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RIDES

EFFECT OF HYDROTHERMAL TREATMENTS ON THE PHYSICOCHEMICAL AND SENSORY QUALITY OF BRAZILIAN PINE SEEDS (*ARAUCARIA ANGUSTIFOLIA*) STORED AT AMBIENT TEMPERATURE

Efeito de tratamentos hidrotérmicos sobre a qualidade físico-química e sensorial de pinhão (araucaria angustifolia) armazenado em temperatura ambiente

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Abstract: Brazilian pine seeds (Araucaria angustifolia) have economic, cultural, and nutritional importance; however, their postharvest conservation is limited by rapid quality losses during storage. This study evaluated the effects of hydrothermal treatments on the physicochemical and sensory quality of Brazilian pine seeds stored under ambient conditions. Two experiments were conducted using a completely randomized design. For physicochemical analyses, seeds were subjected to three treatments: control, immersion in water at 50 °C for 20 min, and immersion in water at 100 °C for 5 min. Evaluations were carried out over 20 days and included weight loss, firmness, pH, soluble solids, titratable acidity, and color parameters. Sensory quality was assessed using a nine-point hedonic scale for aroma, appearance, texture, flavor, and overall acceptability. The treatment at 100 °C for 5 min resulted in greater weight loss, reduced firmness, and more pronounced changes in sensory attributes throughout storage. In contrast, seeds treated at 50 °C for 20 min showed a behavior similar to the control for most variables, preserving physicochemical and sensory quality. Acceptability decreased mainly in the 100 °C treatment from the second week of storage onward. The findings demonstrate that moderate hydrothermal treatments may contribute to maintaining the postharvest quality of Brazilian pine seeds during ambient storage, providing new information on the physicochemical and sensory responses of the seeds to different combinations of temperature and exposure time.

Keywords: Forest seeds; hedonic evaluation; postharvest quality; preservation technology; sociobiodiversity products.

Resumo: O pinhão (Araucaria angustifolia) possui relevância econômica, cultural e nutricional, porém sua conservação pós-colheita é limitada pela rápida perda de qualidade durante o armazenamento. Este estudo avaliou os efeitos de tratamentos hidrotérmicos sobre a qualidade físico-química e sensorial de sementes de pinhão armazenadas em temperatura ambiente. Foram conduzidos dois experimentos em delineamento inteiramente casualizado. Nas análises físico-químicas, as sementes foram submetidas aos tratamentos controle, imersão em água a 50 °C por 20 minutos e imersão em água a 100 °C por 5 minutos, sendo avaliadas durante 20 dias quanto à perda de massa, firmeza, pH, sólidos solúveis, acidez titulável e coloração. A qualidade sensorial foi avaliada por meio de escala hedônica estruturada de nove pontos para os atributos aroma, aparência, textura, sabor e aceitabilidade. O tratamento a 100 °C por 5 minutos promoveu maiores perdas de massa, redução da firmeza e alterações mais intensas nos atributos sensoriais ao longo do

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armazenamento. Em contraste, o tratamento a 50 °C por 20 minutos apresentou comportamento semelhante ao controle para a maioria das variáveis analisadas, preservando a qualidade física e sensorial das sementes. A aceitabilidade foi reduzida principalmente no tratamento a 100 °C a partir da segunda semana de armazenamento. Os resultados demonstram que tratamentos hidrotérmicos moderados podem contribuir para a manutenção da qualidade pós-colheita do pinhão durante o armazenamento em temperatura ambiente, fornecendo informações inéditas sobre a resposta físico-química e sensorial das sementes submetidas a diferentes combinações de temperatura e tempo de exposição.

Palavras-chave: Sementes florestais; análise hedônica; qualidade pós-colheita; tecnologia de conservação; produtos da sociobiodiversidade.

INTRODUCTION

Brazilian pine seed, the edible seed of Araucaria angustifolia, has significant economic, nutritional, cultural, and socio-environmental relevance in Brazil, particularly in the Southern and Southeastern regions. In addition to being an important source of carbohydrates, dietary fiber, minerals, and vitamin C, its harvesting and commercialization represent an important source of income for family farmers, Indigenous peoples, and extractive communities, making it a product associated with Brazilian sociobiodiversity. In recent decades, production and the economic value associated with the species have increased significantly, reinforcing its importance for food security, the valorization of sustainable extractive systems, and regional development (CONAB, 2020; IBGE, 2024; TACO, 2011; Krupek & Anjos, 2021; Beninca, 2019; Santos, 2018).

Despite its importance, the commercialization of Brazilian pine seeds is limited by the rapid loss of quality during postharvest storage. As a recalcitrant seed, Brazilian pine seed exhibits high metabolic activity and sensitivity to water loss, factors that promote physiological changes, reductions in visual and sensory quality, and compromised preservation over extended periods (Amarante et al., 2007; Costa et al., 2020). Recent studies have also demonstrated that maintaining adequate moisture levels and storage conditions is one of the main challenges in extending the shelf life of Araucaria angustifolia seeds, given their susceptibility to postharvest deterioration and gradual quality loss during storage (Costa et al., 2023; Shibata & Coelho, 2016).

Given these limitations, the development of technologies capable of extending the postharvest preservation of Brazilian pine seeds is essential to increase their commercialization period, reduce losses, and add value to the production chain. Among the available alternatives, hydrothermal treatments stand out due to their ease of application, low operating cost, and potential use in postharvest conservation systems. These treatments are based on the controlled exposure of products to heated water for predetermined periods and are widely used in phytosanitary procedures and in maintaining the quality of plant products (Baker, 1939; Oliveira, 2015; Kabelitz et al., 2019). In addition, controlled thermal technologies have been identified as promising tools for increasing stability and reducing losses in stored agricultural products, particularly when integrated with sustainable postharvest strategies (Palumbo et al., 2022).

However, the adoption of any conservation technology should consider not only its operational efficiency but also its effects on quality attributes perceived by consumers. Changes caused by thermal treatment may affect important food characteristics, such as texture, appearance, aroma, and flavor, directly influencing

commercial acceptance. Therefore, physicochemical evaluations combined with sensory analysis are essential for understanding the effects of treatments on the overall quality of the product during storage, since consumer perception and food acceptance depend on the integration of attributes such as appearance, aroma, flavor, and texture (DUTCOSKY, 2019).

Although studies have addressed Brazilian pine seed storage, chemical composition, postharvest quality, and the development of products derived from the species, information regarding the use of hydrothermal treatments on Araucaria angustifolia seeds remains limited. The available literature focuses predominantly on the effects of storage conditions, refrigeration, packaging, and preservation of the physiological viability of the seeds (Amarante et al., 2007; Costa et al., 2023), with limited evidence regarding the simultaneous response of the physicochemical and sensory attributes of Brazilian pine seeds subjected to hydrothermal treatments prior to storage. Furthermore, it remains insufficiently understood how different combinations of temperature and exposure time may influence characteristics that are critical to consumer acceptance, such as firmness, appearance, aroma, texture, and overall acceptability.

In this context, this study aimed to evaluate the effects of different hydrothermal treatment strategies, characterized by distinct combinations of temperature and exposure time, on the physicochemical and sensory quality of Brazilian pine seeds stored at ambient temperature, with the purpose of generating information that may contribute to the development of postharvest conservation strategies compatible with maintaining product quality and sustainably enhancing the value of this important Brazilian sociobiodiversity resource.

MATERIALS AND METHODS

Experimental Design

Brazilian pine seeds were collected in the region of Pinhalzinho, Paraná, Brazil, and transported on the same day of harvest to the Food Technology Laboratory of the State University of Western Paraná (Unioeste), Marechal Cândido Rondon Campus, Paraná, Brazil, where the experiments were conducted.

Two independent experiments were conducted, one aimed at physicochemical evaluations and the other at sensory evaluations, both using a completely randomized design.

The physicochemical experiment was conducted in a 3 × 11 factorial scheme, consisting of three treatments (control, hydrothermal treatment at 50 °C for 20 minutes, and hydrothermal treatment at 100 °C for 5 minutes) and eleven storage periods (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days), with 20 replicates per treatment at each evaluation period. The experimental unit consisted of four seeds, which were processed together to obtain a single analytical sample. The use of four seeds per experimental unit was intended to increase sample representativeness, reduce individual variability among seeds, and provide a sufficient amount of biological material for the physicochemical analyses.

The sensory experiment was conducted in a 4 × 11 factorial scheme, consisting of the control, visual treatment, hydrothermal treatment at 50 °C for 20 minutes, and

hydrothermal treatment at 100 °C for 5 minutes, evaluated over the same eleven storage periods.

The hydrothermal treatments were defined based on two distinct heat-application strategies. The treatment at 50 °C for 20 minutes represented a lower thermal intensity and longer exposure time, allowing gradual heat transfer into the seeds. In contrast, the treatment at 100 °C for 5 minutes represented a higher thermal intensity and shorter duration, in which the shorter exposure time was intended to minimize potential damage associated with excessive heating. Thus, the study aimed to compare different hydrothermal treatment strategies rather than to evaluate the isolated effect of temperature on product quality.

After treatment, the seeds were cooled in water at ambient temperature for 10 minutes and stored without packaging, in bulk, under ambient conditions (20 ± 2 °C), simulating the conditions traditionally observed in the commercialization of Brazilian pine seeds by markets and independent vendors. Evaluations were performed every two days over 20 days of storage. The variables evaluated were weight loss, firmness, hydrogen potential (pH), soluble solids, titratable acidity, shell color (L*, °Hue, Chroma, and Browning Index), and sensory attributes related to aroma, appearance, texture, flavor, and acceptability.

Sensory Analysis

The evaluators were recruited from among students and staff members of the State University of Western Paraná (Unioeste) on a voluntary basis. Only individuals aged 18 years or older were included.

Sensory evaluation was performed using an acceptance test with a nine-point structured hedonic scale, ranging from 1 (“unacceptable”) to 9 (“excellent”), for the attributes of aroma, appearance, texture, flavor, and overall acceptability.

The samples consisted of approximately 10 g of Brazilian pine seeds cooked in a pressure cooker for one hour and subsequently peeled. The samples were presented in containers identified with random three-digit codes and distributed to consumers in a randomized manner.

A total of 220 consumers participated in the study. At each evaluation date, a different group of approximately 20 consumers was used, with no participant being repeated across the different storage periods. Thus, each sensory session was conducted independently, without repeated measurements by the same consumer.

The visual treatment consisted of presenting the samples differently from the other treatments, with the purpose of evaluating the influence of the manner in which the product was presented on consumer perception.

This study was approved by the Research Ethics Committee involving Human Subjects under approval No. 3.047.807 (CAAE 57031616.0.0000.0107), and all procedures were conducted in accordance with the approved ethical protocols.

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using the SISVAR software. The effects of the treatments, storage periods, and the interaction between these factors were evaluated. When significant differences were observed ($p \leq 0.05$), the

means were compared using the Scott-Knott test at a 5% probability level.

For the destructive physicochemical evaluations (firmness, pH, soluble solids, titratable acidity, and color), each storage period consisted of independent experimental units, with each unit comprising four seeds processed together to obtain a single analytical sample.

Weight loss was evaluated non-destructively using the same experimental units throughout the entire storage period.

For the sensory analyses, each storage period involved a different group of consumers, with no participant being repeated across the evaluation dates. Therefore, the observations obtained at each storage period were considered independent of one another.

A total of 2,880 Brazilian pine seeds were used throughout the experiments. Of these, 2,640 seeds were allocated to the destructive physicochemical evaluations, corresponding to the combinations of treatments, storage periods, and experimental replicates, while 240 seeds were used for the non-destructive evaluation of weight loss over the 20-day storage period. Each experimental unit consisted of four seeds processed together to obtain a single analytical sample.

RESULTS AND DISCUSSION

The effects of the hydrothermal treatments on Brazilian pine seed quality were evaluated through physicochemical and sensory analyses over 20 days of storage at ambient temperature. Initially, the results of the analysis of variance are presented (Table 1), followed by an individual discussion of the physicochemical variables and sensory attributes. The interpretation of the results sought to relate the effects of the hydrothermal treatments to the changes observed during storage, as well as to compare the findings with information available in the literature.

The analysis of variance allowed the influence of the hydrothermal treatments, storage periods, and the interaction between these factors on the evaluated variables to be identified. The significance of the treatment × storage period interaction indicates that seed behavior throughout storage depends on the hydrothermal treatment strategy employed, justifying a detailed analysis of the variables in the subsequent sections.

Table 1. Mean squares (MS), degrees of freedom (d.f.), and significance levels for the variables weight loss (WL), firmness, hydrogen potential (pH), soluble solids (SS), titratable acidity (TA), lightness (L*), chroma, hue angle (°hue), and browning (Br) in pine nuts (Araucaria angustifolia) subjected to storage at room temperature and hydrothermal treatment.

Factor	G.L.	PM	Firmness	pH	SS	TA	L*	Croma	°hue	Esc
		Q.M.	Q.M.	Q.M.	Q.M.	Q.M.	Q.M.	Q.M.	Q.M.	Q.M.
D	10	0,081*	352,32*	0,075*	1,222*	0,0006*	81,493*	3,741*	0,059*	51,725*
T	2	0,125*	1591,7*	0,423*	19,482*	0,0003NS	26,025*	21,803*	0,010NS	135,849*
D x T	20	0,003*	98,62*	0,034*	0,753*	0,0001NS	5,688NS	2,856NS	0,005NS	35,699*
Error	99	0,0001	48,600	0,007	0,333	0,0001	5,878	2,069	0,004	17,631
Total	131	-	-	-	-	-				
CV(%) =		5,65	5,65	13,47	1,06	1,04	3,13	3,38	2,88	2,94

Overall Mean :		62,667	62,667	1,660	0,052	0,190	38,978	20,901	0,685	70,503

*Significant and NS, non-significant, at the 5% probability level ($p \leq 0.05$) according to the F-test. Storage period (D) and temperature (T). Source: Prepared by the authors.

Weight loss was influenced by the hydrothermal treatments and storage period, showing a progressive increase in all treatments throughout the 20-day evaluation period (Table 2). The highest values were observed for the treatment at 100 °C for 5 minutes, which reached 33.2% weight loss at the end of storage, whereas the treatment at 50 °C for 20 minutes and the control showed losses of 26.7% and 18.9%, respectively.

Table 2. Mean values of Weight Loss (%) in pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) — 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days — and hydrothermal treatment (control, 50, and 100 °C).

Weight loss			
Days	Treatments		
	Control	50 °C	100 °C
0	0,00% Ea	0,00% Ga	0,00% Ga
2	8,20% Da	9,30% Fa	9,50% Fa
4	11,8% Cc	13,9% Eb	17,4% Ea
6	14,0% Bc	17,2% Db	24,4% Da
8	14,8% Bc	19,3% Cb	27,8% Ca
10	15,4% Bc	20,9% Cb	29,6% Ba
12	16,8% Ac	23,1% Bb	31,7% Ba
14	16,9% Ac	23,7% Bb	31,8% Ba
16	17,5% Ac	24,7% Bb	32,2% Aa
18	18,4% Ac	26,1% Ab	33,1% Aa
20	18,9% Ac	26,7% Ab	33,2% Aa

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

The increase in weight loss is mainly associated with seed transpiration and respiration processes, an expected phenomenon in Brazilian pine seeds due to their high water content and the intense metabolic activity characteristic of recalcitrant seeds. Similar results were observed by Amarante et al. (2007), who reported a significant increase in weight loss during the storage of Brazilian pine seeds subjected to different temperatures, and by Costa et al. (2020), who identified dehydration as one of the main limiting factors for the postharvest conservation of the species.

The greater weight loss observed in the treatment at 100 °C suggests that the higher thermal intensity promoted structural changes capable of accelerating water loss during storage. In contrast, the treatment at 50 °C showed an intermediate behavior, closer to that of the control, indicating a greater capacity to retain moisture and a potential to maintain the postharvest quality of the seeds.

eed coat firmness was influenced by the hydrothermal treatments throughout storage (Table 3). In general, the lowest values were observed in the treatment at 100 °C for 5 minutes, which showed a more pronounced reduction from the 14th day of storage onward, reaching 40.50 N at the end of the experimental period. In contrast, the control and the treatment at 50 °C for 20 minutes showed similar behavior throughout storage, with final values of 58.16 N and 56.64 N, respectively.

The reduction in firmness observed in the treatment at 100 °C may be associated

with the greater weight losses recorded for this treatment, since dehydration promotes structural changes in the tissues of the seed coat, reducing its mechanical resistance. This relationship between water loss and reduced firmness was also observed by Carrasco (2019), who reported a decrease in firmness in Brazilian pine seeds stored at ambient temperature throughout the storage period.

The results indicate that the treatment at 50 °C was more effective in maintaining the physical characteristics of the seeds, showing performance similar to the control and reinforcing its potential for the postharvest conservation of Brazilian pine seeds.

Table 3. Mean values of Firmness in pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) — 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days — and hydrothermal treatment (control, 50, and 100 °C).

Firmness			
Days	Treatments		
	Control	50 °C	100 °C
0	64,92 Aa	64,92 Aa	64,92 Aa
2	70,34 Aa	66,90 Aa	58,52 Ab
4	69,27 Aa	68,31 Aa	67,93 Aa
6	75,51 Aa	66,29 Ab	59,88 Ab
8	65,69 Aa	67,49 Aa	58,82 Aa
10	70,86 Aa	66,66 Aa	65,45 Aa
12	64,67 Aa	71,94 Aa	61,70 Aa
14	69,55 Aa	62,83 Aa	45,08 Bb
16	62,89 Aa	64,95 Aa	42,21 Bb
18	61,42 Aa	64,48 Aa	48,20 Bb
20	58,16 Aa	56,64 Aa	40,50 Bb

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

The pH values were influenced by the hydrothermal treatments and storage period (Table 4); however, they showed a small range of variation throughout the experiment, remaining between 6.11 and 6.59. In general, the treatment at 50 °C for 20 minutes showed greater stability in values throughout storage, whereas the treatment at 100 °C for 5 minutes presented more pronounced fluctuations.

The limited variation observed suggests that the hydrothermal treatments did not cause substantial changes in the compounds responsible for the acidity and alkalinity of the seeds during the 20 days of storage. This behavior indicates that, despite the differences observed in weight loss and firmness, the chemical composition related to pH remained relatively stable, demonstrating the preservation of an important quality characteristic of the product.

Similar results were reported by Daudt et al. (2015) and Acorsi et al. (2009), who also observed pH values close to neutrality in Brazilian pine seed-derived products, with small variations resulting from processing and storage. Thus, the results obtained suggest that the hydrothermal treatments evaluated exerted a greater influence on the physical attributes of the seeds than on their chemical stability.

Table 4. Mean values of pH in pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) — 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days — and hydrothermal treatment (control, 50, and 100 °C).

pH			
Days	Treatments		
	Control	50 °C	100 °C
0	6,59 Aa	6,59 Aa	6,59 Aa
2	6,50 Aa	6,35 Bb	6,22 Bb
4	6,41 Ba	6,47 Aa	6,40 Aa
6	6,39 Ba	6,38 Ba	6,11 Cb
8	6,38 Ba	6,44 Aa	6,26 Bb
10	6,32 Bb	6,49 Aa	6,28 Bb
12	6,37 Bb	6,47 Aa	6,28 Bb
14	6,54 Aa	6,55 Aa	6,29 Bb
16	6,55 Aa	6,59 Aa	6,44 Ab
18	6,51 Aa	6,53 Aa	6,44 Aa
20	6,43 Bb	6,57 Aa	6,38 Ab

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Soluble solids content was influenced by the hydrothermal treatments and storage period (Table 5), with the highest values observed in the treatment at 100 °C for 5 minutes. During several evaluation periods, this treatment presented values above 2.0 °Brix, whereas the control remained close to 1.0 °Brix throughout storage. The treatment at 50 °C for 20 minutes showed an intermediate behavior, with values between those observed for the control and the treatment at 100 °C.

The increase in soluble solids in the hydrothermally treated seeds may be related to the greater weight loss observed in these seeds, particularly in the treatment at 100 °C, resulting in the concentration of solutes present in the tissues. In addition, heating may promote changes in storage compounds, temporarily increasing the availability of sugars and other soluble solids. Similar behavior was observed by Nascimento et al. (2019), who reported an increase in soluble solids concentration associated with a reduction in water content in plant tissues.

The lower variation observed in the treatment at 50 °C suggests a lower impact on the composition of the product during storage, a result consistent with the lower weight losses and better maintenance of firmness observed in this treatment.

Table 5. Mean values of Soluble solids in pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) — 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days — and hydrothermal treatment (control, 50, and 100 °C).

Sólidos Solúveis (°Brix)			
Days	Treatments		
	Control	50 °C	100 °C
0	0,97 Aa	0,97 Ba	0,97 Ba
2	1,4 Aa	1,87 Aa	2,10 Aa
4	1,2 Ab	1,95 Ab	2,85 Aa
6	1,2 Ab	1,12 Bb	2,35 Aa
8	0,95 Ab	1,05 Bb	3,02 Aa
10	0,95 Ab	2,70 Aa	2,75 Aa
12	0,92 Ab	2,12 Aa	2,20 Aa

14	0,92 Ab	1,97 Aa	2,55 Aa
16	0,97 Ab	1,32 Bb	2,22 Aa
18	0,97 Ab	1,30 Bb	2,92 Aa
20	0,85 Ab	1,07 Bb	2,00 Aa

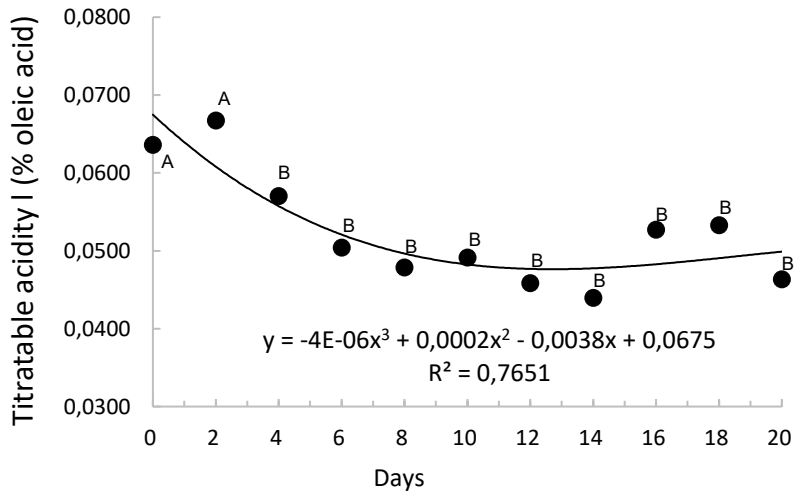
Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Titratable acidity was not influenced by the hydrothermal treatments or storage period, remaining relatively stable throughout the 20-day evaluation period (Figure 1). This behavior indicates that the treatments applied did not cause significant changes in the acidic compounds present in the seeds, preserving an important chemical characteristic related to product quality.

The stability observed for titratable acidity is consistent with the results obtained for pH, which also showed a limited range of variation during storage, suggesting maintenance of the chemical balance of the seeds even after the application of the hydrothermal treatments. Similar results were reported by Rockett et al. (2020) and Moreira (2018), who observed small variations in acidity-related parameters in Brazilian pine seed-derived products subjected to different processing and preservation conditions.

These results suggest that the hydrothermal treatments evaluated had a smaller influence on the chemical attributes of the seeds than on their physical and sensory characteristics throughout storage.

Figure 1. Titratable acidity (% oleic acid) of pine nuts stored at room temperature after different hydrothermal treatment temperatures, as a function of storage days (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days). Uppercase letters compare the means within each day according to the Scott–Knott test ($p \leq 0.05$).

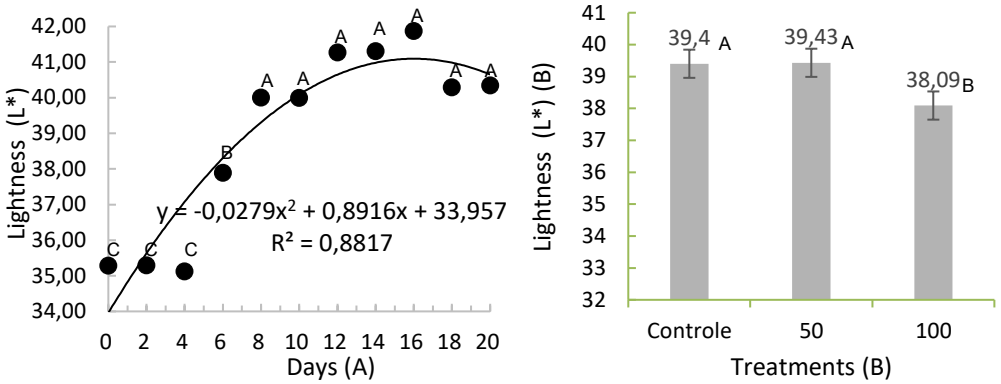


Source: Prepared by the authors (2026).

Seed coat luminosity was influenced by storage period and hydrothermal treatments (Figure 2), showing an increasing trend throughout the experiment. Mean values increased from approximately 35 at the beginning of storage to values above 40

from the 12th day onward, indicating greater surface reflectance of the seed coat and, consequently, a visually lighter appearance of the seeds.

Figure 2. Lightness of pine nuts stored at room temperature after different hydrothermal treatment temperatures (control, 50, and 100 °C) (B), as a function of storage days (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) (A). Uppercase letters compare the means within each day (A) and at each temperature (B) according to the Scott–Knott test ($p \leq 0.05$).

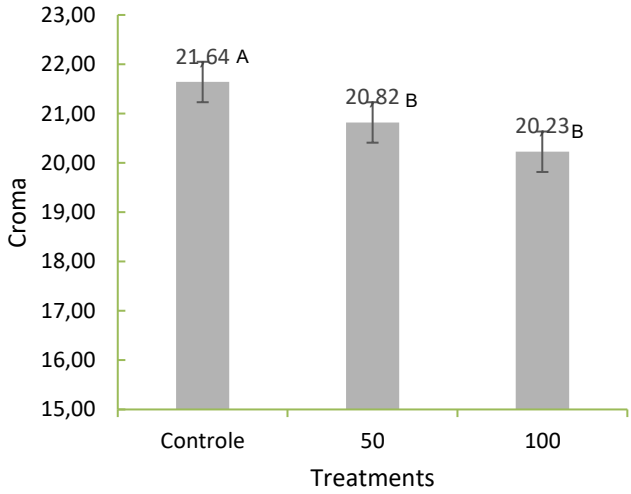


Source: Prepared by the authors (2026).

Among the treatments evaluated, only the treatment at 100 °C for 5 minutes showed lower mean luminosity compared with the control and the treatment at 50 °C for 20 minutes, suggesting greater visual alteration resulting from exposure to the more intense thermal condition. This behavior may be related to changes in surface pigments and seed coat structure caused by heating, phenomena frequently associated with changes in the color of plant products subjected to thermal treatments.

The maintenance of luminosity values in the treatment at 50 °C demonstrates greater preservation of seed appearance during storage.

Figure 3. Chroma of pine nuts stored at room temperature after different hydrothermal treatment temperatures (control, 50, and 100 °C), as a function of storage days. Uppercase letters compare the means within each temperature according to the Scott–Knott test ($p \leq 0.05$).



Source: Prepared by the authors (2026).

Chroma values were not influenced by the storage period; however, differences

were observed among the hydrothermal treatments (Figure 3). The control treatment presented the highest mean chroma value (21.64), whereas the treatments at 50 °C and 100 °C presented lower values (20.82 and 20.23, respectively), indicating a reduction in the intensity or saturation of the seed coat color following the application of the thermal treatments.

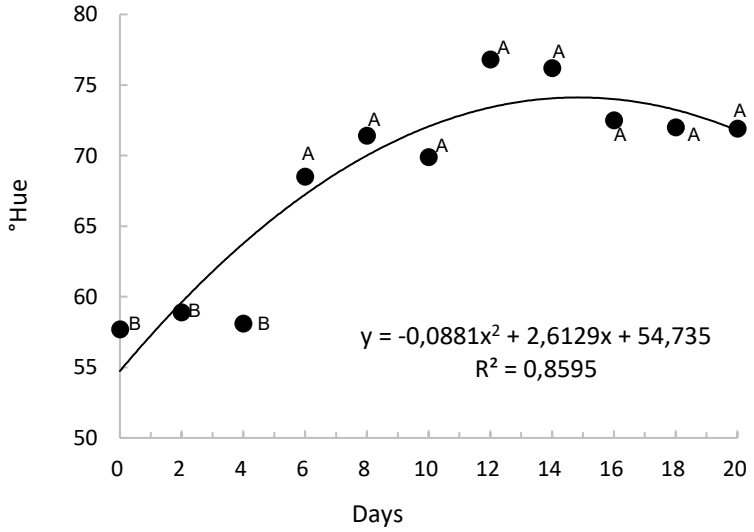
The reduction in chroma values in the hydrothermal treatments suggests that heat exposure promoted changes in the surface pigments of the seed coat, making the coloration less intense compared with untreated seeds. Since no significant effect of the storage period was observed, the changes identified appear to be more closely related to the initial impact of the thermal treatment than to the storage process itself.

Similar results were reported by Dorneles and Noreña (2020) and Dall'Acqua (2021), who observed modifications in the colorimetric parameters of Araucaria angustifolia products as a function of thermal processing. Despite the reduction in color saturation, the values observed were relatively close among the treatments, indicating that the hydrothermal treatments caused only slight visual changes in the overall appearance of the seeds.

The °Hue values were influenced by the storage period, showing an increase during the first days of evaluation followed by stabilization throughout the experiment (Figure 4). Mean values increased from approximately 57.7° at the beginning of storage to values close to 72° after the 12th day, indicating gradual changes in the hue of the seed coat during the storage period.

The absence of a significant effect of the hydrothermal treatments demonstrates that the different heat-application strategies did not alter the hue of the seed coat. This result suggests that the changes observed were mainly caused by the natural processes occurring during storage rather than by the intensity of the treatments applied.

Figure 4. Hue angle (°hue) of pine nuts stored at room temperature after different hydrothermal treatment temperatures, as a function of storage days (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days). Uppercase letters compare the means within each day according to the Scott–Knott test ($p \leq 0.05$).



Source: Prepared by the authors (2026).

Similar results were observed by Singla (2011) and Dorneles and Noreña (2020),

who also reported gradual changes in colorimetric parameters of Araucaria angustifolia products during processing and storage. Thus, the results indicate that the hydrothermal treatments preserved the hue of the seed coat despite the physiological changes occurring throughout storage.

The Browning Index showed an interaction between the hydrothermal treatments and storage period (Table 6), although the variations observed throughout the 20-day evaluation period were relatively small. In general, the treatment at 50 °C for 20 minutes showed behavior similar to the control during most of the evaluation periods, whereas the treatment at 100 °C for 5 minutes promoted more pronounced changes at certain points during storage, particularly between the 4th and 16th days.

The differences observed suggest that the more intense thermal condition partially affected the processes related to seed coat coloration, possibly as a result of changes in pigments and heat-induced browning reactions. However, the magnitude of these changes was limited, indicating that the hydrothermal treatments did not substantially compromise the visual appearance of the seeds during the evaluated period.

The observed behavior corroborates the luminosity results, in which the treatment at 50 °C showed performance similar to the control, indicating greater preservation of the visual attributes of the seed coat. Similar results were described by Carlesso et al. (2022), who observed slight changes in browning-related parameters in plant products subjected to processing and storage conditions, demonstrating that small colorimetric changes do not necessarily result in significant losses in visual quality.

Therefore, the results indicate that the lower-intensity thermal strategy was more effective in maintaining the external appearance of Brazilian pine seeds during storage, reinforcing its suitability for postharvest conservation applications.

Table 6. Mean values of the Browning Index of pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) and hydrothermal treatment (control, 50, and 100 °C).

Browning Index			
Days	Treatments		
	Control	50 °C	100 °C
0	75,92 Aa	75,92 Aa	75,92 Aa
2	72,44 Ba	71,22 Ba	70,70 Aa
4	79,43 Aa	70,21 Bb	65,39 Bb
6	72,83 Ba	74,14 Aa	63,74 Bb
8	71,58 Ba	67,03 Ba	71,27 Aa
10	69,17 Ba	70,43 Ba	70,83 Aa
12	70,86 Ba	69,58 Ba	66,71 Ba
14	72,64 Ba	69,73 Ba	67,88 Ba
16	74,95 Aa	65,97 Bb	69,31 Ab
18	68,05 Ba	67,67 Ba	69,45 Aa
20	69,15 Ba	67,93 Ba	68,43 Ba

Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Regarding the sensory analysis, the analysis of variance demonstrated that only the interaction between treatment and storage period for the aroma variable was not significant (Table 7), indicating that the effect of the treatments on this attribute

remained similar throughout storage. However, significant effects were observed for the individual factors of storage period and hydrothermal treatment, demonstrating that both storage time and the different thermal treatment strategies influenced consumers' perception of the aroma of the samples.

For the other sensory attributes evaluated, a significant interaction between treatments and storage period was observed, demonstrating that consumers' responses varied according to the combination of these factors.

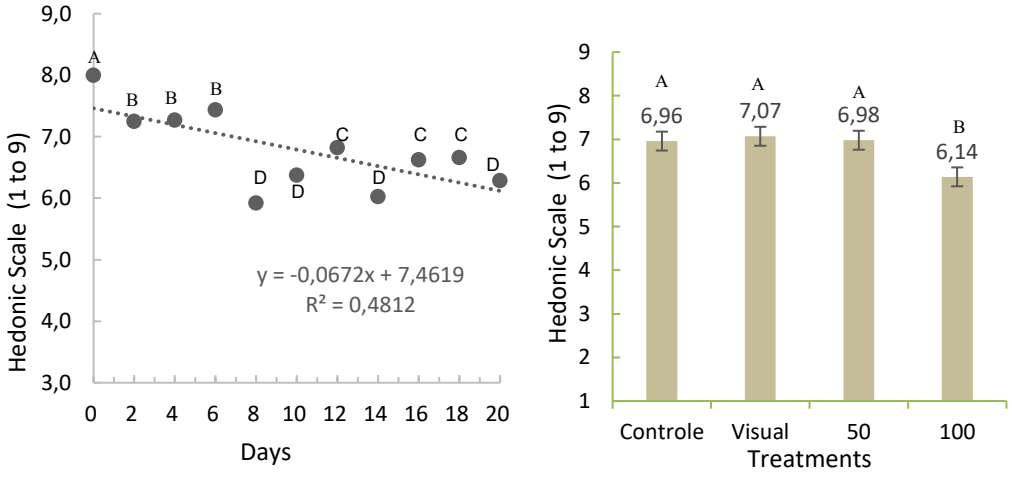
Table 7. Mean squares (MS), degrees of freedom (d.f.), and significance levels for the variables aroma, appearance, texture, flavor, and acceptability in pine nuts (Araucaria angustifolia) subjected to storage at room temperature and hydrothermal treatment.

Factor	G.L.	Aroma	Appearance	Texture	Flavor	Acceptability
		Q.M.	Q.M.	Q.M.	Q.M.	Q.M.
D	10	1,2794*	1,1963*	1,3693*	0,7870*	1,1633*
T	3	1,570*	4,9993*	12,418*	7,5503*	9,2509*
D x T	30	0,1316NS	0,3374*	0,7401*	0,6042*	0,5840*
Error	836	0,1085	0.0998	0,1300	0,1443	0,1224
Total	879	-	-	-	-	-
CV (%)		12,30	11,67	13,83	14,45	13,17
Overall Mean :		6.79	6.95	6.50	6.59	6.73

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Aroma scores were influenced by the interaction between the hydrothermal treatments and storage period (Table 7). In general, the treatment at 100 °C for 5 minutes showed a progressive reduction in acceptance throughout storage, particularly from the 8th day onward. In contrast, the control, visual, and 50 °C for 20 minutes treatments maintained higher aroma scores during most of the evaluation period.

Figure 7. Aroma of pine nuts stored at room temperature after different hydrothermal treatment temperatures (control, visual, 50, and 100 °C) (B), as a function of storage days (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) (A). Uppercase letters compare the means within each day (A) and at each temperature (B) according to the Scott–Knott test ($p \leq 0.05$).



Source: Prepared by the authors (2026).

The lower aroma acceptance observed for the treatment at 100 °C may be associated with the greater thermal intensity applied to the seeds, which may have promoted changes in volatile compounds responsible for their characteristic aroma. The combination of high temperature and storage may also have intensified oxidative and metabolic processes, resulting in sensory changes perceived by consumers.

The treatment at 50 °C showed behavior similar to the control during most of the storage period, indicating that the lower thermal intensity was more effective in preserving the characteristic aroma of the seeds.

Table 8. Mean Appearance scores on the hedonic scale for pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) and hydrothermal treatment (control, visual, 50, and 100 °C).

Appearance				
Days	Treatments			
	Control	Visual	50	100
0	8.15 Aa	8.15 Aa	8.15 Aa	8.15 Aa
2	7.25 Aa	7.40 Aa	7.30 Aa	7.60 Aa
4	7.80 Aa	7.60 Aa	7.20 Aa	7.25 Aa
6	7.45 Aa	8.05 Aa	7.20 Aa	7.20 Aa
8	6.75 Aa	7.15 Aa	6.35 Ba	5.65 Bb
10	7.27 Aa	7.45 Aa	6.95 Aa	5.45 Bb
12	7.80 Aa	7.75 Aa	7.55 Aa	5.25 Bb
14	7.23 Aa	7.23 Aa	6.58 Ba	4.58 Bb
16	7.40 Aa	7.70 Aa	5.75 Bb	5.05 Bb
18	7.50 Aa	8.10 Aa	7.10 Aa	4.55 Bb
20	6.85 Aa	6.50 Aa	6.05 Ba	4.70 Bb

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Appearance scores were influenced by the interaction between the hydrothermal treatments and storage period (Table 8). The treatment at 100 °C for 5 minutes generally presented lower acceptance scores throughout storage, with a more pronounced reduction from the 8th day onward. In contrast, the control, visual, and 50 °C for 20 minutes treatments maintained higher scores during most of the evaluation period.

The lower visual acceptance observed for the treatment at 100 °C is consistent with the results obtained for luminosity and Browning Index, which indicated greater changes in seed coat appearance under the higher-intensity thermal condition. Conversely, the treatment at 50 °C showed behavior similar to the control during a large part of storage, demonstrating greater preservation of the visual characteristics of the product.

According to Gilbert et al. (2016), visual attributes have a strong influence on consumers' perception of food quality and acceptance. Similarly, Godoy et al. (2018) demonstrated that appearance is one of the main attributes considered by consumers when purchasing and consuming Brazilian pine seeds. Therefore, the results obtained

reinforce that the 50 °C treatment strategy was more effective in maintaining the visual quality of the seeds throughout storage.

Texture scores were influenced by the interaction between the hydrothermal treatments and storage period (Table 9). In general, the treatment at 100 °C for 5 minutes showed a significant reduction in acceptance throughout storage, reaching values below 4.0 from the 12th day onward, whereas the control, visual, and 50 °C for 20 minutes treatments maintained scores predominantly above 6.0 during most of the experimental period.

The lower texture acceptance observed for the treatment at 100 °C may be directly related to the greater weight losses and reduction in firmness observed for this treatment. More intense dehydration of the seeds tends to cause structural changes in the tissues, resulting in less desirable characteristics for consumers after cooking. Conversely, the maintenance of firmness and moisture content in the control and 50 °C treatments contributed to preserving the textural characteristics of the product throughout storage.

Similar results were reported by Palhano et al. (2018), who associated the reduction in texture acceptance of stored Brazilian pine seeds with water loss during storage. Thus, the results obtained reinforce the close relationship between the maintenance of the physical characteristics of the seeds and consumers' sensory perception of texture.

Table 9. Mean Texture scores on the hedonic scale for pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) and hydrothermal treatment (control, visual, 50, and 100 °C).

Texture				
Days	Treatments			
	Control	Visual	50	100
0	7.80 Aa	7.80 Aa	7.80 Aa	7.80 Aa
2	7.05 Aa	6.65 Ba	7.45 Aa	7.35 Aa
4	6.90 Aa	7.50 Aa	6.40 Aa	6.35 Ba
6	6.65 Ab	7.85 Aa	6.85 Ab	6.30 Bb
8	6.20 Aa	6.60 Ba	6.40 Aa	4.65 Cb
10	6.80 Aa	6.82 Ba	6.77 Aa	4.15 Cb
12	7.40 Aa	7.05 Ba	7.15 Aa	3.65 Cb
14	7.17 Aa	7.05 Ba	6.70 Aa	3.94 Cb
16	7.55 Aa	7.55 Aa	6.50 Aa	3.30 Cb
18	6.95 Ab	8.05 Aa	6.75 Ab	3.30 Cc
20	6.70 Aa	6.70 Ba	6.15 Aa	3.35 Cb

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Flavor scores were influenced by the interaction between the hydrothermal treatments and storage period (Table 10). Overall, the treatment at 100 °C for 5 minutes presented the lowest acceptance scores throughout the experiment, particularly from the 8th day of storage onward, when it began to show significantly lower scores than those observed for the other treatments. In contrast, the control, visual, and 50 °C for 20 minutes treatments maintained higher levels of acceptance during most of the

experimental period.

The reduction in flavor acceptance in the treatment at 100 °C may be related to the physicochemical changes promoted by the greater thermal intensity, including the greater weight loss, reduction in firmness, and increase in soluble solids observed throughout storage. These changes may influence consumers' sensory perception, altering characteristics that are important for product acceptance.

Similar results were observed by Zortêa-Guidolin et al. (2017), who found that changes resulting from processing can significantly influence the sensory perception of Brazilian pine seed-based products. Thus, the results indicate that the treatment strategy at 50 °C more effectively preserved the sensory characteristics related to flavor, maintaining behavior similar to the control treatment during most of the storage period.

Table 10. Mean Flavor scores on the hedonic scale for pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) and hydrothermal treatment (control, visual, 50, and 100 °C).

Flavor				
Days	Treatments			
	Control	Visual	50	100
0	7.70 Aa	7.70 Aa	7.70 Aa	7.70 Aa
2	7.40 Aa	6.55 Aa	7.10 Aa	7.05 Aa
4	6.90 Aa	7.30 Aa	6.10 Bb	5.95 Bb
6	7.05 Aa	7.05 Aa	6.45 Ba	7.30 Aa
8	5.90 Aa	6.45 Aa	6.90 Aa	4.95 Cb
10	6.57 Aa	6.82 Aa	6.97 Aa	4.57 Cb
12	7.25 Aa	7.20 Aa	7.05 Aa	4.20 Cb
14	7.47 Aa	7.00 Aa	7.11 Aa	4.47 Cb
16	7.80 Aa	7.65 Aa	6.90 Aa	3.70 Cb
18	7.10 Aa	7.90 Aa	7.00 Aa	3.85 Cb
20	6.95 Aa	6.80 Aa	5.70 Bb	4.95 Cb

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Overall acceptability was influenced by the interaction between the hydrothermal treatments and storage period (Table 11). In general, the treatment at 100 °C for 5 minutes presented the lowest scores throughout storage, with more pronounced reductions from the 8th day onward, reaching values close to 4.0 at the end of the experimental period. In contrast, the control, visual, and 50 °C for 20 minutes treatments maintained significantly higher acceptance levels during most of the storage period, demonstrating greater preservation of the overall quality of the product.

The lower acceptability observed for the treatment at 100 °C can be explained by the combined effect of the changes observed in the sensory and physicochemical attributes evaluated. This treatment presented greater weight loss, lower firmness, more pronounced visual changes, and reduced aroma, texture, and flavor scores, factors that contributed to a less favorable overall evaluation by consumers. In contrast, the treatment at 50 °C showed behavior similar to the control for most of the variables analyzed, which was reflected in higher acceptance levels throughout storage.

Similar results were observed by Godoy et al. (2018), who identified appearance, particularly attributes related to color, brightness, and seed size, as determining factors in consumers' perception of quality and purchasing decisions regarding Brazilian pine seeds. Likewise, Conto and Ide (2015) found that attributes such as flavor, texture, and overall acceptance play a fundamental role in the evaluation of products derived from Araucaria angustifolia.

Therefore, the results indicate that the lower-intensity thermal strategy was more effective in maintaining the overall quality of Brazilian pine seeds during storage, preserving characteristics that are important determinants of consumer acceptance.

Table 11. Mean Acceptability scores on the hedonic scale for pine nuts (*Araucaria angustifolia*) subjected to 20 days of storage at room temperature (20 °C and 60% RH) (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days) and hydrothermal treatment (control, visual, 50, and 100 °C).

Acceptability				
Days	Treatments			
	Control	Visual	50	100
0	8.10 Aa	8.10 Aa	8.10 Aa	8.10 Aa
2	7.60 Aa	7.00 Aa	7.45 Aa	7.10 Aa
4	7.20 Ba	7.70 Aa	6.30 Bb	6.15 Bb
6	7.15 Ba	7.40 Aa	6.50 Ba	7.15 Aa
8	6.20 Ba	6.80 Aa	7.00 Aa	4.90 Cb
10	6.67 Ba	7.20 Aa	7.15 Aa	4.65 Cb
12	7.15 Ba	7.60 Aa	7.30 Aa	4.40 Cb
14	7.52 Aa	7.29 Aa	7.17 Aa	4.35 Cb
16	7.95 Aa	7.80 Aa	6.65 Bb	3.70 Cc
18	7.25 Ba	7.85 Aa	7.05 Aa	3.60 Cb
20	7.00 Ba	6.75 Aa	5.70 Bb	4.45 Cc

*Uppercase letters compare storage periods within each treatment, whereas lowercase letters compare treatments within each storage period. Means followed by the same letter do not differ statistically according to the Scott–Knott test at the 5% probability level ($p \leq 0.05$). Source: Prepared by the authors.

Overall, the hydrothermal treatments influenced the physicochemical and sensory quality of pine nuts during storage at room temperature. The high-temperature, short-duration treatment (100 °C for 5 min) resulted in greater weight loss, reduced firmness, and more pronounced changes in parameters related to seed appearance. In contrast, the treatment at 50 °C for 20 min exhibited behavior similar to that of the control for most of the variables evaluated, demonstrating a greater capacity to preserve the physical characteristics of the product throughout the 20-day storage period.

The changes observed in the physicochemical attributes were accompanied by changes in consumer perception, highlighting the relationship between the preservation of the physical characteristics of the seeds and their sensory acceptance. The treatment at 100 °C received lower scores for aroma, appearance, texture, flavor, and overall acceptability, whereas the control, visual, and 50 °C treatments maintained similar levels of acceptance throughout most of the experimental period. These findings reinforce the importance of adopting preservation strategies capable of simultaneously maintaining the physical and sensory attributes of pine nuts during storage.

CONCLUSION

The application of hydrothermal treatments influenced the physicochemical and sensory characteristics of pine nuts during storage at room temperature. The high-temperature, short-duration treatment (100 °C for 5 min) resulted in greater weight loss, reduced firmness, and lower sensory acceptance throughout the evaluated period, indicating a negative effect on product quality.

In contrast, the lower thermal intensity and longer exposure treatment (50 °C for 20 min) exhibited behavior similar to that of the control treatment for most of the variables analyzed, preserving important physical characteristics, such as firmness and lower weight loss, while maintaining satisfactory levels of sensory acceptance throughout most of the storage period.

Under the conditions evaluated in this study, the hydrothermal treatment at 50 °C for 20 min showed promise as an alternative for maintaining the postharvest quality of pine nuts during storage at room temperature. However, further studies addressing microbiological and economic aspects, as well as validation under commercial conditions, are necessary to further elucidate its potential application in the production chain of this species.

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REFERÊNCIAS

ACORSI, D. M.; BEZERRA, J. R. M. V.; BARÃO, M. Z.; RIGO, M. Viabilidade do processamento de biscoitos com farinha de pinhão. **Ambiência**, v. 5, n. 2, p. 207-212, 2009.

AMARANTE, C. V. T.; MOTA, C. S.; MEGGUER, C. A.; IDE, G. M. Conservação pós-colheita de pinhões [sementes de Araucaria angustifolia (Bertoloni) Otto Kuntze] armazenados em diferentes temperaturas. **Ciência Rural**, v. 37, n. 2, p. 346-351, 2007.

BAKER, A. C. **The basis for treatment of products where fruit flies are involved as a condition for entry into the United States**. Florida: USDA, Circular n. 551, p. 8, 1939.

BENINCA, C. **Amido da semente de Araucaria angustifolia: caracterização e efeito das modificações química e física e da incorporação de extratos da casca de pinhão nas suas propriedades.** 2019. 167 p. Tese (Doutorado em Ciência e Tecnologia de Alimentos) – Universidade Estadual de Ponta Grossa, Ponta Grossa, 2019.

CARLESSO, C.; BRANCHER, T. L.; KVITSCHAL, M. V.; HAWERROTH, M. C.; ARGENTA, L. C. Escurecimento de polpa de maçãs 'Fuji', 'Cripps Pink' e 'SCS427 Elenise' para uso como

minimamente processadas. **Agropecuária Catarinense**, v. 35, n. 1, p. 36-39, 2022.

CARRASCO, P. B. **Uso da irradiação e de revestimento comestível na conservação de pinhão [*Araucaria angustifolia* (Bertoloni) Otto Kuntze] in natura e minimamente processado**. 2019. 85 p. Dissertação (Mestrado em Nutrição de Alimentos) – Universidade Federal de Pelotas, Pelotas, 2019.

COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB). Pinhão. **Boletim da Sociobiodiversidade,** v. 4, n. 3, p. 40-46, 2020.

CONTO, L. C.; IDE, G. M. Avaliação físico-química e sensorial de conservas de pinhão (Araucaria angustifolia) processadas em diferentes meios de acidificação. **Ambiência**, v. 11, n. 2, p. 443-455, 2015.

COSTA, F. J. O. G.; LEIVAS, C. L.; GODOY, R. C. B.; WASZCZYNSKYJ, N. Quanto tempo o pinhão mantém sua estabilidade quando armazenado em temperatura ambiente? In: **ARAUCÁRIA: PESQUISA, INOVAÇÃO E TECNOLOGIAS PARA SISTEMAS DE PRODUÇÃO; ERVA-MATE XXI: INOVAÇÃO E TECNOLOGIAS PARA O SETOR ERVATEIRO**. Anais [...], 2020.

COSTA, F. J. O. G.; GODOY, R. C. B.; LEIVAS, C. L.; PEREIRA, L. O.; WASZCZYNSKYJ, N. Alterações na composição físico-química de pinhões (Araucaria angustifolia) armazenados em diferentes embalagens e ambientes. **Brazilian Journal of Food** Technology, 2023.

DALL'ACQUA, K. **Avaliação físico-química de biscoitos com farinha de pinhão e estudo com consumidor.** 2021. 64 p. Monografia (Bacharelado em Tecnologia de Alimentos) – Universidade Estadual do Rio Grande do Sul, 2021.

DAUDT, R. M.; BACK, P. I.; CARDOZO, N. S. M.; MARCZAK, L. D. F.; KÜLKAMP-GUERREIRO, I. C. Pinhão starch and coat extract as new natural cosmetic ingredients: topical formulation stability and sensory analysis. **Carbohydrate Polymers**, v. 134, p. 573-580, 2015.

DAVID, A. A. R.; SILOCHI, R. M. H. Q. Avaliação de métodos para conservação de pinhão. **Faz Ciência**, v. 12, n. 15, p. 207-216, 2010.

DORNELES, M. S.; NOREÑA, C. P. Z. Extraction of bioactive compounds from Araucaria angustifolia bracts by microwave-assisted extraction. **Journal of Food Processing and Preservation**, v. 44, 2020.

DUTCOSKY, S. D. **Análise sensorial de alimentos**. 5. ed. Curitiba: PUCPRESS, 2019.

GILBERT, A. N.; FRIDLUND, A. J.; LUCCHINA, L. A. The color of emotion: a metric for implicit color associations. **Food Quality and Preference**, v. 52, p. 203-210, 2016.

GODOY, R. C. B.; DELIZA, R.; NEGRE, M. F. O.; SANTOS, G. G. Consumidor de pinhão: hábitos, atributos de importância e percepção. **Pesquisa Florestal Brasileira**, v. 38, p. 1-8, 2018.

IBGE. PEVS 2020: com crescimento de 17,9%, valor da produção de silvicultura e extração vegetal chega a R$ 23,6 bilhões. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística, 2024. Disponível em: <https://www.ibge.gov.br>. Acesso em: 7 abr. 2024.

KABELITZ, T.; SCHMIDT, B.; HERPPICH, W. B.; HASSENBERG, K. Effects of hot water dipping on apple heat transfer and post-harvest fruit quality**. LWT - Food Science and Technology**, v. 108, p. 416-420, 2019.

KRUPEK, R. A.; ANJOS, F. E. M. Estimativa do peso da semente de *Araucaria angustifolia*

(Bert.) Kuntze a partir de medidas lineares. **Revista de Ciências Agroambientais**, v. 19, n. 1, 2021.

MOREIRA, M. K. V. **Conservação de pinhões minimamente processados por meio de revestimentos comestíveis com características antimicrobianas**. 2018. 112 p. Dissertação (Mestrado em Nutrição e Alimentos) – Universidade Federal de Pelotas, Pelotas, 2018.

NASCIMENTO, M. A.; SILVA, T. L.; ROSENDO, B. H. B.; SILVA, R. S.; ALMEIDA, L. J. M.; FREITAS, A. B. T. M.; MIELEZRSKI. Teor de sólidos solúveis de duas variedades de cana-de-açúcar submetidas à calagem em dois ciclos produtivos da cultura. **Revista Brasileira de Meio Ambiente**, v. 7, n. 3, p. 80-87, 2019.

OLIVEIRA, E. B. Serviços ambientais em sistemas agrícolas e florestais do Bioma Mata Atlântica. In: **Embrapa**. p. 270-277, 2015.

PALHANO, F. C.; DUARTE, T. R.; COSTA, B. M.; GUEDERT, P. C.; MARCELO, T. L.; SCHEFFER, B. P.; SEIBERT, E. Efeito de diferentes métodos de armazenamento sobre a aceitabilidade e qualidade de pinhões (Araucaria angustifolia) armazenados por até 210 dias. In: **SIMPÓSIO DE INTEGRAÇÃO CIENTÍFICA E TECNOLÓGICA DO SUL CATARINENSE (SICT-SUL)**, 7., 2018. Anais [...].

PALUMBO, M.; ATTOLICO, G.; CAPOZZI, V.; et al. Emerging Postharvest Technologies to Enhance the Shelf-Life of Fruit and Vegetables: An Overview. **Foods**, v. 11, n. 23, 3925, 2022.

ROCKETT, F. C.; SCHMIDT, H.; OLIVEIRA, V. R.; SILVA, V. L.; FLÔRES, S. H.; RIOS, A. O. Composição físico-química, teor de vitaminas, minerais, compostos bioativos e capacidade antioxidante do pinhão (Araucaria angustifolia (Bertol.) Kuntze). In: **SIMPÓSIO DE SEGURANÇA ALIMENTAR**, 7., 2020. Anais [...].

SANTOS, E. L. **Análise dos instrumentos organizacionais e políticos para a construção da cadeia produtiva do pinhão no Rio Grande do Sul.** 2018. 68 p. Dissertação (Mestrado em Engenharia Florestal) – Universidade Federal de Santa Maria, Santa Maria, 2018.

SHIBATA, M.; COELHO, C. M. M. Early harvest increases post-harvest physiological quality of Araucaria angustifolia seeds. **Revista de Biología Tropical**, v. 64, n. 2, p. 885-896, 2016.

SINGLA, N. **Effect of processing on pinhão seeds and extrudability of pinhão flour**. 2011. 108 p. Dissertação (Master of Science in Food Science) – The State University of New Jersey, New Jersey, 2011.

TACO. **Tabela brasileira de composição de alimentos (TACO).** Campinas: Núcleo de Estudos e Pesquisas em Alimentação, Universidade Estadual de Campinas, 2011.

ZORTÉA-GUIDOLIN, M. E. B.; CARVALHO, C. W. P.; GODOY, R. C. B.; DEMIATE, I. M.; SCHEER, A. P. Influence of extrusion cooking on in vitro digestibility, physical and sensory properties of Brazilian pine seeds flour (Araucaria angustifolia). **Journal of Food Science**, v. 82, n. 4, p. 977-984, 2017.

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