

## ANTIOXIDANT ACTIVITY AND PHENOLIC COMPOUNDS IN CACHICHÍN NUTS (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) EXPOSED TO DIFFERENT THERMAL TREATMENTS

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### ABSTRACT

The cachichín tree (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.), present in the Sierra de Misantla, Veracruz, Mexico, produces fruits with bitter-tasting nuts, traditionally consumed as a healthy snack, boiled or toasted. These nuts have significant concentrations of lipids, proteins, fiber, and ash, although their antioxidant capacity and phenolic profile in response to different thermal treatments have not been explored. The objective of this study was to analyze the antioxidant activity and determine the concentrations of free and total phenolic compounds in the raw (T1) cachichín nuts and nuts subjected to different thermal treatments, including boiled (T2), commercial toast (T3), and controlled toast at laboratory level (T4). The nuts subjected to controlled toasting (T4) showed the highest mean in antioxidant activity (20.73 %), followed by commercial toasting (T3; 19.41 %) and raw nuts (T1; 15.38 %), while the boiled nuts (T2) showed the lowest values (9.68 %). Regarding free phenols, the highest concentration of catechin was found in raw nuts (T1), with 278.91 mg g<sup>-1</sup> fresh biomass weight (FBW). Trans-ferulic acid was more abundant in the toasting treatments (7.09 ng g<sup>-1</sup> FBW in T3 and 6.13 ng g<sup>-1</sup> FBW in T4) compared to raw nuts (T1; 3.77 ng g<sup>-1</sup> FBW). Trans-coumaric acid was higher with controlled toasting (T4; 2.67 ng g<sup>-1</sup> FBW). In terms of total phenols, raw nuts (T1) showed the highest concentration of catechin (613.95 mg g<sup>-1</sup> FBW), while chlorogenic acid was more abundant in commercial toasting (T3; 89.12 ng g<sup>-1</sup> FBW). Total trans-ferulic acid was higher in boiled and toasted nuts (T2, T3, and T4), while trans-coumaric acid was highest in controlled toasting (T4) and lowest in boiled (T2). Cachichín nuts are concluded to contain phenolic compounds with beneficial functions, whose concentrations can be altered in response to the thermal treatments applied.

**Keywords:** Metteniusaceae, cacaté, nutraceutical value, antioxidants, phenols.

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## INTRODUCTION

The species *Oecopetalum mexicanum* Greenm. & C.H. Thomps., commonly known as cachichín or cacaté, is a tree that produces fruits with edible nuts. The species belongs to the Metteniusaceae family and is mainly distributed in southeastern Mexico and northern Central America. In the state of Veracruz, its growth and cultivation have deep roots with the indigenous peoples and local residents of the Sierra de Misantla. This plant species produces a globose fruit with a hard shell, greenish in color when immature, and brown when mature. Inside the fruit there is an ovoid nut, with a large endosperm, yellow in color, soft in texture, and a bitter taste (Lascurain *et al.*, 2012; Hernández-Mora *et al.*, 2024). Its cultivation and production happen in several municipalities that make up the Sierra de Misantla, and its marketing reaches the capital city of the state of Veracruz, Xalapa. The nut can be sold raw, boiled, or toasted (Lascurain *et al.*, 2009).

Some research has been carried out on the nutritional properties of these nuts, and it has been found that, on average, they contain 10 % protein, 40 % lipids, 5 % fiber, 2 % ash, and less than 1 % sugars (Hernández-Mora *et al.*, 2021). Additionally, the nuts contain saponins, sterols, and coumarins, which are antioxidant compounds important in nutrition and human health (Hernandez *et al.*, 2013). In an exhaustive literature search, no detailed analyses were found that addressed the concentrations of phenolic compounds in cachichín nut, nor was information found about how various treatments could influence its antioxidant activity. Phenolic compounds can inhibit the development of human diseases, including hypertension, metabolic problems, incendiary infections, and neurodegenerative diseases.

Among the antioxidant compounds that plants can produce, phenols show various functions and, as part of the functional secondary metabolism, offer benefits to other organisms that consume them (Olivares-Vicente *et al.*, 2018). In humans and other biological systems, phenols have shown effectiveness in the control of cholesterol and oxidized low-density lipoprotein (LDL) and important antioxidant and metal chelating activity at toxic concentrations (Kumar *et al.*, 2013).

Although many food products can be consumed fresh, others must be subjected to thermal treatments for consumption. Such processing modifies their biochemical and nutritional properties. These modifications depend on the type of food and other factors such as storage time, pH, water activity, chemical compounds, and concentrations of the plant species, starches, and sugars involved. Furthermore, these factors influence the Maillard reaction, which may start at 115–120 °C, accelerate at 130 °C, and stop at 180 °C (Kumar *et al.*, 2013). Consequently, this reaction produces a variety of early, intermediate, and advanced compounds and has both positive and negative effects on food quality (Chen *et al.*, 2018). The beneficial contributions of the Maillard reaction are the generation of sensory attributes such as color, flavor, aroma, and texture, as well as improvements in antioxidant properties and inhibition of the proliferation of pathogenic microorganisms (Liu *et al.*, 2020). The negative aspects are the appearance of unpleasant flavors, loss of flavor, discoloration, loss of nutritional

value of proteins, and the formation of potentially carcinogenic compounds such as acrylamide (Kathuria *et al.*, 2023).

The objective of this study was to determine the effect of different thermal treatments (i.e., raw nuts [T1], boiled [T2], commercially toasted [T3], and toasted under controlled laboratory conditions [T4]) on the antioxidant activity and the concentrations of free and total phenolic compounds in cachichín nuts.

## MATERIALS AND METHODS

### Obtention of nut samples

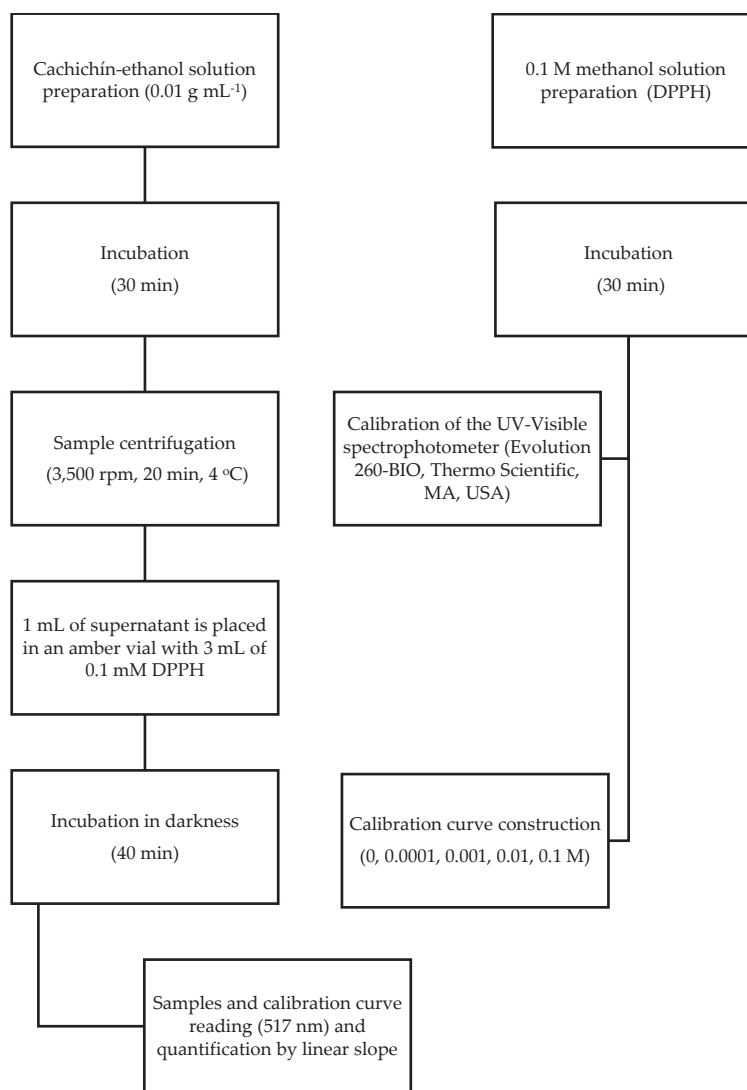
The cachichín nut samples were obtained from the “Café Dorantes” group, a collective of producers located in Misantla, Veracruz, Mexico. The evaluated treatments were: raw nuts (T1); boiled nuts (T2); nuts subjected to commercial toasting (T3); and nuts subjected to controlled toasting (T4). Boiling (T2) was done under empirical conditions in wood stoves, at a temperature of 100 °C for 15 min in a 20 L stainless steel container. Commercial toasting (T3) was carried out on clay or red clay comales from the Sierra de Misantla at temperatures that reached up to 180 °C. Cooking took 20 min over low heat in stoves fueled with firewood from trees in the same region. Controlled toasting at laboratory level was carried out in an aluminum saucepan and a heating grill (Thermo-Scientific SP131015Q; Waltham, MA, USA) at 134 °C for 25 min (Hernández-Mora *et al.*, 2017). The external appearance of the nuts after thermal treatments is shown (Figure 1).



**Figure 1.** Cachichín (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) nuts subjected to different thermal treatments. A: raw nuts; B: boiled nuts; C: commercial toasted nuts; D: controlled toasted nuts.

### Antioxidant activity

The antioxidant activity was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) technique, according to the methodology described by Kuskoski *et al.* (2005) (Figure 2).



**Figure 2.** Methodology used to determine antioxidant activity in cachichín nuts (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) subjected to different thermal treatments.

### Quantification of free phenols and total phenols

#### Sample conditioning

Free and total phenols were determined according to the methodology described by Leucuta *et al.* (2005), with some modifications. Ten previously ground and sifted nuts per treatment were used. A 0.1 g sample from each treatment was taken for total phenol and free phenol quantification. The samples were weighed using an analytical

scale (OHAUS, AV213C; Parsippany, NY, USA) and placed in 1.5 mL microcentrifuge tubes. For free phenols, 200  $\mu$ L of HPLC-grade water (J. T. Baker<sup>®</sup>) and 200  $\mu$ L of methanol (J. T. Baker<sup>®</sup>) were added. For total phenols, 200  $\mu$ L of HPLC-grade water and 200  $\mu$ L of methanol were taken. The samples were incubated at 65 °C for 30 min in a water bath (Precision Fisher Scientific; Waltham, MA, USA) and then with 15 min of sonication in an ultrasonic bath (CS-UB32, Fisher Scientific). The reaction continued for another 20 min, and subsequently, 200  $\mu$ L of methanol were added, and the solution was heated for an additional 10 min. The samples were centrifuged at 4000 rpm for 5 min in a centrifuge (Labnet Hermle, model Z 233 MK-2; Wehingen, Germany). The centrifugation process was repeated two more times, adding 1 mL of HPLC-grade water. The supernatant obtained was filtered through filter paper (Whatman<sup>™</sup> Grade 1, 25 mm) in a 5 mL volumetric flask (Kimax, Kimble; Rockwood, TN, USA). Finally, the samples were filtered using 0.45  $\mu$ m membrane syringe filters (0.45  $\mu$ m Millex-HV, PVDF, 13 mm, Millipore; Carrigtwohill, Ireland) and stored at 4 °C until chromatographic analysis.

#### **Chromatographic conditions for phenol quantification**

The quantification of phenols was carried out in a high-performance liquid chromatography (HPLC) system (Gradient HPLC System, Agilent 1200 Series, Agilent Technologies; Waldbronn, Germany), with a DAD UV/VIS detector. For separation, a C18 150 x 4.6 mm 5  $\mu$ m reversed phase column (Hypersil Gold model, ThermoFisher; Waltham, MA, USA) was used. A G1322A degasser and a G1311A quaternary gradient pump were used for gradient elution. The detection of the compounds was carried out at 330 nm. The chromatographic data were processed using Chemstation software (Agilent; Santa Clara, CA, USA).

The mobile phase was a binary gradient prepared from methanol (solvent A) and buffer (solvent B). The buffer solution was prepared by dissolving potassium dihydrogen phosphate (40 mM) in water. The pH of the solution was adjusted to 2.3 with 85 % orthophosphoric acid. The analysis was started with a linear gradient containing from 5 to 42 % solvent A for the first 35 min, followed by an isocratic elution with 42 % solvent A for the next 3 min. The flow rate was 1 mL min<sup>-1</sup> and the injection volume was 10  $\mu$ L. All the solvents were filtered through 0.5  $\mu$ m filters (Sartorius) and degassed in an ultrasonic bath (Scientific, CS-UB32; Waltham, MA, USA).

#### **Experimental design and statistical analysis**

The treatments in the experiment were arranged in a completely random distribution. The data were processed using the statistical software RStudio version 1.2.5033. Once the assumptions of normality (Shapiro-Wilk test) and homogeneity (Levene test) of variances were proven, a one-way analysis of variance (ANOVA) was performed to determine significant differences with a confidence level of 95 % ( $p \leq 0.05$ ) using Tukey's test.

## RESULTS AND DISCUSSION

Phenolic compounds improve the antioxidant capacity of different edible grains and fruits. In the present study, we found that the different thermal treatments modified the antioxidant activity and the free and total phenolic compound profiles, including catechin, trans-ferulic acid, trans-coumaric acid, and chlorogenic acid.

### Antioxidant activity

A significant increase in oxidant inhibition was observed in the commercial toasting (T3) and controlled toasting (T4) treatments, being 26.2 and 34.8 % higher, respectively, compared to raw nuts (T1). Conversely, the boiled treatment (T2) recorded a decrease of 37.1 %, compared to T1 (Table 1).

**Table 1.** Percentage of oxidant inhibition activity in raw cachichín (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) nuts under four applied thermal treatments.

	Treatment			
	Raw (T1)	Boiled (T2)	Commercial toasting (T3)	Controlled toasting (T4)
Inhibition percentage	15.38 ± 0.04 c	9.68 ± 0.04 d	19.41 ± 0.04 b	20.73 ± 0.10 a

Means ± SE with different letters in each column indicate significant statistical differences between treatments (Tukey,  $p \leq 0.05$ ).

The increase in the percentage of inhibition found in treatments T3 and T4, compared to T1 (raw nuts), could be attributed to the possible solubilization of phenolic compounds exposed to temperatures of around 100–180 °C (Kim *et al.*, 2011), as has been observed in the extraction of phenols from date (*Phoenix dactylifera*) nuts (Mrabet *et al.*, 2022). In the case of controlled toasting at 134 °C, solubilization could also have occurred due to the prolonged exposure time to which the nut was subjected, increasing the internal temperature of the endosperm. The behavior of treatment T2 was inverse to T3 and T4, decreasing the percentage of inhibition by 37 % compared to T1. The reduction in the inhibition percentage during the boiling process could be the result of the leaching of phenolic compounds from the nut into the water, a phenomenon that has been found in previous studies with legumes and cowpea (*Vigna unguiculata* L.) nuts (Xu and Chang, 2008). This phenomenon occurs depending on the polarity of the phenolic compounds, a property inherent to phenols due to the hydroxyl functional groups present in their chemical structure (Yadav *et al.*, 2018).

The highest percentage of inhibition observed in the cachichín nut with the T4 treatment was 55 % lower compared to the value found for black rice (*Oryza sativa*

L.) (Pedro *et al.*, 2016), and 74 % lower than that reported in peanut (*Arachis hypogaea* L.) shells (Franco *et al.*, 2018). It was also lower than those reported for chia (*Salvia hispanica* L.), grape (*Vitis vinifera* L.) nuts, and pistachio (*Pistacia vera* L.) (Munekata *et al.*, 2020).

### Concentration of free phenols

Regarding free phenols, the highest concentration of catechin (Table 2) was found in raw nuts (T1), while boiled (T2) and controlled toasting (T4) showed similar means. The lowest concentration of this phenolic compound was found in commercial toasted nuts (T3). The concentration of trans-ferulic acid was lower in raw nuts (T1) and in boiled nuts, whereas commercial (T3) and controlled (T4) toasted nuts showed higher means compared to raw nuts.

**Table 2.** Concentration of free phenolic compounds in cachichín (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) nuts subjected to four different treatments.

Treatment	Catechin mg g <sup>-1</sup> FBW	Trans-ferulic acid	Trans-coumaric acid
		ng g <sup>-1</sup> FBW	
Raw (T1)	278.91 ± 69.03 a	3.77 ± 0.69 b	1.61 ± 0.15 b
Boiled (T2)	132.32 ± 3.71 b	5.49 ± 0.10 ab	1.30 ± 0.08 b
Commercial toast (T3)	69.57 ± 1.83 c	7.09 ± 0.57 a	1.48 ± 0.21 b
Controlled toast (T4)	124.98 ± 0.57 b	6.13 ± 0.49 a	2.67 ± 0.20 a

Means ± SE with different letters in each column indicate significant statistical differences between treatments (Tukey,  $p \leq 0.05$ ). FBW: fresh biomass weight.

Boiled nuts showed means statistically similar to those observed in both raw nuts and toasted nuts (Table 2). Nuts with controlled toasting (T4) had the highest concentration of free trans-coumaric acid, compared to the rest of the treatments (T1, T2, and T3), which showed an average concentration of 1.46 ng g<sup>-1</sup> FBW of trans-coumaric acid (Table 2).

### Total concentration of phenols

Among the total phenols, catechin, chlorogenic acid, trans-ferulic acid, and trans-coumaric acid were identified in cachichín nuts (Table 3). Catechin showed its highest mean in raw nuts (T1), exceeding the concentrations recorded in the boiled (T2), commercial toasting (T3), and controlled toasting (T4) thermal treatments by 48.1, 37.8, and 44.2 %, respectively. The concentration of total chlorogenic acid (Table 3) was higher in nuts with commercial toasting (T3) by 43.5, 87.1, and 50.6 % compared to the concentrations recorded in raw nuts (T1), boiled nuts (T2), and nuts with controlled toasting (T4), respectively.

**Table 3.** Concentration of total phenolic compounds in cachichín (*Oecopetalum mexicanum* Greenm. & C.H. Thomps.) nuts subjected to four different thermal treatments.

Treatment	Catechin	Chlorogenic acid	Trans-ferulic acid	Trans-coumaric acid
	mg g <sup>-1</sup> FBW		ng g <sup>-1</sup> FBW	
Raw (T1)	613.95 ± 55.08 a	62.12 ± 6.15 b	2.81 ± 0.36 b	1.70 ± 0.16 ab
Boiled (T2)	318.40 ± 12.97 b	47.62 ± 0.92 b	5.04 ± 0.18 a	1.51 ± 0.04 b
Commercial toast (T3)	382.05 ± 25.90 b	89.12 ± 2.41 a	5.89 ± 0.23 a	1.96 ± 0.20 ab
Controlled toast (T4)	342.61 ± 43.62 b	59.16 ± 8.49 b	5.38 ± 0.42 a	2.35 ± 0.17 a

Means ± SE with different letters in each column indicate significant statistical differences between treatments (Tukey,  $p \leq 0.05$ ). FBW: Fresh Biomass Weight.

Regarding total trans-ferulic acid, the highest means occurred in T2, T3, and T4, and were statistically higher than T1 by 93.5 % on average. On the other hand, the concentration of total trans-coumaric acid only showed differences between boiled nuts (T2) and nuts with controlled toasting (T4); T4 was 55.6 % greater than T2.

Phenolic compounds are secondary metabolites synthesized in plants that encompass molecules that contain hydroxybenzene, linked to aromatic or aliphatic structures (Rahman *et al.*, 2021). Phenols are synthesized and genetically regulated in response to biotic and abiotic stress factors (Quideau *et al.*, 2011). Phenolic compounds also contribute to the pigmentation of some plant tissues. For example, anthocyanins provide red, purple, or blue color in leaves, fruits, and flowers (Alappat and Alappat, 2020). Due to their high antioxidant capacity, phenolic compounds have gained great interest in nutrition and human health, and have shown effectiveness in the prevention of cancer, cardiovascular diseases, and neurological diseases such as Alzheimer's (Rahman *et al.*, 2021).

The analysis of the total and free phenol profiles revealed that the thermal treatments applied to cachichín nuts decreased the concentration of free catechin. This reduction can be attributed to the instability of the epistucture of catechins at temperatures above 80 °C, because they tend to epimerize (Vuong *et al.*, 2010). Despite the decrease in catechin concentration, cachichín nut still contained this compound after heat treatment, which shows antioxidant, anticancer, anti-inflammatory, antibacterial, antiviral, immune-regulating, and protective properties against neurodegenerative diseases (Yang *et al.*, 2018).

Compared to raw nuts (T1), heat treatments increased free and total trans-ferulic acid concentrations, specifically in commercial (T3) and controlled (T4) toasts. However, the thermal treatments evaluated (boiling, commercial, and controlled toasting) did not affect the concentrations of total trans-coumaric acid, but they did affect those of free trans-coumaric acid, which increased in the controlled toasting treatment (T4) compared to raw nuts (T1). Chlorogenic acid, identified as total phenol, increased in T3

(commercially toasted) compared to T1 (raw nuts). Mung bean (*Vigna radiata* L.) nuts, dried in a microwave oven and in a conventional oven, had a higher concentration of phenolic compounds (Alkaltham *et al.*, 2020).

Similar studies have found that heat treatments reduce the concentrations of phenolic compounds (Choi *et al.*, 2012; Maghsoudlou *et al.*, 2019). The increase in the concentration of these compounds in the present study can be explained by the rupture of the cellular matrix of the nut exposed to thermal treatments, which allows the release of soluble phenols from insoluble ester bonds (Chandrasekara and Shahidi, 2011; Zhang *et al.*, 2022). In corn (*Zea mays* L.) kernels and corn bran, it was found that increasing the concentration of solubilized ferulic acid increases the total antioxidant activity (Dewanto *et al.*, 2002). In soybean (*Glycine max* [L.] Merr.), the total antioxidant activity increased directly when increasing the concentration of chlorogenic acid. However, the solubilization of some phenolic acids occurs only at elevated temperatures (100–180 °C) (Kim *et al.*, 2011; Choi *et al.*, 2012). The latter is in accordance with the findings of the present study, in which we found significant increases in the concentrations of trans-ferulic acid, trans-coumaric acid, and chlorogenic acid in nuts exposed to the boiled (T2), commercial toasting (T3), and controlled toasting (T4) treatments.

The identification of phenolic compounds in cachichín nuts is of great relevance in nutraceutical terms. Trans-ferulic acid functions as an antioxidant and shows antidiabetic, anticancer, antimicrobial, antiviral, anti-inflammatory, neuro-protective, anti-apoptotic, anti-allergic, hepatoprotective, UV ray absorber (cosmetic use), lung protection, vasodilator, and antithrombotic compound action, in addition to helping increase sperm viability (Fong *et al.*, 2016; Stompor-Gorący and Machaczka, 2021). In the food industry, this compound is a precursor to vanillin, useful as an aromatic compound and as an inhibitor of food discoloration (Rukkumani *et al.*, 2004; Kumar and Pruthi, 2014).

Trans-coumaric acid shows antioxidant, antimicrobial, antiviral, anticancer, analgesic, antipyretic, hypopigmentant, antiulcer, antiarthritis, antiplatelet, and antiplatelet action, as well as being effective in the control of hyperglycemia (Pei *et al.*, 2016). In the gastrointestinal tract, trans-coumaric acid has been observed to show better bioavailability than chlorogenic, caffeic, and trans-ferulic acids (Zhao and Moghadasian, 2010). Chlorogenic acid also presents antioxidant, antibacterial, hepatoprotective, cardioprotective, anti-inflammatory, antipyretic, neuroprotective, anticholesterolemic, antiviral, antimicrobial, antihypertensive, efficient free radical scavenger, and central nervous system stimulator activity (Santana-Gálvez *et al.*, 2017). Furthermore, this phenolic compound can modulate lipid and glucose concentrations in patients with metabolic disorders (Naveed *et al.*, 2018).

The exposure of cachichín nuts to high temperatures induced the Maillard reaction, during which a wide range of compounds known as Maillard reaction products (MRP) are produced. Given that in this work the effects of heat treatments on antioxidant activity and the concentration of phenolic compounds were determined, it is important to point out that the presence of phenols in foods can reduce or inhibit the production

of MRP (Zhang *et al.*, 2007a; Zhang *et al.*, 2007b; Mildner-Szkudlarz *et al.*, 2017). This effect can be attributed to the ability of phenolic compounds to eliminate free radicals. Furthermore, some polyphenols can inhibit acrylamide production through direct interaction with 3-oxo-propanamide, bypassing the reaction with a deamination of 3-aminopropionamide (3-APA) (Cheng *et al.*, 2014; Xu *et al.*, 2015).

During the Maillard reaction, heterocyclic amines (HAs) can also be produced, especially when foods have high protein concentrations. Within the HA, 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP), 2-amino-3,8-dimethylimidazo[4,5-f]quinoxaline (MeIQx), and 2-amino-3,4,8-trimethylimidazo[4,5-f]quinoxaline (4,8-DiMeIQx) are potentially carcinogenic compounds (Salazar *et al.*, 2014; Sabally *et al.*, 2016). Among the phenolic compounds, phloridzin shows inhibitory activity on the production of PhIP and chlorogenic acid in MeIQx. Such effects could be attributed to the capture of phenylacetaldehyde (the precursor of HA) through the formation of the polyphenol-phenylacetaldehyde linkage. These bonds formed by the capture of polyphenols by phenylacetaldehyde could have additional health benefits, such as anticancer capabilities (Cheng *et al.*, 2007).

Regarding advanced glycation end products (AGEs) resulting from the Maillard reaction, these can cause inflammatory responses, oxidative stress, hyperglycemia, and hyperlipidemia, as well as endothelial dysfunction (Shen *et al.*, 2020). The presence of phenolic compounds in foods could inhibit the synthesis and accumulation of AGEs through the elimination of free radicals formed during glycation or the capture of reactive carbonyl species (Yu *et al.*, 2017). In the bark of the cinnamon (*Cinnamomum verum* J. Presl.) tree, proanthocyanidins were identified as causing the inhibition of specific AGEs (Peng *et al.*, 2010). Thus, during the thermal processing of foods, phenolic compounds could have significant potential for reducing the formation of toxic MRPs and participating in the Maillard reaction to form beneficial compounds.

## CONCLUSIONS

Cachichín nuts contain phenolic compounds and showed antioxidant activity, whose values may vary in response to the thermal treatments applied. Raw nuts (T1) showed the highest concentration of catechin, which decreased significantly in nuts subjected to heat treatments. Commercially toasted nuts (T3) showed the highest concentration of chlorogenic acid. Nuts subjected to heat treatments (T2, T3, and T4) presented higher concentrations of trans-ferulic acid compared to raw nuts (T1). Nuts subjected to controlled toasting (T4) showed the highest concentration of trans-coumaric acid. It is concluded that the thermal treatments tested affected the antioxidant capacity and the concentration of phenolic compounds measured, which demonstrates the importance of considering different processing methods for cachichín nut. In all cases, the results shown here reaffirm that cachichín nuts constitute an important source of antioxidant molecules with relevant functions in both nutrition and human health.

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