Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.98522

Extraction and nutritional characterization of baru almond (*Dipteryx alata Vog.*) water-soluble extract

Herberth Diego Martins da SILVA[1], Fabrício Carrião dos SANTOS[1], Bruna Ribeiro Pontes de ANDRADE[1], Danielle Godinho de Araújo PERFEITO[1], Ana Paula Silva SIQUEIRA[1*]

Abstract

This study aimed to evaluate different techniques to obtain the baru water-soluble extract and characterize the most advantageous extract in the production stage. The first part of the experiment was carried out in a factorial scheme (3 × 2) for 24 h. The almonds were used under three physical conditions: A1) raw skin; A2) toast with film; and A3) toast without film, evaluated at two absorption temperatures (25 and 80 °C). The almonds were assessed regarding the percentage of water absorption and water absorption time. After weight stabilization, the extract was obtained and evaluated. The best treatment in this productive stage, considering technological aspects, was nutritionally evaluated in macronutrients and micronutrients. The baru water-soluble extract obtained showed characteristics similar to cow's milk in physical terms. Regarding macronutrients, about 90% of the product is water. The other 10%, in descending order of quantity, are lipids, proteins, carbohydrates, and mineral matter. The mineral composition that deserves to be highlighted in the extract is copper, iron, and zinc. Therefore, it is possible to obtain water-soluble baru extract with a good yield and good physical and nutritional aspects using roasted baru almonds without skin.

Keywords: Cerrado fruit; seed; plants extract; vegetarian food; beverage.

Practical Application: Improving the processing of water-soluble baru extract and providing data on its composition to the literature.

1. Introduction

Whether due to pathological causes or lifestyle changes, specific dietary needs have challenged the food and beverage industry to search for new ingredients and formulate products with a health claim. Therefore, this market has driven the use of vegetables mainly from the Amazon and Cerrado biomes, which have good nutritional composition and findings of satisfactory and diverse biological activity (Magalhães et al., 2020).

Typical of the Brazilian Cerrado, the baru almond is an example of a native Cerrado fruit with potential for agro-industrial use that stands out nutritionally for its high composition of mono and polyunsaturated fatty acids in addition to its high protein content (up to 30%) of good quality and digestibility and because it contains several minerals such as potassium, magnesium, iron, and phosphorus (Reis & Schmiele, 2019; Souza et al., 2019). The almond can be consumed fresh or roasted. It is from it that the baru oil is extracted, and it is the raw material for elaborating the water-soluble baru extract. As far as our knowledge goes, there is no indication in the scientific literature of commercial use of the water-soluble baru extract.

Plant extracts, such as the one mentioned above, are foods obtained from protein parts of vegetable species and water with an aqueous aspect, and the raw materials most used by the industry today are soy and coconut (Nishinari et al., 2018; Oliveira et al., 2016; Rahamat et al., 2019); alternatively, one can also mention the use of almonds, chestnuts, and oats. Several factors can influence the extraction process, such as the vegetable matter used, the processing method, solvent, extraction time, and temperature (Oliveira et al., 2016).

The use of the water-soluble extract from processing plant species in human food as "substitutes" for animal milk can be highlighted due to the absence of lactose. They are protein sources, have a pleasant taste, and are rich in nutrients (Oliveira et al., 2018). Given the above, this study aimed to evaluate different techniques for obtaining the water-soluble extract from baru almond under different physical conditions and characterize the one that stood out as the most advantageous in the production stage.

2. Material and methods

2.1. Obtaining the Raw Material

Baru fruits were collected in the vicinity of the IF Goiano, Urutaí Campus, Urutaí City, State of Goiás, Brazil (coordinates:

Received: 20 Sept., 2022
Accepted: 18 Apr., 2022
[1]*Instituto Federal Goiano, Urutaí, Goiás, Brazil.*
*Corresponding author: ana.siqueira@ifgoiano.edu.br

17°27'51.83" S and 48°12'12.51" W, and elevation of 779 m) and transported to the Post-Harvest of Fruits and Vegetables Laboratory on the Urutaí Campus; the almonds were extracted from the fruits using guillotine-type equipment. Based on the visual selection, broken, chipped, and physical imperfections considered unsuitable for fresh consumption and without apparent contamination were considered suitable for extract preparation. These almonds were dry cleaned with a soft bristle brush and submitted to the water absorption test.

2.2. Water absorption test and obtaining the water-soluble baru extract

The experiment was carried out in a completely randomized design (CRD) in a factorial scheme (3 × 2) for 24 h. The almonds differed physically in three ways: A1) raw with skin; A2) roasted with skin; and A3) roasted without skin, evaluated at two water absorption temperatures, 25 (room temperature) and 80 °C (the conventional temperature used in heat treatment of plant extracts). It is essential to point out that the raw almond was not evaluated without skin because removing it under these conditions is not feasible because it is firmly adhered to the nut. The roasting treatment (A2 and A3) of the almonds took place in an electric oven (Ford brand, model F-945) where they were exposed to heat for 40 min at a temperature of 100 °C. Later, a part of them went through the manual friction process to remove the film (A3).

For the water absorption test, 100 g of almonds were immersed in water at a ratio of 1:3 (one part almond to three parts water) in a 500-mL Becker flask; were weighed at an interval of 1 h, until constant weight (considered after stabilizing 4 decimal places). The entire experiment was performed in quintuplicate. To perform the water absorption test at a temperature of 80 °C, a water bath (Marconi brand, model MA156) was used. At 25 °C, the Becker flasks were kept in an acclimatized room at the indicated temperature.

Each becker was considered a sampling unit, so the almonds were drained every hour with the aid of a stainless-steel sieve, weighed on an analytical scale (WebLabor brand, model M254Ai), and relocated in the same becker.

2.3. Preparation and characterization of the water-soluble baru extract

After weight stabilization, the almonds were crushed with boiling mineral water (100 °C) in a blender (Arno brand, model NL-26 2V) at a ratio of 1:4 (one part almond to four parts water) for 5 min, according to the method proposed by D'Oliveira (2015). Then the liquid was filtered through a voile strainer.

The extract and residue weights were determined by weighing in an analytical balance (WebLabor brand, model M254Ai). The extract yield was calculated considering the weight of the baru almonds used and the weight of the final product obtained, subtracting the weight of water added during processing as described in Maia et al. (2006), using the Equation 1:

$$Yield = \frac{Extract\ weight - Weight\ of\ the\ added\ water}{Inicial\ weight\ of\ the\ alomond} \times 100\% \tag{1}$$

The nutritional composition of the extract was obtained from the amino acid profile determination performed by the HPLC technique according to a combination of the methodologies described by Hagen et al. (1989); Lucas and Sotelo (1980); and White et al. (1986). The lipid profile was determined by gas chromatography according to the Association of Analytical Chemists (2005), method 996.06.

Moisture and crude protein were obtained according to analytical methods 53 (loss on drying) and 45 (Dumas), respectively, both from the Brazilian Compendium of Animal Feed (2017). The ether extract was obtained by gravimetry according to the method 12-12-05 (solvent extraction) of the American Oil Chemists Society (AOCS, 2017). Carbohydrate was determined by the difference, including dietary fiber. The mineral matter was quantified by atomic absorption according to the Brazilian Compendium of Animal Feed (2017) method 40: calcium, magnesium, sodium, potassium, copper, iron, and zinc, whereas chromium was obtained by the same method (40) but 2013 methodology (Brazilian Compendium of Animal Feed, 2013). Phosphorus was determined by colorimetry according to the Association of Official Analytical Chemists (2019) method 965.17 and selenium by a combination of the methods of the Instituto Adolfo Lutz (2005) and the Association of Official Analytical Chemists (1984), also by atomic absorption. Density was performed according to the technique of the World Health Organization (2012) QAS/11450. Oxidative stability by ML Oxipres version 2009.02.01 methodology (European Union, 2009). Vitamin E was assessed according to AOAC (2005) CH 45. The determination of the instrumental color was carried out on a Minolta colorimeter, model CR-300, using the CIELAB system. In the CIELAB colorimetric space, defined by the L* coordinate, which corresponds to the luminosity, a* and b* refer to the green (-) / red (+) or blue (-) chromaticity coordinates/ yellow (+), respectively.

Considering the same methods for similar analyses, the residue generated in obtaining the extract, after being dehydrated in a stove at 85 °C to a constant weight, was physiochemically evaluated concerning its proximal composition and minerals.

2.4. Statistical analysis

To verify the difference between the treatments and the interaction between the factors, an analysis of variance (ANOVA) was performed. Afterward, Tukey's test was applied at the 5% probability level. To verify the difference between the temperatures, the Student's T-test was applied at the 5% probability level. The percentage of water absorption was presented in mean and standard deviation, as well as the composition of macronutrients, micronutrients, and lipid profiles.

3. Results

3.1. Conditions for obtaining the extract

From the results obtained (Table 1), it was noted that the different physical conditions of the almond and the temperature of the process were significant, and there is a significant interaction between both factors, treatment and temperature.

Table 1. Analysis of variance chart to compare mean water absorption in different treatments (roasted almond with skin, roasted almond without skin, and raw almond with skin) at room temperature (25 °C) or 80 °C.

Variation sources	Degrees of freedom (DF)	Sum of squares (SM)	Mean square (MS)	*F* value	*p>F*
Treatment (Treat.)	2	10,364.3174	5,182.1587	1,830.5315	<0.001
Temperature (Temp.)	1	991.3973	991.3973	350.1985	<0.001
Interaction Treat. vs. Temp.	2	4,571.6021	2,285.8010	807.4301	<0.001
Error	94	266.1101	2.8310		

After analyzing the effect of the treatments and temperature alone (Table 2), the one that stood out among the treatments in the percentage of water absorption was the raw almond with skin, with 68%. Between temperatures, 80°C promoted better water absorption conditions, around 60%. When combined, the highest average for water absorption was from the raw almond treatment with film at room temperature (CCA), approximately 76%. It was also observed that the temperature influence was reflected in the best water absorption percentages for the other treatments with roasted almonds.

It was observed from the analysis of the water absorption evolution over time that the maximum time needed for these almonds to absorb the maximum water limit under these experiment conditions was 16 h. The treatment that absorbed the greatest amount of water had the longest stabilization time (16 h) to reach the plateau (Figure 1). On the contrary, the treatment with a shorter stabilization time and greater water absorption proportional to time (Table 2 and Figure 1) was the roasted almond with a film at a temperature of 80 °C, which reached its stabilization point at 5 h. It is also observed that the higher absorption treatments at the beginning of the hydration process were those heated to 80 °C. The best treatment regarding water absorption percentage (CCA) took 11 h more to stabilize at 16% higher than the treatment of the roasted almond with a film at 80 °C (TCQ). The treatment involving unpeeled roasted almonds at 80 °C (TSQ) took only 1 h longer to stabilize hydration than the TCQ.

It is reported that the highest yield corresponded to the treatment with higher water absorption (CCA) proportional to time, as expected (Table 3). For this variable, the extracts of roasted almonds without skin at 80 °C were better than those with skin.

Therefore, the extract evaluated for nutritional composition was the TSQ. For this decision, the hydration time, yield, and visual aspects of the product were considered. The extract was visually clearer for this treatment.

3.2. Extract features

The baru extract was liquid with a density of 0.98 g/cm^3, a viscosity of 0.912 cp at 25 °C, pH of 6.44, a soluble solids content of 4 °Brix, coloration with average values for lightness of 61.12, and a* and b* parameters of 7.60 and 19.57, respectively. The oxidative stability measured was 537 days.

Regarding macronutrients, about 90% of the product is water (Table 4). The other 10%, in descending order of quantity, are lipids, proteins, carbohydrates (including fiber), and mineral matter.

Table 2. Mean and standard deviation of the percentage of water absorption in almonds after stabilization, in grams, submitted to the water absorption test in different treatments (roasted almond with skin, roasted almond without skin, and raw almond with skin) at room temperature or 80 °C*.

		n	Percentage (%)
Roasted almond without skin	Room	15	36.28±1.20^e
	80 °C	20	53.04±0.95^c
Roasted almond with skin	Room	15	48.83±2.11^d
	80 °C	15	63.79±1.96^b
Raw almond with skin	Room	15	75.56±2.24^a
	80 °C	20	62.92±1.50^b
TREATMENT EFFECT			
Roasted almond without skin		35	45.86±8.48^c
Roasted almond with skin		30	56.31±7.86^b
Raw almond with skin		35	68.33±6.60^a
TEMPERATURE EFFECT			
	Room	44	53.56±16.67^b
	80 °C	55	59.56±5.20^a

*Different lowercase letters in the same column and the same evaluative group indicate differences between treatments and interactions (treatment × temperature) by Tukey's test ($p<0.05$) and between temperatures by Student's t-test ($p<0.05$).

Regarding the amino acids characterizing the food protein composition, tryptophan (0.04%) was highlighted as the most important in this extract.

Regarding the lipid profile (Table 5), it can be highlighted that most of the fatty acids that make up the extract are mono- and polyunsaturated, with emphasis on the oleic (Omega 9) and linoleic (Omega 6) compositions and in the ω-6/ω-3 ratio of 117.

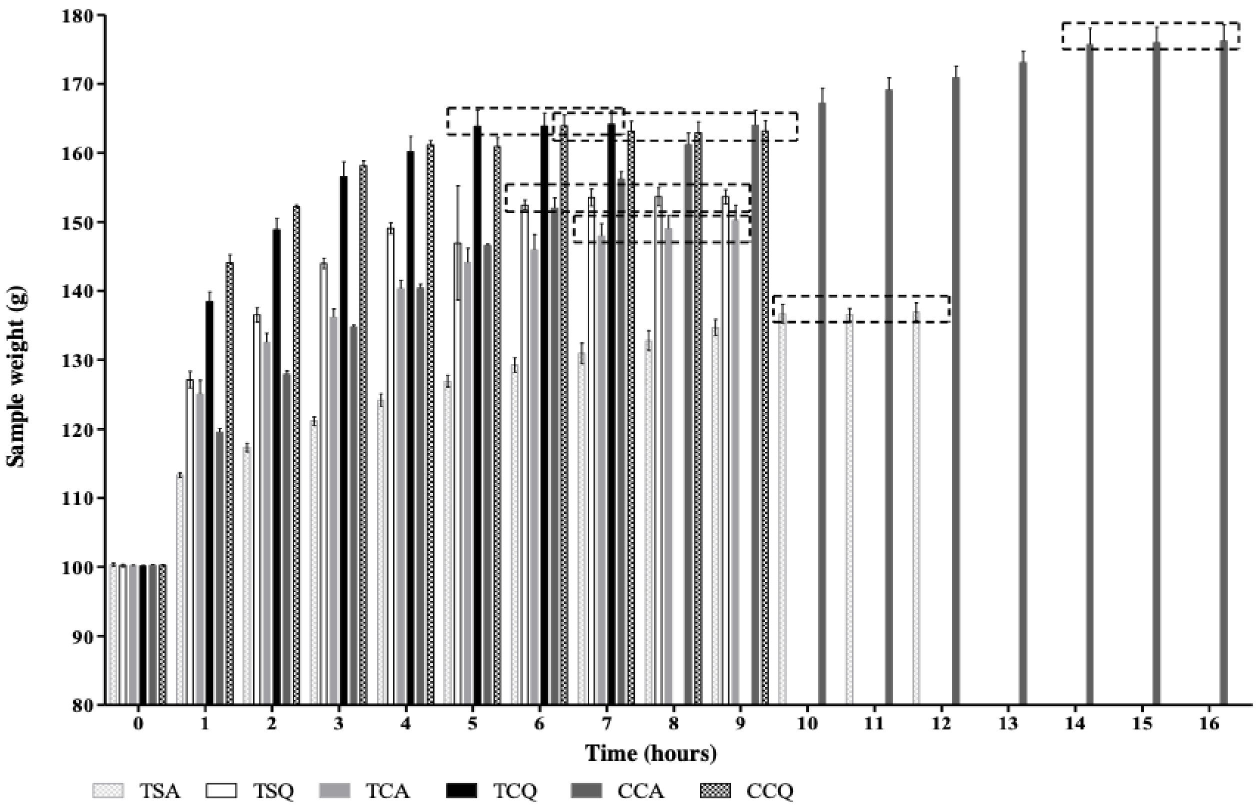
The mineral composition that deserves to be highlighted in the extract is copper, iron, and zinc (Table 6). Vitamin E is also present in high levels in this food.

3.3. Residue composition

When observing the results of macro- and micronutrients of the residue generated after obtaining the extract (Table 7), it is noted that the residue has a high protein and lipid content, in addition to mineral composition, in some cases even higher than that of the water-soluble extract.

4. Discussion

Given the conditions and procedures used to obtain the water-soluble extract, it is understood that, although the raw almond with skin has shown higher water absorption capacity,



TSA: roasted almond without skin assessed at room temperature; TSQ: roasted almond without skin assessed at 80 °C; TCA: roasted almond with skin assessed at room temperature; TCQ: roasted almond without skin assessed at 80 °C; CCA: raw almond without skin assessed at room temperature; CCQ: roasted almond without skin assessed at 80 °C; *the dotted lines on the graph refer to the stability of the hydration process.

Figure 1. Evolution of water absorption by the baru almond*.

Table 3. Mean and standard deviation of the percentage yield of baru almonds submitted to the water absorption test in different treatments (roasted almond with skin, roasted almond without skin, and raw almond with skin) at room temperature or 80 °C*.

		n	Percentage (%)
Roasted almond without skin	Room	5	20.10±6.30[bc]
	80 °C	5	24.91±6.29[b]
Roasted almond with skin	Room	5	22.84±3.56[b]
	80 °C	5	11.86±0.64[c]
Raw almond with skin	Room	5	35.75±3.97[a]
	80 °C	5	20.45±5.72[bc]
TREATMENT EFFECT			
Roasted almond without skin		10	22.51±6.46[b]
Roasted almond with skin		10	17.35±6.27[b]
Raw almond with skin		10	28.10±9.31[a]
TEMPERATURE EFFECT			
	Room	15	26.23±8.33[a]
	80 °C	15	19.07±7.23[b]

*Different lowercase letters in the same column and the same evaluative group indicate differences between treatments and interactions (treatment × temperature) by Tukey's test ($p<0.05$) and between temperatures by Student's t-test ($p<0.05$).

the time for stabilizing this absorption is too long. Therefore, due to the difference of 16% and the yield results obtained, it is believed that it is more feasible, from a technical point of view, to treat roasted almonds without skin at 80 °C. In addition to issues of absorption capacity, yield, and time, the literature has

Table 4. Macronutrients, mineral matter, and moisture of baru water-soluble extract.

Macronutrients (%)	Content
Raw protein	3.24
Carbohydrates (including fibers)	2.12
Ether extract	4.62
Mineral material (%)	0.24
Moisture and volatiles (%)	89.78%

Table 5. Lipid profile of the water-soluble extract of baru.

Lipid profile	(%)
Total monounsaturated fat	2.44
Total polyunsaturated fat	1.20
Total saturated fat	0.99
Specific composition	
Palmitic acid (C16:0)	0.34
Stearic acid (C18:0)	0.23
Oleic acid (C18:1)	2.31
Linoleic acid (C18:2)	1.17
Alpha linoleic acid (C18:3)	0.01
Arachidic acid (C20:0)	0.06
Behenic acid (C22:0)	0.17
Cis-11-Eicosenoic acid (C20:1)	0.12
Lignoceric acid (C24:2)	0.18

Table 6. Micronutrient profile of baru water-soluble extract.

Micronutrients	
Minerals	**Content**
Calcium (%)	0.01
Magnesium (%)	0.01
Sodium (%)	0.01
Potassium (%)	0.01
Copper (mg/kg)	2.87
Iron (mg/kg)	<8
Zinc (mg/kg)	5.30
Selenium (mg/kg)	<0.10
Phosphorous (%)	<0.05
Chromium (mg/kg)	<0.5
Vitamin	
Vitamin E (mg/kg)	138.93

Table 7. Macro- and micronutrient profile of the dry residue generated in obtaining the water-soluble baru extract.

Micronutrients	
Nutrients	**Content**
Protein (%)	30.08
Lipids (%)	18.13
Carbohydrates (%)	18.51
Ashes (%)	1.50
Iron (mg/100 g)	
Sodium (mg/100 g)	6.97
Zinc (mg/100 g)	4.84
Magnesium (mg/100 g)	24.19
Phosphorous (mg/100 g)	4720
Calcium (mg/100 g)	
Potassium (mg/100 g)	

already demonstrated the importance of roasting these almonds for issues of palatability and inactivation of antinutrients (Santos et al., 2012; Siqueira et al., 2015).

All treatments at which a temperature of 80 °C was used had a greater capacity for initial water absorption proportional to the immersion time and shorter stabilization times. This finding leads to considering the temperature effects on the water absorption kinetics, mainly by affecting its viscosity (Marcos-Filho, 2015), justifying the process to be potentialized for treatment at this temperature. Over time, it is believed that a probable gelatinization of the starch present in almonds paralyzes the water absorption process, as this process commonly starts at 59 °C (Choupina et al., 2018), which can be justified by the existing starch in the chestnut being hydrophilic in hot water.

The density and viscosity of extract demonstrate the physical state and fluidity of products, which is expected for a popular product known as "plant milk." Due to its lower saturated fat content than cow's milk, the water-soluble extracts' appearance is watery compared to animal milk. The light coloration allows us to infer that the product is accepted in the consumer's eyes, as it could easily be compared to a conventional dairy drink. This coloring also enables other products to flavor it or give color to new formulations without significant problems in finding the desired color nuances.

The value found in the extract for the soluble solids content (4 °Brix) and pH (6.44) is similar to that found by Carneiro et al. (2014) of 5 °Brix in a study carried out with water-soluble babassu extract at pH 6.64 to 6.80 and close to the Vieira (2017) study, which also evaluated baru extract, finding a pH of 6.67. These values suggest a sweet taste to the food, not acid, of course.

The water-soluble extract characteristics were similar to those of the raw material it was extracted from, which is a fact when comparing the composition of the extract obtained in this study (Table 4) with the almond described in the study by Reis & Schmiele (2019). Baru extract can be considered a source of protein, lipids, and minerals, like the almond itself. It should be noted that, as it is dependent on the raw material, this composition can vary depending on the conditions that affect the almond composition, such as climate, soil, and growing region.

According to the IOM (2006), the protein content that should be ingested per day for adult men and women aged 13–70 years varies from 34 to 56 g/day (an average of 45 g/day). Considering an average 200 mL serving of extract, this product would contribute about 14% of an individual's daily protein requirements. It is also worth considering that this protein is mainly composed of tryptophan, an amino acid considered essential and a precursor of serotonin in the body.

Regarding the lipid content and profile of the extract, especially unsaturated, it is worth considering that according to the IOM (2006), this profile is a great ally in the prevention of chronic non-communicable diseases, and the quality of the ω-6/ω-3 relationship should be observed, which is very positive for baru almond. According to Carrillo et al. (2012), oleic acid, also called omega-9 and in higher proportion in this extract, helps to control cell death and cancer cell proliferation, reducing cancer risk. On the contrary, linoleic acid (omega 6), belonging to a group of essential fatty acids, favors the decrease of low-density lipoproteins (LDL) and the risk of cardiovascular disease.

Regarding minerals, it is essential to emphasize that the sodium content of the extract is low. This fact is vital from a health point of view since there is a proven negative effect of excessive sodium intake on blood pressure (Reinaldo et al., 2017), one of the main non-communicable chronic diseases in Brazil. Tureck et al. (2017) draw attention in their study to the relevant micronutrients found in this extract, such as vitamin E, copper, and zinc, with antioxidant potential in the body, potentially reducing the free radicals' oxidation action thus preventing harmful effects. Vitamin E stands out in this study since the content found in the extract, if a 200-mL portion were consumed, would provide about 28 mg, a higher amount than that indicated for adults of both sexes per day. This high content of tocopherol (vitamin E) also reflects the high oxidative stability of the extract. Its antioxidant effect, already widely reported in the literature, allows that even this food, which has a high content of lipids in its matrix, does not readily oxidize.

The results obtained in the proximal composition of the water-soluble extract analyzed in this work are similar to those reported by D'Oliveira (2015) in his study, which also characterized the water-soluble extract from baru almonds and found moisture values of 85.89%, proteins of 3.87%, and lipids of 4.26%. By characterizing the water-soluble extract of babassu coconut, Carneiro et al. (2014) found values for moisture of up to 76.11%, proteins ranging from 2.45 to 2.7%, and lipids from 19.5 to 20.3%. When comparing the values found for the proximate composition of the water-soluble extract of baru almonds with the water-soluble soy extract, which is more widespread and widely consumed due to its high nutritional value and protein quality, it is possible to observe that both have considerable mineral values of 0.24 and 0.29%, respectively (Barros & Venturini Filho, 2016; Felberg et al., 2004; Uliana & Venturini Filho, 2010). The water-soluble extract of baru also proved to be rich in lipids (4.62%) when compared to the water-soluble extract of soybean, which has a fat content ranging from 1.30 to 2.03% (Barros & Venturini Filho, 2016; Felberg et al., 2004; Uliana & Venturini Filho, 2010), and broken rice and brown rice extracts with 0.41 and 0.59%, respectively (Carvalho et al., 2011).

The residue obtained from the production of the extract has a good nutritional composition, similar to that of the baru almond, highlighting protein content at the expense of lipids and a good mineral matter profile. It is essential to consider that the residue that has been dried influences the results of macro- and micronutrients that will be concentrated in this material.

The most advantageous method for obtaining the water-soluble baru extract, evaluating time, temperature, yield, and visual appearance, is the one in which the almond is roasted without a hydrated film at 80 °C. The physical characteristics of the extract are similar to those of other extracts of almonds or chestnuts. Their nutritional composition stands out for protein quality and content, lipid profile quality, and mineral and vitamin E content. Therefore, this product has agro-industrialization potential and can compete in the water-soluble extracts market with other almonds/chestnuts.

5. Conclusion

It is possible to obtain water-soluble baru extract with a good yield and good physical and nutritional aspects using roasted baru almonds without skin. The nutritional and physical characteristics of the material allow us to consider that it could be a good substitute for conventional dairy beverages in cases of restriction to dairy products or the option for nutritious vegetable beverages.

Funding

This study was supported by the Foundation for Research Support of Goiás State through the Public Call Notice Number 03/2015.

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