Physical, microbiological and sensory quality of gluten-free biscuits prepared from rice flour and potato pulp

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Summary

In order to use the starchy residue recovered from the effluent of fries-processing industry, to reduce losses of the industry and to add value to the products, this study aimed to evaluate the physical and microbiological viability, and sensory acceptability of biscuits formulated with different levels of rice flour (RF), and acidified dehydrated recovered potato pulp (PP). Completely randomized design with five treatments (no PP, and substitution of 200, 400, 600 and 800 g·kg^{-1} of RF by PP) and four replications were used to evaluate physical and sensory characteristics of samples. Biscuits showed water activity of 0.11–0.32, specific volume of 1.38–1.96 l·kg^{-1}, brightness between 76.22 and 81.37, hardness from 16.70 N to 42.98 N, and showed no contamination by coliforms at 45 °C, coagulase positive *Staphylococcus* sp. and *Salmonella* sp. Except for the biscuit without PP, all formulations were above the average score limit set for sensory acceptance (six), but the biscuit which obtained the best score of sensory and physical properties was the one with 600 g·kg^{-1} PP replacing RF. It is concluded that is it is viable to produce gluten-free biscuits with a substitution of up to 80% of RF by PP recovered from effluent of fries-processing industry, considering physical, microbiological and sensory parameters.

Keywords

Solanum tuberosum L.; *Oryza sativa* L.; by-products; gluten-free biscuits; colour; texture; sensory evaluation

In 2010, potato consumption surpassed maize and became the third most consumed food in the world. In the production of potato chain, the main observed change was the growth in consumption of processed potato, mostly the production of starch and potato chips [1]. This phenomenon has increased the production of a highly polluting residue.

There is a specific type of effluent from the fries industry, generated after peeling, cutting and washing the tubers, which is rich in organic compounds. Those compounds can lead to serious environmental problems when indiscriminately discharged into the soil and rivers [2]. In the processing of potato chips, the amount of losses during the peeling step is estimated around 7.5 t per 100 t of the total mass of tubers since it includes the peels, and in the washing and cutting steps it reaches 0.5 t per 100 t [3]. The high demand for the product has increased the generation of this effluent, which consists of cell wall debris from the potato tuber, starch, and large amounts of water contained in the residual potato pulp. Due to their appropriate physical and chemical characteristics, residual potato pulp (PP) of the cultivar Atlantic can be used as an ingredient in the formulation of food products having a high carbohydrate content (979.3 g·kg^{-1}), but low levels of proteins, lipids and minerals, 0.37 g·kg^{-1}, 1.16 g·kg^{-1} and 5.3 g·kg^{-1}, respectively (dry basis) [4].

If this potato pulp was recovered through centrifugal sieves (decanters), it would be expected to reach a moisture content between 300 g·kg^{-1} and 350 g·kg^{-1}, however for their use for human consumption, simultaneous treatments with other technological processes is necessary, such as acidification and drying in order to increase

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microbiological safety of the recovered product [5]. However, recovery, acidification and drying of PP will only become interesting for the industry after the development of alternatives for its use as a food ingredient. For this, one option could be the application of PP in the production of biscuits.

On the other hand, rice is a high-energy food of great nutritional value, high in protein, minerals (phosphate, iron and calcium) and vitamin B complex, easily digestible and gluten-free [6]. During the stages of rice processing, broken grains are generated. From these, only 1 t per 100 t can be added to the final product. The remainder is traded for other purposes, such as the production of rice flour (RF), which is widely used for the production of processed food without gluten. Both PP and RF could be used in the production of biscuits. Thus, this study aimed to evaluate the physical, microbiological and sensory viability of gluten-free biscuits formulated with different substitution levels of RF by PP, in order to reduce losses, increase the use of industrial by-product, and aggregate value to this residue.

MATERIALS AND METHODS

Obtaining and preparing the potato pulp

The effluent from processing of potato chips (*Solanum tuberosum* L. cultivar Atlantic) was donated by the Company Cicopal (Senador Canedo, Goiás, Brazil), and was collected after peeling, cutting and washing steps. It should be pointed out that the effluent was not that from first wash of the tubers, which contains large amounts of soil and other dirt, therefore improper for consumption. The effluent decanting was performed in 20 l vessels for 15 min, which was a sufficient time for sedimentation to occur. A siphon was used to separate the supernatant from the potato pulp. Potato pulp was acidified to pH 3.7 with 0.1 $mol\cdot l^{-1}$ lactic acid solution from Sinth (Diadema, Brazil), dried with forced air circulation at 60 °C until an approximate moisture of 70 $g\cdot kg^{-1}$, ground in a Wiley mill (Marconi, MA 680; Piracicaba, Brazil) with a 0.25 mm sieve and speed 14.17 Hz, packaged in low density polyethylene (LDPE) bags and stored at 5 ± 1 °C until processing and chemical analyses, becoming in this study named potato pulp (PP). PP presented 42.5% of particles between 0.25 mm and 0.15 mm, 24.8% between 0.15 mm and 0.106 mm, 25.4% between 0.106 mm and 0.053 mm, and 7.3% lower than 0.053 mm.

Formulation and processing of biscuits

Completely randomized design with five treatments (0, 200, 400, 600 and 800 $g\cdot kg^{-1}$ of PP substituting RF) and four replications was used. In addition to PP and RF (Urbano Agroindustrial, São Gabriel, Brazil), the other ingredients used in the formulation of the experimental biscuits were crystallized saccharose (Cristal Alimentos, Aparecida de Goiânia, Brazil), commercial sodium chloride Cisne (Refinaria Nacional de Sal, Cabo Frio, Brazil), baking powder Royal (Kraft Foods, São Paulo, Brazil), margarine Qualy (Sadia, São Paulo, Brazil), whole fresh eggs, water and artificial vanilla essence, acquired in the local market in Goiânia, Brazil (Tab. 1).

The experimental biscuits were produced in 0.5 kg batches. The dry ingredients and margarine were mixed manually in a bowl of stainless steel, and then the remaining ingredients were added. In a stainless steel bench with the aid of a roll of polyethylene fluff, the mass was rolled until it had a smooth surface and a height of about 5 mm,

Tab. 1. Formulation of biscuits with different levels of substitution of rice flour by acidified dehydrated potato pulp recovered from the effluent of fries processing.

Ingredient	Biscuit (treatment)				
	B1	B2	B3	B4	B5
Rice flour [g]	1000	800	600	400	200
Acidified dehydrated recovered potato pulp [g]	0	200	400	600	800
Margarine [g]	300	300	300	300	300
Salt [g]	5	5	5	5	5
Baking powder [g]	12	12	12	12	12
Sugar [g]	450	450	450	450	450
Water [l]	0.15	0.15	0.15	0.15	0.15
Vanilla essence [l]	0.05	0.05	0.05	0.05	0.05
Full fresh egg [l]	0.03	0.03	0.03	0.03	0.03

molded with the aid of a round biscuit cutter of 25 mm in diameter, and the pieces placed in an aluminium tray greased with margarine. The biscuits were baked in an industrial oven (Venâncio, FCDT5; Venâncio Aires, Brazil) pre-heated for 23 min at a temperature of 180 °C, cooled at room temperature for 60 min, wrapped in the package of low density polyethylene bags with a thickness of 80 μm, and placed in cardboard boxes for storage (secondary packaging to prevent exposure to light) at room temperature.

Proximate composition of acidified dehydrated recovered potato pulp

Moisture content was determined after drying in oven at 105 °C until constant weight; total nitrogen by Kjeldahl method was converted to crude protein by multiplying by the factor of 6.25; total lipids were determined by Soxhlet using petroleum ether as solvent; ashes were determined by incineration in a muffle furnace at 550 °C; carbohydrates were estimated by subtracting from 1 000 the values obtained for moisture, ash, protein and lipids, all recommended by AOAC (methods 925.10; 923.03; 31.1.08; 920. 39C) [7]. All analyses were performed in triplicate.

Physical properties of biscuits

Moisture content was determined using the procedure AOAC 925.10 [7]; water activity (a_w) was determined using an analyser (Aqua Lab CX-2, Pullman, Washington, Washington, USA); diameter (θ) and thickness (T) were measured with a digital caliper (Messen, Danyang, China); specific volume (*SV*) was calculated as the ratio between the volume and the mass, the volume being determined by displacement by the method of millet seeds, and mass by weighing in an analytical balance; hardness was assessed in a texture analyser (Stable Micro Systems, TA.XT Express, London, United Kingdom), with a load cell of 50 kg, using geometric probe with guillotine (Warner Braztler, London, United Kingdom), pre-test, test and post-test speed being 10 $mm{\cdot}s^{-1}$, 2 $mm{\cdot}s^{-1}$ and 8 $mm{\cdot}s^{-1}$, respectively, and shear rate of 80% (8 mm); instrumental colour parameters were assessed using a colorimeter (Color Quest XE, Reston, Virginia, USA) according to the CIE*Lab* system. The results were expressed in L^*, a^* and b^*. L^* is lightness, ranging from black (0) to white (100), the coordinate a^* varies from green (–60) to red (+60), and the coordinate b^* from blue (–60) to yellow (+60). From a^* and b^* parameters, chroma (C^*) was calculated, which indicated the colour saturation, or intensity of a colour, and hue angle ($H°$) (Eq. 1 and Eq. 2).

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

$$H° = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (2)$$

All physical analyses were performed in triplicate, except for hardness, which was performed 24 h after baking the biscuits, using 15 units of each treatment per replicate, and *SV*, which was calculated as arithmetic mean of 15 random measurements.

Microbiological analyses

The analyses were done according to Resolution RDC 12 of the National Sanitary Surveillance Agency from the Ministry of Health, Brasília, Brazil, and the microbiological standards for biscuits [8]. Counts of coliforms at 45 °C, counts of coagulase-positive staphylococci and presence of *Salmonella* sp. in 0.025 kg samples were determined by the procedures described by the Compendium of Methods for the Microbiological Examination of Foods [9].

Sensory acceptance of biscuits

The colour, texture, odour, taste and overall acceptance were evaluated by using a 9-point hedonic scale, in which the extremes expressed the terms “dislike extremely” (score 1) and “like very much” (score 9), and the intermediate “not liked; nor disliked” (score 5) [10]. Fifty untrained consumers were recruited, adults of both sexes, based on interest and availability to participate in the research. Completely randomized block design was used, with 5 treatments (biscuits) and 50 blocks (judges). The biscuits were prepared on the day of analysis, considering all the standards of good practices in food manufacturing, stored in a safe condition to maintain the hygienic-sanitary characteristics, served in individual cabins illuminated with white light, in the presence of evaluation and consent forms, simultaneously distributed in a randomized and balanced way in portions of 4.5 g (each unit) in coded disposable dishes with a glass of water in the tray, and evaluated for the sensorial attributes, in addition to purchase intent. A cutting point of six (score 6), corresponding to “like slightly” on a hedonic scale of nine points was previously defined as the minimum threshold for the acceptance of biscuits.

Analysis of results

The results of physical and acceptance testing were submitted to analysis of variance, and means were compared by Tukey’s test at 5% probability, using the software Statistica 7.0 (Statsoft, Tulsa, Oklahoma, USA). Pearson’s correlations between the physical and sensory responses were also established.

RESULTS AND DISCUSSION

Proximate composition and energy value of potato pulp

RF had higher moisture content, protein and lipids than PP (51%, 978% and 6 900%, respectively), and lower carbohydrate content and total energy (8.5% and 2.8%, respectively) (Tab. 2). The observed differences among the chemical characteristics of PP and RF were associated with the proximate composition of potato and rice, since rice presents a higher nutritional value than potato, especially in relation to protein and lipid contents.

Physical characteristics of biscuits

There were significant differences among experimental gluten-free biscuits for all the evaluated physical properties (Tab. 3), but B4 did not differ significantly from B5. The highest moisture content was 3.74-times higher than the lowest moisture content, and B4 did not differ significantly from B5. IWASHITA et al. [11] reported a moisture of 59.4 g·kg^{-1} for biscuits made with RF, while GARMUS et al. [12] using RF and potato peel flour (rich in fibre and protein), obtained biscuits with 102 g·kg^{-1} of moisture, higher values than those obtained in this study. Once PP has low protein content (Tab. 2) and fibre [4], the observed differences could be related to formulations, since the higher the protein and fibre, the higher the water absorption by the dough and moisture retention in the final product.

As expected, moisture was positively correlated ($p < 0.05$) with water activity (0.95) and thickness (0.82), and negatively correlated with the diameter (–0.84). The highest a_W value (B1) was 2.9-times higher than the lowest a_W value (B4) (Tab. 3). The a_W values of the biscuits were low, within the range of microbiological stability (< 0.6). The value of B3 was equal to that found by CLERICI et al. [13] in biscuits elaborated with partial substitution of wheat by defatted sesame flour, while the other experimental biscuits of this study had lower values, except B1, also due to protein and fibre values of rice being higher than those of PP.

Regarding the diameter of the experimental gluten-free biscuits, B4 and B5 showed the highest values, B1 and B2 the lowest (Tab. 3). These values confirmed the trend observed in studies of GUTKOSKY et al. [14], who found that the lower the protein content and the higher the starch in the raw material, the higher diameter of the semi-hard biscuits. For thickness, B1, B2 and B3 had the highest values, while B4 and B5 the lowest (Tab. 3). Negative correlation ($p < 0.05$) (–0.90) was obtained between diameter and thickness of biscuits (–0.90).

The highest SV value (B4) was 1.42-times higher than the lowest specific volume value (B1), and B1 did not differ significantly from B2 (Tab. 3). SV of chocolate biscuits with sorghum flour found by FERREIRA et al. [15] was 1.46–1.54 l·kg^{-1}, values within the range observed in the present study. According to MORAIS, MIRANDA and COSTA [16], the SV is affected by several factors such as the quality of the ingredients used in the formulation of the dough, especially the flour. This influences the absorption and retention of water by increasing the mass of the product and, consequently, by decreasing SV (volume/mass). Despite moisture content was not significantly correlated with SV in this study, diameter of the biscuits was positively correlated ($p < 0.01$) with the specific volume (0.94), and negatively with water, indicating the tendency of moisture to influence SV.

Luminosity (L^*) of the experimental biscuits varied between 76.2 and 81.4 (6.8%), the lightest were B1 and B3, B4 and B2 the darkest, and B5 did not differ from others (Tab. 3). As for the coordinate a^*, the values ranged from 2.04 to 3.43, approaching neutrality (close to zero), and B4 was slightly more reddish than the others, which did not differ. Coordinate b^* varied from 15.78 to 18.63 (18.1%), and B5 presented less yellowish than the others, which also did not differ.

By analysing chroma (C^*), which represents the colour saturation of the biscuits, that is, indicates the intensity or purity of a colour relative to white [17], a variation of 17.8% was observed, the less saturated being B3 and B5. For Hue angle ($H°$), the values ranged between 76.26° and 83.22°

Tab. 2. Proximate composition and total energy value of the acidified dehydrated potato pulp recovered from the effluent of fries processing and rice flour.

Component or parameter	Potato pulp	Rice flour*
Moisture [g·kg^{-1}]	68.1 ± 2.3	103.2 ± 1.8
Protein [g·kg^{-1}]	3.8 ± 0.9	41.0 ± 1.9
Lipíds [g·kg^{-1}]	0.1 ± 0.0	7.0 ± 0.5
Ash [g·kg^{-1}]	3.4 ± 0.2	3.0 ± 0.1
Carbohydrates [g·kg^{-1}]	924.6	845.8
Total energy [kJ·kg^{-1}]	15526.61	15090.64

Values are expressed as mean.
*Composition obtained from the label of the commercial product.

Tab. 3. Physical properties of the biscuits prepared with different levels of substitution of rice flour by acidified dehydrated potato pulp recovered from the effluent from processing chips.

Physical property	Biscuit (treatment)				
	B1	B2	B3	B4	B5
Moisture [g·kg^{-1}]	31.8 ± 2.9^{a}	15.1^{b,c} ± 3.8^{bc}	21.6 ± 3.2^{b}	8.5 ± 2.2^{d}	9.7 ± 2.4^{cd}
Water activity a_w	0.32 ± 0.02^{a}	0.15 ± 0.02^{c}	0.21 ± 0.02^{b}	0.11 ± 0.01^{d}	0.17 ± 0.01^{c}
Diameter [mm]	24.7 ± 0.6^{c}	25.7 ± 0.2^{c}	27.2 ± 0.3^{b}	30.5 ± 0.7^{a}	29.3 ± 0.5^{a}
Thickness [mm]	10.7 ± 0.2^{a}	10.5 ± 0.3^{a}	10.7 ± 0.3^{a}	9.1 ± 0.4^{b}	9.0 ± 0.4^{b}
Specific volume [l·kg^{-1}]	1.38 ± 0.18^{c}	1.39 ± 0.11^{c}	1.59 ± 0.10^{b}	1.96 ± 0.12^{a}	1.64 ± 0.10^{b}
L^*	80.97 ± 0.55^{a}	79.98 ± 0.45^{ab}	81.37 ± 0.88^{a}	76.22 ± 0.44^{b}	80.00 ± 0.78^{ab}
a^*	2.71 ± 0.55^{b}	2.15 ± 0.38^{b}	2.04 ± 0.55^{b}	3.43 ± 0.12^{a}	2.64 ± 0.21^{b}
b^*	18.63 ± 1.22^{a}	18.09 ± 0.88^{a}	17.34 ± 0.99^{a}	18.08 ± 0.92^{a}	15.78 ± 0.58^{b}
Chroma C^*	18.84 ± 1.10^{a}	18.22 ± 0.81^{a}	17.46 ± 1.44^{ab}	18.41 ± 0.59^{a}	16.00 ± 1.32^{b}
Hue angle $H°$ [°]	1.43 ± 0.02^{ab}	1.45 ± 0.02^{a}	1.45 ± 0.03^{a}	1.38 ± 0.02^{c}	1.41 ± 0.03^{bc}
Hardness [N]	42.98 ± 1.52^{a}	41.15 ± 1.89^{a}	16.70 ± 1.74^{b}	17.90 ± 2.22^{b}	17.45 ± 1.33^{b}

Values are expressed as mean. Values followed by the same letters in the same row are not different at 5% probability.
Content of potato pulp: B1 – 0 g·kg^{-1}, B2 – 200 g·kg^{-1}, B3 – 400 g·kg^{-1}, B4 – 600 g·kg^{-1}, B5 – 800 g·kg^{-1}.

(9.1%), the highest values being observed for B1, B2 and B3, due to the presence of PP. *H*° indicates the tone, where 0° or 360° indicates red; 90° yellow, 180° green and 270° the blue tone. Therefore, all the biscuits presented colour tending to yellow, as commonly observed in most types of biscuits.

According to BASSINELLO et al. [18], the instrumental colour parameters in this type products vary with the type of flour and processing, especially the baking. Once the baking conditions were the same for all treatments, the most important source of variation in this study was the composition. The higher protein content in RF than in PP increased the formation of Maillard reaction products during baking, thus the biscuits with highest levels of RF and lowest of PP presented more yellowish (b^* and $H°$) due to the increased content of generated pigments. L^* was negatively correlated ($p < 0.05$) with a^* (–0.84), the more red pigments, the darker the biscuits, as well as b^* positively correlated ($p < 0.05$) with C^* (0.99), the more yellow the more intense colour of the product.

The instrumental hardness presented a considerable variation of 157.4%, the highest values being obtained for B1 and B2, which did not differ, while the lowest were observed for B3, B4 and B5, which also did not differ. In general, hardness of the biscuits decreased with the reduction of RF, which is richer in proteins and fibres than PP and, for this reason, retained more moisture. According to ESTELLER and LANNES [19], hardness evaluated for bakery products depends on many factors, such as the flour quality, moisture of the dough, the preservation and amount of fats, saccharides, emulsifiers and enzymes, among others.

Microbiological parameters

No experimental sample presented contamination by coliforms at 45 °C, coagulase positive staphylococci or *Salmonella* sp. (Tab. 4). This could be attributed to good quality of ingredients used,

Tab. 4. Count of coliforms, coagulase positive *Staphylococcus* sp., and screening of *Salmonella* sp. in the experimental biscuits.

Microorganism	Biscuit (treatment)					Maximum allowed [8]
	B1	B2	B3	B4	B5	
Coliforms at 45 °C [CFU·g^{-1}]	< 10	< 10	< 10	< 10	< 10	10
Coagulase positive *Staphylococcus* sp. [CFU·g^{-1}]	< 500	< 500	< 500	< 500	< 500	500
Salmonella sp. (in 0.025 kg of sample)	Absence	Absence	Absence	Absence	Absence	Absence

Content of potato pulp: B1 – 0 g·kg^{-1}, B2 – 200 g·kg^{-1}, B3 – 400 g·kg^{-1}, B4 – 600 g·kg^{-1}, B5 – 800 g·kg^{-1}.

Tab. 5. Scores for colour, texture, taste, odour and overall acceptance obtained for the experimental biscuits in the sensory test.

Attribute	Biscuit (treatment)				
	B1	B2	B3	B4	B5
Colour	6.5 ± 1.4 a	6.9 ± 1.6 a	7.0 ± 1.1 a	6.7 ± 1.6 a	6.9 ± 1.3 a
Texture	5.8 ± 1.5 a	6.3 ± 1.6 a	6.4 ± 1.1 a	6.2 ± 1.1 a	6.4 ± 1.7 a
Taste	5.6 ± 1.7 a	6.5 ± 0.8 a	6.6 ± 1.4 a	6.0 ± 2.0 a	6.1 ± 1.3 a
Odour	6.5 ± 0.8 a	6.8 ± 0.8 a	6.7 ± 0.9 a	6.5 ± 0.7 a	6.6 ± 0.7 a
Overall acceptance	6.2 ± 0.9 a	6.7 ± 1.0 a	6.9 ± 0.8 a	6.6 ± 1.1 a	6.7 ± 1.1 a

Values are expressed as mean. Values followed by the same letters in the same row are not different at 5% probability. Content of potato pulp: B1 – 0 g·kg^{-1}, B2 – 200 g·kg^{-1}, B3 – 400 g·kg^{-1}, B4 – 600 g·kg^{-1}, B5 – 800 g·kg^{-1}.

including PP, the effect of treatment of PP with lactic acid, the heat treatment during baking, and good manufacturing practices employed throughout the preparation of PP and the experimental biscuits.

Sensory characteristics of biscuits

There were no significant differences among the experimental biscuits for all sensory attributes evaluated in the acceptance test (Tab. 5). All formulations of biscuits with PP presented scores for colour, aroma, taste, texture and overall acceptance between like slightly (6.0) and like moderately (7.0). Score 6 (six) was established as the minimum threshold for the acceptance of cookies. Therefore, all experimental biscuits were accepted except B1, which received average scores below six for texture and taste.

PP has sensory characteristics similar to RF, little affecting colour and odour of the experimental gluten-free biscuits, but slightly improves the taste and texture. According to Ijah et al. [20], sensory evaluations indicated that wheat flour could be substituted for potato flour in commercial bread making without sacrificing consumer acceptability, and that use of potato flour in bread making can reduce the cost of the bread production. The authors of this study agree that this statement can be applied to cookies made with RF and PP.

CONCLUSION

It is possible to use the potato pulp recovered from the effluent of processing potato chips in the production of gluten-free biscuits. From the physical, microbiological and sensory points of view, it is viable to produce gluten-free biscuit with a substitution of up to 80% of rice flour by potato pulp, in order to reduce losses, increase the use of industrial by-product, and to aggregate value to this residue.

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