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Flour of Winged-stem Passion Fruit Peel: Nutritional Composition, Incorporation in Cookies, and Sensory Acceptability

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HIGHLIGHTS

- The flour of the sweet passion fruit peel has a high dietary fiber content.
- Adding sweet passion fruit peel flour increases the fiber content in cookies.
- Cookies enriched with passion fruit peel flour have good sensory acceptability.
- Full use of sweet passion fruit reduces waste and improves nutritional value.

Abstract: The development of new products by adding value to residues such as passion fruit peel, which may contribute to additional nutritional value, is of great interest. Thus, the objective of this study was to characterize the flour of winged-stem passion fruit peel and use it in the preparation of cookies, along with the evaluation of its nutritional quality and sensory acceptability. Flavedo and albedo flours were produced from the winged-stem passion fruit, and 6 biscuit formulations were made, one standard and the others containing different amounts of this flour (8.5% to 17%). In addition to the physical and chemical characterization of the flour obtained from flavedo and albedo, cookies with greater sensory acceptability were also analyzed. Flavedo and albedo flours of passion fruit had different nutritional compositions; however, both have high dietary fiber content, showing values of 79.37% and 63.59%, respectively. All cookie formulations obtained good sensory acceptability. The formulations added to the flour had a higher content of protein, ash, and dietary fiber in relation to the standard cookie formulation. This study presents the

feasibility of using a by-product, which is normally discarded, in the preparation of cookies, increasing the nutritional value of this product, and indicating the potential of these flours to increase fiber content in the diet.

Keywords: *Passiflora alata*; albedo flour; flavedo flour; products for dietary purposes.

GRAPHICAL ABSTRACT

INTRODUCTION

Passion fruit is one of the most highly produced and popular fruits in Brazil; it is greatly appreciated by the general population due to its characteristics and properties [1]. *Passiflora edulis f. flavicarpa*, commonly known as the yellow passion fruit, is the most common variety in Brazil; however, the cultivation of the winged-stem passion fruit (*Passiflora alata Curtis*) has been increasing and gaining more importance in the fresh fruit market. *P. alata* is found in the state of Pará, central-western Brazil, the state of Bahia, and southern Brazil [2].

The winged-stem passion fruit belongs to the family *Passifloraceae* and genus *Passiflora*. It uses the trunk of other plants for support, has entire and ovate leaves, large flowers with carmine petals, and purple and white striped filaments. Its fruits are ovoid, similar to the shape of a small papaya, yellow to orange when very ripe, and with beige pulp, a sweet taste, pleasant aroma, and low acidity [2]. Passion fruit peel has a significant amount of dietary fiber, mainly pectin [3] in addition to antioxidants such as ascorbic acid, phenolic compounds and carotenoids, and can be used in the production of dietary foods such as cookies for example [4-5]. In addition, effects such as prevention of insulin resistance and hepatic steatosis induced by a diet supplemented with passion fruit peel flour have already been demonstrated in bioassays, which may be related to the presence of phenolic compounds such as caffeic acid and isoorientin in its composition [6].

Most passion fruits produced in Brazil are intended for fresh consumption, and the remainder is used for the production of juice and derivatives, while the peels are commonly discarded. The passion fruit peel is separated into two parts, the albedo (white part) and the flavedo (yellow/orange part), both of which are important sources of soluble fiber (pectin). Soluble fibers have the ability to form gels, delaying gastric emptying and intestinal transit time, decreasing the rate of absorption of glucose and cholesterol, in addition to serving as a substrate for bacterial fermentation, resulting in gases and short-chain fatty acids, contributing to human health [7]. Dietary fibers can interfere with the availability of minerals in a positive or negative way, depending on the type of fiber, and while insoluble fibers decrease the absorption of minerals, soluble fibers can even increase the bioavailability of calcium [8] as well as iron and zinc, depending on the fiber in question [9]. Therefore, albedo and flavedo may be offered as alternative low-cost ingredients that can be used to increase dietary fiber [10-12]

Adding value to residues such as passion fruit peel is of great interest in the development of new products; however, it is necessary to consider the sensory aspect in addition to its nutritional attributes. Thus, the present study aimed to use sweet passion fruits integrally to develop cookies with increased nutritional value while ensuring its sensory quality.

MATERIAL AND METHODS

Preparation of Winged-Stem Passion Fruit Peel Flours

The ingredients for cookie and flour production were purchased from the local market. Passion fruits were initially selected, cleaned and sanitize using a chlorine solution (2.5%) according to the manufacturer's recommendations, depulped, and peeled. The pulp of albedo and flavedo were separated manually, since the chemical composition of these parts was not found in the scientific literature. The albedo remained immersed in water for 5 h and the flavedo for 24 h, with water changes every hour, to reduce the compounds responsible for the bitterness present in the passion fruit peel. The albedo and flavedo were then placed in trays lined with waxed paper and left to dry in a forced air circulation oven at 60 °C for 29 and 20 h, respectively. The peels were then ground using a household blender and sieved using a sieve of mesh size 28 mm to obtain homogenous flours. The flours were stored in the dark in polyethylene bags and sealed using a sealer.

Nutritional Composition of Flours and Cookies

Moisture was quantified by drying in a forced air circulation oven at 105 °C. The mineral matter was determined by incineration in a muffle furnace at 550 °C. Lipids were extracted by Soxhlet hot extraction using petroleum ether as the solvent. Protein content was determined by nitrogen determination using the Kjeldahl method and then using a conversion factor of 6.25. Food fiber was determined by the enzymatic-gravimetric method 985.29 and available carbohydrates by difference between 100 and the sum of moisture, protein, lipid, ash and total dietary fiber content [13]. The total caloric value (TCV) was calculated according to the RDC nº 360 [14].

Cookie Preparation

Considering the standard formulation of Ishimoto, Harada, Branco, Conceição, and Coutinho [15] and the food fiber content of winged-stem passion fruit peel, five formulations were prepared with partial substitution of wheat flour with passion fruit peel flour in the standard formulation, based on the previous tests regarding the sensory characteristics (Table 1). Fat reduction was also tested. Albedo flour was mixed with flavedo flour for cookie production at a ratio of 100 g of albedo flour to 40 g of flavedo flour, based on the total flour yields obtained.

Table 1. Cookie formulations with winged-stem passion fruit flour.

Ingredients	F1	F2	F3	F4	F5	SF
White wheat flour	349.5 g	316.5 g	349.5 g	316.5 g	333 g	382.5 g
White sugar	127.5 g	127.5 g	127.5 g	127.5 g	127.5 g	127.5 g
Unsalted margarine	105 g	105 g	127.5 g	127.5 g	116.25 g	127.5 g
Winged-stem passion fruit pulp	270 mL	270 mL	270 mL	270 mL	270 mL	270 mL
Flour of winged-stem passion fruit peel	33 g	66 g	33 g	66 g	49.5 g	-
Egg yolk	3 units	3 units	3 units	3 units	3 units	3 units
Chemical yeast	5.25 g	5.25 g	5.25 g	5.25 g	5.25 g	5.25 g
Vanilla	3 mL	3 mL	3 mL	3 mL	3 mL	3 mL
Salt	1.5 g	1.5 g	1.5 g	1.5 g	1.5 g	1.5 g

F1: 8.5 % substituted flour/fat reduction; F2: 17 % substituted flour/ fat reduction; F3: 8.5 % substituted flour/no fat reduction; F4: 17 % substituted flour/no fat reduction; F5: 13 % substituted flour/partial fat reduction; SF: standard formulation.

All ingredients were manually weighed and homogenized, except the pulp, which was ground in a household blender. The resulting dough was wrapped in an aluminum foil and stored in cold (6 °C) for 30 min, cut into cookie-shaped segments, stored in a freezer for 1 h, and then baked in a pre-heated oven at 170 °C for 12 min.

Sensory Analysis

Tests were performed in the sensory analysis laboratory, using 45 untrained panelists on different days due to a large number of samples. All panelists accepted and signed a free and informed consent form, previously approved by the Human Research Ethics Committee (protocol no. 1.005.028). Tests were performed in individual booths under white light, and samples were served in a monadic and balanced, coded with three-digit numbers. Sensory analysis was performed using a structured nine-point hedonic scale evaluating appearance, color, flavor, aroma, texture, and overall acceptability, with score one corresponding to “dislike extremely” and nine to “like extremely” [16]. Purchase intent of cookies was surveyed using a questionnaire with a five-point scale, wherein a score of one indicated “definitely would not buy”, three “maybe/maybe not”, and five “definitely would buy” [17].

Statistical Analysis

Data from physical analyses was submitted to one-way ANOVA and the sensory data was submitted to two-way ANOVA, considering samples and consumers as factors. Then, when the difference between the samples was detected, the comparison of the variables mean was performed using the Tukey test and Student’s test for comparing nutritional composition of albedo and flavedo flour of winged-stem passion fruit. The analysis was performed using the Origin® 6.0 software and XLSTAT statistical software for Microsoft Excel.

RESULTS

The present study showed that approximately 70% of the weight of fresh sweet passion fruit corresponds to passion fruit peel, and the flour yield was 5.4% of the total weight of the fruit. Passion fruit peel has a high moisture content of approximately 90%, which lowers the flour yield [18].

Nutritional Composition of Flours

The nutritional composition of the flours differed for all components evaluated, except for the lipid content. Albedo flour (AF) presented higher protein, moisture, and ash than flavedo flour (FF), which had higher food fiber contents (Table 2).

Table 2. Nutritional composition per 100 g of albedo and flavedo flour of winged-stem passion fruit.

Components (g)	AF	FF
Moisture	4.24 ± 0.09[a]	3.54 ± 0.04[b]
Protein	11.08 ± 0.01[a]	8.75 ± 0.64[b]
Lipids	0.64 ± 0.03[a]	0.63 ± 0.10[a]
Ashes	7.48 ± 0.19[a]	2.57 ± 0.04[b]
Total dietary fiber	63.59± 0.01[a]	79.37± 0.01[b]
Available carbohydrates	13.55 ± 1.10	5.15 ± 0.68
Total caloric value (Kcal)	228.5 ± 0.74	219,95 ± 0.77

AF: albedo flour of winged-stem passion fruit; FF: flavedo flour of winged-stem passion fruit; Averages labeled with different superscript letters (a and b) in the same row are significantly different according to Student’s test ($p \leq 0.05$).

The lower flour moisture content observed in the present study is a positive quality because the water content is an important factor in determining rates of food deterioration by microorganisms and changes due to enzymatic reactions. Therefore, a reduction in water content is considered an effective food preservation method [19].

Sensory Analysis

Some formulations were as acceptable as the standard formulation (SF) in relation to the sensory characteristics evaluated. Considering their overall acceptability, all formulations tested were well accepted (Table 3).

Table 3. Sensory acceptability of cookies with winged-stem passion fruit flour.

Characteristics	F1	F2	F3	F4	F5	SF	F-Fisher from ANOVA	p-value from ANOVA
Appearance	7.2 ± 1.2	7.0 ± 1.2	7.0 ± 1.5	6.8 ± 1.5	7.0 ± 1.4	7.2 ± 1.3	0.642	0,51
Color	7.3 ± 1.2^{ab}	7.3 ± 1.2^{ab}	7.5 ± 1.1^{ab}	7.2 ± 1.3^{ab}	7.1 ± 1.3^{a}	7.6 ± 1.2^{b}	1.33	<0.0001
Aroma	7.0 ± 1.6	6.9± 1.5	7.0 ± 1.3	7.0 ± 1.3	6.9 ± 1.5	7.5 ± 1.4	1.06	0,21
Flavor	6.7 ± 1.6^{a}	6.3 ± 1.7^{a}	6.9 ± 1.7^{ab}	6.2 ± 1.9^{a}	6.9 ± 1.6^{ab}	7.5 ± 1.4^{b}	3,41	<0.0001
Texture	6.7 ± 1.6	6.4 ± 1.6	7.0 ± 1.3	6.6 ± 1.8	6.7 ± 1.6	7.0 ± 1.6	1.05	0,20
Overall acceptability	6.8 ± 1.4^{ab}	6.5 ± 1.4^{ab}	6.8 ±1.6^{ab}	6.3 ± 1.9^{a}	6.8 ± 1.5^{ab}	7.3 ± 1.4^{b}	1,82	<0.0001

F1: 33 g substituted flour/fat reduction; F2: 66 g substituted flour/fat reduction; F3: 33 g substituted flour/no fat reduction; F4: 66g substituted flour/no fat reduction; F5: 49.5g substituted flour/partial fat reduction; SF: standard formulation. Averages followed by the same superscript letters in the same row are not significantly different according to Tukey's test ($p \leq 0.05$).

For all evaluated characteristics and formulations tested, the minimum grade corresponded to the expression "like slightly (score 6)", and the maximum to "like moderately (score 7)" to "like very much (score 8)". Therefore, the results indicated that all samples were well accepted in terms of all the characteristics evaluated.

No significant differences in appearance, texture, and aroma were observed between samples. The flavor was not significantly different between the SF and formulations F5 and F3, but was significantly higher than the other alternative formulations. However, only formulation F4 presented significantly lower overall acceptability than the SF.

The purchase intent survey showed that most panelists probably or definitely would buy cookies prepared using F3, F5, and standard formulations (Figure 1).

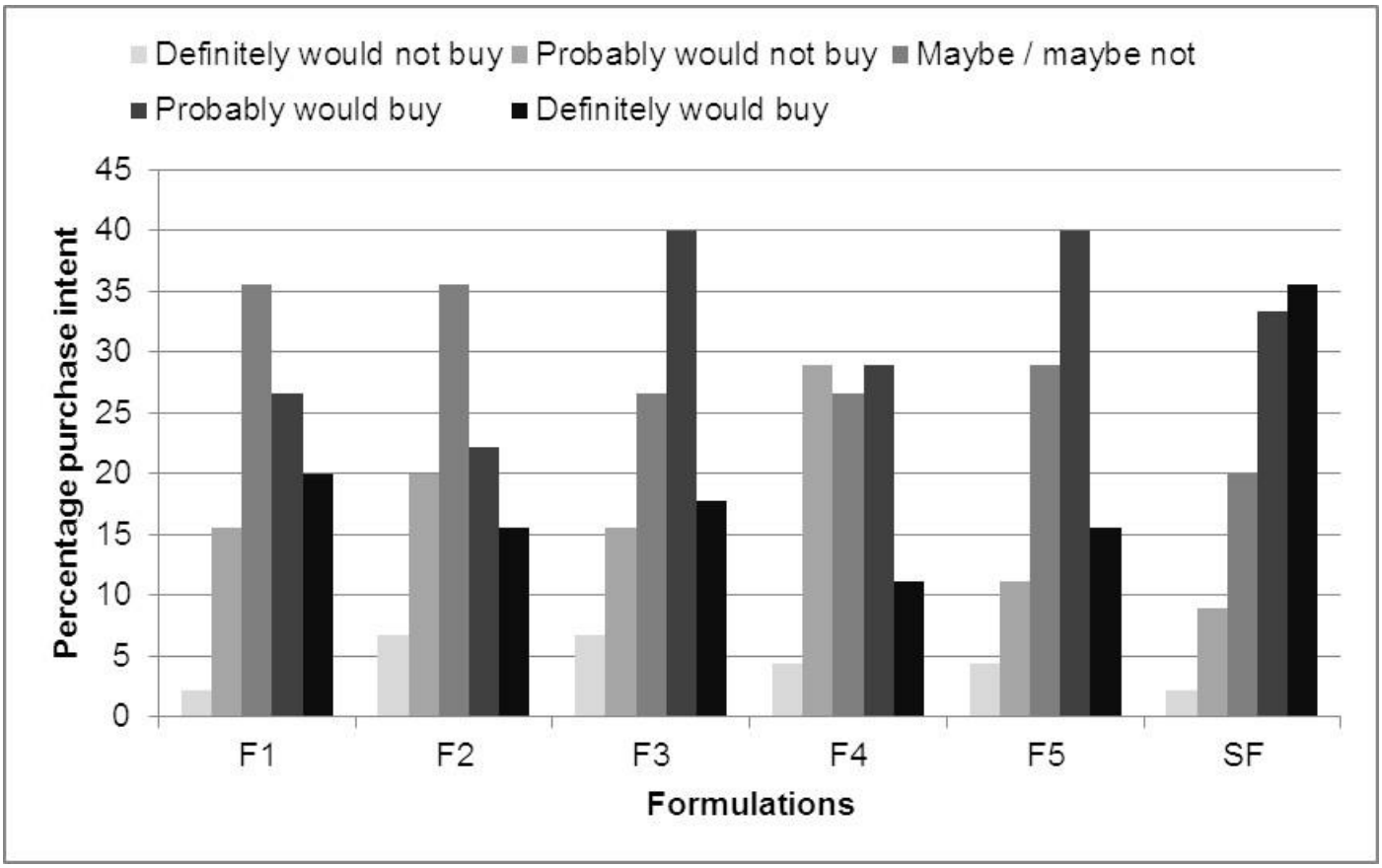

Figure 1. Purchase intent for the formulations containing winged-stem passion fruit flour. F1: 33 g substituted flour/fat reduction; F2: 66 g substituted flour/fat reduction; F3: 33 g substituted flour/no fat reduction; F4: 66 g substituted flour/no fat reduction; F5: 49.5 g substituted flour/partial fat reduction; SF: standard formulation.

Nutritional Composition of Cookies

The nutritional composition of cookies was determined for the formulations with higher acceptability (SF, F2 and F5), considering all evaluated characteristics and the amount of substituted flour. There were significant differences between samples for all components evaluated, except for carbohydrate content (Table 4).

Table 4. Nutritional composition per 100 g of cookies with winged-stem passion fruit flour.

Components	SF	F5	F2
Moisture	14.81 ± 0.11^{a}	7.07 ± 0.06^{b}	9.28 ± 1.19^{c}
Protein	7.30 ± 0.40^{a}	9.45 ± 0.45^{b}	8.90 ± 0.39^{b}
Lipids	13.31 ± 1.49^{a}	16.09 ± 0.10^{b}	13.43 ± 1.16^{a}
Ashes	1.13 ± 0.05^{a}	1.82 ± 0.04^{b}	1.73 ± 0.03^{c}
Total dietary fiber	4.04 ± 0.01^{a}	5.04 ± 0.01^{b}	6.78 ± 0.01^{c}
Available carbohydrates	59.56 ± 1.27	60.54 ± 0.43	59.88 ± 2.33
TCV	394.57 ± 6.88	434.70 ± 0.85	409.52 ± 1.58

F2: formulation with 66 g of winged-stem passion fruit peel flour and fat reduction; F5: formulation with 49.5 g of winged-stem passion fruit peel flour and partial fat reduction; SF: standard formulation; TCV: total caloric value in Kcal. Averages labeled with different superscript letters (a and b) in the same row are significantly different according to Tukey's test ($p \leq 0.05$).

Significant differences in moisture, ash, or food fiber content were observed between the three cookies. The SF had the highest moisture content and the lowest protein, ash, and food fiber contents. Formulation F5 showed the highest ash, lipid, and TCV contents, and F2 had the highest food fiber content; the two samples did not differ in protein content. In addition, formulations F5 and F2 showed a significantly higher fiber content with values of 24.7% and 67.8%, respectively, compared to the SF.

DISCUSSION

The available carbohydrates, ash, protein, and food fiber contents of the flours observed here were similar to those obtained in previous studies that evaluated yellow passion fruit peel flour, considering flavedo and albedo together [10,20]. And according to the results, this flour can be considered to have a high fiber content and can be used for fiber extraction or application of the flour itself in the development of food preparations and products aimed at providing fiber.

The cookies developed in the present study exhibited equal or higher sensory acceptability than those reported in other studies of biscuits with added yellow passion fruit peel flour [14,21], cakes and honey bread with added yellow passion fruit peel [22,23] and jaboticaba peel flour [24], confirming that winged-stem passion fruit peel flour can be used in the development of cookies.

Acceptability indices higher than 70% (minimum 70.61%) were also obtained for cookie formulations with yellow passion fruit peel flour in previous studies [8,14]. Miranda, Caixeta, Flávio, and Pinho [25] tested the acceptability of passion fruit flavored cakes enriched with yellow passion fruit peel flour, partially replacing common wheat flour (0, 7, 10, and 14%), and recorded good acceptability, with averages equal to or higher than 7.16% for flavor, corresponding to "like moderately" to "like very much" They also obtained satisfactory overall acceptability indices higher than 72%. Yellow passion fruit peel flour has also been included in fresh pasta formulations as a substitute for wheat flour and was observed to not significantly affect the characteristics of the standard pasta formulation, except for being considered a fiber source [26].

The use of fruit peel is becoming attractive for many researchers aiming to develop products with higher nutritional quality and pleasant sensory characteristics [27,28]. Other studies tested formulations with pine banana and orange peels, all obtained acceptability values higher than 70% [29-31]. The addition of passion fruit peel flour increased the nutritional value of the cookies, contributing to a protein, mineral and fiber intake. Therefore, it is possible to use passion fruit peel flour to develop cookies with sensory acceptability, which additionally has a promising market potential.

CONCLUSION

Albedo and flavedo flours produced from winged-stem passion fruit present different nutritional compositions; however, both are significant contributors to high food fiber content.

All cookie formulations developed had good sensory acceptability, and the addition of flour in formulations contributed to an increase in the nutritional quality.

The use of winged-stem passion fruit flour is viable, and peel flour can be used for the fiber enrichment of cookies, contributing to improved human health and reducing residue accumulation in the environment.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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