



Germination and Roasting Effects on Nutritional, Chromatic and Functional Properties of Flours from the Pseudocereals Quinoa (*Chenopodium quinoa* Willd.) and Amaranth (*Amaranthus* spp.)

Cyntia Valeria Rodríguez-Sánchez¹, Pablo Alan Rodríguez-Salinas¹,
Juanita Guadalupe Gutiérrez-Soto¹, Vania Urías-Orona², Guillermo Niño-Medina¹

10.18805/LRF-960

ABSTRACT

Background: Quinoa (*Chenopodium quinoa* Willd.) and amaranth (*Amaranthus* spp.) are pseudocereals with potential as functional foods or raw materials for production of functional foods because of their high nutritional value and phenolic content. However, quinoa and amaranth are low consumed because of flours obtained from their native grains do not have attractive flavor and their nutrients and phenolics have low bioavailability. Germination and roasted of quinoa and amaranth seeds are alternatives for improvement of flour characteristics.

Methods: Proximate composition was obtained by AOAC and AOCS official methods. The chromatic characterization was done by CIELAB (L^* , a^* , b^*) and CIELCH (L^* , C^* , h^*) systems. The content of total phenols, total flavonoids and condensed tannins were evaluated by Folin-Ciocalteu, aluminum chloride and vanillin-sulfuric acid reactions, respectively. Finally, antioxidant capacity was evaluated by using DPPH, ABTS and FRAP assays.

Result: Germination and roasting did not affect the content of protein (10.49 to 11.80%), crude fiber (1.19 to 1.96%) and carbohydrates (72.76 to 74.77%), while moisture, ash and fat were affected resulting A-NG (5.23%), A-G (3.35%) and Q-G (6.98%) treatment with higher content, respectively. There was statistical difference in all color variables resulting with higher values A-NG in L^* (78.73) C^* (25.40) and h^* (73.77). Regarding to functional properties, in free extracts Q-G resulted with higher levels of total phenolics (6940 mg GAE/kg), condensed tannins (8064 mg CatE/kg) and ABTS (41005 $\mu\text{mol TE/kg}$), while A-G obtained higher levels in total flavonoids (1141 mg CatE/kg), DPPH (25351 $\mu\text{mol TE/kg}$) and FRAP (44327 $\mu\text{mol TE/kg}$). Finally, in bound extracts the higher levels were for Q-G in total phenolics (412 mg GAE/kg) and FRAP (4869 $\mu\text{mol TE/kg}$), A-NG in total flavonoids (263 mg CatE/kg), A-G in condensed tannins (584 mg CatE/kg), Q-NG in DPPH (1823 $\mu\text{mol TE/kg}$) and ABTS (4869 $\mu\text{mol TE/kg}$). The characteristics obtained from germinated and roasted quinoa and amaranth flours make them good ingredients for the development of pseudocereals based functional beverages in the near future.

Key words: Antioxidant capacity, Germination, Nutritional value, Phenolic compounds, Pseudocereals, Roasting.

INTRODUCTION

Within the functional foods market, a global annual demand growth of 15% has been estimated between 2023 and 2028 (Rachtan-Janicka *et al.*, 2025). This increase is attributed to a society that is more aware of healthier lifestyles and follows a growing trend toward consuming foods that provide positive health benefits, ranging from better body weight control to slowing the progression of chronic diseases (Vajdovich *et al.*, 2025).

Pseudocereals such as quinoa and amaranth are considered ingredients with functional potential due to their numerous health benefits associated with their high nutritional and phytochemical profiles (Jan *et al.*, 2023; Toimbayeva *et al.*, 2025). Quinoa (*Chenopodium quinoa* Willd.) possesses a balanced combination of essential amino acids and is a good source of minerals and proteins, some of which are present in higher amounts than in traditional cereal crops but also is low in prolamins which indicates that it is gluten free and, therefore, non-allergic (Anuhya and Dobhal, 2024). It also contains a wide variety of antioxidant compounds, such as phenolics (Jan *et al.*, 2023) and furthermore, quinoa contains polysaccharides

¹Universidad Autónoma de Nuevo León, Facultad de Agronomía, Laboratorio de Química y Bioquímica. Francisco Villa S/N, Col. Ex Hacienda El Canadá, C.P. 66050, General Escobedo, Nuevo León, México.

²Universidad Autónoma de Nuevo León, Facultad de Salud Pública y Nutrición, Laboratorio de Fitoterapia. Av. Dr. Eduardo Aguirre Pequeño y Yuriria, Col. Mitras Centro, C.P. 64460, Monterrey, Nuevo León, México.

Corresponding Author: Guillermo Niño-Medina, Universidad Autónoma de Nuevo León, Facultad de Agronomía, Laboratorio de Química y Bioquímica. Francisco Villa S/N, Col. Ex Hacienda El Canadá, C.P. 66050, General Escobedo, Nuevo León, México. Email: guillermo.ninomd@uanl.edu.mx

ORCIDs: <https://orcid.org/0000-0003-2110-9729>, <https://orcid.org/0000-0001-9754-7755>, <https://orcid.org/0000-0003-0430-9438>, <https://orcid.org/0000-0003-3316-2316>

How to cite this article: Rodríguez-Sánchez, C.V., Rodríguez-Salinas, P.A., Gutiérrez-Soto, J.G., Urías-Orona, V. and Niño-Medina, G. (2026). Germination and Roasting Effects on Nutritional, Chromatic and Functional Properties of Flours from the Pseudocereals Quinoa (*Chenopodium quinoa* Willd.) and Amaranth (*Amaranthus* spp.). *Legume Research*. 49(10): 1804-1813. doi: 10.18805/LRF-960.

Submitted: 19-05-2026 **Accepted:** 08-06-2026 **Online:** 01-07-2026

that have a prebiotic action (Mu *et al.*, 2023). Amaranth (*Amaranthus spp.*), similar to quinoa, is characterized by a balanced amino acid composition, including essential amino acids. It is also rich in dietary fiber, minerals, as well as antioxidants such as polyphenols (Toimbayeva *et al.*, 2025).

Despite these attributes, both quinoa and amaranth exhibit limited bioavailability due to antinutritional factors (tannins, phytic acid and saponins) that bind to nutrients, reducing their availability for absorption. Soaking, germination and thermal treatments are useful methods for reducing antinutritional compound content while simultaneously improving nutritional value and bioactive potential (Thakur *et al.*, 2021; Li *et al.*, 2025).

Germination is an effective process for improving the nutritional properties of grains through various biochemical reactions. This process begins with water imbibition, which activates the seed's metabolism and concludes with radicle elongation (Zhang *et al.*, 2024; Benincasa *et al.*, 2019). Likewise, germination activates antioxidant synthesis as a protective mechanism against oxidative damage induced by enzymatic activation, while also increasing the levels of free and bound phenolic compounds (Aung *et al.*, 2022). In addition to nutrient activation, the antinutritional compounds naturally present in the seed are reduced, resulting in improvements in both flavor and digestibility (Thepthanee *et al.*, 2024).

Although germination improves the nutritional and sensory characteristics of grains, excessive germination periods may promote microbial growth and the development of undesirable flavors. Therefore, post-germination treatments, such as roasting, are considered viable methods for preservation and flavor enhancement, as they suppress organic acids, including acetic and ethanoic acids, formed during germination (Kim *et al.*, 2021).

Germinated and/or roasted pseudocereals can be used as ingredients to make basic dough for pasta and baked gluten free products (cookies, bread, pancakes) and beverages, which have shown higher nutritional and functional properties than raw flours (Schmidt *et al.*, 2023; Pilco-Quesada *et al.*, 2020; Jyoti *et al.*, 2025; Muyonga *et al.*, 2014).

The aim of the present study was to evaluate the effect of germination and roasting on the nutritional, chromatic and functional properties of quinoa (*Chenopodium quinoa* Willd.) and amaranth (*Amaranthus spp.*) flours.

MATERIALS AND METHODS

Experimental site

The experiments were conducted at Chemistry and Biochemistry Lab in the Agronomy Faculty of Universidad Autónoma de Nuevo León from February to November 2025.

Plant material

Quinoa (*Chenopodium quinoa* Willd.) seeds were obtained from different commercial establishments in the city of Monterrey and its metropolitan area, with Bolivia and Peru as countries of origin. Amaranth (*Amaranthus*

hypochondriacus L.) seeds were obtained from the state of Puebla, Mexico.

Seed treatment

For the preparation of non-germinated quinoa (Q-NG) and amaranth seed (A-NG) seeds, 10 g sample were dried at 50°C for 24 h, roasted at 145°C for 30 min (Felisa, 291A), milled, sieved to 60 mesh (0.25 mm) and stored at -20°C, protected from light, until further analysis.

The germinated quinoa (Q-G) and germinated amaranth (A-G) samples were obtained according to the method described by Choque-Quispe *et al.* (2021) with some modifications. A 10 g sample was weighed and disinfected with commercial sodium hypochlorite (500 ppm) for 5 min. After that, the samples were rinsed with bidistilled water by hand-friction to remove saponins until no foam was observed. The seeds were then soaked in darkness for 2.5 h at 25°C, following by excess water removing and they were placed on filter paper inside of germination boxes for 72 h. After germination, the samples were dried at 50°C for 24 h, roasted at 145°C for 30 min (Felisa, 291A), ground, sieved to 60 mesh (0.25 mm) and stored at -20°C, protected from light, until further analysis.

Proximate composition

Proximate analysis of flour samples was conducted following the Association of Official Analytical Chemists AOAC (2000) and American Oil Chemists' Society (AOCS). The content of moisture, ash and crude protein were obtained by AOAC methods 925.10, 923.03 and 960.52, respectively, while the content of crude fiber and crude fat was obtained by AOCS methods Ba 6a-05 (AOCS, 2005) and Am 5-04 (AOCS, 2004), respectively. The total carbohydrates content was obtained by difference.

Color evaluation

Flour color parameters were obtained according to Ramirez-Cortez *et al.* (2025) using a Minolta® colorimeter (model CR-20, Japan). A petri dish was filled with flour and chromatic parameters were obtained using CIELAB (L^* , a^* , b^*) and CIELCH (L^* , C^* , h^*) color systems according to International Commission of Illumination (CIE, 2004). In these color systems, L^* defines lightness (0= black, 100= white), a^* indicates red (positive a^*) or green value (negative a^*), b^* indicates yellow (positive b^*) or blue value (negative b^*). In addition, C^* indicates saturation level of h^* and h^* indicates a color tone (0°= red, 90°= yellow, 180°= green and 270°= blue). Color view of flours was obtained by online software ColorHexa color converter using L^* , C^* and h^* values (ColorHexa, 2024).

Phenolic compounds and antioxidant capacity

Extraction of phenolics, phenolic content and antioxidant capacity assays were carried out as described by Rodríguez-Salinas *et al.* (2020), with some modifications.

Extraction of free and bound phenolic compounds

For the extraction of free phenolic compounds, 0.2 g of dry sample was mixed with 3 mL of 80% methanol, purged

with gaseous nitrogen for 30 s and shaken for 2 h at 250 rpm (Labnet, Orbit 1900). Subsequently, the samples were centrifuged at room temperature for 10 min at 4,600 rpm (Eppendorf, 5804 R-15 AMP version) and the supernatant was recovered in amber flasks and stored at -20°C.

The extraction of bound phenolic compounds was performed using the precipitate obtained from the previous procedure by adding 9 mL of 2 M NaOH. The samples were purged with gaseous nitrogen and shaken for 2 h. Afterwards, the pH of the samples was adjusted to 2 using concentrated HCl and the phenolic compounds were extracted twice with 6 mL of diethyl ether. The diethyl ether extracts were combined, centrifuged at 4,500 rpm (25°C, 5 min), evaporated using a rotary evaporator at 40°C (Yamato Rotary Evaporator RE200, Yamato Water Bath BM200) and stored at -20°C. Prior to determining phenolic compounds and antioxidant capacity, the samples were resuspended in 80% methanol.

Total phenolics, total flavonoids and condensed tannins

Total phenolics content was determined using the Folin-Ciocalteu assay. A 0.2 mL aliquot of the sample was used, followed by the addition of 2.6 mL of bidistilled water and 0.2 mL of Folin-Ciocalteu reagent for oxidation. After 5 min, the reaction was neutralized with 2 mL of 7% sodium carbonate (Na_2CO_3). The samples were allowed to react for 90 min in the dark. Sample absorbance was measured at 750 nm. A calibration curve was prepared using gallic acid (0-200 mg/L) and the results were expressed as milligrams of gallic acid equivalents per kg of dry sample (mg GAE/kg).

Total flavonoids were evaluated using the aluminum chloride colorimetric method. A 0.2 mL aliquot of the sample was mixed with 3.5 mL of bidistilled water and 0.15 mL of 5% sodium nitrite (NaNO_2). After 5 min, 0.15 mL of 10% aluminum chloride (AlCl_3) was added and after another 5 min, 1 mL of 1 N sodium hydroxide (NaOH) was incorporated. The samples were allowed to react for 15 min in the dark. Absorbance was measured at 510 nm. Catechin was used to construct a calibration curve (0-200 mg/L) and the results were reported as milligrams of catechin equivalents per kg of dry sample (mg CE/kg).

Condensed tannins were determined using the vanillin-sulfuric acid (H_2SO_4) assay. A 0.4 mL aliquot of the sample was mixed with 1.3 mL of 1% vanillin solution, then with 1.3 mL of 25% H_2SO_4 (Both prepared in 80% methanol). The samples were incubated at 30°C for 15 min. Absorbance was measured at 500 nm. A calibration curve was prepared using catechin (0-200 mg/L) and the results were reported as milligrams of catechin equivalents per kg of dry sample (mg CE/kg).

Antioxidant capacity

For the determination of antioxidant capacity by DPPH, a working solution at a concentration of 60 μM (in 80% methanol) was prepared and its absorbance was adjusted to 1.0 at a wavelength of 517 nm. A 0.05 mL

volume of extract was mixed with 1.5 mL of the DPPH working solution, samples were allowed to react for 30 min at room temperature in darkness and finally absorbance was measured.

The ABTS antioxidant capacity assay was initiated preparing a working solution by mixing 1 mL of 7.4 mM ABTS and 1 mL of 2.7 mM potassium persulfate ($\text{K}_2\text{S}_2\text{O}_8$), which was allowed to react for 12 h protected from light. After this reaction period, the absorbance of the ABTS working solution was adjusted to 1.0 at 734 nm using 80% methanol. Subsequently, 0.05 mL of the sample was mixed with 1.5 mL of the ABTS working solution. Absorbance was recorded after 30 min of reaction in darkness at room temperature.

FRAP antioxidant capacity was determined using a working solution prepared from a mixture of 300 mM sodium acetate ($\text{C}_2\text{H}_3\text{NaO}_2 \cdot 3\text{H}_2\text{O}$, pH 3.6), 10 mM TPTZ (2,4,6-tripyridyl-s-triazine in 40 mM HCl) and ferric chloride hexahydrate ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$) in a 10:1:1 ratio (v:v:v). A 0.05 mL volume of the sample was mixed with 1.5 mL of the FRAP working solution and absorbance was measured at 593 nm after 30 min at 37°C.

For all three antioxidant capacity assays, calibration curves were prepared using Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) at concentrations ranging from 0 to 500 $\mu\text{mol/L}$. Results were reported as micromoles of Trolox equivalents per kg of dry sample ($\mu\text{mol TE/kg}$).

Statistical analysis

Data were expressed as mean $\pm$ standard deviation ($n = 3$) and they were analyzed as a completely randomized design with a general linear model procedure using Tukey's test for mean comparison with statistical significance of $p \leq 0.05$ by using Minitab statistical software 17.0.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of roasted non-germinated and roasted germinated quinoa and amaranth flours is shown in Table 1. Moisture content (%) showed statistically significant differences ($p \leq 0.05$) among the evaluated treatments, with A-NG showing the highest moisture at 5.23%, followed by 4.61%, 4.33% and 4.31% for Q-NG, Q-G and A-G, respectively.

Similarly, ash content (%) showed statistically significant differences ($p \leq 0.05$) among treatments, with values of 3.35%, 2.52%, 2.50% and 2.28% for A-G, A-NG, Q-NG and Q-G, respectively.

Regarding protein content (%), no significant differences were observed among treatments ($p \geq 0.05$), with values of 11.36%, 11.15%, 10.49% and 11.80% for Q-NG, A-NG, Q-G and A-G, respectively. On the other hand, fat content (%) showed significant differences among treatments ($p \leq 0.05$), with values of 6.98% in Q-G, followed by 6.86% in Q-NG, 6.10% in A-NG and 5.33% in A-G.

Concerning crude fiber content (%), no significant differences were observed among treatments ($p \geq 0.05$). The recorded values were 1.96% for Q-NG and 1.84%, 1.19% and 1.87% for A-NG, Q-G and A-G, respectively. Finally, carbohydrate content (%) was not significantly different among treatments ($p \geq 0.05$), with values of 72.76% for Q-NG, 73.19% for A-NG, 74.77% for Q-G and 73.39% for A-G.

The recorded moisture content (%) was slightly similar to the values reported by Mukunzi and Ryee (2025) in roasted tricolor quinoa (120°C, 8 min) and by Tekgül *et al.* (2023) in roasted chickpea (*Cicer arietinum* L.) (250°C, 3 min), with values of 4.97% and 4.52%, respectively.

Ash content (%) differed from that reported by Mufari *et al.* (2024) in germinated quinoa (1.89%) and by Kang *et al.* (2022), who reported 1.45% and 1.38% in germinated red-pigmented rice (30 h) and germinated red-pigmented rice subsequently roasted (180°C, 6 min), respectively. Although these authors observed a slight decrease after roasting, the change was not significant.

Guardianelli *et al.* (2019) observed an increase in protein content (%) in germinated amaranth (*Amaranthus caudatus*) flour from 14.4% to 15.5% after 24 h of germination. On the other hand, Tekgül *et al.* (2023) confirmed a decrease in protein content (%) in roasted chickpea, from 21.53% to 18.46% (250°C, 3 min) and 19.57% (150°C, 5 min), which could be attributed to protein denaturation and the possible loss of volatile nitrogenous compounds induced by the application of high temperatures.

Regarding fat content, Ramos-Pacheco *et al.* (2024) identified a slight decrease after 72 h of germination in white quinoa, from 6.60% to 6.44%, similar to the findings of Beniwal *et al.* (2019) in quinoa flour, where fat content

decreased from 8.1% to 5.26% after germination and from 8.1% to 6.06% after roasting. In germinated amaranth flour, they found a decrease in fat content from 7.53% to 4.06%, while in roasted amaranth flour, it decreased from 7.73% to 5.66%. The reduction in fat content may be attributed to the activation of lipolytic enzymes during germination and the subsequent hydrolysis of lipids into fatty acids and glycerol for embryo development.

Joshi *et al.* (2026), reported a decrease in crude fiber content in germinated amaranth flour from 5.31% to 2.58% after roasting at 120°C for 10 min. A similar decreasing trend in fiber content was reported by Chauhan *et al.* (2022) in roasted black soybean (*Glycine max* L.), where values decreased from 6.23% to 6.12% under roasting conditions of 180°C for 10 s. This decrease may be related to changes in cell wall structure induced by the high temperatures applied, which break weak polysaccharide-glycosidic bonds within the fiber matrix, thereby facilitating depolymerization and subsequent solubilization (Obboh *et al.*, 2010).

Finally, Mukunzi and Ryee (2025) reported an increase in carbohydrate content from 69.01% to 71.59% in roasted tricolor quinoa, attributed to the concentration of macronutrients resulting from high-temperature processing.

Color evaluation

Color parameters are shown in Table 2. All evaluated chromatic properties were significantly different ($p \leq 0.05$) among treatments. A decrease in lightness (L^*) was observed in the samples after germination, with values of 72.17, 78.73, 64.67 and 61.90 for Q-NG, A-NG, Q-G and A-G, respectively.

The samples showed higher values of the chromatic parameter a^* after germination, with A-G showing the highest at 9.17, followed by Q-G, Q-NG and A-NG at 8.57,

Table 1: Proximate composition of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	Component (%)					
	Moisture	Ash	Protein	Fat	Crude fiber	Carbohydrates
Q-NG	4.61±0.03 ^b	2.50±0.03 ^b	11.36±0.62 ^a	6.86±0.63 ^a	1.96±0.46 ^a	72.76±0.44 ^a
A-NG	5.23±0.09 ^a	2.52±0.01 ^b	11.15±0.31 ^a	6.10±0.20 ^{ab}	1.84±0.06 ^a	73.19±0.52 ^a
Q-G	4.33±0.13 ^b	2.28±0.04 ^c	10.49±0.62 ^a	6.98±0.06 ^a	1.19±0.48 ^a	74.77±0.98 ^a
A-G	4.31±0.07 ^b	3.35±0.08 ^a	11.80±0.10 ^a	5.33±0.31 ^b	1.87±0.38 ^a	73.39±0.53 ^a

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean ± standard deviation.

Table 2: Chromatic characterization of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	Color parameter					View
	L^*	a^*	b^*	C^*	h^*	
Q-NG	72.17±1.80 ^a	8.00±0.10 ^{ab}	20.03±0.40 ^b	21.60±0.27 ^b	68.27±0.71 ^{bc}	
A-NG	78.73±1.86 ^a	6.17±0.99 ^b	21.03±1.67 ^b	21.90±1.87 ^b	73.77±1.19 ^a	
Q-G	64.67±3.02 ^b	8.57±1.02 ^a	23.90±0.76 ^a	25.40±1.05 ^a	70.37±1.67 ^b	
A-G	61.90±3.38 ^b	9.17±0.31 ^a	19.90±0.00 ^b	21.93±0.15 ^b	65.27±0.76 ^c	

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean ± standard deviation.

8.00 and 6.17, respectively, indicating a greater red hue after germination. The chromatic parameter b^* showed values of 23.90, 21.03, 20.03 and 19.90 for Q-G, A-NG, Q-NG and A-G, respectively.

Regarding chroma (C^*) of the samples, the highest value was recorded in Q-G with 25.40, while the lowest value was observed in Q-NG with 21.60. The remaining treatments presented values of 21.93 and 21.90 for A-G and A-NG, respectively. Finally, hue angle (h^*) values showed a tendency toward yellow tones, ranging from 65.27 in A-G to 73.77 in A-NG, with intermediate values of 68.27 in Q-NG and 70.37 in Q-G.

Joshi *et al.* (2026), individually applied germination (72 h) and roasting (120°C, 10 min) treatments to amaranth seeds, obtaining L^* values of 76.47 and 75.96; a^* values of 3.64 and 5.95 and b^* values of 22.17 and 25.10, respectively. These results show slight similarity in the trend of decreased lightness and increased reddish and yellowish tones after roasting, due to non-enzymatic browning reactions such as the Maillard reaction and caramelization.

Beniwal *et al.* (2019) also applied germination and roasting (180°C, 10 s) individually to white quinoa and amaranth. They reported a decrease in L^* values for quinoa flour from 76.38 to 73.59 and 72.47, respectively. For a^* , the reported values increased slightly from 0.62 to 0.63 after germination, then increased further to 4.44 after roasting. Regarding b^* , values decreased from 15.28 to 13.46 during germination and subsequently increased to 21.65 after roasting.

For amaranth flour, they recorded a decrease in L^* values from 78.35 to 71.47 and 70.44 for the previously mentioned treatments, respectively. Conversely, the reddish hue parameter a^* increased from 1.31 to 1.41 and 6.62, respectively, while b^* values slightly decreased from 13.95 to 12.34 after germination and increased to 24.55 after roasting.

Phenolic compounds in free fractions

The content of total phenolics (mg GAE/kg), total flavonoids (mg CE/kg) and condensed tannins (mg CE/kg) in the free extracts of non-germinated and germinated quinoa and amaranth seeds is shown in Table 3. The evaluated treatments showed statistically significant differences ($p \leq 0.05$) in total phenolic content, with an increase from 3366.91 to 6940.59 mg GAE/kg for Q-NG and Q-G, respectively and from 796.94 to 6330.91 mg GAE/kg for A-NG and A-G, respectively. Similarly, total flavonoid content

increased ($p \leq 0.05$), with values of 160.16, 620.13, 851.24 and 1141.19 mg CE/kg for A-NG, Q-NG, Q-G and A-G, respectively. Condensed tannin content showed the same increasing trend across treatments, with values of 443.94, 2435.28, 5044.34 and 8064.69 mg CE/kg for A-NG, Q-NG, A-G and Q-G, respectively.

Phenolic compounds, such as phenolic acids and flavonoids, increase significantly during germination due to enzymatic activity and metabolic processes (Günel-Köroğlu *et al.*, 2025). The hydrolysis of cell wall polymers as a result of germination produces an increase in free phenolic compounds and, consequently, an increase in their availability (Borges-Martínez *et al.*, 2022).

Ramos-Pacheco *et al.* (2024) reported values of 288.6 mg GAE/kg in quinoa samples (Choclo ecotype) after 72 h of germination, with initial values of 236.4 mg GAE/kg dry sample. On the other hand, Younis *et al.* (2024) reported initial phenolic compound contents in quinoa seeds of 2525.7 mg GAE/kg dry sample, which decreased to 2407.1 mg GAE/kg after roasting treatment (120°C, 15 min) and further declined to 1377.0 mg GAE/kg after germination (96-120 h). According to Karaman *et al.* (2024), the phenolic compound content in sprouts depends on factors such as crop type, germination conditions and extraction method.

Regarding total flavonoids, Li *et al.* (2022) reported the highest total flavonoid values in licorice (*Glycyrrhiza uralensis* Fischer) intended for beverage preparation, reaching 74.7 mg CE/kg under roasting conditions of 180°C for 20 min. Similarly, Aung *et al.* (2022) reported values of 800 mg CE/kg in wheat, representing the highest value obtained after germination treatment (17.6°C, 46.18 h), drying (45°C, 16 h) and roasting (180°C, 50 min). The authors attributed this increase to the degradation of internal tissues and the subsequent release of bound phenolic compounds and flavonoids during roasting.

Antioxidant capacity in free fractions

The antioxidant capacity in the free extracts of non-germinated and germinated quinoa and amaranth seeds is shown in Table 4. Statistically significant differences ($p \leq 0.05$) were observed in the antioxidant capacity of the evaluated treatments using the previously described methods. For DPPH, the values were 2533.00, 12512.80, 24922.20 and 25351.50 $\mu\text{mol TE/kg}$ for A-NG, Q-NG, Q-G and A-G, respectively. The values recorded for ABTS were 7196.40, 20935.60, 40224.70 and 41005.10 $\mu\text{mol TE/kg}$ for A-NG, Q-NG, A-G and Q-G, respectively. Finally, the

Table 3: Phenolic compounds in free extracts of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	Total phenolics (mg GAE/kg)	Total flavonoids (mg CE/kg)	Condensed tannins (mg CE/kg)
Q-NG	3366.91±246.00 ^b	620.13±15.84 ^b	2435.28±98.80 ^{bc}
A-NG	796.94±78.90 ^c	160.16±26.80 ^c	443.94±37.80 ^c
Q-G	6940.59±1493.00 ^a	851.24±142.40 ^b	8064.69±2706 ^a
A-G	6330.91±784.00 ^a	1141.19±127.00 ^a	5044.34±1156.00 ^{ab}

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean $\pm$ standard deviation.

antioxidant capacity values obtained by FRAP were 5735.10, 22871.30, 42402.00 and 44327.60 $\mu\text{mol TE/kg}$ for A-NG, Q-NG, Q-G and A-G, respectively.

Antioxidant capacity is primarily associated with phenolic compounds synthesized or released during germination. Due to their hydroxyl groups and double bonds, phenolic compounds neutralize free radicals as a result of their ability to donate electrons or hydrogen atoms (Woolfolk-Chávez *et al.*, 2026).

Zhang *et al.* (2023) evaluated antioxidant capacity in black barley (*Hordeum vulgare*) under different treatments, including germination (28°C, 60 h). Their results showed higher antioxidant capacity than non-germinated grain, with DPPH values increasing from 57393.2 to 64086.9 $\mu\text{mol TE/kg}$, ABTS values reaching 36634.7 $\mu\text{mol TE/kg}$ and FRAP values increasing from 32175.3 to 48832.4 $\mu\text{mol TE/kg}$.

On the other hand, Woolfolk-Chávez *et al.* (2026) reported values of 12700 $\mu\text{mol TE/kg}$ for DPPH and 20490 $\mu\text{mol TE/kg}$ for ABTS in germinated amaranth (*Amaranthus hypochondriacus*) samples (30°C, 72 h). Regarding FRAP, the authors reported values of 15580 $\mu\text{mol TE/kg}$ after 48 h of germination at 30°C.

Phenolic compounds in bound fractions

The content of total phenolic compounds (mg GAE/kg), total flavonoids (mg CE/kg) and condensed tannins (mg CE/kg) in the bound extracts of roasted non-germinated and roasted germinated quinoa and amaranth seeds is shown in Table 5.

The contents of total phenolics, total flavonoids and condensed tannins were not significantly affected ($p \geq 0.05$) by the evaluated treatments. The recorded values for total phenolics were 389.42 mg GAE/kg in Q-NG, 348.76 mg GAE/kg in A-NG, 412.72 mg GAE/kg in Q-G and 372.34 mg GAE/kg in A-G. Regarding total flavonoids, the obtained

values were 188.68, 263.58, 206.30 and 170.83 mg CE/kg for Q-NG, A-NG, Q-G and A-G, respectively.

Regarding to condensed tannins, although no significant differences were observed among treatments ($p \geq 0.05$), an increase was observed from 58.27 mg CE/kg in A-NG to 584.75 mg CE/kg in A-G, while the values in Q-NG and Q-G were 174.76 and 171.82 mg CE/kg, respectively.

The results obtained in this study showed a higher concentration of phenolic compounds in the free fraction than in the bound fraction. However, Bhinder *et al.* (2021) reported a higher content of phenolic compounds in the bound fraction (5380 mg GAE/kg dry sample) than in the free fraction (3050 mg GAE/kg dry sample) in germinated white quinoa samples (72 h, dried at 50±5°C for 24 h). Nevertheless, the difference between both fractions could already be observed in the raw sample, with free fraction values of 2390 mg GAE/kg, while the bound fraction values reached 4710 mg GAE/kg dry sample. This behavior may be attributed to both genotype and cultivation conditions (Schutte *et al.*, 2024).

Conversely, Mohamed *et al.* (2024) reported a higher total phenolic content in the free fraction (16681.00 mg GAE/kg) than in the bound fraction (8222.00 mg GAE/kg) in black quinoa, observing an increase in both fractions after a roasting treatment (120°C, 30 min). In the free fraction, total phenolics slightly increased to 16722.00 mg GAE/kg, while in the bound fraction, they increased to 16153.00 mg GAE/kg. The same authors reported total flavonoid values in the free fraction increasing from 4910.00 to 5060.00 mg CE/kg. Likewise, the values in the bound fraction increased from 1401.00 to 2207.70 mg CE/kg.

In contrast, the results obtained in this study showed a decrease in both fractions after germination and subsequent roasting treatment. Phenolic compounds and flavonoids concentrated in the bound fraction are released

Table 4: Antioxidant capacity in free extracts of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	DPPH ($\mu\text{mol TE/kg}$)	ABTS ($\mu\text{mol TE/kg}$)	FRAP ($\mu\text{mol TE/kg}$)
Q-NG	12512.80±807.00 ^b	20935.60±1018.00 ^b	22871.30±1098.00 ^b
A-NG	2533.00±347.00 ^c	7196.40±2886.00 ^b	5735.10±1329.00 ^b
Q-G	24922.20±5829.00 ^a	41005.10±9090.00 ^a	42402.00±9676.00 ^a
A-G	25351.50±4369.00 ^a	40224.70±8694.00 ^a	44327.60±8643.00 ^a

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean ± standard deviation.

Table 5: Phenolic compounds in bound extracts of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	Total phenolics (mg GAE/kg)	Total flavonoids (mg CE/kg)	Condensed tannins (mg CE/kg)
Q-NG	389.42±8.18 ^a	188.68±62.90 ^a	174.76±44.10 ^a
A-NG	348.76±52.10 ^a	263.58±62.40 ^a	58.27±0.07 ^a
Q-G	412.72±51.40 ^a	206.30±10.64 ^a	171.82±54.10 ^a
A-G	372.34±170.20 ^a	170.83±54.70 ^a	584.75±857.00 ^a

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean ± standard deviation ($n = 3$).

during roasting due to the degradation of the cellular structure (Aung *et al.*, 2022). However, applying even higher temperatures may reduce these compounds due to the thermal degradation of the phenolic compounds themselves (Schutte *et al.*, 2024).

Similar to total flavonoids, condensed tannins also showed a decrease in content after germination, followed by roasting in the bound fraction. Thakur *et al.* (2021) reported the same trend, observing a decrease in tannin content from 0.065% to 0.044% after 72 h of germination (25°C, drying at 40°C for 24 h) in amaranth seeds and from 0.048% to 0.035% in quinoa seeds, attributing this decrease to the solubility of the compounds in water during the seed soaking process.

Processes such as roasting, steaming, among others, may improve the nutritional quality of quinoa and other pseudocereals or cereals by reducing the negative effects of tannins (Manzanilla-Valdez *et al.*, 2024), as reported by Sharma and Gujral (2020), who observed a decrease from 3.01% to 1.13% (catechin equivalent, dry basis) after 48 h of germination in millet seeds and by Prashanth *et al.* (2024), who reported a range of 0.19 to 0.28 mg CE/g (dry basis) when evaluating millet (*Pennisetum glaucum*) after a hydrothermal treatment.

Antioxidant capacity in bound fractions

The antioxidant capacity in bound extracts of roasted non-germinated and roasted germinated quinoa and amaranth flours is shown in Table 6. The antioxidant capacity determined by DPPH, ABTS and FRAP did not show significant changes ($p \geq 0.05$) after the evaluated treatments. The antioxidant capacity of roasted quinoa seed flour (Q-NG) was 1823.26 $\mu\text{mol TE/kg}$, while 1622.21 $\mu\text{mol TE/kg}$ was recorded after germination and roasting (Q-G). On the other hand, the values for A-NG and A-G were 1574.11 and 1563.53 $\mu\text{mol TE/kg}$, respectively.

The antioxidant capacity recorded by ABTS was 4960.50 $\mu\text{mol TE/kg}$ in Q-NG and 4524.43 $\mu\text{mol TE/kg}$ in Q-G. Meanwhile, the observed results in A-NG and A-G were 4262.85 $\mu\text{mol TE/kg}$ and 4403.39 $\mu\text{mol TE/kg}$, respectively. On the other hand, the antioxidant capacity values determined by FRAP were 4717.71, 4869.93, 3907.56 and 4062.66 $\mu\text{mol TE/kg}$ for Q-NG, Q-G, A-NG and A-G, respectively.

Authors such as Zhang *et al.* (2022) reported higher antioxidant capacity, as determined by DPPH and ABTS, in the bound fraction compared with the free fraction in red

quinoa flour, which differs from the results obtained in this study. Bhinder *et al.* (2021) also reported higher average antioxidant capacity by DPPH in the bound fraction of quinoa (4290 $\mu\text{mol TE/kg}$) than in the free fraction (3610 $\mu\text{mol TE/kg}$), maintaining the same trend after a malting process (72 h germination and 24 h drying at 50°C), with values of 5290 $\mu\text{mol TE/kg}$ in the bound fraction and 4740 $\mu\text{mol TE/kg}$ in the free fraction. However, in black quinoa, they obtained higher antioxidant capacity in the free fraction (6900 $\mu\text{mol TE/kg}$) than in the bound fraction (5250 $\mu\text{mol TE/kg}$) under the same conditions.

The results of Živković *et al.* (2021) showed an increasing trend in antioxidant capacity determined by DPPH and ABTS in the bound fraction of germinated buckwheat (8 h soaking, 96 h germination at 20°C), from 16580 $\mu\text{mol TE/kg}$ dry weight to 32562 $\mu\text{mol TE/kg}$ dry weight and from 23730 $\mu\text{mol TE/kg}$ to 26569 $\mu\text{mol TE/kg}$, respectively.

The antioxidant capacity values determined by ABTS were higher than those determined by DPPH, suggesting greater reactivity of phenolic compounds with the ABTS radical. Similarly, Hu *et al.* (2017) reported higher antioxidant capacity determined by ABTS in the bound fraction compared with the free fraction in red rice (2101 and 749 $\mu\text{mol TE/kg}$, respectively). The antioxidant capacity of the bound fraction increased after germination (12 h soaking, 48 h germination at 30°C) to 2208 $\mu\text{mol TE/kg}$; however, it decreased to 306 $\mu\text{mol TE/kg}$ in the free fraction.

The results were consistent with those reported by Ti *et al.* (2014) for germinated brown rice (48 h, 20°C), which obtained antioxidant capacity values determined by FRAP of 4215 $\mu\text{mol TE/kg}$ dry weight. Conversely, Zhang *et al.* (2021) observed a decrease in antioxidant capacity determined by FRAP in roasted mung bean (*Vigna radiata*) previously soaked (25°C, 8 h), from 15260 $\mu\text{mol TE/kg}$ to 7220 $\mu\text{mol TE/kg}$ in the bound fraction after roasting treatment (150°C, 30 min), despite having initially presented higher values compared with the free fraction prior to roasting.

Taking into account the increasing in the consumption of plant-based beverages, but also, the color developed in flours from quinoa and amaranth by germination and roasted treatments, as well as, the content of protein, the levels of phenolic compounds and their antioxidant capacity, they are optimal raw materials for formulation of pseudocereals based functional beverages.

Table 6: Antioxidant capacity in bound extracts of roasted non-germinated and roasted germinated quinoa and amaranth flours.

Treatment*	DPPH ($\mu\text{mol TE/kg}$)	ABTS ($\mu\text{mol TE/kg}$)	FRAP ($\mu\text{mol TE/kg}$)
Q-NG	1823.26 $\pm$ 120.80 ^a	4960.50 $\pm$ 770.00 ^a	4717.71 $\pm$ 618.00 ^a
A-NG	1574.11 $\pm$ 67.30 ^a	4262.85 $\pm$ 736.00 ^a	3907.56 $\pm$ 522.00 ^a
Q-G	1622.21 $\pm$ 29.50 ^a	4524.43 $\pm$ 253.00 ^a	4869.93 $\pm$ 366.00 ^a
A-G	1563.53 $\pm$ 910.00 ^a	4403.39 $\pm$ 2021.00 ^a	4062.66 $\pm$ 1832.00 ^a

*Q-NG: Non-germinated quinoa; A-NG: Non-germinated amaranth; Q-G: Germinated quinoa; A-G: Germinated amaranth. Means with different letters indicate significant differences ($p \leq 0.05$). Values are presented as mean $\pm$ standard deviation ($n = 3$).

CONCLUSION

The proximate composition of quinoa and amaranth flours was affected by the roasting and germination treatments in moisture, ash and fat, which showed slight differences. Germination and roasting together affected the color parameters of the flours, showing lower values in parameter L^* and higher values for parameters a^* , b^* and C^* . In addition, germination and roasting together proved to be viable processes for enhancing bioactive compounds and their antioxidant capacity, due to the positive effect on the results of this study. The flours characteristics obtained make them good ingredients for the development of pseudocereals based functional beverages in the near future.

ACKNOWLEDGEMENT

The authors thank to Programa de Apoyo a la Publicación Científica en Revistas Indexadas en el Journal Citation Report (JCR) 2026 of the Universidad Autónoma de Nuevo León for covering the Article Processing Charge. Cynthia Valeria Rodríguez-Sánchez thanks to Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI) for the scholarship 4032898 granted.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

- Anuhya, D.N. (2024). Evaluation of physical characteristics and impact of germination on functional properties of quinoa (*Chenopodium quinoa* Willd.). *Asian Journal of Dairy and Food Research*. 1-6. doi: 10.18805/ajdr.DR-2148.
- Association of Official Analytical Chemist International (AOAC). Methods of Analysis of AOAC International, 17th ed.; AOAC: Gaithersburg, MD, USA, 2000.
- American Oil Chemists' Society. (2005). AOCS Approved Procedure Ba 6a-05: Crude Fiber in Feed by Filter Bag Technique. AOCS. Urbana, IL: AOCS.
- American Oil Chemists' Society (AOCS). (2004). AOCS Official Method Am 5-04: Rapid Determination of Oil/Fat Utilizing High-Temperature Solvent Extraction. Champaign, IL: AOCS.
- Aung, T., Kim, B.R. and Kim, M.J. (2022). Optimized roasting conditions of germinated wheat for a novel cereal beverage and its sensory properties. *Foods*. **11**(3): 481.
- Benincasa, P., Fancinelli, B., Luttus, S., Stagnari, F., Galieni, A. (2019). Sprouted grains: A comprehensive review. *Nutrients*. **11**(2): 1-29. 421
- Beniwal, S.K., Devi, A. and Sindhu, R. (2019). Effect of grain processing on nutritional and physicochemical, functional and pasting properties of amaranth and quinoa flours. *Indian Journal of Traditional Knowledge*. **18**(3): 500-507.
- Bhinder, S., Kumari, S., Singh, B., Kaur, A. and Singh, N. (2021). Impact of germination on phenolic composition, antioxidant properties, antinutritional factors, mineral content and maillard reaction products of malted quinoa flour. *Food Chemistry*. **346**: 128915.
- Borges-Martínez, E., Gallardo-Velázquez, T., Cardador-Martínez, A., Moguel-Concha, D., Osorio-Revilla, G., Ruiz-Ruiz, J.C. and Martínez, C.J. (2022). Phenolic compounds profile and antioxidant activity of pea (*Pisum sativum* L.) and black bean (*Phaseolus vulgaris* L.) sprouts. *Food Science and Technology*. **42**: e45920.
- Chauhan, D., Kumar, K., Ahmed, N., Thakur, P., Rizvi, Q.U.E.H., Jan, S. and Yadav, A.N. (2022). Impact of soaking, germination, fermentation and roasting treatments on nutritional, anti-nutritional and bioactive composition of black soybean (*Glycine max* L.). *Journal of Applied Biology Biotechnology*. **10**(5): 186-192.
- Choque-Quispe, D., Ligarda-Samanez, C.A., Ramos-Pacheco, B.S., Damiano, S.L., Calla-Florez, M., Puma, L.M.Z., Condeña, L.C. (2021). Phenolic compounds, antioxidant capacity and protein content of three varieties of germinated quinoa (*Chenopodium quinoa* Willd.). *Ingeniería e Investigación*. **41**(2): 1-7.
- ColorHexa: Color Encyclopedia: Information and Conversion. (2024). Computer Software. Available Online: www.colorhexa.com (accessed on April 14 2026).
- Commission Internationale de l'Eclairage (CIE) (2004). CIE 15: Technical Report: Colorimetry, 3rd Edition. Vienna, Austria. p.17.
- Guardianelli, L.M., Salinas, M.V. and Puppo, M.C. (2019). Chemical and thermal properties of flours from germinated amaranth seeds. *Journal of Food Measurement and Characterization*. **13**(2): 1078-1088.
- Günel-Köroğlu, D., Esatbeyoglu, T. and Capanoglu, E. (2025). Effect of germination on the phenolic compounds: Content, bioavailability, food applications and health benefits. *Journal of Food Measurement and Characterization*. **19**(11): 8144-8164.
- Hu, Z., Tang, X., Liu, J., Zhu, Z. and Shao, Y. (2017). Effect of parboiling on phytochemical content, antioxidant activity and physicochemical properties of germinated red rice. *Food Chemistry*. **214**: 285-292.
- Jan, N., Hussain, S.Z., Naseer, B. and Bhat, T.A. (2023). Amaranth and quinoa as potential nutraceuticals: A review of anti-nutritional factors, health benefits and their applications in food, medicinal and cosmetic sectors. *Food Chemistry: X*. **18**: 100687.
- Joshi, M.M., Pawar, V.S., Pawar, G.S., Anerao, K.K., Bachate, A.H., Rodge, S.M. and Giri, S.A. (2026). Effect of soaking, roasting and germination on nutritional composition, colour characteristics and functional properties of amaranth seed flour. *Asian Journal of Dairy and Food Research*. 1-7. doi: 10.18805/ajdr.DR-2429.

- Jyoti, S.V. and Rani, V. (2025). Effect of amalgamation of quinoa on contents of essential amino acids, proximates, dialyzable minerals and storage stability of gluten and egg free maize muffins. *Asian Journal of Dairy and Food Research*. **44**(5): 794-798. doi: 10.18805/ajdrf.DR-1917.
- Kang, S.J., Jeong, S.Y., Islam, M.Z., Shin, B.K., Park, Y.J., Kim, J.K., Lee, Y.T. and Lee, J.H. (2022). Bioactive compounds and quality evaluation of red-pigmented rice processed by germination and roasting. *Foods*. **11**(18): 2735.
- Karaman, R., Akgün, İ. and Türkay, C. (2024). Nutritional, phenol content and antioxidant activity of edible sprouts of commonly occurring plants. *Vegetos*. **37**: 2131-2137.
- Kim, H.J., Han, J.A., Lim, S.T. and Cho, D.H. (2021). Effects of germination and roasting on physicochemical and sensory characteristics of brown rice for tea infusion. *Food Chemistry*. **350**: 129240.
- Li, H., Zhu, F. and Li, G. (2025). Beverages developed from pseudocereals (Quinoa, buckwheat and amaranth): Nutritional and functional properties. *Comprehensive Reviews in Food Science and Food Safety*. **24**(1): e70081.
- Li, Y.Y., Lee, K.Y. and Lee, H.G. (2022). Effects of roasting conditions on korean rice wine (*Makgeolli*) with licorice (*Glycyrrhiza uralensis* Fischer). *Food Science and Biotechnology*. **31**: 323-332.
- Manzanilla-Valdez, M.L., Boesch, C., Orfila, C., Montañó, S. and Hernández-Álvarez, A.J. (2024). Unveiling the nutritional spectrum: A comprehensive analysis of protein quality and antinutritional factors in three varieties of quinoa (*Chenopodium quinoa* Wild). *Food Chemistry: X*. **24**: 1-14. 101814.
- Mohamed, I.A., Özcan, M.M., Uslu, N., Mohammed, B.M. and Adiamo, O. (2024). The role of roasting on changes in bioactive properties, fatty acid and phenolic compound profiles in the free and bound fraction of black quinoa seeds. *International Journal of Food Science Technology*. **59**(2): 807-815.
- Mu, H., Xue, S., Sun, Q., Shi, J., Zhang, D., Wang, D. and Wei, J. (2023). Research progress of quinoa seeds (*Chenopodium quinoa* Wild.): Nutritional components, technological treatment and application. *Foods*. **12**(10): 2087.
- Mufari, J.R., Miranda-Villa, P.P., Bergesse, A.E., Rodríguez-Ruiz, A.C. and Calandri, E.L. (2024). Changes in the chemical composition and bioactive compounds of quinoa seeds by germination. *Biology and Life Sciences Forum*. **37**(1): 11. <https://doi.org/10.3390/blsf2024037011>.
- Mukunzi, Y. and Ryee, A.N.A. (2025). Effect of dry roasting on the physicochemical, nutritional and techno-functional properties of tri-color quinoa flours. *Foods*. **14**(18): 3237.
- Muyonga, J.H. and abati, B. and Ssepuuya, G. (2014). Effect of heat processing on selected grain amaranth physicochemical properties. *Food Science and Nutrition*. **2**(1): 9-16.
- Oboh, G., Ademiluyi, A.O. and Akindahunsi, A.A. (2010). The effect of roasting on the nutritional and antioxidant properties of yellow and white maize varieties. *International Journal of Food Science and Technology*. **45**(6): 1236-1242.
- Pilco-Quesada, S., Tian, Y., Yang, B., Repo-Carrasco-Valencia, R. and Suomela, J.P. (2020). Effects of germination and kilning on the phenolic compounds and nutritional properties of quinoa (*Chenopodium quinoa*) and kiwicha (*Amaranthus caudatus*). *Journal of Cereal Science*. **94**: 1-7.
- Prashanth, P., Joshi, T.J., Singh, S.M. and Rao, P.S. (2024). Hydrothermal treatment of pearl millet grains: Effects on nutritional composition, antinutrients and flour properties. *Grain Oil Science and Technology*. **7**(2): 87-95.
- Rachtan-Janicka, J., Gajewska, D., Szajewska, H., Włodarek, D., Weker, H., Wolnicka, K., Wicniewska, K., Socha, P. and Hamulka, J. (2025). The role of plant-based beverages in nutrition: An expert opinion. *Nutrients*. **17**(9): 1562.
- Ramírez-Cortez, N., Treviño-Ramírez, J., Pedroza-Flores, J., Urías-Orona, V., Salas-Cruz, L. and Niño-Medina, G. (2025). Agronomic performance and industrial quality of bread wheat (*Triticum aestivum* L.) genotypes cultivated in the northeast of Mexico. *Revista de la Facultad de Agronomía de la Universidad del Zulia*. **42**(2): e254228.
- Ramos-Pacheco, B.S., Choque-Quispe, D., Ligarda-Samanez, C.A., Solano-Reynoso, A.M., Palomino-Rincón, H., Choque-Quispe, Y., Peralta-Guevara, D.E., Moscoso-Moscoso, E. and Aiquipa-Pillaca, Á.S. (2024). Effect of germination on the physicochemical properties, functional groups, content of bioactive compounds and antioxidant capacity of different varieties of quinoa (*Chenopodium quinoa* Willd.) grown in the high andean zone of Peru. *Foods*. **13**(3): 417.
- Rodríguez-Salinas, P. A., Zavala-García, F., Urías-Orona, V., Muiy-Rangel, D., Heredia, J.B. and Niño-Medina, G. (2020). Chromatic, nutritional and nutraceutical properties of pigmented native maize (*Zea mays* L.) genotypes from the northeast of Mexico. *Arabian Journal for Science and Engineering*. **45**: 95-112.
- Schmidt, D., Verruma-Bernardi, M.R., Forti, V.A. and Borges, M.T.M.R. (2023). Quinoa and amaranth as functional foods: A review. *Food Reviews International*. **39**(4): 2277-2296.
- Schutte, M., Hayward, S. and Manley, M. (2024). Nonenzymatic browning and antioxidant properties of thermally treated cereal grains and end products. *Journal of Food Biochemistry*. **2024**: 3865849.
- Sharma, B. and Gujral, H.S. (2020). Modifying the dough mixing behavior, protein starch digestibility and antinutritional profile of minor millets by sprouting. *International Journal of Biological Macromolecules*. **153**: 962-970.
- Tekgöl, B.Y., Çalışkan Koç, G., Rayman Ergün, A., Bozkır, H. and Pandiselvam, R. (2023). Effect of different roasting methods on the proximate by composition, flow properties, amino acid compositions, colour, texture and sensory profile of the chickpeas. *International Journal of Food Science and Technology*. **58**(1): 482-492.
- Thakur, P., Kumar, K., Ahmed, N., Chauhan, D., Eain H.R.Q.U., Jan, S., Singh, T.P. and Dhaliwal, H.S. (2021). Effect of soaking and germination treatments on nutritional, anti-nutritional and bioactive properties of amaranth (*Amaranthus hypochondriacus* L.), quinoa (*Chenopodium quinoa* L.) and buckwheat (*Fagopyrum esculentum* L.). *Current Research in Food Science*. **4**: 917-925.

- Thepthanee, C., Li, H., Wei, H., Prakitchaiwattana, C. and Siriamornpun, S. (2024). Effect of soaking, germination and roasting on phenolic composition, antioxidant activities and fatty acid profile of sunflower (*Helianthus annuus* L.) seeds. *Horticulturae*. **10(4)**: 387.
- Ti, H., Zhang, R., Zhang, M., Li, Q., Wei, Z., Zhang, Y., Tang, X., Deng, Y., Liu, L. and Ma, Y. (2014). Dynamic changes in the free and bound phenolic compounds and antioxidant activity of brown rice at different germination stages. *Food Chemistry*. **161**: 337-344.
- Toimbayeva, D., Saduakhasova, S., Kamanova, S., Kiykbay, A., Tazhina, S., Temirova, I., Muratkhan, M., Shaimenova, B., Murat, L., Khamitova, D. and Ospankulova, G. (2025). Prospects for the use of amaranth grain in the production of functional and specialized food products. *Foods*. **14(9)**: 1603.
- Vajdovich, D.K., Csobod, É.C. and Benedek, C. (2025). Pseudocereal-based functional beverages: Main properties and nutritional evaluation with an emphasis on amino acid content: A review. *Foods*. **14(12)**: 2080.
- Woolfolk-Chávez, D.C., Montañó-Leyva, B., Menchaca-Armenta, M., Sarabia-Sainz, J.A., Silvas-García, M.I., Buitimea-Cantúa, N.E., Gerardo-Rodríguez, J.E., Córdova-López, J.H. and Ledesma-Osuna, A.I. (2026). Effect of germination conditions on the nutritional, bioactive profile and *in vitro* gastrointestinal digestion of *Amaranthus hypochondriacus*. *ACS Food Science Technology*. **6(2)**: 379-389.
- Younis, M., Ahmed, I.A.M., AlJuhaimi, F., Wang, D., Uslu, N. and Özcan, M.M. (2024). Effect of heating and germination on bioactive properties, phenolic compounds, fatty acid and mineral contents of quinoa (*Chenopodium quinoa* Willd.) seeds. *International Journal of Food Science and Technology*. **59(7)**: 4765-4773.
- Zhang, J., Guo, J., Dang, B., Zhang, W., Zheng, W. and Yang, X. (2023). Enhancement of polyphenols and antioxidant activity in germinated black highland barley by ultrasonication. *Molecules*. **28(9)**: 3679.
- Zhang, J., Yang, J. and Yin, Y. (2024). Germination promotes flavonoid accumulation of finger millet (*Eleusine coracana* L.): Response surface optimization and investigation of accumulation mechanism. *Plants*. **13(16)**: 2191.
- Zhang, S., Feng, Y.C., Fu, T.X., Sheng, Y.N., Diao, J.J. and Wang, C.Y. (2021). Effect of processing on the phenolics content and antioxidant properties of mung bean. *Cereal Chemistry*. **98(2)**: 355-366.
- Zhang, Y., Bai, B., Yan, Y., Liang, J. and Guan, X. (2022). Bound polyphenols from red quinoa prevailed over free polyphenols in reducing postprandial blood glucose rises by inhibiting α -glucosidase activity and starch digestion. *Nutrients*. **14(4)**: 728.
- Živković, A., Polak, T., Cigić, B. and Požrl, T. (2021). Germinated buckwheat: Effects of dehulling on phenolics profile and antioxidant activity of buckwheat seeds. *Foods*. **10(4)**: 740.