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Tahiti lime peel flour as an alternative for increasing fiber content in new food products

Farinha de casca de limão-taiti como alternativa para aumentar o teor de fibras em novos produtos alimentícios

La harina de cáscara de lima tahití como alternativa para aumentar el contenido de fibra en los nuevos productos alimenticios

Laís Donata Bento Correia[1]
Raquel Flôres Sampaio[2]
Viviane da Cruz Lima[3]
Thaise Mariá Tobal[4]

[1] Graduated in Nutrition from the Faculty of Health Sciences of the Federal University of Grande Dourados. Email: lays.donatta@hotmail.com, ORCID: https://orcid.org/0000-001-9446-3003

[2] Graduated in Nutrition from the Faculty of Health Sciences of the Federal University of Grande Dourados. Email: raquel_floresdds@hotmail.com, ORCID: https://orcid.org/000-000-9850-8627

[3] Graduated in Nutrition from the Faculty of Health Sciences of the Federal University of Grande Dourados. Email: vivianecruz_lima@hotmail.com, ORCID: https://orcid.org/0000-0002-7957-7034

[4] PhD in Food and Nutrition from the Faculty of Pharmaceutical Sciences of the Paulista State University Júlio de Mesquita Filho (UNESP). Master in Food Science and Engineering from UNESP. Graduated in Nutrition from the University Center of Votuporanga. Associate professor in Faculty of Health Sciences and Nutrition course at the Federal University of Grande Dourados. Collaborator in the Postgraduate Program in Food, Nutrition and Health at UFGD. She has experience in Food and Nutrition areas, with emphasis in assessing the nutritional, sanitary and sensory quality of food and beverages and the development of preparations for dietary purposes. She works in the Food and Health Surveillance lines of research, and Food Science and Health. E-mail: thaisetobal@ufgd.edu.br, ORCID: https://orcid.org/0000-0001-6484-3822

Abstract: The development of new products by adding value to residues such as Tahiti lime peel, which may contribute to additional nutritional value, is of great interest. Thus, this study aimed to characterize the flour of Tahiti lime peel and use it in the preparation of cake, along with the evaluation of its nutritional quality and sensory acceptability. The flour was produced from the Tahiti lime peel, and six cake formulations were made, one standard and the others containing different amounts of this flour (5% to 14%). In addition to the physical and chemical characterization of the flour obtained, cakes with greater sensory acceptability were also analyzed. The Tahiti lime peel flour had high dietary fiber content, 67.70%. All cakes formulations obtained good sensory acceptability, with an acceptability index above 70%. The formulations added to the flour had a higher content of dietary fiber and a lower content of lipid and caloric value in relation to the standard cake formulation. Thus, it can be concluded that there is feasibility of using the Tahiti lime peel flour in the preparation of cakes, adding nutritional value to this product and indicating the potential of the flour to increase fiber content in the diet.
Keywords: nutritional composition; sensory acceptability; fruit peel; fruit residue.

Resumo: O desenvolvimento de novos produtos agregando valor a resíduos como a casca do limão-taiti, que pode contribuir com valor nutricional adicional, é de grande interesse. Assim, o objetivo deste estudo foi caracterizar a farinha da casca de limão-taiti e utilizá-la no preparo de bolos, juntamente à avaliação de sua qualidade nutricional e aceitabilidade sensorial. A partir da casca do limão-taiti, foram produzidas a farinha e seis formulações de bolos, sendo uma padrão e as demais contendo diferentes quantidades dessa farinha (5% a 14%). Além da caracterização físico-química da farinha obtida, os bolos com maior aceitabilidade sensorial também foram analisados. A farinha da casca do limão-taiti apresentou alto teor de fibra alimentar, 67,70%. Todas as formulações de bolos obtiveram boa aceitabilidade sensorial, com índice de aceitação acima de 70%. As formulações adicionadas da farinha apresentaram maior teor de fibra alimentar e menor teor de lipídeos e valor energético em relação à formulação de bolo padrão. Sendo assim, pode-se concluir que há viabilidade da utilização da casca do limão-taiti no preparo de bolos, agregando valor nutricional a este produto e indicando o potencial da farinha no aumento do teor de fibras na dieta.
Palabra-chave: composição nutricional; aceitabilidade sensorial; casca de frutas; resíduo de frutas.

Resumen: Es de gran interés el desarrollo de nuevos productos que agreguen valor a los residuos como la cáscara de limón tahití, que puede aportar un valor nutricional adicional. Así, el objetivo de este estudio fue caracterizar la harina de cáscara de limón tahití y utilizarla en la elaboración de tortas, junto con la evaluación de su calidad nutricional y aceptabilidad sensorial. Las formulaciones de harina y seis tortas se elaboraron a partir de la cáscara del limón tahití, siendo una estándar y las otras conteniendo diferentes cantidades de esta harina (5% a 14%). Además de la caracterización fisicoquímica de la harina obtenida, también se analizaron las tortas con mayor aceptabilidad sensorial. La harina de cáscara de limón tahití tenía un alto contenido de fibra dietética, 67,70%. Todas las formulaciones de torta tuvieron una buena aceptabilidad sensorial, con una tasa de aceptación superior al 70%. Las formulaciones agregadas con harina tenían un mayor contenido de fibra dietética y un menor contenido de lípidos y valor energético en comparación con la formulación de torta estándar. Así, se puede concluir que existe la factibilidad de utilizar la cáscara de limón tahití en la elaboración de tortas, agregando valor nutricional a este producto e indicando el potencial de la harina para incrementar el contenido de fibra en la dieta.
Palabras clave: composición nutricional; aceptabilidad sensorial; cáscara de fruta; residuos de frutas.

1 INTRODUÇÃO

The Tahiti lemon has a high production in tropical countries, being considered one of the most commercially relevant citrus in Brazil. The country has a high rate of waste production, which includes bark, leaves, and stems, mainly due to the lack of information on the properties existing in these unconventional parts, contributing to an increase in waste. Fruit peels and seeds often have higher nutritional content than the edible parts, especially when it comes to fibers and bioactive compounds. As such, they can be used to enhance the nutritional value of food, and by encouraging the food industry to use them, waste can be reduced.

In the characterization of the chemical composition and yield of industrial residues of the Tahiti lime peel, a higher content of vitamin C, ash, pectins and crude fiber was found than the pulp, which can be considered as an excellent resource for reuse and enrichment of preparations. In addition to the significant amount of dietary fiber, lime peel has antioxidants, which fight free radicals and slow the progress of many chronic diseases.

Several studies, which aim at including nonconventional parts of fruits in the development of bakery products such as cakes, cookies, and breads, have been carried out. Lime peel flour has already been used in the preparation of cookies, with an increase in fiber, ash, polyphenols and antioxidant activity, and the results demonstrate a good sensory acceptance regarding appearance, aroma, flavor, and purchase intention.

The addition of flours obtained from fruit residues to bakery preparations can improve the nutritional quality of the final product, thereby appealing to the requirements of the consumer. Out of all the bakery products, cake stands out in the food industry due to its large-scale production. Therefore, the Tahiti lime peel flour was produced, evaluating its chemical composition and subsequently cake formulations with different concentrations were prepared, evaluating its sensory acceptability and nutritional composition.

2 MATERIALS AND METHODS

2.1 Acquisition of the Tahiti lime peel flour

Limes were selected, according to their shape and size, and cleaned using a sodium hypochlorite solution at 50 ppm of free residual chlorine. The fruits were then peeled, removing the flavedo along with the albedo, and cut in half, extracting the juice present in the pulp. The peels were placed in water for 20 hours, with the water being changed every hour in order to reduce the bitterness (CRIZEL *et al.*, 2013).

The products obtained were weighed and the skin was dried in an air draught oven at 105 ºC until weight was constant (approximately 20 hours). In order to produce the flour, the dehydrated peels were milled using a domestic blender Philips-Walita until the smallest possible particles were obtained. These were then sieved using a size 28 mesh screen (28 wires per 2.54 cm). The flour thus obtained was packed in sealed polyethylene bags and stored at room temperature.

2.2 Production of lime cake

The ingredients needed for making the lime cakes were acquired in local grocery stores. Starting from a standard formulation for lime cake (Table 1), several tests were completed in order to find an inclusion of lime peel flour that guaranteed a cake with a good sensory acceptability. Based on these tests, five formulations for lime cake with added lime peel flour were standardized (Table 1).

Table 1- Formulations used to prepare cakes

Ingredients	Formulation					
	0%	5% with fat reduction	14% with fat reduction	5%	14%	7% with fat reduction
Wheat flour (g)	304	290	262	290	262	283
Lime peel flour (g)	0	14	42	14	42	21
Granulated sugar (g)	320	320	320	320	320	320
Unsalted margarine (g)	180	120	120	180	180	150
Baking powder (g)	20	20	20	20	20	20
Egg (units)	4	4	4	4	4	4
Tahiti lime juice (ml)	240	240	240	240	240	240

Source: Own authorship.

The ingredients were first weighed using a Marte analytical balance (São Paulo-Brazil) with a precision of 0.1g. The lime juice was then homogenized with the eggs, sugar, and margarine using a Philips blender (São Paulo-Brazil). The wheat flour and baking powder, in that order, were then added to the mixture. For the formulations that contained lime peel flour, this was added between the wheat flour and baking powder. The doughs were poured into cupcake molds and baked for 15 minutes in an oven that had been preheated to 160°C.

2.3 Determination of the nutritional composition

In order to determine the nutritional composition of the lime peel flour and the cake samples that obtained a better sensory acceptance, the standards described by the Association of Official Analytical Chemists (AOAC, 1990) were used, as follows: water content in the drying oven at 105 ºC until weight was constant; total nitrogen by the Kjeldahl method was converted to protein, using a factor of 6.25; lipid was extracted by a Soxhlet extraction apparatus using petroleum ether as a solvent; ash was determined by incinerating in a muffle furnace at 550 ºC; dietary fiber was determined according to the 985.29 enzymatic-gravimetric method (AOAC, 1997) and carbohydrates by difference. The caloric value was obtained using Atwater conversion factors, with 4 kCal/g for carbohydrates and proteins and 9 kCal/g for lipid (BRASIL, 2020a).

2.4 Sensory analysis

The sensory analysis was completed at a sensory analysis laboratory, in individual booths illuminated with white light, with 60 untrained tasters, of both sexes, who agreed to participate in the research and signed the Informed Consent Form, which was previously approved by the Ethics Committee on Research with Human (protocol number 1.005.028). Samples were marked with random three-digit numbers, mixed, and served one by one in complete randomized blocks.

The sensory acceptability of the cake formulations was evaluated using a 9-point hedonic scale, in which 1 = dislike extremely and 9 = like extremely, considering the following attributes: appearance, color, aroma, texture, flavor, and overall acceptability (Figure 1). A 5-point scale, in which 1 = definitely would not buy and 5 = definitely would buy, was also used to test purchase intent (Figure 2) (DUTCOSKY, 2013, p. 531).

Figure 1- 9-point hedonic scale

Name: _____Date: ___/___/_____

You are getting lemon cupcake samples. Please try and use the scale below to indicate how much you liked or disliked it.

9- Like extremely
8- Like very much
7- Like moderately
6- Like Slightly
5- Neither like nor dislike
4- Dislike Slightly
3- Dislike moderately
2- Dislike very much
1- Dislike extremely

Note				
Sample code	_____	_____	_____	_____
Appearance	_____	_____	_____	_____
Color	_____	_____	_____	_____
Aroma	_____	_____	_____	_____
Flavor	_____	_____	_____	_____
Texture	_____	_____	_____	_____
Overall	_____	_____	_____	_____

Source: Dutcosky, 2013.

Figure 2- Test purchase intent

After evaluating, indicate according to the scale below the degree of certainty to which you would be willing to buy this product, if you found it on sale:

	Sample code	Note
1. Certainly would not buy	_____	_____
2. Possibly would not buy	_____	_____
3. Maybe would buy/ maybe would not buy	_____	_____
4. Probably would buy	_____	_____
5. Certainly would buy	_____	_____

Source: Dutcosky, 2013.

The results were evaluated through an analysis of variance (ANOVA) and the means were compared using Tukey's test ($p < 0.05$), using the Origin 6.0. The mean and standard deviation were calculated using three replications per sample.

3 RESULTS AND DISCUSSION

According to the nutritional composition of the Tahiti lime peel flour (Table 2), the water content, which should not be higher than 15% for flours as per Anvisa regulations (BRASIL, 2005), was found to be within the limit.

Table 2 - Nutritional composition of the Tahiti lime peel flour

Parameter	Obtained values
Moisture (g/100g)	4.28 ± 0.32
Protein (g/100g)	7.13 ± 0.05
Lipid (g/100g)	0.4 ± 0.45
Carbohydrates (g/100g)	83.87 ± 0.60
Dietary fiber (g/100g)	67.70 ± 0.14
Ash (g/100g)	4.31 ± 0.32

Parameter	Obtained values
Total caloric value (kCal/100g)	97.23 ± 3.72

Values expressed as mean ± standard deviation. TCV (Total Caloric Value): calculated using the Atwater conversion factors, 4 kCal/g for carbohydrates (discounting fibers) and proteins and 9 kCal/g for lipid.

Source: Own authorship.

Tahiti lime peel flour has a higher protein and carbohydrate content than is found in orange albedo flour (with 3.72% and 46.04%, respectively (SANTOS; STORCK; FOGAÇA, 2011)) and sicilian lemon peel flour (4.81% and 72.81%, respectively (THOMAZ *et al.*, 2012)). The amount of protein is also greater than that found in the study completed by Mendonça *et al.* (2006), who evaluated the flavedo, albedo, and pulp of Tahiti lime separately, and measured 5.80%, 3.67%, and 6.77% protein, respectively. The amount of lipid and the total energy value is lower than that of other flours, including flours made out of sicilian lemon peel (3.84%) (THOMAZ *et al.*, 2012), mango peel (2.26%) (NOOR AZIAH; LEE MIN; RAJEEV BHAT, 2011), and wheat (1.18%) (SANTOS; STORCK; FOGAÇA, 2014).

The flour made out of Tahiti lime peel contained enough dietary fiber to be considered a product of "high" fiber content (BRASIL, 2020b), having a higher content of dietary fiber than the mango peel flour (NOOR AZIAH; LEE MIN; RAJEEV BHAT, 2011). The amount of ash found in this flour, as well as in other flours made out of citrus fruit peels (SANTOS *et al.*, 2011; SANTOS; STORCK; FOGAÇA, 2014) is higher than in wheat flour (0.45%) (SANTOS; STORCK; FOGAÇA, 2014). The addition of Tahiti lime peel flour could add nutritional value, mainly contributing to the increase of fiber in a diet.

Table 3 shows the score for all the cake samples with respect to the evaluated sensory properties, using a hedonic scale structured in nine categories.

Table 3 - Sensory acceptability scores obtained by the lime cake with different formulations

Formulations	Appearance	Color	Aroma	Flavor	Texture	Overall
0%	7.96 ± 1.34^{b}	7.81 ± 1.29^{b}	7.39 ± 1.51^{a}	7.72 ± 1.45^{a}	8.04 ± 1.00^{a}	7.79 ± 1.28^{a}
5% with fat reduction	7.60 ± 1.61^{ab}	7.53 ± 1.45^{ab}	7.28 ± 1.36^{ab}	7.47 ± 1.47^{a}	7.72 ± 1.28^{ab}	7.40 ± 1.39^{ac}
14% with fat reduction	7.42 ± 1.41^{ac}	7.37 ± 1.30^{abc}	7.07 ± 1.66^{ab}	6.70 ± 1.57^{b}	7.35 ± 1.25^{bc}	6.79 ± 1.51^{bd}
5%	7.04 ± 1.53^{ac}	7.28 ± 1.26^{ac}	7.05 ± 1.44^{ab}	7.23 ± 1.58^{ab}	7.68 ± 1.53^{abc}	7.16 ± 1.31^{cd}
14%	7.00 ± 1.41^{c}	6.96 ± 1.28^{c}	6.82 ± 1.43^{b}	5.65 ± 1.98^{c}	7.11 ± 1.72^{c}	6.23 ± 1.68^{b}
7% with fat reduction	7.95 ± 0.97^{b}	7.65 ± 1.23^{ab}	7.47 ± 1.31^{a}	7.60 ± 1.18^{a}	8.09 ± 0.85^{a}	7.51 ± 1.18^{ac}

Results expressed as mean ± standard deviation; n=60; 9-point hedonic scale (1 = greatly disagreed to 9 = greatly liked). The same letters in the same column indicate that there was no significant difference by the Tukey's test ($p < 0.05$).

Source: Own authorship.

Table 4 shows the calculated percentage of sensory acceptability considering that, in order for them to be a well-accepted product, the index of acceptability needs to be ≥ 70% (TEIXEIRA; MEINERT; BARBERTA, 1987). With respect to the acceptability index, all formulations obtained acceptabilities above 70%, with the 0%, 5% with fat reduction, and 7% with fat reduction formulations showing a above 80% percentage, while all cakes were well accepted by the tasters.

Table 4 - Sensory acceptability index of the lime cakes with different formulations

Acceptance index	0%	5% with fat reduction	14% with fat reduction	5%	14%	7% with fat reduction
	86.55%	82.22%	75.44%	79.55%	77.87%	83.44%

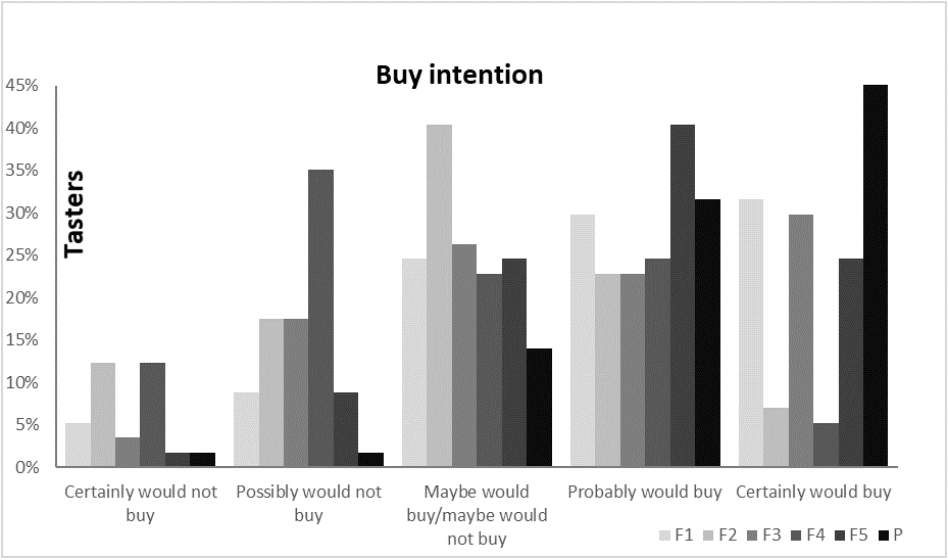
Calculated as mean score obtained in overall acceptance, divided by the highest score received in each formulation, and multiplied by 100.

Source: Own authorship.

When it comes to the sensory acceptability of the lime cakes, samples 5% with fat reduction and 7% with fat reduction got the highest scores, not differing from the standard sample in any of the evaluated properties. All the formulations yielded scores above 7.0 for overall acceptance, which corresponds to “like moderately” in the scale used, except for samples 14% with fat reduction and 14%, which got a score above 6.0. The lower score in overall acceptance for samples 14% with fat reduction and 14% is a consequence of poorer flavor, which is probably due to the fact that the formulations included a greater amount (3%) of Tahiti lime peel flour.

According to the purchase intention test, most tasters would probably or definitely buy samples 5% with fat reduction, 5%, 7% with fat reduction, and 0%, as they obtained values above 50% when adding up the definitely and probably would purchase options, with 61.40 %, 52.63%, 64.91%, and 82.45%, respectively (Figure 3).

Figure 3- Distribution of the frequency of intent to purchase for the lime cakes



F1 and F2: 5% and 14% lime peel flour, respectively, with fat reduction; F3 and F4: 5% and 14% lime peel flour, respectively, without fat reduction; F5: 7% lime peel flour with fat reduction; P: standard formulation without the addition of lime peel flour.

Source: Own authorship.

Therefore, the amount of citrus peel flour added while preparing food products should be considered in order to guarantee, along with the nutritional value, the sensory quality. Citrus peel has a characteristically bitter taste (OLIVEIRA *et al.*, 2016). Sensory acceptability can be decisive in food consumption, and there are studies that evaluate only the sensory impact of ingredients in food, as in the case of Martínez-girón, Figueroa-Molano and Ordóñez-Santos (2017), who evaluated the effect of adding pupunha peel flour on the sensory characteristics of cake.

Based on the results of the analysis of sensory acceptability, acceptability index, and purchase intent, the most acceptable samples (5% with fat reduction, 7% with fat reduction, and 0%) were selected for nutritional composition analysis (Table 5). The formulations containing 5% and 7% of peel flour with fat reduction showed an increase of 65% and 148% in relation to the total dietary fiber content, when compared to the standard formulation.

Table 5 - Nutritional composition of lime cakes that were preferred by a panel of tasters in respect of appearance, color, aroma, texture, flavor, and overall acceptability (mean ± standard deviation, n = 3)

Parameters	**0%**	**5% with fat reduction**	**7% with fat reduction**
Moisture (g/100g)	22.84 ± 0.35ª	24.69 ± 0.14^{b}	24.73 ± 0.83^{b}
Protein (g/100g)	7.12 ± 0.17ª	7.44 ± 0.56ª	6.84 ± 0.10^{a}
Lipid (g/100g)	11.88 ± 0.07ª	7.51 ± 0.09^{b}	10.64 ± 0.25^{c}
Carbohydrates (g/100g)	56.43 ± 0.36ª	58.55 ± 0.97ª	56.30 ± 1.00^{a}
Dietary fiber(g/100g)	0.69 ± 0.01ª	1.14 ± 0.01^{b}	1.71 ± 0.07^{c}
Ash (g/100g)	1.89 ± 0.13ª	1.81 ± 0.04ª	1.49 ± 0.13^{b}
TCV (kCal/100g)	358.39 ± 2.79ª	326.99 ± 1.36^{b}	341.48 ± 5.00^{c}

TCV (Total Caloric Value): calculated using the Atwater conversion factors, 4 kCal/g for carbohydrates (discounting fibers) and proteins and 9 kCal/g for lipid. The same letters in the same line indicate that there was no significant difference by the Tukey's test ($p < 0.05$).

Source: Own authorship.

Formulations with added lime peel flour had more moisture than the standard cake, a result similar to the study performed by Thomaz *et al.* (2012), where the formulation for cream cracker cookies with added lemon peel flour also had a higher moisture content. Formulations with a higher proportion of fibers are higher in water content because the fibers themselves retain water (MONDINI; MONTEIRO, 1995).

The content of protein and carbohydrate did not differ between the standard and peel flour cakes. This result is similar to that found for the recipes of cookies with Tahiti lime peel flour in a study completed by Santos, Storck and Fogaça (2014). Formulations 5% with fat reduction and 7% with fat reduction had a lower content of lipid and caloric value and a higher content of crude fiber than the standard sample. Other studies have demonstrated that the addition of citrus peel flour to the preparation of food products increases the amount of fiber (OLIVEIRA *et al.*, 2016; THOMAZ *et al.*, 2012).

4 CONCLUSION

Tahiti lime peel flour has interesting nutritional characteristics, especially with respect to dietary fiber, which might allow for it to be considered as a food with a high fiber content. Lime peel flour can be used effectively as a replacement for conventional flours, providing more fiber without compromising sensory acceptability.

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