Foods rich in insoluble fiber, which stimulate bowel movement, help regulate the functioning of the digestive tract and resulting in gastrointestinal comfort.

Farinaceous food products with higher content of dietary fiber than conventional sources, such as wheat and oat brans, were also produced in previous research from waste materials and by-products generated by several agribusinesses, such as the cassava starch agroindustry (RAUPP et al., 2002, 2004a), the apple agroindustry (RAUPP et al., 2000), the corn mill (ALESSI et al., 2003) and the agribusiness of hearts-of-palm (RAUPP et al., 2004b). After assessing the nutritional characteristics and also some functional properties of digestive fibrous ingredient, such developed products were suggested for use as an alternative formulation in functional food intended for human digestion.

The values of 59.1 to 65.5 g 100 g^{-1} (Table 1) determined in the current study for total dietary fiber were similar to those of some other fibrous food sources evaluated in previous research, including: (i) Raupp et al. (2004b) who determined a value of 62.25 g 100 g^{-1} for total dietary fiber in a flour called ‘fibrous bran pupunha’ obtained from the usable portion of the stem of peach palm, the stem or basal portion; (ii) Raupp et al. (2004a) that enzymatically treated the waste generated in cassava starch production to obtain a product named ‘partially hydrolyzed cassava bagasse’, in which the total dietary fiber was concentrated to 60.90 g 100 g^{-1}; (iii) and, Alessi et al. (2003) that found 59.49 g 100 g^{-1} of total dietary fiber in a fraction called ‘maize bran’, obtained from the waste produced in a corn mill that was not used for human consumption.

In two of the previous researches, the fibrous products differed significantly from the current research considering the total dietary fiber: (i) the farinaceous product called 'fiber from cassava bagasse' prepared by Raupp et al. (2004a) from the waste generated by a starch mill showed about a three times less total dietary fiber, equal to 43.10 g 100g^{-1} and (ii) the farinaceous product prepared by Raupp et al. (2000) called 'refined pulp apple' showed 91.91 g 100 g^{-1}, about a three times more total dietary fiber.

The flour prepared in this study showed proportions of total dietary fiber at least 19.3 g 100 g^{-1} greater than commercial wheat brans analyzed by Raupp et al. (2000, 2004a), which are considered a major source of conventional fiber for human consumption.

The flours showed large variations in protein, from 1.9 to 6.3 g 100 g^{-1} (Table 1), which can be attributed to the concentration of this nutrient in the different structures of the sheaths (the stalk of the peach palm). These results greatly differ from those of the ‘peach palm fibrous bran’ produced by Raupp et al. (2004b), which was equal to 20.29 g 100 g^{-1} and was prepared from fresh edible stalk-of-palm. The difference can also be associated with the methodology, since in the current study the conversion of the protein content was only from the protein nitrogen. Another possible factor is that the present research used only non-edible parts not used for hearts-of-palm, namely, portions of the stem that generate waste during the processing of palm in agroindustry. In addition, in that Raupp’s et al. (2004b) research, the fiber value was presented on a dry basis, whereas in this study, it is on a wet basis.

With respect to minerals (ash), some flours showed higher levels whereas in others the levels were lower (Table 1) than values for the product prepared by Raupp et al. (2004b) from the stem portion for heart-of-palm.

Caloric values per 100g of the product related to nutrient carbohydrates and lipids ranged from 96.1 kcal (408.2 kJ) to 101.1 kcal (429.5 kJ) (Table 1) and were lower than found by Raupp et al. (2000, 2004a) for two wheat brans, which totaled 125.6 kcal (533.5 kJ) and 142.5 kcal (605.3 kJ), respectively. However, the present peach palm fibrous flour had more calories than the product 'fibrous bran pupunha' prepared by Raupp et al. (2004b), which showed 53.3 kcal (226.4 kJ). Such differences can be attributed to the methodology for determining the carbohydrate nutrient, which was calculated by percentage difference in that research, while it was evaluated analytically in this study.

The values for lipids in the flour (Table 1), although higher than that of the product produced by Raupp et al. (2004b), which was 0.56 g 100 g^{-1}, can still be regarded as insignificant because represent very little to the total calories in this product.

The carbohydrates, which amounted 17.1 to 27.8 g 100 g^{-1}, significantly contributed to the total calories. However, the soluble carbohydrates can be easily removed by washing the product in water followed by settling or centrifugation processes for separating the insoluble part. Moreover, the starch can also be removed through a process of hydrolysis with specific enzymes such as alpha amylase (thermal stable) and amyloglucosidase (also known as glucoamylase). Thus, the calorific value of the peach palm fiber flour can be minimized with the implementation of processes to withdraw the carbohydrates, especially soluble sugars, which are the most representative. With this procedure, besides to reduce the total calories, the resulting product will present a higher content of dietary fiber nutrient.

Regarding the fractionation of flour (Table 2) there was little differentiation. The sum of two fractions containing particles of smaller sizes (< 0.35 mm) was slightly higher for flour 2 and flour 3, obtaining values of 57.4 and 57.1 g 100 g^{-1}, while in flour 1 and flour 4 these particles totaled 48.8 and 43.9 g 100 g^{-1}, respectively. Therefore, flours 2 and 3 showed a comparatively smaller size. Apparently, the results can be assigned to differences in plant tissues of the raw waste material used for the production of these flours. Besides that, the drying process may have changed the structure of the stem tissue of peach palm.

Table 2. Mean proportion (g 100g^{-1}) of flours fractions.

Fractions	Flour 1		Flour 2		Flour 3		Flour 4	
Mm	(g)	(g 100 g^{-1})	(g)	(g 100 g^{-1})	(g)	(g 100 g^{-1})	(g)	(g 100 g^{-1})
Total	20.0	100.0	20.0	100.0	20.0	100.0	20.0	100.0
> 0.50	4.1	20.1	2.0	9.9	2.3	11.4	2.7	13.3
0.50-0.35	6.2	31.0	6.5	32.7	6.3	31.5	8.5	42.8
0.35-0.25	4.9	24.4	4.8	24.2	4.8	24.3	2.9	14.7
< 0.25	4.9	24.4	6.6	33.2	6.5	32.8	5.8	29.2

The results of the drying of flours are listed in Table 3. At the end of drying, all flours showed residual moisture below 4.0 g 100 g^{-1}, ensuring thus the stability of the final product.

Table 3. Average values* of moisture (g 100 g^{-1}, w w^{-1}) of flour at different drying times.

Flours	T_0	T_1	T_2	T_3	T_4
1	89.57 (0.08)	14.35 (0.45)	2.07 (0.19)	1.18 (0.07)	2.94 (0.16)
2	89.15 (0.26)	12.19 (0.66)	1.51 (0.17)	1.26 (0.13)	3.41 (0.07)
3	85.30 (0.32)	17.52 (0.63)	3.46 (0.00)	3.04 (0.02)	3.93 (0.25)
4	83.07 (1.26)	19.39 (0.00)	6.18 (0.03)	5.97 (0.01)	3.06 (0.19)

*In triplicate; T0, beginning of drying; T1, after 2h at 90°C; T2, after 2h at 80°C; T3, after 17h at 60°C; T4, after 64h at 60°C.

The drying behavior was very similar among the four waste materials, and wastes that have originated flours 1 and 2 had greater ease of moisture loss. In these, the residual moisture content was always slightly lower than in the other two drying products.

The demand for new food products containing specific functional and nutritional properties combined with the need for waste reduction have encouraged researches focusing the exploration of usage from waste generated by agribusiness systems, such as peach palm. The transformation of waste materials generated by food industries into high added-value products is possible, as demonstrated in this research, provided proper processing technology is used to minimizing the loss of its nutritional and/or functional properties, as well as to ensure food security of the product intended for human consumption.

The drying process for obtaining fibrous products is gaining attention and growing in the food industry because it is an important technique that, besides increasing the shelf-life of foods, offers differentiated food products to a select group of consumers, such as the product of this research with high content of dietary fiber (Table 1).

Based on the nutritional composition, the 'peach palm fibrous flour' constitutes a food product that has a high content (59.1 to 65.5 g 100 g^{-1}) of dietary fiber (Table 1) and is similar to other alternative sources of fiber already suggested in previous research for consumption as food, such as 'corn bran' (ALESSI et al., 2003) and 'partially hydrolyzed cassava bagasse' (RAUPP et al., 2004a) and the 'heart of palm fibrous bran' (RAUPP et al., 2004b). Moreover, with a significant removal of carbohydrates, as suggested in this research, the 'peach palm fibrous flour' product may come to resemble the 'refined pulp apple' prepared by Raupp et al. (2000), at the proportion of fiber and total calories. Also, besides having a greater proportion of dietary fiber than the wheat bran (RAUPP et al., 2002, 2004a), a commonly consumed source, the 'peach palm fibrous flour' has the advantage of being less caloric.

The flour produced in this research can be used as an ingredient for food products formulated to increase dietary fiber, especially the insoluble fraction, since that the product is in accordance with the microbiological standards. It can also be used as a food supplement, a source of dietary fiber.

The promising results will benefit the peach palm agricultural industry if small farmers include a novelty food product as a source of fiber for human consumption in their small agribusiness, it will also help adding value to their production and marketing, while presenting a new fibrous food product to the consumer market.

Conclusion

The average yield (dry weight) of peach palm stem wastes in farinaceous products ('peach palm fibrous flours') was 129.8 g kg^{-1}. The flours showed higher values for the total dietary fiber, 59.1 to 65.5 g 100 g^{-1}, almost entirely represented by insoluble fiber. The flours had a low proportion of calories, 96.1 to 101.1 kcal 100 g^{-1} (408.2 to 429.5 kJ 100 g^{-1}), compared to wheat bran (conventional source of dietary fiber).

The flour is recommended for use as an ingredient in formulated food products to enhance the content of the insoluble fiber. Also, it is recommended as a dietary supplement, as a source of insoluble fiber.

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