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Handmade savory crackers made with baru cake and oil (*Dipteryx alata Vog*)

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Abstract

The extraction of baru oil from almonds, generates the partially defatted cake. The use of this coproduct in bakery products reduces wastage of materials and nutrients, thereby improving nutritional aspects, and contributing to a sustainable environment. The aim of this study was to characterize the physico-chemical properties of crackers made with oil and partially defatted baru cake as partial substitutes for olive oil and wheat flour, respectively. The formulations presented interesting nutritional benefits to consumers, as they can be considered as a source of dietary fiber (13.58 g/100 g), magnesium (61.76 mg/30 g) and zinc (1.72 mg/30 g) and high in manganese (1.55 mg/30 g) and iron (4.56 mg/30 g) according to values established by Brazilian legislation, in addition, they have an interesting content of proteins (19.55 g/100 g) and lipids (19.24 g/100 g). The use of baru almond coproducts in savory crackers might be a good alternative to add nutrients that provide nutritional benefits to consumers.

Keywords: baru coproducts; sustainable development; cold oil extraction; residue reuse.

Practical Application: Baru cake increases lipids, protein, fibers, and minerals in crackers.

1 Introduction

Baru (*Dipteryx alata Vog.*) is an edible almond, native to the Brazilian savanna, belonging to the *Leguminosae family (Faboidae*). It is a drupoid, fibrous, ovoid fruit of brown color and soft texture that flowers from November to February and produces fruit from December (Alves-Santos et al., 2021; Pineli et al., 2015b; Silva et al., 2021).

Due to their high lipid content (32 to 46 g/100 g) (Alves-Santos et al., 2021), baru almonds are used for oil extraction (Cruz, 2010). The oil from baru almonds can be extracted by cold pressing the almonds, with or without prior roasting, resulting in the partially defatted almond cake (Cruz, 2010). Both the oil and the partially defatted baru cake (PDBC) are coproducts with commercial usability in food and, in the case of the partially defatted cake, have an interesting protein content (20 to 32 g/100 g) (Alves-Santos et al., 2021; Guimarães et al., 2012).

However, during the pressing process for oil extraction, the baru cake is usually discarded, even though this coproduct retains nutrients and bioactive compounds present in almonds (Pineli et al., 2015b). Thus, the use of PDBC in bakery products may be an important alternative for the productive sustainability of baru (Bento et al., 2014; Pineli et al., 2015a), for example, as a substitute for wheat in foods for people with celiac disease (Silva et al., 2019). The use of different industrial coproducts is interesting to promote nutritional improvements in bakery products, such as increasing the content of dietary fiber, bioactive compounds, and proteins (Martins et al., 2017; Siqueira et al., 2015).

In cereal-based bakery products, such as biscuits, the nutritional quality can be improved by adding ingredients such as oil and PDBC. Caetano et al. (2017) reported, in a sweet oatmeal cookie, that soybean oil was completely replaced by baru oil and wheat flour was partially replaced by defatted baru flour. The products had higher protein content, more fiber, lower calorie content, and significant concentrations of iron and fatty acids compared to the control cookie. The crackers could therefore have great potential to meet various special nutritional needs.

Thus, the aim of the present study was to characterize the physico-chemical and nutritional properties of handmade crackers made with baru oil as a partial substitute for olive oil and partially defatted baru cake as a partial substitute for whole meal flour.

2 Materials and methods

2.1 Extraction of the oil and the partially defatted baru cake

Roasted baru almonds were obtained from the Goiânia municipal market (Brazil) and subjected to cold oil extraction in an expeller press, with a processing capacity of 40 to 60 kg/h (ECIRTEC, MPE - 40, Bauru, Brazil) (ITAL, Campinas, Brazil), according to Caetano et al. (2017). The duration of each pressing was about 10 min. The oil was stored in amber vials and the partially defatted cake (PDBC) in hermetically sealed plastic containers at -20 °C. In Figure 1 we can see the almond, the PDBC and the baru oil.

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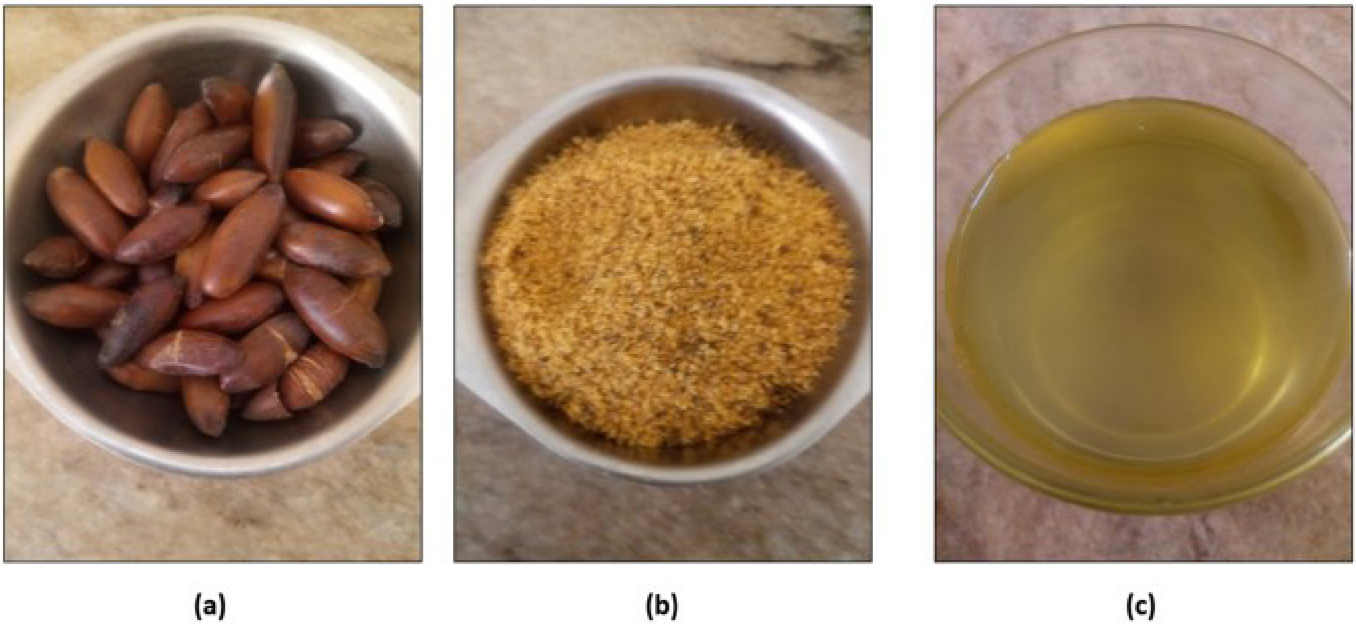

Figure 1. Baru almond (a); partially defatted baru cake (b); baru oil (c).

2.2 Handmade production of the savory baru crackers

The savory crackers were formulated using baru oil as a partial substitute for olive oil and PDBC as a partial substitute for whole wheat flour. Two formulations were developed, as described in Table 1. Except for the oil and PDBC, all ingredients used in the formulations were purchased from traditional markets in the city of Campinas (Brazil). The homemade crackers were prepared according to the American Association of Cereal Chemists, method 10-31.03 (American Association of Cereal Chemists, 2000). The ingredients were mixed, and the dough was cut into slices 6 cm in diameter and 2 mm thick and baked at 180° C for 30 min in a conventional oven (Clarice Brand, Delicato, Pinhalzinho, Brazil). They were then cooled to room temperature (20 ºC ± 3), packed in airtight low-density polyethylene (LDPE) bags containing approximately 50 g of crackers, and protected from light at room temperature (20 ºC ± 3) and relative humidity of 57% ± 11 for 24 h (1 day) and 360 h (15 days). Determination of percentages and mineral composition was performed after 24 h. Determination of the breaking force, color, and whiteness index was carried out after 24 and 360 h of storage.

Table 1. Savory cracker formulations containing oil and partially defatted baru cake (PDBC).

Ingredients	Baru Crackers	
	Formulation 1-F1 (g)	Formulation 2-F2 (g)
Whole wheat flour	48	12
PDBC	12	48
Baru oil	5.6	11.9
Extra virgin olive oil	8.4	2.1
Water	24	24
Oatmeal	14	14
Salt	1	1
Oregano	1	1
Baking powder	1	1
Total (g)	**100**	**100**

2.3 Characterization of the oil and the partially defatted baru cake

Centesimal composition

Determination of the centesimal composition of the PDBC was carried out according to the methods of the Association of Official Analytical Chemists (Association of Official Analytical Chemists, 2005) and the values were expressed on a dry basis. Moisture content (Method 935.29), protein content by the micro-Kjeldahl method N x 6.25 (method 920.87), and ash content (method 923.03) were analyzed in triplicate. Lipid content was determined by the Soxhlet method (method 920.85) with ethyl ether. Total dietary fiber content was determined using the enzymatic-gravimetric method of Prosky et al. (1984). Carbohydrate content was calculated from the difference between 100 (total percentage) and the sum of the percentages for moisture, ash, protein content, dietary fiber, and fat. Caloric value (CV) was expressed in kilocalories (kcal) using Atwater's conversion factors (Watt & Merril, 1963) according to Equation 1:

$$CV\left(kcal.100\,g^{-1}\right)=\left(g\ protein\times4\right)+\left(g\ lipids\times9\right)+\left(g\ carbohydrates\times4\right) \quad (1)$$

Mineral composition

The mineral composition of PDBC was determined by elemental microanalysis using scanning electron microscopy (SEM) (Hitachi Tabletop Microscope, TM 3000, Tokyo, Japan) and an Energy Dispersive System (EDS) (Hitachi, Swift ED3000, Tokyo, Japan) following the method of Goldstein et al. (1992).

Fatty acid profile of baru oil

The fatty acid profile of baru oil was analyzed using a capillary gas chromatograph (Agilent, 6850 Series GC System, U.S.A.) after esterification (Hartman & Lago, 1973). The methyl esters of the fatty acids were separated according to the American Oil Chemists' Society (American Oil Chemists' Society, 2009) method using an Agilent DB-23 capillary column (50% cyanopropyl methyl polysiloxane) with dimensions of 60 m, Ø int: 0.25 mm, 0.25 µm film. The operating conditions of the chromatograph were as follows: column flow 1.00 mL/min; linear velocity 24 cm/sec; detector temperature 280 °C; injector temperature 250 °C; furnace temperature 110 °C; C-5 min 110-215 °C (5 °C/min), 215 °C-24 min. Helium was used as the carrier gas, and an aliquot of 1 µL of the samples was injected into the instrument. The fatty acids were determined by comparing the peak retention times with the respective fatty acid standards.

2.4 Savory cracker characterization

Centesimal and mineral composition

The analyses were carried out according to the methods described in items Centesimal composition and Mineral composition. The percentages in relation to the recommended daily value (%DV) was calculated from the proportion that the product represents in relation to the table of recommended dietary allowance values (RDA) for the purposes of nutrition labelling of foods presented in Normative Instruction (Annex II) n° 75 from 8th October 2020 (Brasil, 2020).

Determination of breaking force

The breaking force was determined using a texturometer (Stable Micro Systems, TA.XT2, Godalming, England) and according to Moraes et al. (2010). The individual cracker samples were placed on a flat platform supported on the central axis and broken from the center. Breaking was performed with a rectangular Warner-Bratzler steel blade (dimensions: 12 × 7 cm) placed 15 mm from the sample and moving at a speed of 2 mm.s^{-1}. Seven random replicates were performed for each cracker. The results were expressed in N (Newton) and the value recorded was the highest peak force.

Color determination

The color was determined according to the conditions described by Morales & Jiménez-Pérez (2001) in the Colorimeter (Hunter Lab, Color Quest II -Sphere, Reston USA) using the CIEL*a*b* system, where the lightness values (L*) range from zero (black) to 100 (white), and the chromaticity coordinates a* and b*, range from -a* (green) to +a* (red), and from -b* (blue) to +b* (yellow) respectively.

Whiteness index

The Whiteness Index (WI) was calculated using Equation 2 (Lohman & Hartel, 1994).

$$WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{0.5} \quad (2)$$

WI = Whiteness Index; L* = lightness values, a* and b* = chromaticity coordinates.

2.5 Statistical analysis

All determinations were done at least in triplicate. The data were compared using the t-test with statistical significance (α) set at $p < 0.05$, using SAS 9.0 software.

3 Results and discussion

3.1 Physico-chemical properties of oil and partially defatted baru cake

The PDBC had a protein content of approximately 18% (17.87 g/100 g) (Table 2), which makes it a good raw material to replace wheat flour with a protein content of 12% (10.7 g/100 g) (Brazilian table of food composition - TBCA, 2020) in the production of savory crackers. This protein content was similar to that of the partially defatted baru almond flour obtained by Siqueira et al. (2015). As the cake has a high lipid content of 46% (Table 2), it could be used to make "buttery" cookies that use high concentrations of lipids in their formulation (Novaes et al., 2015). The fiber content (9%) of PDBC could expand the range of high-fiber savory crackers, for both healthy consumers and those suffering from certain diseases (constipation, high cholesterol, obesity, and other conditions).

PDBC has a high concentration of minerals, especially potassium, calcium, magnesium, and phosphorus (Table 2). This mineral composition was similar to the results obtained in the partially defatted baru flours characterized by Pineli et al. (2015b) and Siqueira et al. (2015).

The oil obtained from the toasted baru almonds had a high concentration of unsaturated fatty acids (78.46%), with a high concentration of oleic acid (MUFA) and linoleic acid (PUFA) (Table 3). The oil had a low concentration of saturated fatty acids (SFA) (20.86%). In addition, a higher ω-6 : ω-3 ratio was observed. Since a ratio of 5 : 1 (ω-6 : ω-3) is recommended (Institute o Medicine, 2005), this ω-6 : ω-3 ratio in baru almond oil is of great significance.

The fatty acid composition of the roasted baru almonds purchased in the Goiânia, GO, Brazil, urban market was similar

Table 2. Chemical and mineral composition of Partially Defatted Baru Cake (PDBC).

Nutrients	(g/100 g[a])	Minerals	(mg/100 g[a])
Lipids	46.12 ± 0.05	K	246.66 ± 28.46
Proteins	17.87 ± 0.30	Ca	222.44 ± 19.22
Total dietary fiber	9.05 ± 0.45	Mg	164.47 ± 14.89
Moisture	5.41 ± 0.03	P	108.28 ± 8.55
Ash	3.54 ± 0.04	Fe	19.37 ± 8.16
Carbohydrates	18.01	Zn	6.30 ± 5.92
Total energy value (kcal)	522.40	Mn	3.12 ± 4.09
		Cu	1.22 ± 1.18

[a]Values expressed on a dry basis.

to that of the unroasted almonds used by our research group to prepare oatmeal cookies (Caetano et al., 2017). Thus, the roasting process used by the Brazilian industry that supplied the product did not significantly alter the fatty acid composition of the baru. Lemos et al. (2016) also observed that the roasting process at 150 °C for 45 min did not alter the fatty acid composition of baru almonds. Therefore, the baking (180 °C during 30 min) used in the preparation of the savory crackers should not significantly alter the fatty acid composition shown in Table 3. The savory crackers made with this oil are thus rich in unsaturated fatty acids, which should prevent the development of metabolic diseases, such as type 2 diabetes mellitus, and reduce cardiovascular events (Billingsley et al., 2018).

3.2 Physico-chemical properties of the savory baru crackers

Centesimal composition and recommended daily value of the savory baru crackers

The baru crackers had high lipid content in their composition: F1 contained 19.24 g/100 g and F2 contained 25.33 g/100 g (Table 4). These values are slightly higher than the average value found in the similar savory cracker commonly consumed, which contain 13.7 g/100 g on average (Brazilian table of food composition - TBCA, 2020). However, Formulations 1 and 2 contain 12.98% and 17.07% respectively (Table 4) of the daily recommendation for lipids, so the lipid content of the crackers, if consumed in moderation and as part of a healthy diet, would not pose a health risk.

Table 3. Fatty acid profile from baru oil (g/100 g).

Fatty acids	g/100 g
C18:1 (oleic) – ω9	45.78 ± 0.06
C18:2 (linoleic) – ω6	29.74 ± 0.04
C16:0 (palmitic)	6.71 ± 0.04
C24:0 (lignoceric)	5.14 ± 0.02
C18:0 (stearic)	4.23 ± 0.03
C22:0 (behenic)	3.68 ± 0.00
C20:1(elaidic/gadoleic)	2.79 ± 0.01
C20:0 (arachidonic)	1.10 ± 0.01
C18:3 (linoleic) – ω3	0.15 ± 0.01
Humidity (%)	0.04 ± 0.00
Acid value (%)	0.17 ± 0.01
Peroxide value ($mEq.kg^{-1}$)	6.16 ± 0.04

The lipid content of the savory baru crackers increased with increasing oil and PDBC in the formulations (Tables 1 and 3). Similar results in terms of increases in oil in the formulation, were observed by Chaves et al. (2013) for whole grain cookies prepared with flour and oil from avocado pulp. However, in that study it was found that the lipid content did not increase with increasing addition of avocado flour, which could also be investigated in our study, as F2 also has higher flour replacement by PDBC, and it is difficult to evaluate the effects of the oil and cake separately.

In terms of protein content, the crackers had 16.24 g/100 g protein in F1 and 19.55 g/100 g in F2, values higher than those of cookies prepared with a partial replacement of wheat flour with defatted sesame flour, where a 10% replacement resulted in 10.88 g/100 g protein (Clerici et al., 2013).

When we compared the results with biscuits containing no wheat flour and designed for people with celiac disease (Freitas et al., 2014), we found that replacing 10% starch with pumpkin seed flour or baru seed flour resulted in protein contents of 3.92 g/100 g and 3.63 g/100 g, respectively, which were lower than those found in our study. Although the two studies cited had lower protein levels compared to our results, they achieved higher protein levels compared to their respective controls, showing that the use of these coproducts is a good alternative for nutrient fortification.

The total dietary fiber content of the two cracker formulations (Table 4) allows them to be classified as foods as a source of dietary fiber, as they contain more than 10% of the DV for dietary fiber per reference serving (Brasil, 2020). Thus, it is noted that daily consumption of one serving of the F1 savory cracker would provide the consumer with 13.56% (Table 4) of the daily recommendation for dietary fiber, while consumption of one serving of F2 would provide 16.28% (Table 4) of the daily dietary fiber recommendation. Freitas et al. (2014) and Alves et al. (2010) concluded that the use of baru cake and baru pulp in biscuits significantly increases the concentration of dietary fiber in the products, with good sensory acceptability. Pineli et al. (2015a), developed a cake in which 100% of the wheat flour was replaced with partially defatted baru cake and obtained a product rich in

Table 4. Chemical composition of 100 g of savory baru crackers, of a portion (30 g), and respective daily nutrient values.

Nutrients	Baru crackers (g/100 g)		Nutritional value per cracker portion (g/30 g)[a] Formulations		Percentage in relation to the recommended daily value (%DV)[b]	
	F1	F2	F1	F2	F1	F2
Lipids	19.24 ± 0.50*	25.33 ± 0.60	5.77	7.59	12.98	17.07
Proteins	16.24 ± 0.44	19.55 ± 0.20*	4.87	5.86	6.49	7.81
Total dietary fiber	11.32 ± 0.45	13.58 ± 0.50*	3.39	4.07	13.56	16.28
Moisture	13.66 ± 0.02*	12.08 ± 0.05	4.09	3.62	-	-
Ash	5.19 ± 0.03*	3.65 ± 0.04	1.55	1.09	-	-
Carbohydrates	34.35	25.81	10.30	7.74	3.16	2.38
Energy (kcal)	285.52	355.09	85.65	106.52	4.28	5.32

[a]Values expressed on a dry basis. [b]Brasil, 2020. *Values differ at $p < 0.05$ according to t-test . Results were expressed as average (± SD) (n = 3).

dietary fiber with a high concentration of phenolic compounds, flavonoids, and proteins. The high concentration of dietary fiber from the addition of baru flour can be attributed to its baru almond skin content (Pineli et al., 2015b).

Mineral composition of the savory baru crackers

According to Brazilian legislation (Brasil, 2020), our crackers can be considered as rich in manganese (Mn) and iron (Fe), as they contain more than 30% of the DV per serving (Table 5), and as a source of magnesium (Mg) (F2) and zinc (Zn), as they contain more than 15% of the DV per serving (Table 5). Minerals are important for the development of the individual and their analysis is of great importance for the overall health of the individual (Cozzolino, 2007).

Manganese acts in immune function, blood sugar regulation, cellular energy, reproduction, digestion, bone growth, blood clotting, and defense against reactive oxygen species (Aschner & Erikson, 2017). Eating one serving of F1 per day would provide a person with 67.39% of the daily Mn recommendations, while one serving of F2 would provide 64.78%. The maximum Tolerable Upper Intake Level (UL) recommended for manganese is 11 mg per day (Ross et al., 2011). This means that a serving of Formulation 1 would reach 23.64% and a serving of Formulation 2 would reach 27.63% of the safe intake limit for manganese, showing that the amount of the mineral in one serving (30 g), although high, does not pose a risk to human health.

Anemia is the most common form of nutritional deficiency, occurring in both developed and developing countries (Rodrigues et al., 2011). Therefore, the production of crackers with a high content of this important mineral is interesting. The iron levels found in our crackers (Table 5) are close to those found in crackers made with added iron and with almond flour (2.73 mg/100 g Fe) and peanut flour (3.19 mg/100 g Fe) (Granato et al., 2009).

Table 5. Mineral compositions and percentages in relation to the recommended daily value of savory baru crackers.

Nutrients	Nutritional value per cracker portion (mg/30 g)		Percentage in relation to the recommended daily value (%DV)[a]	
	Formulations			
	F1	F2	F1	F2
Mn	1.55 ± 0.39	1.49 ± 0.37	67.39	64.78
Fe	3.78 ± 0.95	4.56 ± 1.14	47.25	57.00
Mg	57.49 ± 4.37	61.76 ± 5.44	14.37	15.44
Zn	1.77 ± 0.44	1.72 ± 0.43	16.09	15.63
P	89.57 ± 2.39*	73.27 ± 8.32	12.79	10.46
Ca	67.36 ± 6.84	71.18 ± 7.8	6.73	7.11
Na	70.24 ± 7.56	69.62 ± 7.41	4.68	4.64
Cu	0.03 ± 0.0075	0.04 ± 0.01	3.33	4.40
K	10.26 ± 2.57	16.36 ± 4.09	0.21	0.34

[a]Brasil, 2020. *Significant difference between the means by t-test ($p < 0.05$). Results were expressed as average (± SD) (n = 3).

It can be observed that iron is a mineral that stands out in both cracker formulations (Table 5). Consuming one serving of F1 per day would provide the consumer with 47.25% of the daily iron recommendations. One serving of F2 would provide 57% of the daily iron recommendations. However, further studies should be conducted to analyze the bioavailability of this mineral when consuming the crackers with baru coproducts.

Zinc deficiency can lead to alopecia, weight loss, diarrhea, immune disorders, healing problems, and ulcers (Muhamed & Steen, 2014). The savory baru crackers had higher zinc levels (Table 5) than in the study by Granato et al. (2009), where the cookie with almond flour contained 0.134 mg/100 g and the cookie with peanut flour contained 0.153 mg/100 g. However, the intake of this mineral may affect the bioavailability of iron as it is present in greater amounts in the cookies, an effect that could also be opposite if the zinc is present in lesser amounts than the iron (Cozzolino, 1997).

Magnesium is required for DNA and RNA synthesis and is important for the regulation of muscle contraction, blood pressure, insulin metabolism, cardiac excitability, and neurotransmission (Gröber et al., 2015). F1 had lower magnesium levels (Table 5) than those reported by Granato et al. (2009) for cookies made from almond and peanut flours (134.20 mg/30 g and 106 mg/30 g, respectively). Nevertheless, our Formulation 2 contains 15.44% of the DV and can be considered a source of magnesium.

Breaking force (N) of the baru cracker

The savory baru crackers had low values for breaking force which is almost certainly due to the high content of baru oil in the two formulations (Figure 2). The values found were similar to those reported for biscuits made with partial replacement of wheat flour with defatted sesame flour (Clerici et al., 2013). In the work of Drakos et al. (2019), replacing 30-40% of wheat flour with rye and barley flour in cookies resulted in values around 20N, which were higher than ours, possibly due to the lower lipid content of the raw material used.

In the study by Pineli et al. (2015b), there was no difference in the fracturability (breaking force) of cookies with up to 50 g/100 g substitution with partially defatted baru flour. However, higher substitutions led to an increase in this variable, with the results attributed to higher protein and fiber contents, while also considering the reduction in starch due to the replacement of wheat flour and reduction in the oil content of the lower substitution formulations.

After 15 days of storage, the breaking force of the cookies increased significantly (Table 6), probably due to the high fiber content in the formulation.

Color and whiteness index of the baru crackers

Regarding the color of the crackers it was found that the F1, that is, with a lower concentration of baru derivatives, had a higher L*, while the F2 with a higher content of baru coproducts had a darker color (Figure 2), which may be related to the caramelization associated with the Mailard reaction (Morales & Jiménez-Pérez, 2001). The luminosity (L*) tended to decrease, i.e. the biscuits became darker the more wheat flour was replaced by the partially defatted baru cake (Figure 3). Increasing the proportion of baru coproducts in the crackers reduced the intensity of the yellow color of the biscuits.

On the other hand, the parameters color and whiteness index did not change as a function of the 15-day storage period, suggesting that these formulations are stable regarding these properties (Table 6).

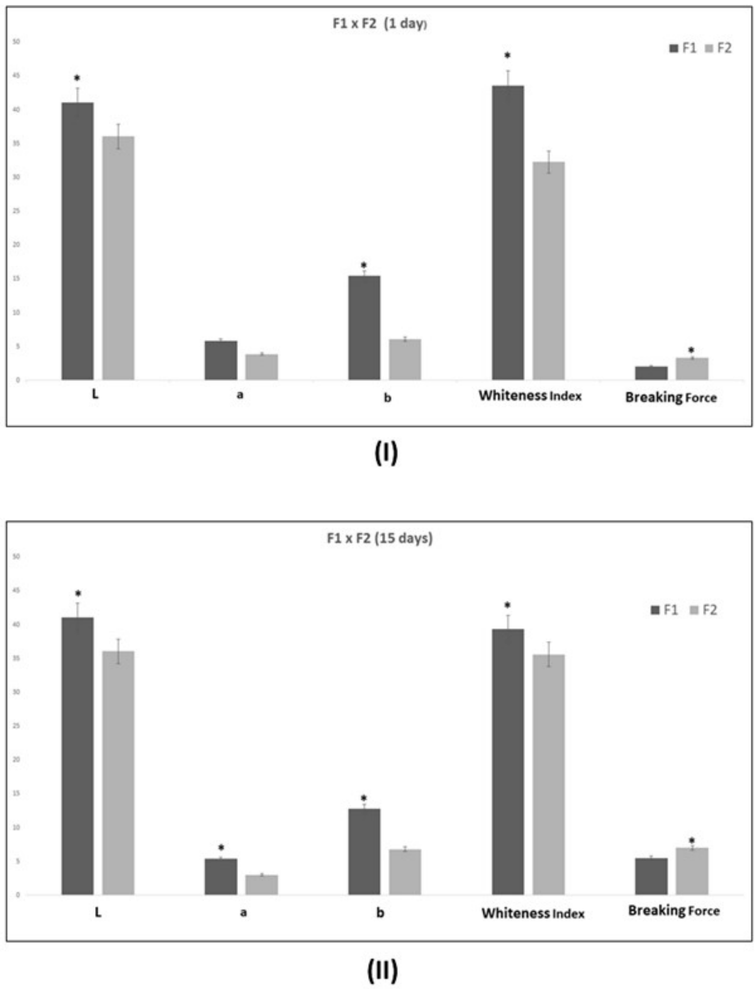

Figure 2. Effect of storage time on color parameter, whiteness index and breaking force comparing F1 and F2. F1 and F2 on day 1 (I); F1 and F2 on day 15 (II). In each bar, "*" means significantly differences between color parameters ($p < 0.05$) according to the t-test.

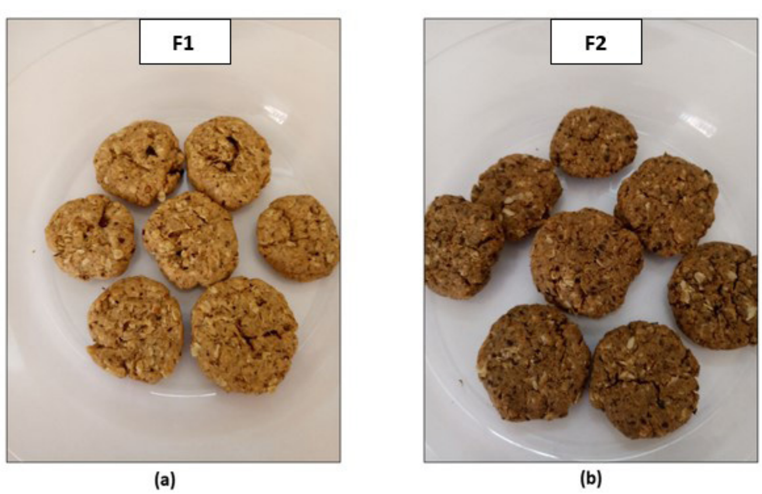

Figure 3. Baru crackers a: Formulation 1; and b: Formulation 2.

Table 6. Effect of storage time on the color parameters, whiteness index and breaking force of two savory baru crackers formulations.

Parameters	Formulation 1		Formulation 2	
	1 day	15 days	1 day	15 days
L[1]	46.05 ± 1.84*	41.09 ± 2.67	32.85 ± 1.92	36.08 ± 2.44
a[2]	5.80 ± 1.09*	5.39 ± 1.20	3.89 ± 0.81*	3.03 ± 0.68
b[2]	15.42 ± 0.89	12.83 ± 2.37	6.05 ± 5.15	6.81 ± 1.99
Whiteness Index	43.57 ± 1.82*	39.39 ± 2.20	32.29 ± 2.02	35.61 ± 2.41*
Breaking Force	2.05 ± 0.52	5.52 ± 0.59*	3.32 ± 0.59	7.01 ± 0.54*

[1]Lightness. [2]Cromaticity coordinates. *Significant difference between the means by paired t-test ($p < 0.05$) using F1 and F2 in separated. Results were expressed as average (± SD) (n = 3).

4 Conclusions

The partially defatted baru cake and oil showed interesting nutritional results, such as high content of unsaturated fatty acids, protein, and fiber. The crackers produced with these coproducts offer interesting nutritional benefits to the consumer, such as high fiber and mineral content with moderate consumption due to the high lipid content. The physical properties (color parameters, whiteness index, and breaking force) of the crackers did not show significant changes after 15 days of storage. The use of the coproducts of the baru almond, such as the oil and the baru cake, in the artisanal production of savory crackers favors the use of Brazilian regional products and represents an important value for the sustainable development of Brazil's indigenous areas.

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References

Alves, A. M., Mendonça, A. L., Caliari, M., & Cardoso-Santiago, R. A. (2010). Avaliação química e física de componentes do baru (Dipteryx alata Vog.) para estudo da vida de prateleira. *Pesquisa Agropecuária Tropical*, 40(3), 266-273.

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

American Association of Cereal Chemists – AAAC. (2000). *Approved methods of the American Association of Cereal Chemists*. Eagan: AAAC.

American Oil Chemists' Society – AOCS. (2009). *Official methods and recommended practices of the American Oil Chemists' Society* (5th ed.). Urbana: AOCS.

Aschner, M., & Erikson, K. (2017). Manganese. *Advances in Nutrition*, 8(3), 520-521. http://dx.doi.org/10.3945/an.117.015305. PMid:28507016.

Association of Official Analytical Chemists – AOAC. (2005). *Official methods of analysis of AOAC International* (18th ed.). Rockville: AOAC.

Bento, A. P. N., Cominetti, C., Simões, A. Fo., & Naves, M. M. V. (2014). Baru almond improves lipid profile in mildly hypercholesterolemic subjects: a randomized, controlled, crossover study. *Nutrition, Metabolism, and Cardiovascular Diseases*, 24(12), 1330-1336. http://dx.doi.org/10.1016/j.numecd.2014.07.002. PMid:25149894.

Billingsley, H. E., Carbone, S., & Lavie, C. J. (2018). Dietary fats and chronic noncommunicable diseases. *Nutrients*, 10(10), 1385. http://dx.doi.org/10.3390/nu10101385. PMid:30274325.

Brasil, Agência Nacional de Vigilância Sanitária – ANVISA. (2020, October 9). *Estabelece os requisitos técnicos para declaração da rotulagem nutricional nos alimentos embalados. Instrução Normativa n° 75, de 8 de outubro de 2020. Diário Oficial da República Federativa do Brasil*, seção 1.

Caetano, K. A., Ceotto, J. M., Ribeiro, A. P. B., Morais, F. P. R., Ferrari, R. A., Pacheco, M. T. B., & Capitani, C. D. (2017). Effect of baru (Dipteryx alata Vog.) addition on the composition and nutritional quality of cookies. *Food Science and Technology*, 37(2), 239-245. http://dx.doi.org/10.1590/1678-457x.19616.

Chaves, M. A., Mendonça, C. R. B., Borges, C. D., & Porcu, O. M. (2013). Elaboração de biscoito integral utilizando óleo e farinha da polpa de abacate. *Boletim do CEPPA*, 31(2), 215-226. http://dx.doi.org/10.5380/cep.v31i2.34844.

Clerici, M. T. P. S., Oliveira, M. E., & Nabeshima, E. H. (2013). Qualidade física, química e sensorial de biscoitos tipo cookies elaborados com a substituição parcial da farinha de trigo por farinha desengordurada de gergelim. *Brazilian Journal of Food Technology*, 16(2), 139-146. http://dx.doi.org/10.1590/S1981-67232013005000017.

Cozzolino, S. M. (2007). Mineral deficiencies. *Estudos Avançados*, 21(60), 119-126. http://dx.doi.org/10.1590/S0103-40142007000200009.

Cozzolino, S. M. F. (1997). Biodisponibilidade de minerais. *Revista de Nutrição*, 10(2), 87-98. http://dx.doi.org/10.1590/S1415-52731997000200001.

Cruz, K. S. (2010). *Isolamento, fracionamento e caracterização parcial das proteínas de amêndoas de Baru (Dipteryx alata Vog.)* (Master's thesis). Universidade Estadual Paulista "Júlio de Mesquita Filho", Araraquara.

Drakos, A., Andrioti-Petropoulou, L., Evageliou, V., & Mandala, I. (2019). Physical and textural properties of biscuits containing jet milled rye and barley flour. *Journal of Food Science and Technology*, 56(1), 367-375. http://dx.doi.org/10.1007/s13197-018-3497-z. PMid:30728579.

Freitas, C. D. J., Valente, D. R., & Cruz, S. P. (2014). Physical, chemical and sensory characteristics of cookies made of pumpkin seed flour (PSF) and baru seed flour (BSF) for celiac disease. *DEMETRA: Food, Nutrition & Health*, 9(4), 1003-1018.

Goldstein, J. I., Newbury, D. E., Echlin, P., Joy, D. C., Romig, A. D., Lyman, C. E., Fiori, C., & Lifshin, E. (1992). *Scanning electron microscopy and x-ray microanalysis: a text for biologists, materials scientists, and geologists* (2nd ed.). New York: Springer. http://dx.doi.org/10.1007/978-1-4613-0491-3.

Granato, D., Boas, F. V., Piekarski, W., & Ribani, R. H. (2009). Composição mineral de biscoitos elaborados a partir de farinhas de amêndoa ou amendoim adicionadas de ferro. *Pesquisa Agropecuária Tropical*, 39(2), 92-97.

Gröber, U., Schmidt, J., & Kisters, K. (2015). Magnesium in prevention and therapy. *Nutrients*, 7(9), 8199-8226. http://dx.doi.org/10.3390/nu7095388. PMid:26404370.

Guimarães, R. C. A., Favaro, S. P., Viana, A. C. A., Braga, J. A. No., Neves, V. A., & Honer, M. R. (2012). Estudo das proteínas da farinha desengordurada e concentrado protéico de castanhas de baru (Dipteryx alata Vog). *Food Science and Technology*, 32(3), 464-470. http://dx.doi.org/10.1590/S0101-20612012005000065.

Hartman, L., & Lago, R. C. (1973). Rapid preparation of fatty acid methyl esters from lipids. *Laboratory Practice*. 22(6), 475-476.

Lemos, M., Zambiazi, R., Almeida, E., & Alencar, E. (2016). Tocopherols and fatty acid profile in baru nuts (Dipteryx Alata Vog.), raw and roasted: important sources in nature that can prevent diseases. *Food Science and Nutrition Technology*, 1(2), 2-11. http://dx.doi.org/10.23880/FSNT-16000107.

Lohman, M., & Hartel, R. (1994). Effect of milk fat fractions on fat bloom in dark chocolate. *Journal of the American Oil Chemists' Society*, 71(3), 267-276. http://dx.doi.org/10.1007/BF02638052.

Martins, Z. E., Pinho, O., & Ferreira, I. M. P. L. V. O. (2017). Food industry by-products used as functional ingredients of bakery products. *Trends in Food Science and Technology*, vol. 67, pp. 106-128. http://dx.doi.org/10.1016/j.tifs.2017.07.003

Moraes, K. S., Zavareza, E. R., Miranda, M. Z., & Salas-Mellado, M. M. (2010). Avaliação tecnológica de biscoitos tipo cookie com variações nos teores de lipídio e de açúcar. *Food Science and Technology*, 30(suppl. 1), 233-242. http://dx.doi.org/10.1590/S0101-20612010000500036.

Morales, F. J., & Jiménez-Pérez, S. (2001). Free radical scavenging capacity of Maillard reaction products as related to colour and fluorescence. *Food Chemistry*, 72(1), 119-125. http://dx.doi.org/10.1016/S0308-8146(00)00239-9.

Muhamed, P. K., & Steen, V. (2014). Zink er vores vigtigste spormetal. *Ugeskr Læger*, 176(5), 431-433. PMid:25096007.

Novaes, M. D. S., Oliveira, A. P., Hernandes, T., Rodrigues, E. C., Sigarini, K. S., Pedro, F. G. G., & Villa, R. D. (2015). Composição proximal e mineral de biscoitos tipo amanteigado enriquecidos com diferentes farinhas de casca de frutas. *Revista do Instituto Adolfo Lutz*, 74(4), 390-398.

Pineli, L. L. O., Aguiar, L. A., Oliveira, G. T., Botelho, R. B. A., Ferreira, M. D., Ibiapina, P., Lima, H. C., & Costa, A. M. (2015a). Use of baru (Brazilian almond) waste from physical extraction of oil to produce gluten free cakes. *Plant Foods for Human Nutrition*, 70(1), 50-55. http://dx.doi.org/10.1007/s11130-014-0460-7. PMid:25577329.

Pineli, L. L. O., Carvalho, M. V., Aguiar, L. A., Oliveira, G. T., Celestino, S. M. C., Botelho, R. B. A., & Chiarello, M. D. (2015b). Use of baru (Brazilian almond) waste from physical extraction of oil to produce flour and cookies. *Lebensmittel-Wissenschaft + Technologie*, 60(1), 50-55. http://dx.doi.org/10.1016/j.lwt.2014.09.035.

Prosky, L., Asp, N.-G., Furda, I., Devries, J. W., Schweizer, T. F., & Harland, B. F. (1984). Determination of total dietary fiber in foods, food products and total diets: interlaboratorial study. *Journal of AOAC International*, 67(6), 1044-1052. http://dx.doi.org/10.1093/jaoac/67.6.1044.

Rodrigues, V. C., Mendes, B. D., Gozzi, A., Sandrini, F., Santana, R. G., & Matioli, G. (2011). Deficiência de ferro, prevalência de anemia e fatores associados em crianças de creches públicas do oeste do Paraná, Brasil. *Revista de Nutrição*, 24(3), 407-420. http://dx.doi.org/10.1590/S1415-52732011000300004.

Institute of Medicine. (2005). *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids (macronutrientes)* (pp. 476-478). Washington, DC: The National Academies Press. https://doi.org/10.17226/10490.

Silva, S. R., Ferreira, T. H. B., Souza, C. F. Fo., & Sanjinez-Argandoña, E. J. (2021). Dipteryx alata Vog. In: F. F. Lima, C. H. Lescano & I. P. Oliveira (Eds.), *Fruits of the Brazilian Cerrado* (pp. 99-113). Cham: Springer. http://dx.doi.org/10.1007/978-3-030-62949-6_6.

Silva, T. A. A., Alves, N. M. C., Galle, N. C. B., & Silva, M. I. P. (2019). Study of wholemeal and partially defatted baru flour in bioriented polypropylene packing. *Agrarian*, 12(46), 487-494. http://dx.doi.org/10.30612/agrarian.v12i46.9637.

Siqueira, A. P. S., Pacheco, M. T. B., & Naves, M. M. V. (2015). Nutritional quality and bioactive compounds of partially defatted baru almond flour. *Food Science and Technology*, 35(1), 127-132. http://dx.doi.org/10.1590/1678-457X.6532.

Brazilian table of food composition – TBCA. (2020). *Tabela Brasileira de Composição de Alimentos (TBCA). Versão 7.1*. Retrieved from: http://www.fcf.usp.br/tbca

Watt, B. K., & Merril, A. L. (1963). *Composition of foods: raw, processed, prepared*. Washington: Consumer and Food Economics Institute/Agricultural Research Service/U.S. Department of Agriculture.