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Characterization of baru (*Dipteryx alata* Vog.) and application of its agro-industrial by-product in the formulation of cookies

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ABSTRACT

The Brazilian cerrado has a range of unexplored plant species with high technological potential for the food industry. The edible fraction of baru (*Dipteryx alata* Vog.) is the nut, while agro-industrial by-products (endocarp, mesocarp, and epicarp) are still rarely used in human nutrition. This study evaluated the nutritional composition, bioactive compounds, and antioxidant activity of baru nuts and its agro-industrial by-product (mesocarp or pulp). Hence, to determine the nutritional enrichment, cookies were produced with different concentrations of baru pulp powder, and the proximate composition, bioactive compounds, and antioxidant activity were investigated. The results obtained demonstrate that the baru nut presented a high lipid (31.80 ± 0.65 g 100 g^{-1}) and protein (22.38 ± 0.37 g 100 g^{-1}) content. The baru agro-industrial by-product was rich in phenolic compounds (276.56 ± 13.16 mg 100 g^{-1}), flavonoids (19.59 ± 0.30 mg 100 g^{-1}), and tannins (137.21 ± 31.21 mg 100 g^{-1}), which reflected its high antioxidant capacity. The replacement of wheat flour by baru agro-industrial by-product in the formulation of cookies improved the protein, phenolic compounds, flavonoids, tannins, and antioxidant activity. Therefore, the application of baru agro-industrial by-product is a viable alternative as a cookie ingredient, while the use of baru in foods can contribute to the exploration of regional products to promote the sustainable development of unexplored plant species.

1. Introduction

In Brazil, there are six large biomes (Amazon, Atlantic Forest, Cerrado, Caatinga, Pampa, and Pantanal). The Brazilian Cerrado has a high level of naturalness and biodiversity richness, where several fruit species are found with great importance for local consumption in natural form or through processed products [1]. The fruits from the Brazilian Cerrado show *sui generis* flavors and important nutrients for human metabolism, such as sugars, proteins, minerals, and fatty acids [2].

The most popular fruits from the Cerrado are cashew (*Anacadium othanianum* Rizz.), baru (*Dipteryx alata* Vog.), cagaita (*Eugenia dysenterica*), Cerrado pear (*Eugenia klotzschiana* Berg), mangaba (*Hancornia speciosa*), and pequi (*Caryocar brasiliense* Camb.) [3]. The baru stands out for its multifunctionality (Fig. 1) [4]. Baru consists of a thin, dark shell of brown color, pulp with sweet and astringent flavor that houses a hard and edible kernel [5,6]. Baru nuts have considerable market value, reacing US$ 5.1 million in 2022, where Brazil is the largest exporter and accounts for more than 50% of cultivation [7,8]. The conventional consumption of baru occurs mainly through the nut, which is rich in proteins, fatty acids, fibers, minerals, and bioactive compounds with strong antioxidant and anti-inflammatory activity [8]. However, the agro-industrial by-products of baru (endocarp, mesocarp, and epicarp) are still rarely used in human food [9]. Considering that the pulp (mesocarp) can be used for other purposes (e.g., food processing in new formulations such as cakes, biscuits, and bread), the percentage of useable fruit yield increases to more than 50% [10], which can be an alternative to avoid the incorrect deposition of this valuable fruit. The application of agro-industrial by-products into food products guarantees nutritional enrichment at a low cost, as well as the important task of reusing these by-products generated during processing [11].

Cookies produced with different formulations are accepted and consumed by people of any age, which can be produced in large quantities and are widely distributed due to their high shelf life [12]. Therefore, this study evaluated the nutritional composition, bioactive

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compounds, and antioxidant activity of baru nuts and its agro-industrial by-product (mesocarp or pulp) generated during food industry processing. Hence, different formulations of cookies were produced by replacing wheat flour with baru agro-industrial by-product (pulp powder), which were characterized to determine the nutritional enrichment, bioactive compounds, and antioxidant capacity.

2. Materials and methods

2.1. Plant material

The fruits of baru (approximately 5 kg) were collected at the species maturation point in the Brazilian Cerrado (São Salvador, Tocantins, Brazil). The fruits were manually separated into peel, pulp, and nuts. Approximately 200 g of pulp and nut were homogenized for the chemical analyses. The pulp of baru was used for the formulation of a powder, which was used in the formulation of cookies. For this, the pulp was sanitized using NaClO (2 mg L^{-1}) and placed in an oven with forced air circulation (60 ± 2 °C) for one week. The dried pulp was submitted to a knife mill to reduce the diameter of the particles. The baru pulp powder (BPP) was homogenized and stored (6 ± 2 °C) for further characterization and application in the formulation of cookies.

2.2. Baru yield

Baru's whole fruit yield was calculated by weight, size, and width. For this, 15 representative fruits were selected and measured using an analytical balance and a digital electronic caliper with 0.001 mm accuracy. After this, samples were individually separated into peel, pulp, and nuts, and the weight of each fraction was quantified to calculate the yield of each fraction.

2.3. Formulation of cookies with baru pulp powder addition

Cookies were produced with different proportions of BPP in the replacement of wheat flour. Fig. 2 shows a flowchart for the cookies preparation. The control sample was produced with 200 g wheat flour, 27 g soy oil, 2.5 g baking soda, 2.5 g yeast powder, 100 g brown sugar, 1 egg (50 g), and 50 mL water. This study investigated the replacement of wheat flour by BPP in cookie formulations. For this, different concentrations of BPP (7.5, 15, 30, and 50%, w/w) were added in relation to the mass of wheat flour. A control was prepared without BPP addition. After the complete homogenization of the dough, the cookies were baked in an electric oven at 200 °C for 30 min. The cookies were coded as follows:

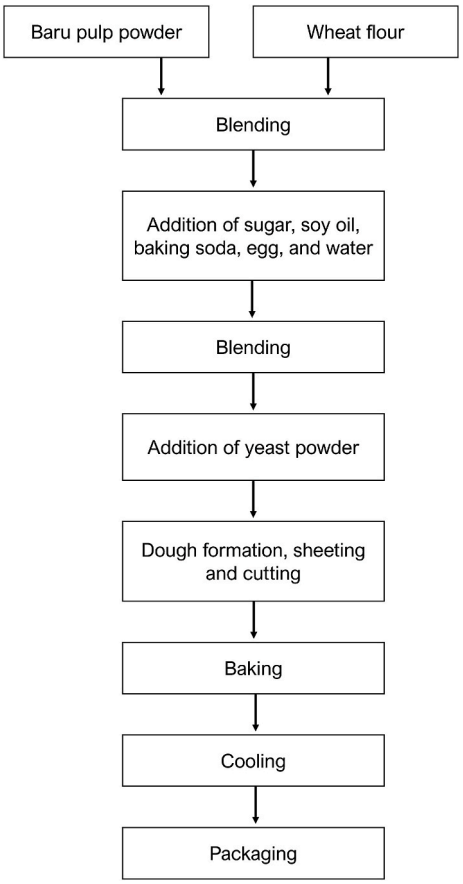

Fig. 2. Flowchart for cookie preparation.

control cookie without BPP (BPP-Control); cookie with the addition of 7.5% BPP (BPP-7.5%); cookie with the addition of 15% BPP (BPP-15%); cookie with the addition of 30% BPP (BPP-30%); and cookie with the addition of 50% BPP (BPP-50%).

2.4. Proximate composition

Moisture, ashes, crude protein, lipids, and carbohydrates were quantified according to the AOAC methods [13]. The moisture content was determined by drying the samples at 105 °C for 24 h. The ash

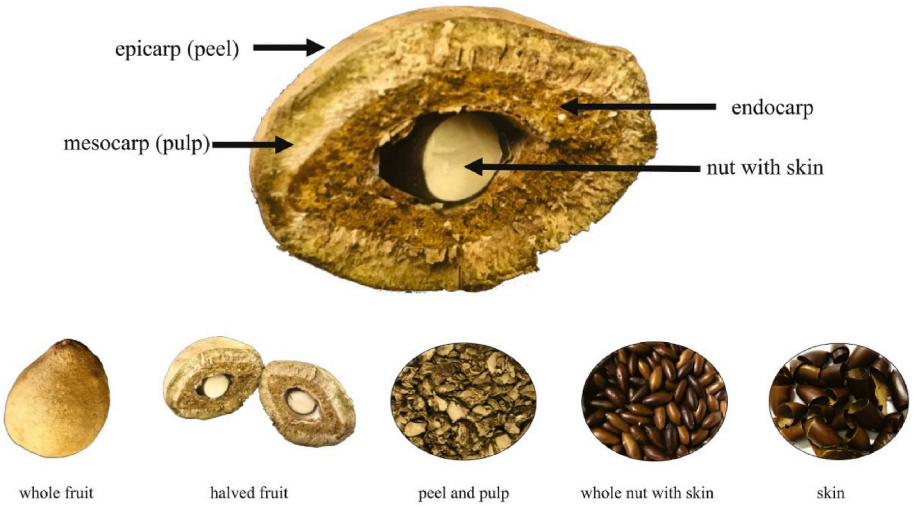

Fig. 1. Overview of baru (*Dipteryx alata* Vog.) fruit. Reproduced from Alves-Santos et al. [4], with permission from Elsevier.

content was quantified by calcination of the dried samples at 550 °C for 12 h. Crude protein was quantified following the methodology of Micro Kjeldahl (Nitrogen × 6.25). Total lipids were determined by cold extraction [14]. Total carbohydrates were calculated by the difference method (carbohydrate = 100 − (moisture + ash + protein + lipid). Total calories were determined by using the values recommended for lipids (9 kcal g^{-1}), proteins (4 kcal g^{-1}), and carbohydrates (4 kcal g^{-1}) [15]. All analyses were conducted in triplicate.

2.5. Extraction and quantification of bioactive compounds and antioxidant activity

The quantification of bioactive compounds and antioxidant activity were determined after extraction with ethanol:water solution (70:30, v/v) [16,17]. The extracts of baru nuts, pulp, BPP, and cookies were prepared using a solid:liquid ratio of 1:10 (w/v). Extracts were kept under refrigeration (6 ± 2 °C) for one week, filtered on qualitative filter paper, and stored in a dark amber bottle for further analysis.

2.5.1. Phenolic compounds

The total phenolic compounds were determined according to Swain and Hillis [18], with modifications. The reaction was composed of 104 μL of the sample extract diluted in 1667 μL of deionized water. Folin-Ciocalteu reagent (104 μL, 0.25 mol L^{-1}) was added to the reaction, followed by incubation (3 min) in a dark environment. Then, sodium carbonate (208 μL, 1 mol L^{-1}) was added to the reaction, and after 2 h, the absorbance was measured in a spectrophotometer (UV–Vis 752D, Labman, China) at 725 nm. A standard curve was prepared using different concentrations of gallic acid, and the results were expressed as mg gallic acid equivalent (GAE) per 100 g of sample (mg GAE 100 g^{-1}).

2.5.2. Flavonoids

Total flavonoids were quantified according to Park et al. [19], with modifications. The reaction was composed of 250 μL of the sample extract and diluted with 2150 μL of an ethanolic solution (80%, v/v). Then, 50 μL of aluminum nitrate (10%, w/v) and 50 μL of potassium acetate (1 mol L^{-1}) were added to the reaction. After 40 min of incubation, the absorbance was measured in a spectrophotometer (UV–Vis 752D, Labman, China) at 415 nm. A standard curve was prepared using different concentrations of quercetin, and the results were expressed as mg quercetin equivalent (QE) per 100 g of sample (mg QE 100 g^{-1}).

2.5.3. Tanins

Total tannins were measured by the method reported by Nasar-Abbas et al. [20], with modifications. First, 1 mL of extract was diluted with 1 mL of water and 100 mg of polyvinyl polypyrrolidone. The samples were vortexed and cooled at 5 °C for 15 min. The samples were centrifuged at 7500×*g* for 15 min. The supernatant (non-tannic TPC) was quantified according to the methods described in Section 2.5.1. The concentration of total tannins was obtained by subtracting the content of non-tannic TPC from the content of TPC previously quantified in the sample. The analysis was conducted in triplicate, and the results were expressed as mg tannins 100 g^{-1}.

2.5.4. Antioxidant activity by DPPH assay

The antioxidant activity was determined by the removal of the radical DPPH (2,2-diphenyl-1-picrylhydrazyl), according to the methodology of Brand-Williams, Cuvelier and Berset [21]. The reaction was composed of 150 μL of extract and 2850 μL of DPPH 0.1 mmol L^{-1} solution. After 24 h of incubation in a dark environment, the measurement was conducted in a spectrophotometer (UV–Vis 752D, Labman, China) using 515 nm as the wavelength. A calibration curve was carried out with Trolox, and the results were expressed as mg of Trolox equivalent antioxidant capacity (TEAC) per 100 g (mg TEAC 100 g^{-1}).

2.5.5. Antioxidant activity by ABTS assay

Antioxidant activity through the removal of the radical ABTS (2,2′-azino-di-(3-ethylbenzthiazoline sulfonic acid)) was determined according to Re et al. [22], with modifications. The reaction was composed of 30 μL of extract and 3000 μL of ABTS solution. After 6 min in the dark, the absorbance was measured at 734 nm in a spectrophotometer (UV–Vis 752D, Labman, China), and the Trolox standard was used as a calibration curve. The results were expressed as mg TEAC 100 g^{-1}.

2.5.6. Antioxidant activity by FRAP assay

Antioxidant activity through FRAP was determined according to Benzie and Strain [23] and Arnous, Makris and Kefalas [24]. The reaction was composed of 100 μL of extract, 100 μL of ferric chloride (3 mmol L^{-1}) and 1800 μL of TPTZ (2,4,6-Tris (2-pyridyl)-s-triazine) (1 mmol L^{-1}). After 30 min in a water bath (37 °C), the absorbance was measured at 620 nm (UV–Vis 752D, Labman, China), and Trolox was used for the calibration curve. The results were expressed as mg TEAC 100 g^{-1}.

2.6. Statistical analysis

The results were expressed as the mean values ± standard deviations. Analysis of variance (ANOVA) and Tukey's test ($p < 0.05$) were carried out to identify significant differences between the samples. All statistical analyses were conducted with Statistica® software (Statsoft Inc., version 10.0, Tulsa, OK, USA).

3. Results and discussion

3.1. Yield of baru

The whole fruit of baru used in this study presented an average weight of 33.65 ± 3.56 g, length of 52.40 ± 1.97 mm, and width of 39.28 ± 0.97 mm. The literature demonstrates that baru presents a mass of 38.11 ± 9.36 g, length of 61.17 ± 7.98 mm and width of 31.30 ± 2.64 mm [25]. Moreover, the sum of the epicarp (peel) and mesocarp (pulp) of baru is responsible for 49% of the total yield of the fruit, while the endocarp represents 49% of the total fruit mass. Finally, the nut, which is the conventional edible part of baru, represents 2% of the fresh weight. In the agro-industrial processing of baru, the amount of by-products generated is high, mainly because the edible fraction represents approximately half of the total fruit mass. Therefore, the by-products of this fruit present huge potential for insertion into new food products, being a potential alternative to the reduction of vegetable residues.

3.2. Characterization of baru and its agro-industrial by-product

Table 1 shows the physicochemical characterization of baru nut, pulp, and BPP. The analysis of the unconventional parts of fruits is crucial for the elaboration of new products since it is desired to verify and quantify the macronutrients in the sample.

Table 1
Nutritional composition of baru nut, pulp, and pulp powder.

Parameters	Nut	Pulp	BPP	Unit
Moisture	6.70 ± 0.08^{c}	14.11 ± 0.02^{a}	8.95 ± 0.01^{b}	g 100 g^{-1}
Ashes	3.21 ± 0.03^{b}	4.01 ± 0.24^{b}	14.74 ± 1.87^{a}	g 100 g^{-1}
Proteins	31.80 ± 0.65^{a}	10.05 ± 0.37^{b}	8.79 ± 0.34^{c}	g 100 g^{-1}
Lipids	22.38 ± 0.37^{a}	1.79 ± 0.01^{b}	1.41 ± 0.10^{b}	g 100 g^{-1}
Carbohydrates	35.88 ± 0.35^{c}	70.05 ± 0.09^{a}	66.06 ± 1.49^{b}	g 100 g^{-1}
Calories	472.18 ± 2.23^{a}	336.49 ± 0.94^{b}	312.07 ± 8.20^{c}	kcal 100 g^{-1}

Label: The results are expressed as the average ± standard deviation (analysis performed in triplicate, n = 3). Different letters in each row represent a significant difference by Tukey's test ($p < 0.05$). BPP, baru pulp powder.

The moisture content in the baru samples presented a significant difference ($p < 0.05$), and the pulp had a higher moisture content (14.11 ± 0.02 g 100 g^{-1}), differing from BPP (8.95 ± 0.01 g 100 g^{-1}) and nut (6.70 ± 0.08 g 100 g^{-1}). Studies have shown that the moisture content in baru nuts can range between 5.80 and 6.10 g 100 g^{-1} [26], which is consistent with that obtained in this study. According to the Brazilian Health Regulatory Agency [27], to frame a food as flour, it should have less than 15 g moisture 100 g^{-1}, and the BPP produced in this study is framed in the current Brazilian legislation. The ash content was higher for BPP (14.74 ± 1.87 g 100 g^{-1}) when compared with the nut (3.21 ± 0.03 g 100 g^{-1}) and pulp (4.01 ± 0.24 g 100 g^{-1}). The literature demonstrates that the ash content in baru nuts ranges between 2.70 and 4.34 g 100 g^{-1} [25,26].

The baru nuts presented 31.80 ± 0.65 g proteins 100 g^{-1}. The agro-industrial waste in fresh matter (pulp) presented 10.05 ± 0.37 g 100 g^{-1}, and after drying, the BPP presented 8.79 ± 0.34 g 100 g^{-1}. The literature demonstrates that baru is a rich source of proteins, especially raw nut (19.72–30.0 g 100 g^{-1}) [28]. In addition, the pulp and peel contain a lower protein content than the nut, with an average of 3.8 g 100 g^{-1} for the pulp and 2.5 g 100 g^{-1} for the peel [29,30]. This study demonstrated that BPP is a rich source of proteins, and its incorporation into food products can be an alternative in the context of new plant-based market products [31,32].

Evaluating the lipid content, the baru nut (22.38 ± 0.37 g 100 g^{-1}) presented a higher content ($p < 0.05$) when compared with the pulp (1.79 ± 0.01 g 100 g^{-1}) and BPP (1.41 ± 0.10 g 100 g^{-1}). The literature has shown that the lipids obtained from baru nuts are composed of 75.58 g 100 g^{-1} unsaturated fatty acids and 22.92 g 100 g^{-1} saturated fatty acids [33]. The major unsaturated fatty acids are oleic (47.15%), linoleic (25.51%) and gadoleic (2.71%) acids, while the major saturated fatty acids are palmitic acid (6.10%), stearic acid (5.27%), and behenic acid (4.39%) [4,26]. Given that a diet high in unsaturated fatty acids decreases risk factors and the mortality associated with cardiovascular diseases, the fatty acid profile of the baru nut is advantageous for health when consumed in appropriate concentrations [4,34].

Finally, the carbohydrate content demonstrated that the pulp (70.05 ± 0.09 g 100 g^{-1}) and the BPP (66.06 ± 1.49 g 100 g^{-1}) presented values higher when compared with the nut (35.88 ± 0.35 g 100 g^{-1}). This fact can be associated with the presence of lignocellulose compounds in the agro-industrial by-product of baru [35,36]. In addition, the dried pulp is composed of dietary fibers (29.5 g 100 g^{-1}), soluble fibers (1.3 g 100 g^{-1}), insoluble fibers (28.2 g 100 g^{-1}), and starch (38.1 g 100 g^{-1}) [4]. Otherwise, the baru nut presented the highest calories (472.18 ± 2.23 kcal 100 g^{-1}) when compared with the pulp (336.49 ± 0.94 kcal 100 g^{-1}) and BPP (312.07 ± 8.20 kcal 100 g^{-1}).

Table 2 shows the content of total phenolics, flavonoids, tannins, and antioxidant activity by DPPH, ABTS, and FRAP assays in baru nut, pulp, and BPP. The nut of baru presented the highest values of total phenolic compounds (529.50 ± 12.44 mg GAE 100 g^{-1}) and flavonoids (29.47 ± 1.76 mg QE 100 g^{-1}). In this study, the values of phenolic compounds in the pulp (202.15 ± 1.88 mg GAE 100 g^{-1}) are similar to those obtained by Togashi and Sgarbieri [10] for baru pulp (292 mg GAE 100 g^{-1}). Moreover, the drying of the baru pulp to obtain the BPP favored the concentration of phenolics and flavonoids. For instance, the fresh pulp presented 202.15 ± 1.88 mg GAE 100 g^{-1}, and the BPP presented 276.56 ± 13.16 mg GAE 100 g^{-1}, an increase of 1.36-fold. The tannin content was higher for the BPP (137.21 ± 31.21 mg 100 g^{-1}), indicating that it is an adstringent material. The tannin content obtained in this study is lower than the value reported in the literature [4]. The antioxidant capacity of the nut was higher than that of the pulp and BPP in the DPPH (636.34 ± 22.49 mg TEAC 100 g^{-1}), ABTS (2404.41 ± 17.71 mg TEAC 100 g^{-1}), and FRAP (4163.03 ± 109.6649 mg TEAC 100 g^{-1}) assays. In addition, the analysis of the antioxidant activity by the FRAP assay presented the highest values. Finally, the production of BPP promoted a concentration in the antioxidant capacity, which was statistically higher when compared with the raw pulp. This fact must be related to the presence of bioactive compounds, which were higher in the BPP and lower in the fresh pulp.

Table 2
Bioactive compounds (phenolic, flavonoids, and tannins) and antioxidant activity (DPPH, ABTS, and FRAP assays) of baru nut, pulp, and pulp powder.

Parameters	Nut	Pulp	BPP	Unit
TPC	529.50 ± 12.44^{a}	202.15 ± 1.88^{c}	276.56 ± 13.16^{b}	mg GAE 100 g^{-1}
TF	29.47 ± 1.76^{a}	17.17 ± 0.34^{c}	19.59 ± 0.30^{b}	mg QE 100 g^{-1}
TT	55.59 ± 9.45^{c}	98.64 ± 15.39^{b}	137.21 ± 31.21^{a}	mg 100 g^{-1}
DPPH	636.34 ± 22.49^{a}	509.36 ± 16.37^{b}	592.79 ± 20.10^{b}	mg TEAC 100 g^{-1}
ABTS	2404.41 ± 17.71^{a}	467.73 ± 9.50^{c}	653.73 ± 16.66^{b}	mg TEAC 100 g^{-1}
FRAP	4163.03 ± 109.66^{a}	2715.75 ± 314.80^{c}	3335.83 ± 417.72^{b}	mg TEAC 100 g^{-1}

Label: The results are expressed as the average ± standard deviation (analysis performed in triplicate). Different letters in each row represent a significant difference by Tukey's test ($p < 0.05$). TPC, total phenolic compounds; TF, total flavonoids; TT, total tanins; BPP, baru pulp powder.

Recently, studies have demonstrated that combating oxidative stress in human metabolism is directly associated with the consumption of food containing bioactive compounds with antioxidant properties [37]. The presence of antioxidant molecules (e.g., phenolics, flavonoids, and tanins) helps in the mechanism of defense and control of cellular damage caused by free radicals [38]. The consumption of these compounds has been associated with the prevention and treatment of obesity, cardiovascular disease and diabetes [39,40]. In addition, the application of baru and its by-products in food products can be an alternative to promote a healthy diet [41].

3.3. Characterization of cookies with the addition of baru agro-industrial by-product

The BPP formulated by drying the agro-industrial by-product of baru (pulp) was used in the formulation of cookies. For this, up to 50% of BPP was included in the cookie formulation and nutritionally compared with the cookie without the addition of BPP. BPP was added to replace wheat flour, which is the conventional flour used in cookie formulations. The

Table 3
Nutritional composition of cookies produced with different concentrations of baru pulp powder.

Parameters	BPP-Control	BPP-7.5%	BPP-15%	BPP-30%	BPP-50%	Unit
Moisture	12.71 ± 0.38^{a}	6.41 ± 0.11^{b}	6.35 ± 0.50^{b}	10.23 ± 0.03^{a}	9.23 ± 0.02^{a}	g 100 g^{-1}
Ashes	2.31 ± 1.10^{a}	2.33 ± 0.01^{a}	2.67 ± 0.02^{a}	2.44 ± 0.01^{a}	2.47 ± 0.08^{a}	g 100 g^{-1}
Proteins	10.46 ± 0.06^{d}	12.38 ± 1.11^{c}	13.65 ± 0.12^{b}	14.79 ± 0.01^{b}	17.36 ± 0.19^{a}	g 100 g^{-1}
Lipids	5.42 ± 0.86^{a}	5.33 ± 0.13^{a}	5.51 ± 0.36^{a}	5.37 ± 0.42^{a}	5.07 ± 0.05^{a}	g 100 g^{-1}
Carbohydrates	68.84 ± 0.77^{b}	73.64 ± 0.98^{a}	71.80 ± 0.28^{a}	67.09 ± 0.52^{b}	65.84 ± 0.10^{c}	g 100 g^{-1}
Calories	365.80 ± 4.70^{c}	397.01 ± 0.64^{a}	391.45 ± 3.85^{a}	375.81 ± 1.73^{b}	388.45 ± 0.04^{b}	kcal 100 g^{-1}

Label: The results are expressed as the average ± standard deviation (analysis performed in triplicate). Different letters in each row represent a significant difference by Tukey's test ($p < 0.05$).

results of the physicochemical characterization of the cookies are presented in Table 3.

Regarding the moisture content, it was observed that there was a significant difference between the different concentrations of BPP used in the cookie formulation. The moisture content ranged from 6.35 to 12.71 g 100 g^{-1} for BPP-15% and BPP-control, respectively. The moisture results corroborated those of Ishimoto et al. [42], who obtained a moisture content of approximately 6.39 g 100 g^{-1} when incorporating passion fruit peel flour in the production of cookies. The Brazilian Health Regulatory Agency establishes that a cookie must have a maximum moisture content of 14 g 100 g^{-1} [43]. Therefore, all cookies produced are within the current legislation. The presence of BPP can be an alternative to promote the development of cookies with lower water activity and a safe limit for safe storage [44,45]. In addition, the variation in the moisture content of the cookies produced with BPP can be associated with the complex interaction between proteins and carbohydrates, where possible aggregation can change the viscosity of the dough and increase the release of water during the oven cooking process [46,47].

There was no statistically significant difference regarding the ash content in the formulated cookies, where an average content of 2.5 g 100 g^{-1} was obtained. The ash content obtained in this study is below the maximum limit (3 g 100 g^{-1}) stipulated by the Brazilian Health Regulatory Agency [43]. The BPP presented an ash content of 14.74 ± 1.87 g 100 g^{-1}, and the addition of this product in food could be a problem due to the high ash content. However, the addition of up to 50% BPP promoted a suitable value of ashes in the developed cookies.

The lipid content of wheat flour (1.7 g 100 g^{-1}) was similar to the lipid content of BPP (1.4 g 100 g^{-1}). Therefore, there were non-significant differences in the cookies produced with the addition of BPP. A similar value of lipids was observed in the literature with the addition of vegetable residues to substitute wheat flour [48].

The highest protein content was obtained for the cookie with the addition of 50% BPP (17.36 ± 0.19 g 100 g^{-1}), which can be considered an advantage regarding protein functionalization when compared with the BPP-Control (10.46 ± 0.06 g 100 g^{-1}). The cookies produced in this study also showed a high concentration of protein, similar to the literature [25,49]. The consumption of high-protein cookies implies their potential use as a food, with the aim of contributing to essential amino acid intake [50]. The presence of high protein content can be associated with other characteristics of cookies, such as higher foaming capacity and stability due to protein and carbohydrate aggregation [51].

BPP addition affected the carbohydrate and caloric contents of the cookies. The addition of 7.5% BPP promoted the highest content of carbohydrates (73.64 ± 0.98 g 100 g^{-1}) and calories (397.01 ± 0.64 kcal 100 g^{-1}). The replacement of wheat flour with BPP at concentrations higher than 30% decreased the carbohydrate content of the cookies, which can be associated with the decrease in the amount of starch used in the cookies. The consumption of cookies with high fiber and protein content can be an advantage to the formulation of functional foods, and BPP was demonstrated to be a promising material for that.

Table 4 shows the content of bioactive compounds (phenolic, flavonoids, and tannins) and antioxidant activity (DPPH, ABTS, and FRAP assays) of the cookies produced with different concentrations of BPP. As the level of BPP increased in the formulation of the cookies, the content of bioactive compounds and antioxidants significantly increased. The formulation BPP-50% was composed of phenolic compounds (72.11 ± 1.21 mg GAE 100 g^{-1}), flavonoids (12.43 ± 0.97 mg QE 100 g^{-1}), and tannins (32.54 ± 0.56 mg 100 g^{-1}). The antioxidant capacity by DPPH (139.54 ± 3.12 mg TEAC 100 g^{-1}), ABTS (325.93 ± 3.25 mg TEAC 100 g^{-1}), and FRAP (428.14 ± 9.65 mg TEAC 100 g^{-1}) was expressive and suitable for the formulation of active food products. Hence, the addition of BPP as a flour fortifier and as an ingredient in the production of functional foods is recommended [52,53]. These results indicate that BPP can be considered a suitable product for food functionalization, as demonstrated by its application in cookies.

Finally, the use of baru in foods can contribute to the exploration of regional products, as well as the diversification of products with functional appeal to promote the sustainable development of native areas [50,54]. The application of agri-food by-products in food products can be an alternative source of nutrients to support the global demand for functional foods and as one of the strategies to reduce waste [55,56].

Table 4
Bioactive compounds (phenolic, flavonoids, and tannins) and antioxidant activity (DPPH, ABTS, and FRAP assays) of cookies produced with different concentrations of baru pulp powder.

Parameters	BPP-Control	BPP-7.5%	BPP-15%	BPP-30%	BPP-50%	Unit
TPC	6.29 ± 1.45^{e}	37.28 ± 3.23^{d}	54.23 ± 2.54^{c}	67.92 ± 2.13^{b}	72.11 ± 1.21^{a}	mg GAE 100 g^{-1}
TF	1.35 ± 0.97^{e}	5.97 ± 0.63^{d}	7.42 ± 0.83^{c}	9.51 ± 0.15^{b}	12.43 ± 0.97^{a}	mg QE 100 g^{-1}
TT	n.d.	12.53 ± 0.98^{d}	19.73 ± 0.14^{c}	25.36 ± 0.73^{b}	32.54 ± 0.56^{a}	mg 100 g^{-1}
DPPH	14.98 ± 1.23^{e}	64.24 ± 2.78^{d}	79.64 ± 2.47^{c}	98.36 ± 3.23^{b}	139.54 ± 3.12^{a}	mg TEAC 100 g^{-1}
ABTS	67.24 ± 2.34^{e}	126.97 ± 4.12^{d}	187.76 ± 6.94^{c}	209.32 ± 3.25^{b}	325.93 ± 3.25^{a}	mg TEAC 100 g^{-1}
FRAP	98.56 ± 3.84^{e}	179.14 ± 10.97^{d}	257.87 ± 13.28^{c}	321.56 ± 9.67^{b}	428.14 ± 9.65^{a}	mg TEAC 100 g^{-1}

Label: The results are expressed as the average ± standard deviation (analysis performed in triplicate). Different letters in each row represent a significant difference by Tukey's test ($p < 0.05$). TPC, total phenolic compounds; TF, total flavonoids; TT, total tanins; n.d., not detected.

4. Conclusion

This study evaluated the nutritional composition, bioactive compounds, and antioxidant activity of baru nuts and its agro-industrial by-product (pulp). Hence, to determine the nutritional enrichment, cookies were produced with different concentrations of BPP by replacing wheat flour, and the proximate composition, bioactive compounds, and antioxidant activity were investigated. The sum of the epicarp (peel) and mesocarp (pulp) of baru is responsible for 49% of the total yield of the fruit, while the endocarp represents 49% of the total fruit mass. The nut represents only 2% of the whole fruit, which represents a high generation of by-products during processing. The BPP presented high ash (14.74 ± 1.87 g 100 g^{-1}), protein (8.79 ± 0.34 g 100 g^{-1}), and carbohydrate (66.06 ± 1.49 g 100 g^{-1}) contents. In addition, the baru agro-industrial by-product is rich in phenolic compounds (276.56 ± 13.16 mg 100 g^{-1}), flavonoids (19.59 ± 0.30 mg 100 g^{-1}), and tannins (137.21 ± 31.21 mg 100 g^{-1}), which reflected its high antioxidant capacity by DPPH (592.79 ± 20.10 mg TEAC 100 g^{-1}), ABTS (653.73 ± 16.66 mg TEAC 100 g^{-1}), and FRAP (3335.83 ± 417.72 mg TEAC 100 g^{-1}) assays. Hence, the physicochemical composition, bioactive compounds, and antioxidant activity demonstrate that BPP is a promising alternative for application in food products. The formulated cookies demonstrate that it is possible to replace wheat flour with BPP up to 50% (w/w). The main advantage in the use of BPP is the increase in the protein content from 10.46 ± 0.06 to 17.36 ± 0.19 g 100 g^{-1} for BPP-Control and BPP-50%, respectively, which can contribute to the daily intake of essential amino acids. In addition, the cookies produced with 50% BPP presented a high content of total phenolics (72.11 ± 1.21 mg GAE 100 g^{-1}), flavonoids (12.43 ± 0.97 mg QE 100 g^{-1}), and tanins (32.54 ± 0.56 mg 100 g^{-1}), which is associated with the high

antioxidant capacity of the cookies. Therefore, the application of baru agro-industrial by-product is a viable alternative as a cookie ingredient.

CRediT authorship contribution statement

Helena Nadya Alves Campos Viana: Methodology, Investigation. William Gustavo Sganzerla: Conceptualization, Methodology, Investigation, Validation, Writing – original draft, Writing review and editing. Luiz Eduardo Nochi de Castro: Writing – review & editing. Ana Paula de Lima Veeck: Supervision, Resources, Project administration, Funding acquisition, Writing review and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

[1] M. Giongo, M.M. Santos, D.B. da Silva, J.N. Cachoeira, G. Santopuoli, in: R. Tognetti, M. Smith, P. Panzacchi (Eds.), Climate-Smart Forestry in Brazil BT - Climate-Smart Forestry in Mountain Regions, Springer International Publishing, Cham, 2022, pp. 545–570, https://doi.org/10.1007/978-3-030-80767-2_17.

[2] F.G. de Souza, F.F. de Araújo, E.A. Orlando, F.M. Rodrigues, D.W.H. Chávez, J.A. L. Pallone, I.A. Neri-Numa, A.C.H.F. Sawaya, G.M. Pastore, Characterization of buritirana (mauritiella armata) fruits from the Brazilian cerrado: biometric and physicochemical attributes, chemical composition and antioxidant and antibacterial potential, Foods 11 (2022) 786, https://doi.org/10.3390/foods11060786.

[3] D.C. dos Santos, J.G. de Oliveira Filho, T.L. de Sousa, C.B. Ribeiro, M.B. Egea, Ameliorating effects of metabolic syndrome with the consumption of rich-bioactive compounds fruits from Brazilian Cerrado: a narrative review, Crit. Rev. Food Sci. Nutr. 62 (2022) 7632–7649, https://doi.org/10.1080/10408398.2021.1916430.

[4] A.M. Alves-Santos, D.C. Fernandes, M.M.V. Naves, Baru (Dipteryx alata Vog.) fruit as an option of nut and pulp with advantageous nutritional and functional properties: a comprehensive review, NFS J 24 (2021) 26–36, https://doi.org/10.1016/j.nfs.2021.07.001.

[5] S.R. da Silva, T.H.B. Ferreira, C.J.F. de Souza, E.J. Sanjinez-Argandoña, Dipteryx alata vog, in: Fruits of the Brazilian Cerrado, Springer International Publishing, Cham, 2021, pp. 99–113, https://doi.org/10.1007/978-3-030-62949-6_6.

[6] G. de M. Monteiro, E.E.N. Carvalho, E.V.B.V. Boas, Baru (Dipteryx alata Vog.): fruit or almond? A review on applicability in food science and technology, Food Chem. Adv. 1 (2022), 100103, https://doi.org/10.1016/j.focha.2022.100103.

[7] Baru Nuts Market Outlook (2022-2032), Mark. Res. Surv., 2023. https://www.factmr.com/report/1362/baru-nuts-market.

[8] S.R. da Silva, T.H.B. Ferreira, A.J. Giunco, E.J.S. Argandoña, Nutritional potential and effect of the solvent on the extraction of secondary metabolites from pulp and bark of baru (Dipteryx alata), J. Food Meas. Char. 15 (2021) 3453–3460, https://doi.org/10.1007/s11694-021-00926-6.

[9] M.C. de Oliveira, P.N. Curi, R. Pio, D. da H. Farias, M.R. Rigote, M.C.E.V. Schiassi, M. Pasqual, V.R. de Souza, Physicochemical characterization, bioactive compounds and correlations in native fruits of western Mato Grosso do Sul, Br. Food J. 122 (2020) 841–851, https://doi.org/10.1108/BFJ-06-2019-0423.

[10] G. de L. Santiago, I.G. de Oliveira, M.A. Horst, M.M.V. Naves, M.R. Silva, Peel and pulp of baru (Dipteryx Alata Vog.) provide high fiber, phenolic content and antioxidant capacity, Food Sci. Technol. 38 (2018) 244–249, https://doi.org/10.1590/1678-457x.36416.

[11] A. Vastolo, S. Calabrò, M.I. Cutrignelli, A review on the use of agro-industrial CO-products in animals' diets, Ital. J. Anim. Sci. 21 (2022) 577–594, https://doi.org/10.1080/1828051X.2022.2039562.

[12] M. Gagneten, D.A. Archaina, M.P. Salas, G.E. Leiva, D.M. Salvatori, C. Schebor, Gluten-free cookies added with fibre and bioactive compounds from blackcurrant residue, Int. J. Food Sci. Technol. 56 (2021) 1734–1740, https://doi.org/10.1111/ijfs.14798.

[13] AOAC, Official Methods of Analysis of the Association of Official Analytical Chemistry, seventeenth ed., Association of Official Analytical Chemistry, Washington, 2006.

[14] E.G. Bligh, W.J. Dyer, A rapid method of total lipid extraction and purification, Can. J. Biochem. Physiol. 37 (1959) 911–917, https://doi.org/10.1139/o59-099.

[15] W.O. Atwater, C. Woods, The Chemical Composition of American Food Materials, 1896. https://www.ars.usda.gov/ARSUserFiles/80400530/pdf/hist/oes_1896_bul_28.pdf.

[16] W.G. Sganzerla, P.C. Beling, A.L.A. Ferreira, M.S. Azevedo, J.P. Ferrareze, R. A. Komatsu, M.R. Nunes, A.P. Lima Veeck, Geographical discrimination of uvaia (Eugenia pyriformis Cambess) by principal component analysis, J. Sci. Food Agric. 99 (2019) 6778–6787, https://doi.org/10.1002/jsfa.9961.

[17] W.G. Sganzerla, P.C. Beling, J.P. Ferrareze, R. Akitoshi Komatsu, M. Ramos Nunes, A.P. de Lima Veeck, Nutritional, physicochemical and antimicrobial properties of uvaia pulp (Eugenia pyriformis Cambess), Commun. Plant Sci. (2018), https://doi.org/10.26814/cps2018001.

[18] T. Swain, W.E. Hillis, The phenolic constituents ofPrunus domestica. I.—the quantitative analysis of phenolic constituents, J. Sci. Food Agric. 10 (1959) 63–68, https://doi.org/10.1002/jsfa.2740100110.

[19] Y.K. Park, M. Ikegaki, J.A. da S. Abreu, N.M.F. Alcici, Estudo da preparação dos extratos de própolis e suas aplicações, Ciência Tecnol. Aliment. 18 (1998) 313–318, https://doi.org/10.1590/S0101-20611998000300011.

[20] S.M. Nasar-Abbas, J.A. Plummer, K.H.M. Siddique, P. White, D. Harris, K. Dods, Cooking quality of faba bean after storage at high temperature and the role of lignins and other phenolics in bean hardening, LWT–Food Sci. Technol. 41 (2008) 1260–1267, https://doi.org/10.1016/j.lwt.2007.07.017.

[21] W. Brand-Williams, M.E. Cuvelier, C. Berset, Use of a free radical method to evaluate antioxidant activity, LWT–Food Sci. Technol. 28 (1995) 25–30, https://doi.org/10.1016/S0023-6438(95)80008-5.

[22] R. Re, N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, C. Rice-Evans, Antioxidant activity applying an improved ABTS radical cation decolorization assay, Free Radic. Biol. Med. 26 (1999) 1231–1237, https://doi.org/10.1016/S0891-5849(98)00315-3.

[23] I.F.F. Benzie, J.J. Strain, The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay, Anal. Biochem. 239 (1996) 70–76, https://doi.org/10.1006/abio.1996.0292.

[24] A. Arnous, D.P. Makris, P. Kefalas, Correlation of pigment and flavanol content with antioxidant properties in selected aged regional wines from Greece, J. Food Compos. Anal. 15 (2002) 655–665, https://doi.org/10.1006/jfca.2002.1070.

[25] A.M. Alves, A.L. De Mendonça, M. Caliari, R. De Andrade Cardoso-Santiago, Avaliação química e física de componentes do baru (Dipteryx alata Vog.) para estudo da vida de prateleira, Pesqui. Agropecuária Trop. 40 (2010) 266–273, https://doi.org/10.5216/pat.v40i3.6343.

[26] E. Takemoto, I.A. Okada, M.L. Garbelotti, M. Tavares, S. Aued-Pimentel, Chemical composition of seeds and oil of baru (Dipteryx alata Vog .) native from Pirenópolis , State of Goiás , Brazil, Rev. Inst. Adolfo Lutz. 60 (2001) 113–117.

[27] Brasil, Resolucao da Diretoria Colegiada - RDC no 360 de 23/12/2003. Aprova o regulamento tecnico sobre rotulagem nutricional de alimentos embalados, tornando obrigatoria a rotulagem nutricional., Ministerio Da Saude. Agencia Nac. Vigilancia Sanitaria - Diario Of. Da Uniao, Pod. Exec. DF, Brasilia. 251 (2003) 1-15. http://antigo.anvisa.gov.br/legislacao#/visualizar/27327.

[28] D.C. Lima, M. da R. Alves, N.H. Noguera, R. de P. do Nascimento, A review on Brazilian baru plant (Dipteryx alata Vogel): morphology, chemical composition, health effects, and technological potential, Futur. Foods 5 (2022), 100146, https://doi.org/10.1016/j.fufo.2022.100146.

[29] R.G.M. de Souza, A.C. Gomes, I.A. de Castro, J.F. Mota, A baru almond–enriched diet reduces abdominal adiposity and improves high-density lipoprotein concentrations: a randomized, placebo-controlled trial, Nutrition 55–56 (2018) 154–160, https://doi.org/10.1016/j.nut.2018.06.001.

[30] M.L.L. Campidelli, J.D.S. Carneiro, E.C. Souza, M.L. Magalhães, E.E.C. Nunes, P. B. Faria, M. Franco, E.V.B. Vilas Boas, Effects of the drying process on the fatty acid content, phenolic profile, tocopherols and antioxidant activity of baru almonds (Dipteryx alata Vog.), Grasas Aceites 71 (2020) 343, https://doi.org/10.3989/gya.1170182.

[31] A.G.A. Sá, Y.M.F. Moreno, B.A.M. Carciofi, Food processing for the improvement of plant proteins digestibility, Crit. Rev. Food Sci. Nutr. 60 (2020) 3367–3386, https://doi.org/10.1080/10408398.2019.1688249.

[32] D.M. Otero, G. da Rocha Lemos Mendes, A.J. da Silva Lucas, A. Christ-Ribeiro, C.D. F. Ribeiro, Exploring alternative protein sources: evidence from patents and articles focusing on food markets, Food Chem. 394 (2022), 133486, https://doi.org/10.1016/j.foodchem.2022.133486.

[33] R. Vera, M.S. Soares Junior, R.V. Naves, E.R.B. de Souza, E.P. Fernandes, M. Caliari, W.M. Leandro, Características químicas de amêndoas de barueiros (dipteryx alata vog.) de ocorrência natural no cerrado do estado de Goiás, Brasil, Rev. Bras. Frutic. 31 (2009) 112–118, https://doi.org/10.1590/S0100-29452009000100017.

[34] H. Billingsley, S. Carbone, C. Lavie, Dietary fats and chronic noncommunicable diseases, Nutrients 10 (2018) 1385, https://doi.org/10.3390/nu10101385.

[35] N.R. Leite, L.C.A. de Araújo, P. dos S. da Rocha, D.A. Agarrayua, D.S. Ávila, C. A. Carollo, D.B. Silva, L.M. Estevinho, K. de Picoli Souza, E.L. dos Santos, Baru pulp (dipteryx alata vogel): fruit from the Brazilian savanna protects against oxidative stress and increases the life expectancy of Caenorhabditis elegans via SOD-3 and DAF-16, Biomolecules 10 (2020) 1106, https://doi.org/10.3390/biom10081106.

[36] F.A. Morais, C.M. Belisário, R. Favareto, G.P.A.G. Maia, V.D.F. Carvalho, Influência das temperaturas de secagem nas características físico-químicas da polpa do baru, Agrarian 14 (2021) 119–126, https://doi.org/10.30612/agrarian.v14i51.10563.

[37] A. Patra, S. Abdullah, R.C. Pradhan, Review on the extraction of bioactive compounds and characterization of fruit industry by-products, Bioresour. Bioprocess. 9 (2022) 14, https://doi.org/10.1186/s40643-022-00498-3.
[38] S. Caporali, A. De Stefano, C. Calabrese, A. Giovannelli, M. Pieri, I. Savini, M. Tesauro, S. Bernardini, M. Minieri, A. Terrinoni, Anti-inflammatory and active biological properties of the plant-derived bioactive compounds luteolin and luteolin 7-glucoside, Nutrients 14 (2022) 1155, https://doi.org/10.3390/nu14061155.
[39] L. López-Hortas, N. Flórez-Fernández, M.D. Torres, H. Domínguez, Update on potential of edible mushrooms: high-value compounds, extraction strategies and bioactive properties, Int. J. Food Sci. Technol. 57 (2022) 1378–1385, https://doi.org/10.1111/ijfs.15544.
[40] P. Espitia-Hernández, M.L. Chávez González, J.A. Ascacio-Valdés, D. Dávila-Medina, A. Flores-Naveda, T. Silva, X. Ruelas Chacón, L. Sepúlveda, Sorghum (Sorghum bicolor L.) as a potential source of bioactive substances and their biological properties, Crit. Rev. Food Sci. Nutr. 62 (2022) 2269–2280, https://doi.org/10.1080/10408398.2020.1852389.
[41] P.N. Cruz, L.A. Gama, M.F. Américo, P.B. Pertuzatti, Baru (Dipteryx alata Vogel) almond and dairy desserts with baru regulates gastrointestinal transit in rats, J. Food Process. Preserv. 43 (2019), https://doi.org/10.1111/jfpp.14167.
[42] F.Y. Ishimoto, A.I. Harada, I.G. Branco, W.A. dos S. Conceição, M.R. Coutinho, Aproveitamento Alternativo da Casca do Maracujá- Amarelo (Passifl ora edulis f . var . fl avicarpa Deg .) para Produção de Biscoitos Alternative Use of Yellow Passionfruit Skin (Passifl ora edulis f . var . fl avicarpa Deg .) for the Production of Cooki, Production, 2007.
[43] Brasil, Resolução n 12 de 1978, Ministério Da Saúde. Agência Nac. Vigilância Sanitária - Diário Of. Da União, Pod. Exec. DF, Brasília., 1978.
[44] R. Theagarajan, L. Malur Narayanaswamy, S. Dutta, J.A. Moses, A. Chinnaswamy, Valorisation of grape pomace (cv. Muscat) for development of functional cookies, Int. J. Food Sci. Technol. 54 (2019) 1299–1305, https://doi.org/10.1111/ijfs.14119.
[45] Y.K. Bhosale, T. Perumal, S.M. Varghese, H. Vincent, S.V. Ramachandran, Utilization of shallot bio-waste (Allium cepa L. var. aggregatum) fractions for the production of functional cookies, Int. J. Food Eng. 18 (2022) 27–39, https://doi.org/10.1515/ijfe-2021-0169.
[46] B. Jagadiswaran, V. Alagarasan, P. Palanivelu, R. Theagarajan, J.A. Moses, C. Anandharamakrishnan, Valorization of food industry waste and by-products using 3D printing: a study on the development of value-added functional cookies, Futur. Foods 4 (2021), 100036, https://doi.org/10.1016/j.fufo.2021.100036.
[47] S. Mildner-Szkudlarz, J. Bajerska, R. Zawirska-Wojtasiak, D. Górecka, White grape pomace as a source of dietary fibre and polyphenols and its effect on physical and nutraceutical characteristics of wheat biscuits, J. Sci. Food Agric. 93 (2013) 389–395, https://doi.org/10.1002/jsfa.5774.
[48] A. Alkozai, S. Alam, Utilization of fruits and vegetable waste in cereal based food (cookies), Int. J. Eng. Res. Technol. 7 (2018), IJERTV7IS070132.
[49] L. de O. Pineli, L.A. de Aguiar, G.T. de Oliveira, R.B.A. Botelho, M. do D.F.P Ibiapina, H.C. de Lima, A.M. Costa, Use of baru (Brazilian almond) waste from physical extraction of oil to produce gluten free cakes, Plant Foods Hum. Nutr. 70 (2015) 50–55, https://doi.org/10.1007/s11130-014-0460-7.
[50] K.A. Caetano, J.M. Ceotto, A.P.B. Ribeiro, F.P.R. de Morais, R.A. Ferrari, M.T. B. Pacheco, C.D. Capitani, Effect of baru (Dipteryx alata Vog.) addition on the composition and nutritional quality of cookies, Food Sci. Technol. 37 (2017) 239–245, https://doi.org/10.1590/1678-457x.19616.
[51] M. Ahmad, W.N. Baba, T.A. Wani, A. Gani, A. Gani, U. Shah, S.M. Wani, F. A. Masoodi, Effect of green tea powder on thermal, rheological and functional properties of wheat flour and physical, nutraceutical and sensory analysis of cookies, J. Food Sci. Technol. 52 (2015) 5799–5807, https://doi.org/10.1007/s13197-014-1701-3.
[52] W. Cao, J. Chen, L. Li, G. Ren, X. Duan, Q. Zhou, M. Zhang, D. Gao, S. Zhang, X. Liu, Cookies fortified with Lonicera japonica thunb. Extracts: impact on phenolic acid content, antioxidant activity and physical properties, Molecules 27 (2022) 5033, https://doi.org/10.3390/molecules27155033.
[53] Z. Najjar, J. Kizhakkayil, H. Shakoor, C. Platat, C. Stathopoulos, M. Ranasinghe, Antioxidant potential of cookies formulated with date seed powder, Foods 11 (2022) 448, https://doi.org/10.3390/foods11030448.
[54] Â.A. Nunes, S.P. Favaro, C.H.B. Miranda, V.A. Neves, Preparation and characterization of baru (Dipteryx alata Vog) nut protein isolate and comparison of its physico-chemical properties with commercial animal and plant protein isolates, J. Sci. Food Agric. 97 (2017) 151–157, https://doi.org/10.1002/jsfa.7702.
[55] K.Q. Lau, M.R. Sabran, S.R. Shafie, Utilization of vegetable and fruit by-products as functional ingredient and food, Front. Nutr. 8 (2021), https://doi.org/10.3389/fnut.2021.661693.
[56] C. de Souza Paglarini, M. de Souza Queirós, S.S. Tuyama, A.C.V. Moreira, Y. K. Chang, C.J. Steel, Characterization of baru nut (Dipteryx alata Vog) flour and its application in reduced-fat cupcakes, J. Food Sci. Technol. 55 (2018) 164–172, https://doi.org/10.1007/s13197-017-2876-1.