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Phenolic content and lipid quality of nuts of *baru* fruits submitted to pest management and stored at different temperatures

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Abstract

Baru is a fruit produced only once a year which requires adequate planning of seasonal maintenance to maintain the quality of its nut for consumption. This study aimed to evaluate the effect of hydrothermal treatment on pest control and temperature and storage time on *baru* fruits on the phenolic content and the lipidic quality of the nuts. We stored the fruits at ambient temperature (29°C) and climatized at 18°C. We evaluated them at 0, 60, 120, and 180 days for insect damage, water content, total phenols, tannins, antioxidant activity, lipid profile, acidity, peroxide and iodine indices, and oxidative stability by Rancimat. The integrated management was efficient in pest control, and nuts extracted from fruits preserved the bioactive compounds independently of storage temperature and presented chemical characteristics acceptable for consumption. The fatty acids found in higher proportions in *baru* nuts were oleic (50%) and linoleic acids (27%) and remained preserved over time. Thus, it promotes the supply of oilseeds to the market with consistency and quality between crops, avoiding unnecessary losses during storage.

Keywords: *Dipteryx alata* Vogel; post-harvest; stability; pests.

Practical Application: Baru fruits have nuts with high nutritional and bioactive value, with high market potential to meet the present consumer demand for nutritive, functional, organic, and sustainably produced foods. The fruits are prone to storage pests; thus, preventive storage methods are needed which allow nut availability throughout the year. The nuts have a high lipid content, whose stability depends on storage conditions.

1 INTRODUCTION

Nuts, walnuts, chestnuts, and edible seeds belong to the oilseed group and are consumed worldwide for their practicality and nutritional composition (Dikariyanto et al., 2020). The inclusion of oilseeds in the diet is related to the reduction of risk factors for cardiovascular and metabolic diseases as they are rich in unsaturated fatty acids and bioactive compounds such as dietary fiber, phenolic compounds, and minerals, in addition to their high protein content (Eslampour et al., 2020; Wang et al., 2020).

The seed of baru (*Dipteryx alata* Vogel), known as baru nut, is an oilseed belonging to the Fabaceae family, native to the Brazilian Cerrado, also known as *baruzeiro*, *cumbaru*, and *coco-feijão* (Rocha & Cardoso Santiago, 2009). Regarding its nutritional composition, the nut has a high protein (22.3–31.0%) and lipid (35.7–41.0%) (Bento et al., 2014; Czeder et al., 2012) contents, of which about 80% is composed of unsaturated fatty acids such as oleic acid (ω-9) and linoleic acid (ω-6) (Bento et al., 2014). It also presents high contents of phenolic compounds with 390–1300 mg GAE 100 g^{-1} (Pelvan et al., 2018).

The baru is a seasonal fruit produced only once a year, between August and October, which requires adequate storage to maintain the quality of its nuts for consumption between harvests (Reis et al., 2019; Sano et al., 2004). The pulp and the nuts of the fruits are susceptible to storage pests, beetles, and lepidoptera, in the natural ambient (Almeida et al., 1987), so preventive storage methods are needed to offer the nut in the off-season. According to Lorini et al. (2015), integrated pest management during storage is a valuable tool to minimize quantitative and qualitative losses and reduce the need for chemical control (Trematerra and Colacci, 2020). Physical methods can be applied isolated or combined with pest control such as cleaning and sanitization of the storage environment, use of high temperatures, and diatomaceous earth, obtained from fossil diatomaceous algae which is considered a natural insecticide (Lorini et al., 2015).

The nuts become susceptible to lipid oxidation during storage as a consequence of their high content of lipids, mainly monounsaturated fatty acids. Lipid oxidation results in low-molecular-weight secondary compounds, such as aldehydes,

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ketones, and alcohols, which are responsible for promoting rancidity. The reactions caused by this process alter the nutritional value and the sensory attributes and determine its stability and consumption safety during storage (Di Stefano & Melilli, 2020; Martin-Rubio et al., 2020).

Other extrinsic factors such as moisture, temperature, storage time, and insect infestation can affect the quality (Luo et al., 2021; Prabakaran et al., 2018) of the nuts during the storage of *baru* fruits. Thus, this study aimed to evaluate the effect of hydrothermal treatment on pest control, the chemical composition of nuts, and the temperature and storage time of *baru* fruits on the phenolic content and lipid quality of nuts.

2 MATERIALS AND METHODS

Figure 1 shows the stages of the experiments developed with fruits of baru harvested in 2018 and 2019.

2.1 Hydrothermal treatment for pest control of baru *fruits during storage*

We collected approximately 60 kg of *baru* fruits in October and November 2018 from the municipality of Campo Grande, Mato Grosso do Sul (-20.46683078905582, -54.60882963247712). After completing the physiological development and naturally falling off the tree, the fruits were stored in a laboratory environment under favorable conditions for pest development, without control of temperature and relative air moisture (26 ± 4°C; 71 ± 15%), identified as *Plodia interpunctella*, a moth with 20 mm wingspan.

A month after the beginning of infestation in January 2019, the infested fruits were washed, sanitized with chlorinated water at 200 mg L^{-1} for 10 min, hydrothermally treated, and dried in a cabinet-type oven, with forced air circulation, at 40°C until 13% (bu) of moisture. The fruits were packaged in new raffia bags, piled on polyethylene dais at 30 cm off the wall, and stored for 4 months (25 ± 4°C; 74 ± 15%). Before storage, we applied the insecticide k-othrine® on the floor and walls. The hydrothermal treatment consisted of fruit immersion in potable water at 100°C for 2 min. We evaluated the treated fruits in alternate months for the percentage of pest infestation. We considered infested fruits when presenting larvae, caterpillars, pupae, or alive insects. Nuts were checked according to Brasil (2009).

2.2 Effect of the hydrothermal treatment of baru fruits on the physical-chemical nut quality

The *baru* fruits were collected in August and September 2019, selected, eliminating the deteriorated, homogenized, washed in running water, and sanitized in chlorinated water at 200 mg L^{-1}. The fruits were hydrothermally treated at 100°C for 2 min and dehydrated in a cabinet-type oven at 40°C, with forced air circulation until 13% moisture.

The hydrothermally treated fruits were divided into two batches: the first with approximately 5 kg and the second with approximately 360 kg of fruits. The nuts of the fruits of batch 1 were physicochemically evaluated for moisture content, water activity, total phenols, tannins, antioxidant activity, and indices of acidity, peroxide, and iodine and compared with nuts from control fruits (not hydrothermally treated) of approximately 5 kg, which were reserved for these evaluations.

2.3 Phenolic content and lipid quality of baru *nuts from fruits submitted to integrated pest management and stored under different temperatures*

The dehydrated fruits of batch 2 were spread on stainless steel benches for temperature reduction, mixed with diatomaceous earth in the proportion of 10 g kg^{-1}, and packaged in raffia bags. We divided the raffia bags into two lots and stored them for 6 months, the first in the laboratory, at ambient temperature (29.3 ± 3.15°C; 48.37 ± 18°C), on polyethylene daises, 30 cm off the wall, and the second in a BOD frame at 18°C.

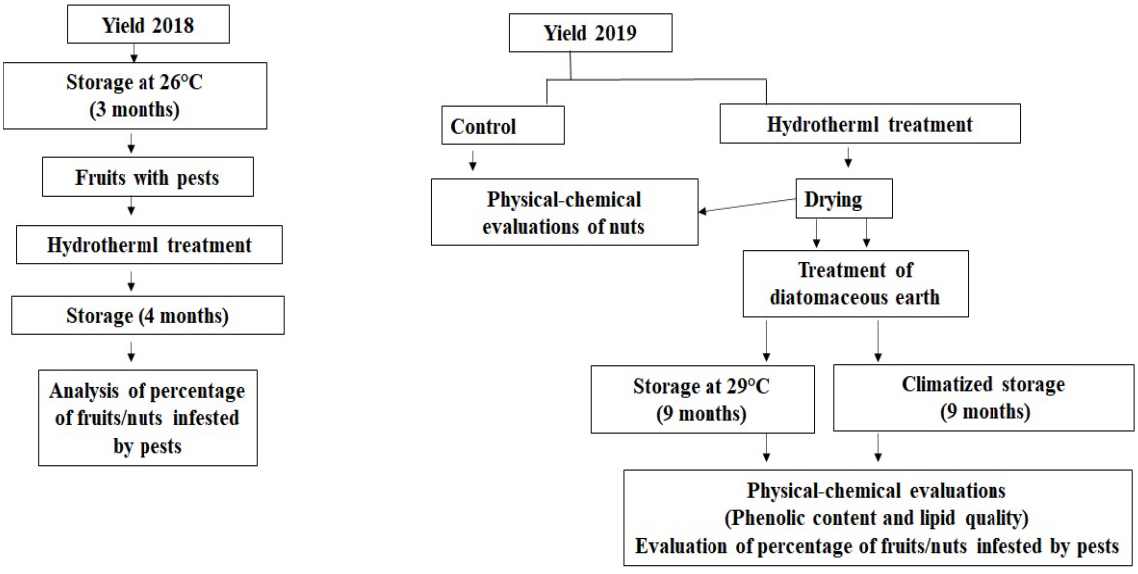

Figure 1. Representation of the steps of the experiments performed with fruits of baru harvested in 2018 and 2019.

At every 60-day storage period, the nuts were extracted from the fruit using a manual cracker for later evaluation of the following parameters in three replicates: percentage of insect-damaged seeds, water content and activity, total phenols, tannins, antioxidant activity, lipidic profile, indices of acidity, iodine peroxide, and Rancimat.

2.4 Physical-chemical analyses

We determined the percentage of fruits and nuts infested with insects in 30 units taken at random. The fruits were examined, and the nuts were cut with a scalpel to observe the internal mass, considering those infested with larvae, pupae, and adult insects and all presenting exit holes (Brasil, 2009).

The moisture content of chestnuts was evaluated in an oven at 105°C for 24 h (Brasil, 2009). Measuring equipment (Hydroplam®, model Aw 43) assessed water activity.

A hydroethanolic extract was used in the proportion of 1:6 $m \cdot m^{-1}$ fruit and alcohol (P.A) to determine the bioactive compounds. Subsequently, the extracts were diluted with absolute alcohol in the proportion of 1:4. We determined total phenols by colorimetry according to the methodology proposed by Swain and Hillis (1959). The ability to scavenge free radicals was expressed as the extract mean inhibition (IC50) mg·mL (Melo et al., 2008; Roesler et al., 2007). Tannins were determined according to the Adolfo Lutz Institute (2008), and for comparison purposes, the results were converted to 6% moisture.

We extracted the oil with hexane (seed:solvent ratio of 1:10). Samples with 200 g of seeds were ground in a mill (Tecnal/TE-631), packed in filter paper cartridges (J.Prolab/205 µm), and tied with a string. After immersion in solvent for 24 h, the micelle (oil + solvent) was transferred to a rotary evaporator (802d, Fisatom, Brazil) under reduced pressure for solvent separation. Subsequently, the oil was transferred to amber vials and kept under refrigeration (4°C).

The fatty acids were esterified according to the methodology adapted from Maia and Rodriguez-Amaya (1993). The methyl esters were analyzed by gas chromatography (GC 2010 AOC-20I, Shimadzu, Japan) to obtain their peaks identified by comparing their relative retention time with the pattern of 37 fatty acid methyl esters (FAMEs) (Supelco C22, 99% pure).

The oil acidity, peroxide, and iodine indices were determined by the official adapted methodology described by the Adolfo Lutz Institute (2008).

According to the EN 14112 method, oxidative stability was determined by obtaining the induction period (IP) through the Rancimat test, using the Rancimat equipment (893 Professional Biodiesel Rancimat, Metrohm, Brazil) (European Committee for Standardization, 2003).

The experiment was installed using a completely randomized design (DIC) in a factorial scheme with two temperatures (ambient and acclimatized at 18°C), four storage times (0, 30, 60, 120, and 180 days), and three repetitions. The results were submitted to analyses of variance (ANOVA). The means were compared using the Tukey's test, adopting a 5% significance level.

3 RESULTS AND DISCUSSION

3.1 Hydrothermal treatment in pest control of fruits stored at ambient temperature

During storage, we did not find signs of pests in fruits and nuts, suggesting that the integrated management was efficient in pest control. According to Lorini et al. (2015), high temperatures and inert powders are physical methods that can retard and/or eliminate the existing pests in stored grains.

3.2 Effect of the hydrothermal treatment of baru fruits on the physical-chemical quality of nuts

Table 1 presents the physical-chemical characterization of nuts of hydrothermally treated fruits and control fruits. The fruits submitted to hydrothermal treatment presented nuts with a lower content of moisture and total phenols and lower antioxidant capacity than control fruits. We did not find significant differences for other variables such as water activity and tannins. The moisture and water activity of nuts, independent of treatment, are considered low (Table 1). The presented Aw values impede the development of microorganisms (Guiné et al., 2015).

The hydrothermally treated nuts conserved 72% of the phenolic compounds and 91.32% of tannins (Table 1). Santiago et al. (2018) also verified a reduction of 34% in phenolic compounds by heating nuts to roast them. According to Li et al. (2020), high temperatures can unstabilize the bond of phenolic compounds with food substracts and lead to degradation.

Independently of post-harvest management, nut oil presented indices of acidity and peroxide below the limits established by the RDC n° 270 of 2005 of Anvisa for crude oils, which presents the technical rule for vegetable oils, plant fats, and vegetal cream (Brasil, 2005).

3.3 Physical characterization, phenolic content, and lipid quality of baru *fruits and nuts submitted to integrated pest management and stored under different temperatures*

The mean values found in this study were similar to those cited in the literature, which ranged from 6.63 to 9.9 g ($100\ g^{-1}$) *in natura* nuts (Santiago et al., 2018). These variations may be related to the genetic and environmental variability of the fruits. During storage, the moisture content of nuts stored under

Table 1. Physical-chemical characterization of the *in natura* de baru submitted to hydrothermal treatment and control*.

Parameter	Control	Hydrothermal treatment
Moisture content (%)	6.52 ± 0.06a	6.00 ± 0.24b
Water activity (AW)	0.56 ± 0.01a	0.55 ± 0.00a
Total phenols (mg EAG/100 g)	651.96 ± 19.99a	469.32 ± 30.98b
Taninns (mg EAG/100 g)	317.04 ± 9.44a	289.51 ± 78.14a
IC50	3.58 ± 0.51b	5.70 ± 0.36a
Acidity index (mg NaOH/g)	0.38 ± 0.04a	0.30 ± 0.02b
Peroxide index (mEq/1000 g)	2.68 ± 0.13b	3.25 ± 0.78a
Iodine index (g I/100 g)	57.25 ± 2.02a	62.83 ± 9.59a

*Means followed by the same lowercase letter in the line do not differ by the Tukey's test at 5% probability. Calculation, sample with 6% moisture; Control: fruits nonhydrothermally treated.

acclimatized temperature was significantly lower than those at room temperature (Table 2).

The breakdown of interactions showed that this reduction was significant at 120–180 days (Table 3). The determination of the moisture content of grains is a critical quality indicator as the moisture content in the food directly affects storage and marketing (Zambrano et al., 2019).

Table 2. Determination of moisture and water activity of *in natura baru* nuts as a function of temperature and time in days of storage.

	Parameter	
	Water content (%)	**Water activity (AW)**
Temperature (°C)		
Air-conditioned at 18°C	5.35 ± 0.49b	0.501 ± 0.05b
Ambient	6.25 ± 0.63[a]	0.561 ± 0.010a
Test F	24.38*	547.6*
Time (days)		
0	6.00 ± 0.21a	0.552 ± 0.0009a
60	5.31 ± 0.68a	0.555 ± 0.023a
120	5.91 ± 0.90a	0.518 ± 0.043b
180	5.98 ± 0.82a	0.499 ± 0.070c
Test F	3.23NS	113.5*
Treatment × time	3.26*	101.8*
CV (%)	12.39	8.5

*Significant at 5% probability level. NS: non-significant. Means followed by the same lowercase letters in the column do not differ by the Tukey's test at 5% probability. Calculation, sample with 6% moisture.

The water activity levels obtained during the entire storage were kept below the recommended parameter (< 0.6) to maintain the quality and prolong shelf life as it becomes less susceptible to deterioration reactions (Guiné et al., 2015). Table 3 shows that the trends observed for moisture content were similar to those obtained for water activity, and refrigeration showed better control than ambient temperature, which remained unstable during the entire storage.

An analysis of the effect of temperature on hazelnut storage showed that artificial cooling is an ally in conservation as low air temperatures and RH promote the maintenance of low levels of water activity available for chemical reactions (Ghirardello et al., 2013).

3.4 Effect of storage time and temperature on bioactive stability and antioxidants

The total phenols, tannins, and antioxidant capacity did not show differences under the storage temperature used (Table 4). After 120 days, we observed an increase in total phenols and antioxidant capacity, whereas tannins remained stable. *Baru* nuts have been identified as a relevant source of bioactive compounds such as phenolic compounds (Lemos et al., 2012). Phenols are

Table 3. Breakdown of significant interactions of treatments × times obtained for moisture and water activity of *in natura baru* nuts as a function of temperature and time in days of storage.

Temperature (°C)	**Storage time (days)**			
	0	**60**	**120**	**180**
	Moisture (%)			
Air-conditioned at 18°C	6.00 ± 0.24aA	4.91 ± 0.31aA	5.23 ± 0.42aB	5.27 ± 0.17aB
Ambient	6.01a ± 0.24A	5.72 ± 0.75aA	6.58 ± 0.69aA	6.69 ± 0.37aA
	Water activity (AW)			
Air-conditioned at 18°C	0.552 ± 0.001aA	0.535 ± 0.008aB	0.479 ± 0.003bB	0.439 ± 0.009cB
Ambient	0.552 ± 0.001dcA	0.575 ± 0.008abA	0.557 ± 0.003dcA	0.559 ± 0.008bcA

*Means followed by at least one lowercase letter in the lines and by at least one uppercase letter in the columns do not differ, according to the Tukey's test ($p < 0.05$).

Table 4. Determination of total phenols, tannins, and antioxidant activity via DPPH of *in natura baru* nuts as a function of temperature and time in days of storage.

Temperature (°C)	**Parameters**		
	Total phenols (mg GAE/100g)	**Tannins (mg TAE/100g)**	**IC50**
Air-conditioned at 18°C	494.06 ± 52.88a	307.03 ± 50.09a	4.69 ± 1.18a
Ambient	521.56 ± 71.03a	320.56 ± 45,84a	4.28 ± 1.32a
Test F	4.08NS	0.59NS	2.39NS
Time (days)			
0	469.32 ± 27.71b	289.51 ± 69.89a	5.70 ± 0.02a
60	444.15 ± 23.01b	337.51 ± 12.95a	4.99 ± 0.26a
120	565.20 ± 58.54[a]	346.49 ± 30.30a	2.77 ± 1.13b
180	552.58 ± 20.87a	281.65 ± 22.07a	4.49 ± 0.61b
Test F	19.46*	3.48NS	22.24*
Treatment × time	1.04 NS	0.22 NS	0.52NS
CV (%)	12.37	15.13	28.02

*Significant at the 5% probability level. NS: non-significant. Means followed by the same lowercase letter in the column do not differ by the Tukey's test at 5% probability. Calculation, sample with 6% humidity; GAE: gallic acid equivalent; TAE: tannic acid equivalent.

secondary plant metabolism substances synthesized from the degradation of other organic compounds in the food matrix in response to biotic and abiotic stresses (Isah, 2019).

Increased phenol content can be related to physiological responses of maturation, the temperature used, or the beginning of oxidative reactions as they have high levels of unsaturated fatty acids, prone to oxidation processes (Brewer, 2011).

Santiago et al. (2018) found higher phenolic content (1107 mg GAE·100 g^{-1}) of fresh *baru* nuts than we observed. Compared with other oilseeds, *baru* nut has higher concentrations of phenols than cashew nut (3.7 mg GAE·100 g^{-1}), hazelnut (10.21–23.28 mg GAE·100 g^{-1}), walnut (6.1–10.9 mg GAE·100 g^{-1}), and pistachio (1.65 mg GAE·100 g^{-1}) (Taş & Gökmen, 2017).

The antioxidant activity is related to various food compounds such as flavonoids, phenolic compounds, and tannins. The phenolic compounds in their chemical structure, hydroxyls and aromatic rings, give them reducing properties, whose intensity of antioxidant action depends on the concentration of these phytochemicals (Soares Júnior, 2007). High levels of phenols may be responsible for our finding of increased antioxidant capacity (Table 4).

Tannins, in turn, did not show significant reduction during storage, which indicates that they remained preserved (Table 4). Tannins or tannic acid are considered antinutrient factors that bind proteins and micronutrients (e.g., calcium, phosphorus, iron, and zinc) and reduce their bioavailability (Silva & Fernandes, 2011). However, including these compounds associated with a balanced diet may have beneficial health effects such as anti-inflammatory and protective actions against oxidative processes (Fuster et al., 2017).

3.5 Effect of time and temperature on the quantity and quality of fatty acids in natura baru *nut oil*

Table 5 presents the lipid profile of roasted *baru* nuts in different packages and stored for 180 days. The fatty acids such as oleic (C18:1n9c) and linoleic (C18:2n6c) acids, found in roasted *baru* nuts in the highest percentage of about 50% and 27%, respectively, did not differ during storage time and temperature, indicating that they were preserved.

In smaller proportions, considering the range between 0.3% and 6%, the nuts presented the following fatty acids: C16:0 (5.89%), C18:0 (4.54%), C20:0 (1.05%), C20:1 (2.18%), C20:3n3 (3.32%), C24 (3.80%), and C20:0 (0.39%). Contents of these fatty acids did not change over storage time and temperature, except C16:0, with a significant reduction trend after 180 days.

Studies show that the composition of monosaturated and polyunsaturated fatty acids such as oleic (C18:1n9c), linoleic (C18:2n6c), and α-linolenic (C18:3n-3) acids in *baru* oil gives relevant health benefits (Alves et al., 2016; De Souza et al., 2018; Rocha & Cardoso Santiago, 2009; Schincaglia et al., 2020).

3.6 Effect of storage time and temperature on the quality and chemical and lipid stability of baru *nut oil*

The acid, peroxide, and iodine values did not differ with storage temperature (Table 6).

Acidity is a parameter of the degree of conservation of oils and fats, indicating whether the oil has undergone oxidation (Instituto Adolfo Lutz, 2008). In this study, we observed that the acidity index showed a trend to increase over storage time. *Baru* nut oil from fruits stored under acclimatized temperature showed a significantly higher value at 120 days, not differing from the others. However, room temperature gave the highest values at 120 and 180 days. Our results were below the maximum indicator value established for crude oils (4.0 mg KOH g^{-1} oil) (FAO/WHO, 2003).

The peroxide index in edible oils is an essential indicator to be monitored as an oxidative process threshold of the deterioration of nutritional constituents, such as essential fatty acids, as it determines whether the oil is in an oxidative process (Siqueira et al., 2016). During 180 days of storage, we observed that the values varied from 2.83 to 7.43 mEq·kg^{-1} (Table 6). However, the values remained within the limits established by the legislation in which the peroxide content must not exceed 15 mEq·kg^{-1} for crude oils (Brasil, 2005; FAO/WHO, 2003).

The iodine index determines the degree of unsaturation of the fatty acids present in the oil and allows the identification of possible adulterations. In this study, the iodine index values

Table 5. Determination of the profile of major fatty acids present *in natura baru* nut oil.

	C16	C18:0	C18:1n9c	C18:2n6c	C18:3n3	C20:0	C20:1	C20:3n3	C22:1n9	C23:0	C24:0
18°C	5.8 ± 0.23a	4.5 ± 0.17a	50.8 ± 0.46a	27.41 ± 0.68a	0.08 ± 0.04a	1.06 ± 0.08a	2.18 ± 0.11a	3.24 ± 0.30[a]	0.21 ± 0.73a	0.04 ± 0.03a	3.71 ± 1.26a
Ambient	5.94 ± 0.17a	4.56 ± 0.09a	50.75 ± 0.37a	27.47 ± 0.34a	0.09 ± 0.00a	1.04 ± 0.02a	2.17 ± 0.04a	3.16 ± 0.10[a]	0.23 ± 0.02[a]	0.05 ± 0.02a	3.91 ± 0.15a
Test F	1.91NS	0.69NS	0.2NS	0.06NS	1.73NS	0.65NS	0.06NS	0.80NS	0.72NS	1.20NS	0.32NS
Time											
0	6.02 ± 0.08a	4.53 ± 0.06[a]	50.56 ± 0.49a	27.57 ± a	0.09 ± 0.00a	1.04 ± 0.03a	2.18 ± 0.04a	3.14 ± 0.12a	0.22 ± 0.01a	0.06 ± 0.02a	3.95 ± 0.18a
60	5.89 ± 0.21ab	4.53 ± 0.10a	50.82 ± 0.32a	27.56 ± a	0.08 ± 0.04a	1.04 ± 0.03a	2.16 ± 0.06a	3.14 ± 0.07a	0.24 ± 0.04a	0.05 ± 0.02a	3.19 ± 1.56a
120	5.94 ± 0.21ab	4.57 ± 0.14a	50.81 ± 0.30a	27.47 ± a	0.10 ± 0.02a	1.04 ± 0.02a	2.46 ± 0.04a	3.15 ± 0.10a	0.23 ± 0.03a	0.06 ± 0.01a	3.88 ± 0.11a
180	5.70 ± 0.17b	4.52 ± 0.23a	50.94 ± 0.48a	27.16 ± a	0.08 ± 0.04a	1.09 ± 0.11a	2.21 ± 0.16a	3.37 ± 0.39a	0.20 ± 0.10a	0.02 ± 0.03b	4.23 ± 0.61a
Test F	3.95*	0.11NS	0.9NS	0.78NS	0.79NS	1.15NS	0.36NS	1.56NS	0.69NS	6.15*	1.62NS
T. × time	1.35NS	0.53NS	1.4NS	1.51NS	0.63NS	1.04NS	0.47NS	0.71NS	0.91NS	2.30NS	1.25NS
CV (%)	3.48	3.01	0.80	1.93	3.08	5.86	3.86	6.94	10.90	19.21	8.78

*Significant at the 5% probability level. NS: non-significant; CV: coefficient of variation. Means followed by the same lowercase letter in the column do not differ by the Tukey's test ($p < 0.05$); T: treatment.

Table 6. Values of acid, peroxide, and iodine *in natura* nut oil as a function of temperature and time in days of storage.

Temperature	Parameters		
	Acidity index (mg KOH g^{-1})	Peroxide index (mEq kg^{-1})	Iodine index (g 100 g^{-1})
Air-conditioned at 18°C	0.37 ± 0.08a	4.93 ± 2.01a	58.44 ± 16.93a
Ambient	0.38 ± 0.06a	5.05 ± 3.24a	57.33 ± 9.66a
Test F	0.03NS	0.21NS	0.12NS
Time (days)			
0	0.30 ± 0.01c	3.25 ± 0.06b	62.83 ± 7.83ab
60	0.32 ± 0.03b	2.83 ± 0.34c	69.99 ± 9.41a
120	0.46 ± 0.06[a]	6.44 ± 3.27ab	56.03 ± 8.36b
180	0.37 ± 0.04b	7.43 ± 0.32a	42.69 ± 10.07c
Test F	23.14*	7.73*	12.77*
Treatment × time	5.89*	0.01NS	3.83*
CV (%)	18.58	52.88	23.31

*Significant at the 5% probability level. NS: non-significant. Means followed by the same lowercase letter in the column do not differ by the Tukey's test ($p < 0.05$).

diminished during storage, from 62.83 to 42.69 g·100 g^{-1} (Table 6), which reduced more significantly in the nut oil under acclimatized temperature for 180 days.

The decrease in the iodine number may be associated with a reduction in the content of polyunsaturated fatty acids due to oxidation. It can be seen that *baru* oil is composed of about 80% monounsaturated and polyunsaturated fatty acids. However, no significant reductions in these fatty acids were observed (Al-Bachir, 2015).

The high content of unsaturated fatty acids in vegetable oils, such as essential linoleic and linolenic fatty acids, in addition to the health benefits already elucidated, also raises concerns about the production and storage processes as they become more susceptible to oxidative reactions (Gama et al., 2018; Simoes Grilo et al., 2020).

The oxidative stability of the oil is directly related to the degree of unsaturation, the presence of antioxidant compounds, and storage conditions. Vegetable oil must have good oxidative stability to maintain the quality of flavor, color, and aroma and, consequently, a longer shelf life (Durmaz & Gökmen, 2019).

Determining oxidative stability is a standard parameter of oil quality control and an indicator of shelf life. The IP of *natura* nut oil stored at acclimatized temperature was similar to that under room temperature and did not differ during storage. This result shows that neither storage temperature nor time influenced the oxidative stability of the oil. On average, the IP of *baru* oil samples was 6.45 h, which was above the oxidation IP for peanut oil (5 h) and corn oil (4.85 h) (Maszewska et al., 2018), thus demonstrating higher oxidative stability of *baru* oil.

Vegetable oils contain several elements that act as antioxidants or pro-oxidants such as tocopherols, phenolic compounds, and sterols. Phenolic compounds are commonly used in the food industry as they can attenuate the effects of oxidation and prolong shelf life (Redondo-Cuevas et al., 2018).

The ability of phenolic compounds to act as protectors of the oxidative process is due to donating hydrogen atoms and neutralizing free radicals, preventing the oxidation chain reaction (Pateiro et al., 2018). Moreover, the reduction of these compounds is directly related to reduced oxidative stability (Martínez Nieto et al., 2010).

The main phenolic compounds identified in *baru* nuts were gallic acid and its derivatives, such as gallic acid esters and gallotannins, which have a high degree of antioxidant activity due to an aromatic ring in their molecules (Oliveira-Alves et al., 2020). When analyzing the content of total phenols and antioxidant potential of the *baru* nut, Borges et al. (2014) showed that these properties were superior to commonly consumed oilseeds such as peanuts, cashew, macadamia, and Brazil nuts.

4 CONCLUSION

Integrated management is efficient in pest control. The hydrothermally treated nuts retain 70% of the bioactive compounds, maintaining the lipid quality of the nuts, with acidity and peroxide indices within limits established by the legislation for crude oils. Besides, *baru* nuts extracted from stored fruits preserve their bioactive compounds independently of storage temperature and present chemical characteristics acceptable for consumption. The fatty acids that are found in higher proportions in *baru* nuts are oleic (50%) and linoleic (27%) acids, indicating that they are preserved over time.

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