Partial substitution of wheat flour with taro (Colocasia esculenta) flour on cookie quality

Substituição parcial de farinha de trigo por farinha de taro (Colocasia esculenta) na qualidade de biscoito tipo cookie

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Abstract: The objective of the present study was to evaluate the effects of partial substitution of wheat flour (WF) with taro (Colocasia esculenta) flour (TF) on the physical, nutritional and sensorial properties of cookie. WF was substituted with TF at increasing levels (0% [control], 10%, 20% and 30%) in the cookie formulation. Thickness increase (%) was lower for cookies made with TF. Baking yield and spread ratio varied from 84.4 to 87.5% and 9.3 and 9.8% respectively. The substitution of WF with TF increased the dark color (lower L* value) of cookies. In addition, cookies made with 20% and 30% TF had the highest a* (red), b* (yellow), C* (color intensity) and oh* values. Sensory analysis indicated that there were no significant differences in the sensory attributes among the control and TF cookies, except for texture. In addition, cookies made with 30% TF had higher ash and fiber contents than the control. In conclusion, this study has shown that it was possible to replace up to 30% of WF with TF in cookie production.

Key words: taro flour; physical properties; proximate composition; sensory analysis.

Resumo: O objetivo do presente trabalho foi avaliar os efeitos da substituição parcial de farinha de trigo (WF) por farinha de taro (Colocasia esculenta) (TF) nas propriedades físicas, nutricionais e sensoriais de biscoito tipo cookie. WF foi substituída por TF nas concentrações de 0% (controle), 10%, 20% e 30% na formulação de biscoito. O aumento de espessura (%) foi menor para biscoitos com TF. O rendimento no assamento e o fator de expansão variaram de 84,4 a 87,5% e 9,3 e 9,8%, respectivamente. A substituição de

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WF por TF aumentou a cor escura (valor de L* mais baixo) dos biscoitos. Além disso, os biscoitos elaborados com 20% e 30% de TF tiveram os maiores valores de a* (vermelho), b* (amarelo), C* (intensidade da cor) e oh*. A análise sensorial indicou que não houveram diferenças significativas nos atributos sensoriais entre o controle e os biscoitos com TF, exceto para textura. Adicionalmente, os biscoitos feitos com 30% de TF tiveram maior teor de fibras e cinzas do que o controle. Em conclusão, o presente estudo mostrou que foi possível substituir em até 30% da WF por TF na produção de biscoito tipo cookie.

Palavras-chave: farinha de taro; propriedades físicas; composição centesimal; análise sensorial.

1 Introduction

Taro (Colocasia esculenta) is also popularly known as yam in Brazil [1]. Taro's rhizomes have high nutritional and energetic values (96 kcal/100 g), with high starch (18,2%) and low lipid contents (0.2%) [2]. It is rich in vitamin B-complex and minerals (1,1%), such as potassium, phosphorus and calcium [1, 2, 3].

According to the Food and Agriculture Organization of the United Nations (FAO), between 1993 and 2013, the leading producer of taro was Africa with 75.2% of world production, followed by Asia (20.8%), Oceania (3.8%) and the Americas (0.3%) [4]. Nigeria accounted for 40% of world production with 3.4 million t year-1 and other top producers were China, Ghana and Cameroon [4]. In Brazil, taro is an uncommon crop, cultivated by small farmers and mainly used for subsistence [5]. Despite the low economic importance and relatively small-cultivated area, it can be found in several Brazilian states.

Taro plays an important role in food security [6], because it is used as a subsistence crop in Brazil and other developing countries. In some cases, this species provides the main source of starch in meals; however, it is also prepared in the form of sweet and snack products in different countries [7, 8, 9]. Additionally, the rhizomes can be processed into flour, which has high carbohydrate content, especially starch [10, 11, 12].

It was previously reported that taro flour can be used as a partial substitute for wheat flour in bakery products decreasing the production costs and enhancing the nutritional value of food products [10, 12, 13, 14]. Besides this, the commercial utilization of taro could be an alternative to decrease the dependency of imported wheat by developing countries [14, 15].

Despite the taro cultivation potential, nutritional value and the diversity of products that can be prepared from taro, there is still little research [15, 16, 17, 18] available on the use of taro flour as an ingredient to substitute wheat flour in baked products, such as bread and biscuits. The objective of this work was to study the influence of partial substitution of wheat flour with taro (Colocasia esculenta) flour on the physical, nutritional and sensorial properties of cookies.

2 Material and Methods

2.1 Material

Taro (Colocasia esculenta) rhizomes and ingredients were purchased from a local market in Laranjeiras do Sul in the state of Paraná. Ingredients for cookie preparation were wheat flour (WF) (Anaconda, Curitiba, Brazil), baking powder, vegetable shortening, sugar and salt. All the chemicals used were of analytical grade.

2.2 Taro flour production

The taro rhizomes were processed into flour, as described previously [13] with some modifications. The rhizomes were washed in tap water and sanitized with a 50 ppm sodium hypochlorite solution for 15 min. They were manually peeled and sliced into approximately 2 cm thick round pieces, which were cooked in boiling water for 5 min to promote starch gelatinization and rhizome's softening. Next, they were cooled to room temperature and cut into slices of 0.5 cm thick. The slices were dried in a forced-air drier (mod. 102-SL, Solab, Piracicaba-SP, Brazil) at 60°C for 21 h. The dried slices were milled using a knife mill (Wyllie mod. Start FT-50, Fortinox, Piraciba-SP, Brazil) into flour with granules size that passed through a 30-mesh sieve to obtain flour of uniform size. The taro flour (TF) was stored in polypropylene bags and placed into an airtight container in a dry place until further use. The percent yield of TF was determined by dividing the final weight of flour with the initial weight of rhizomes [19].

2.3 Production of cookies

Cookies were produced according to formulation described by Fasolin et al. [20] with some modifications. Wheat flour (WF) was substituted with different levels of taro flour (TF): 0% – control, 10%, 20% and 30%. The control (0% TF) consisted of 58% WF, 1.44% baking powder, 0.58% salt, 17% sugar, 23% vegetable shortening, and 33 ($\pm$2) mL distilled water.

Vegetable shortening, sugar, salt and baking powder were mixed manually for 3 min; afterward, part of the distilled water was added (quantitatively) and mixed for 2 min. The flours were then added and mixed for 2 min. The mixture was kneaded and the remaining water was added quantitatively until it became a dough. Lastly, the dough was divided into small portions and rolled using an automatic sheeter (mod. MF-05, G.Paniz, Caxias do Sul-RS, Brazil). The dough was rolled to a thickness of 5 mm and cut into cookies of 6 cm diameter, using a circular cutter. The cookies were baked in a preheated conventional oven (mod. 52Sx, Electrolux, Curitiba-PR, Brazil) at 205°C for 13 to 15 min. They were allowed to cool at room temperature. Each formulation was produced in triplicate and the presented results are the average of three trials. Sensory analysis was performed approximately 24 h after baking.

2.4 Physical properties of cookies

Baking yield was determined by dividing the baked cookie weight with the raw cookie weight. Diameter (D) and thickness (T) before and after baking were measured using a digital caliper. The diameter increase (%) was calculated using Equation 1

$$\text{Diameter increase (\%)} = (FinalD - InitialD)/(InitialD) \times 100 \tag{1}$$

Final D was the cookie diameter after baking and initial D was the raw cookie diameter before placing in the oven. Similarly, thickness increase (%) was determined using the thickness values before and after baking. Spread ratio was calculated from the ratio of spread (diameter) to thickness [21] for the baked cookies. Ten cookies of each formulation in triplicate were randomly chosen for the measurement of physical properties, totaling 30 cookies.

2.5 Color measurement

The color of the baked cookies was measured by L*, a*, b*, C* and °h*, using a colorimeter (Chroma Meter CR-400/410, Konica Minolta Optics Inc., Japan) calibrated with a white ceramic plate. The measurements were performed with C illuminant at observer angle 2°. In this color system, L* represents lightness (L * = 0 is black and L* = 100 is white) and a* and b* are the color coordinates representing chromaticity: +a* is red and -a* is green; +b* is yellow and -b* is blue [22]. The parameters chroma (C*=(a*2 + b*2)0,5) and hue angle (°h*=tang-1 b*. a*-1) were automatically calculated by the colorimeter. Chroma (C*) is expressed as the intensity of the color. Hue angle (°h*) is the observable color and is expressed in degrees: 0° would be red, 90° would be yellow, 180° would be green and 270° would be blue. Color measurements were performed on the top surface of ten baked cookies per treatment randomly chosen from triplicate batches.

2.6 Sensory evaluation

The sensory test was approved by the Human Research Ethics Committee (CEPSH) / UFFS with the process number CAAE: 31897114.4.0000.5564. The panelists were recruited from the University students, staff, and faculty. Cookies formulated with 0%, 10%, 20% and 30% TF were evaluated with three-digit random numbers and were randomly presented to panelists. The samples were presented to 60 untrained panelists (32 women and 28 men), over 18 years old, who were instructed to evaluate each cookie sample, using the 9-point hedonic scale (1 = "dislike extremely", 9 = "like extremely") for the following attributes: appearance, aroma, flavor, texture, and overall liking. The panelists also recorded their purchase intention, using the 5-point scale (1 ="definitely would not buy", 5 ="definitely would buy").

2.7 Proximate composition

The proximate composition was carried out for the taro flour and the baked cookies with 0% TF (control) and 30% TF. Moisture (air oven method), ash (incineration method), lipids (Soxhlet) contents were determined by approved methods [23]. Crude fiber and protein were analyzed according to n. 044/IV [24] and Kjeldahl method (%N x 6.25) [25], respectively. Total carbohydrates were determined by difference. Results were expressed as g/100 g of sample in wet basis. All analyses were performed in triplicate.

2.8 Water activity

Water activity (aw) was measured for the taro flour and the baked cookies with 0% TF (control) and 30% TF. Water activity was measured at 25°C using a water activity meter (mod. LabMaster, Novasina, Switzerland) with direct readings. All determinations were performed in triplicate.

2.9 Statistical analysis

Analysis of variance (ANOVA) was used to determine significant difference ($p < 0.05$) among formulations. Post hoc analysis was performed using Tukey's test. Differences were considered to be signifcant when $p < 0.05$. Data was expressed as mean $\pm$ standard error of means. Data was analyzed using the Statistica for Windows (Statsoft Inc., Tulsa, USA).

3 Results and Discussion

3.1 Taro flour production

The percent yield of taro flour was 9.0 $\pm$ 0.6%. A previous study [7] obtained a higher yield (17%) for taro flour production. The lower yield obtained in this study was probably due to the steps of selection and peeling, which had the greatest loss (28.8 $\pm$ 9.1%), due to the removal of undesirable parts and the manual peeling. The yield also depends on the flour moisture content. Taro flour obtained in the present study had low moisture content (7.45 $\pm$ 0.07 g/100 g of sample). Water activity (aw) was (0.41 $\pm$ 0.01) which is below the minimum aw (0.6) range at which microorganisms can grow.

The proximate composition (g/100 g) of taro flour, in wet basis, was 0.56 $\pm$ 0.11 (Lipids), 10.25 $\pm$ 0.04 (Crude protein), 4.32 $\pm$ 0.01 (Ash), 4.94 $\pm$ 0.03 (Crude fiber), and 72.48 $\pm$ 1.62 (Total carbohydrates). Moisture, lipids and ash contents were similar to previous reported studies [26, 27]. Other studies [7, 27, 28, 29] obtained lower protein contents, ranging from 3 % to 8 %. It is known that taro composition depends on the variety [11, 26, 30]. Crude fiber and total carbohydrates were similar to the ones found for a variety grown in Africa [11].

3.2 Physical properties

Baking yield, thickness increase, diameter increase and spread ratio of cookies with 0% (control), 10%, 20% and 30% taro flour, are shown in Table 1.

Table 1. Physical properties of cookies.

% Substitution of WF with TF	Baking yield (%)	Thickness increase (%)	Diameter increase (%)	Spread ratio (D/T)
0% (control)	87.5 ± 0.9^{a}	25.6 ± 1.2^{a}	6.2 ± 0.3^{a}	9.3 ± 0.1^{c}
10%	$87.4 \pm 0.6a$	23.7 ± 1.0^{ab}	6.4 ± 0.3^{a}	9.6 ± 0.1^{ab}
20%	84.4 ± 0.5^{b}	19.8 ± 1.4^{bc}	6.5 ± 0.3^{a}	9.5 ± 0.1^{bc}
30%	86.2 ± 0.5^{ab}	16.7 ± 0.9^{c}	6.9 ± 0.3^{a}	9.8 ± 0.1^{a}

Values are mean ± standard error of means of three determinations (n = 3). Different letters in the same column indicate significant difference by Tukey's test (p < 0.05). TF (Taro flour); WF (Wheat flour).

Baking yield varied from 84.4% to 87.5%. 0% (control) and 30% TF cookies was not significantly different for this physical property. A previous study showed that cookies made with higher banana flour content had lower baking yield [20]. The authors [20] concluded that banana flour decreased the water retention capacity. Therefore, our results indicate that the taro flour did not affect the water retention capacity of the cookie dough. Taro flour is known for increasing water absorption for wheat-taro bread dough [10]. The thickness increase (%) was lower for the 30% TF cookies. These results are in agreement with wheat-taro composite breads [17]. They found that the thickness decreased with increasing ratios of TF in the bread. Gluten content is responsible for the expansion (thickness increase) and dough formation. A previous work reported that a gluten matrix was not formed when gluten was replaced by soy protein isolate at certain levels [31]. Similarly, thickness increase was lower for cookies made with higher levels of green banana flour [20]. This thickness decrease was caused by the lack of gluten in the banana flour, which interfered with the formation of the gluten network. As taro flour has no gluten, the formation of the gluten network was impaired and consequently the final thickness was reduced significantly. On the other hand, the diameter increase (%) was not significantly different among formulations.

The spread ratio varied from 9.3 and 9.8. 30% TF cookie had a higher spread ratio than the control. This was due to its lower thickness increase. A similar value of spread ratio (9.1) for biscuit made with 30% roasted bran was found [21]. They reported that biscuits that had the lowest spread ratio were also thicker, which is in agreement with our results. Additionally, a previous research reported that spread ratio of cookies decreased with increasing levels of water chestnut flour [32].

3.3 Color measurements

Table 2 shows the color measurements for the baked cookies. The development of color during baking is due to the Maillard reaction in which a chemical reaction between reducing sugars and amino acids forms a brown color, called melanoidins [33]. This reaction is related to the amount of sugar used in the formulation, the amino acids, and the baking temperature [33, 34, 35]. Color is a very important parameter for the initial acceptability of the baked product by the consumer [18].

Table 2. Color measurements of cookies.

% Subst. of WF with TF	**L***	**a***	**b***	**C***	**oh***
0% (control)	76.0 ± 1.5^a	0.1 ± 0.7^c	26.0 ± 1.2^b	26.1 ± 0.4^b	90.0 ± 0.5^a
10%	73.2 ± 0.6^b	1.2 ± 0.3^b	26.0 ± 0.6^b	26.1 ± 0.2^b	87.4 ± 0.2^b
20%	69.8 ± 1.3^c	2.1 ± 0.8^a	28.7 ± 2.1^a	28.8 ± 0.7^a	85.8 ± 0.4^c
30%	67.2 ± 0.9^d	12.6 ± 0.5^a	28.0 ± 1.0^a	28.1 ± 0.3^a	84.7 ± 0.3^c

Values are mean ± standard error of means of ten determinations (n = 10). Different letters in the same column indicate significant difference by Tukey's test ($p < 0.05$). TF (Taro flour); WF (Wheat flour).

The cookies made with 20% and 30% TF were darker (lower L*). They were also redder (higher a* values) and more yellow (higher b* values) than 0% and 10% TF cookies. Consequently, 20% and 30% TF cookies had more intense colors (higher C* values) and had hue angles (oh*) closer to the red axis. TF has a darker color than the WF which is white. In addition, the degree of browning increased with drying during taro flour production [36]. Browning is a non-enzymatic reaction due to starch hydrolysis during cooking and drying, and free amino acids form the off-colors [36].

3.4 Sensory evaluation

Sensory evaluation of the cookies is shown in Table 3. TF had no effect on appearance, aroma, flavor and overall liking of cookies, with values closer to 7 ”liked moderately” on the scale.

Table 3. Measurement of sensory evaluation and purchase intention of cookies.

	% Substitution of WF with TF			
	0% (control)	**10%**	**20%**	**30%**
Appearance	7.0 ± 0.2^a	7.2 ± 0.2^a	7.0 ± 0.2^a	7.1 ± 0.2^a
Aroma	6.9 ± 0.2^a	6.9 ± 0.2^a	6.6 ± 0.2^a	6.8 ± 0.2^a
Flavor	7.2 ± 0.2^a	7.4 ± 0.2^a	6.8 ± 0.2^a	7.1 ± 0.2^a
Texture	7.5 ± 0.2^a	7.4 ± 0.2^a	6.6 ± 0.2^b	97.0 ± 0.2^{ab}
Overall liking	$7.1 \pm 0.2a$	$7.2 \pm 0.2a$	$6.6 \pm 0.2a$	$6.9 \pm 0.2a$
Purchase intention	3.7 ± 0.1^a	4.0 ± 0.1^a	3.5 ± 0.1^a	3.8 ± 0.1^a

Values are mean ± standard error of means of sixty determinations (n = 60). Different letters in the same line indicate significant difference by Tukey's test ($p < 0.05$). TF (Taro flour); WF (Wheat flour).

Cookies had significant difference only in the texture attribute. The cookie made with 20% TF had a lower texture score than the control and 10% TF cookie. Products with score values higher than 5 are considered good quality products [19]. Regarding the purchase intention, the cookies presented values between 'probably would buy' and 'maybe would buy' / 'maybe would not buy'. Consequently, it is possible to replace up to 30% WF with TF with no significant differences in the sensory attributes.

A previous study [37] also found that biscuits with TF were acceptable. However, control biscuit (0% TF) had better appearance and flavor than biscuits made with 75% TF. It was also possible to produce good quality cookies with up to 50% substitution of WF with unripe banana flour [19].

3.5 Proximate composition and water activity of cookies

The proximate composition and water activity (aw) were carried out for the 0% (control) and 30% TF cookies, as shown in Table 4.

Table 4. Proximate composition in wet basis (g/100g of sample) and water activity (aw) of cookies.

	% Substitution of WF with TF	
	0% (control)	**30%**
Moisture	2.9 ± 0.1^b	3.6 ± 0.1^a
Lipids	22.6 ± 0.4^a	22.8 ± 0.1^a
Crude protein	7.2 ± 0.1^a	6.9 ± 0.1^b
Ash	1.5 ± 0.1^b	2.3 ± 0.1^a
Crude fiber	1.0 ± 0.1^b	1.86 ± 0.1^a
Total carbohydrate	64.7 ± 4.0^a	62.6 ± 3.9^b
aw	0.32 ± 0.01^a	0.31 ± 0.01^b

Values are mean ± standard error of means of three determinations (n = 3). Different letters in the same line indicate significant difference by Tukey's test ($p < 0.05$). TF (Taro flour); WF (Wheat flour).

Cookies made with 30% TF had higher moisture content. It is known that taro flour has fibers with high hygroscopicity which promotes high water retention [38, 39]. The protein content decreased with the replacement of WF by TF. Similarly, a previous study [40] reported similar results for cookies made with partial replacement of wheat flour by jatobá (Hymenaea stigonocarpa) flour. In addition, there was no significant difference in the lipid content. Cookies made with 30% TF had higher ash and crude fiber contents. This result is in agreement with a previous study [10] that reported that ash and fiber contents increased with the TF addition in bread. Taro flour is rich in minerals, such as K, P, Mg, Zn, Fe, Cu and Cd [3], which are incorporated in the final products improving their nutritional values [41]. Total carbohydrate content was lower for cookies made with 30% TF. Cookie produced with jatobá flour also had a lower carbohydrate content [40].

4 Conclusions

This study has shown that substitution of wheat flour with different levels of taro flour could be an alternative for cookie production. Cookies made with 20% and 30% TF had a darker and redder color. For nutritional content, the cookies made with 30% TF had higher mineral and crude fiber contents. However, the protein content was lower than the control. Cookies made with TF were acceptable by the panelists.

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