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Bioaccessibility of phenolic compounds, antioxidant activity, and consumer acceptability of heat-treated quinoa cookies

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Abstract

Quinoa (Chenopodium quinoa Willd) stands out because of its high nutritional value and bioactive compounds, which can benefit human health. Heat treatments can improve the content of these compounds; however, few reports have investigated the behavior of phenolic compounds in quinoa when subjected to *in vitro* gastrointestinal digestion. This work aimed to evaluate the effect of heat treatments on: (1) Total phenols and flavonoids, individual phenolics, and antioxidant activity of quinoa flour subjected to two different heat processes (boiling and microwaving); (2) Bioaccessibility of total phenols, flavonoids, individual phenolics, and the intestinal recovery of antioxidant activity of cookies made using heat-treated quinoa flours and (3) Consumer opinions of cookies made using heat-treated quinoa flours. The results demonstrated that cookies formulated with microwave-treated quinoa flour had greater bioaccessibility of phenols (647%), flavonoids (98%), ferulic acid (144%), rutin (65%), quercetin (85%), and kaempferol (97%) than cookies made with raw or boiled quinoa. Cookies made with heat-treated quinoa showed better consumer acceptability than those made with uncooked quinoa. Therefore, the microwave treatment of quinoa may be a viable alternative for producing healthier foods.

Keywords: functional food; bioactive compounds; pseudocereals; improved flours.

Practical Application: The use of improved quinoa flours could be a strategy for developing functional foods.

1 Introduction

Over the last ten years, quinoa has become very popular in human nutrition, mainly because of its high nutritional value and bioactive compounds (Vilcacundo & Hernández-Ledesma, 2017; Nowak et al., 2016). Clinical and experimental studies have shown that consumption of quinoa grains is inversely associated with the development of chronic noncommunicable diseases (CNCDs) (Valenzuela Zamudio & Segura Campos, 2020; Li et al., 2018). This protective effect has been attributed to antioxidant activity, which is one of the most studied mechanisms of action (Paśko et al., 2019). Several studies have shown that phenolic compounds (e.g., ferulic, caffeic, vanillic, and gallic acids) and flavonoids (e.g., rutin, quercetin, kaempferol, myricetin, and hesperidin) may be responsible for this protective effect (Hernández-Ledesma, 2019; Li et al., 2019; Khursheed et al., 2020; Meinhart et al., 2020). Given its healthy properties, the consumption of quinoa has been increasing; it is now used in cookies, pasta, soups, beverages, porridges, and other foods and drinks (Xu et al., 2020; Yadav, 2020; Zhang et al., 2019; Demir & Kılınç, 2017). However, to be fit for human consumption, quinoa grains must be cooked (Mhada et al., 2020). Given the grain's potential protective and antioxidant activities, it is worthwhile to explore a thermal processing method that minimizes the loss of phenolic compounds and maintains the quinoa grain's antioxidant properties. Microwaving could be a suitable alternative to the traditional thermal procedures used for quinoa, as it is highly efficient, saves energy, and is less damaging to nutrients (Luo et al., 2020; Guzik et al., 2022). On the other hand, little information is available concerning the behavior of the phenolic compounds present in raw quinoa, heat-treated quinoa, and derived products during *in vitro* gastrointestinal (GI) digestion. Such information could improve our understanding of the health benefits and potential of phenolic compounds. Therefore, this study aimed to make cookies using heat-treated quinoa (boiling and microwaving) and determine whether the type of heat treatment modifies the phenolic compounds content, antioxidant activity, and bioaccessibility. Cookies were selected for this study due to their long shelf life, high nutrient density, function as a food carrier of bioactive compounds, and convenience as a functional "ready-to-eat" food (Köten, 2021).

2 Materials and methods

2.1 Plant material

Quinoa seeds were commercially obtained in Hermosillo, Sonora, México. Whole and saponin-free quinoa grains were

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used according to the specifications indicated on the product label. The quinoa was stored in polyethylene bags at −20 °C until the heat treatment.

2.2 Heat treatment by boiling

The thermal boiling procedure followed that proposed by Nickel et al. (2016), with slight modifications. In a glass container, 900 mL of purified water was heated to boiling, and then 300 g of quinoa was added to the boiling water. When boiling temperature was again reached, the mixture was boiled for 20 min, during which time the grain absorbed the water. The cooked material was removed from the heat and immediately cooled in an ice bath.

2.3 Heat treatment by microwave

For this method, a domestic digital microwave oven (MS2047GR, LG, USA) with technical features of 120V~ 60 Hz and maximum output of 1650 W was used. The dimensions of the microwave cavity were 45 cm × 45 cm × 35 cm in size and consisted of a rotating glass plate of 32 cm diameter at the base of the oven. In the experiment, 100 g of quinoa grains were placed in a microwave container with 900 mL of water and microwaved at 1650 W for 15 min. Finally, the container was subjected to rapid cooling in an ice bath. The boiled and microwaved quinoa samples were packed in polyethylene bags and frozen at −85 °C for later lyophilization. The lyophilized samples were ground using a Pulvex 200 mill to pass the product through a 0.5 mm sieve. The quinoa flours treated with boiling and microwaving were labeled BQ and MQ, respectively. Additionally, quinoa flour was obtained without heat treatment and labeled RQ (raw quinoa). From each of the flours, 5 g samples were taken for the analyses, and the remainder of the flours were used to prepare the cookies.

2.4 Preparation of cookies

Four cookies were prepared and coded as follows: raw quinoa cookies (RQC), boiled quinoa cookies (BQC), and microwaved quinoa cookies (MQC) were made using RQ, BQ, and MQ flour, respectively. Additionally, a wholemeal oat cookie (WOC) was included as a commercial control and was used only in the consumer test. Cookies were formulated and baked according to the official AACC (American Association of Cereal Chemists, 2000) method (10-53.01 method) with slight modifications, which included the use of butter (50 g), sugar (40 g), baking soda (5.0 g), salt (5.0 g), and experimental flours (100 g). In the case of the RQC, it was necessary to add 20 mL of water to obtain dough with a consistency that was suitable for making cookies. The doughs were rolled out to a thickness of 6 mm, and a cookie-cutter mold with a diameter of 25 mm was used. The cookies were placed on a 20 × 30 cm tray and baked at 160 ºC for 13 min. The cookies were subsequently cooled, ground, and stored at −20 °C until analysis.

2.5 Preparation of methanolic extracts

Extracts were prepared according to the procedure described by Alvarez-Jubete et al. (2010), with slight modifications. Briefly, 1 g of each cookie sample was weighed in a 25-mL conical tube and then mixed with 15 mL of aqueous methanol (80:20 v/v). The mixture was sonicated at room temperature for 60 min. Next, the samples were centrifuged (1,500 x *g*, 15 min), and the supernatant was separated. The residue was subjected to the same procedure. Finally, the supernatants were collected and filtered through Whatman number 1 paper and evaporated to dryness in a rotary evaporator at 35 °C. The samples were redissolved in 5 mL of 50% methanol. These extracts were stored at −20 °C until analysis.

2.6 Total phenols and total flavonoids content

The total phenols content was determined using the Folin–Ciocalteu assay; measurement at 765 nm was performed using a microplate reader (FluoStar Omega; BMG Labtech Inc., Ortenberg, Germany). Briefly, in a 96-well microplate, 30 µL of each sample was mixed with 150 µL of Folin–Ciocalteu reagent (diluted 10-fold before use) and 120 µL of 7.5% Na_2CO_3 solution (Salazar López et al., 2016). Final results were given as gallic acid equivalents (GAE). To quantify the total flavonoids content, the procedure described by Robles-Sánchez et al. (2009) was used and adapted to the microplate reader. Flavonoids extracted with 5% $NaNO_2$, 10% $AlCl_3 \times 6H_2O$, and 1 M NaOH were measured at 415 nm, with known quercetin concentrations as standard, and expressed as micrograms of quercetin equivalents per gram of dry weight.

2.7 Antioxidant capacity to sequester 2,2'-azino-bis -3-ethylbenzothiazoline-6-sulfonic acid (ABTS • +)

ABTS radical-scavenging measurements were performed according to Salazar-López et al. (2016), and adapted to the microplate reader. The ABTS radical cation was generated by the interaction of ABTS with $K_2S_2O_8$. The ABTS • + working solution was prepared before use by diluting the stock solution in ethanol (1:88, v/v), and its absorbance was adjusted to 0.7 ± 0.02 at 734 nm. Then, 280 µL of the ABTS working solution was combined with 10 µL of each extract in a microplate well. A standard curve was prepared using Trolox as a standard, which was used to convert the changes in absorbance of the samples to micromoles of Trolox equivalents (TE) per gram of the sample.

2.8 Analysis of phenolic compounds using ultra high-performance liquid chromatography (UPLC-DAD)

Phenolic compounds were quantified following the methodology described by Velderrain-Rodríguez et al. (2018), with slight modifications. Briefly, components were separated using an Acquity UPLC™ BEH C18 column (1.7 µm; 3.0 × 100 mm) at 60 °C. A binary phase solvent system was used: water with 0.5% formic acid (A) and 100% methanol (B). The solvent gradient was as follows: 0–0.25 min 80% A (flow 0.4 mL/min); 5 min 80% A (0.2 mL/min); 12 min 55% A (0.180 mL/min); and an additional 2 min for column equilibration (80% A, 0.4 mL/min). The identification of phenolic compounds was performed, considering the retention time, according to commercial standards. The results were expressed as micrograms of phenolic compound per gram of dry weight (µg/g DW) using standard calibration curves.

2.9 Simulated in vitro gastrointestinal digestion

To mimic the *in vivo* GI digestion conditions, namely the oral, gastric, and intestinal phases, the protocols suggested by Salazar López et al. (2018) were followed, with slight modifications. Even though this study did not involve experimentation in humans or of a clinical or epidemiological nature, all tests followed ethical guidelines (Council for International Organizations of Medical Sciences, 2016). Three laboratory staff members volunteered to participate. Thus, three healthy and fasted volunteers chewed 1 g of each of the experimental cookies (RQC, BQC, and MQC) for 15 s. Subsequently, the participants expelled each chewed sample into a 50-mL conical tube, rinsed their mouth twice with 5 mL of water for 60 s, and then expelled the liquid into the respective tubes, which stood for 3 min at 37 °C to obtain the mouth digest. The digestion process beyond the mouth (i.e., gastric digestion) was simulated by adding 5 mL of 0.2 M HCl-KCl buffer solution to the digests and adjusting the pH to 1.5. Next, 667 µL of pepsin solution (300 mg/mL) was added, and the tubes were incubated for 1 h in a water bath with constant shaking at 37 °C (Precision Scientific Mod. 66800; Winchester, VA, USA). At the end of the incubation period, 9.0 mL of phosphate solution (0.1 M, pH 7.5) was added, and the pH was adjusted to 7.5. Next, 1 mL of pancreatin solution (17 mg/mL) and bile salts (80 mg) were added, and the mixture was incubated for 6 h in a shaking water bath (37 °C, 100 rpm) to obtain the intestinal fraction. For this digestion phase, a control was prepared that did not contain a cookie sample, but that was subjected to the same simulated digestion conditions. All samples and the control from the intestinal phase were centrifuged (10 min, 1,500 x*g*, 4 °C) and the recovered supernatants were frozen at −80 °C and subsequently lyophilized. The lyophilized digests were re-dissolved in 50% methanol, filtered (Econofltr Nylon 0.25 mm 0.45 µm; Santa Clara, CA, United States), and stored at −20 °C in amber vials until analysis. The intestinal fractions were analyzed for total phenols, total flavonoids, individual phenolic compounds content, and antioxidant activity using the procedures described above. Bioaccessibility was calculated as the ratio of the concentration of the bioactive component in the intestinal digestion (supernatants) to its respective concentration in the cookies before digestion (Equation 1). The results are expressed as percentages (B%).

$$Bioaccessibility\ (\%) = 100\ x\ \frac{content\ of\ phenolic\ compounds\ /\ antioxidant\ activity\ in\ digests}{phenolic\ compound\ content\ /\ antioxidant\ activity\ undigested\ samples} \quad (1)$$

2.10 Consumer test

Eighty-seven consumer panelists were recruited randomly from the students and staff of the University of Sonora. Cookie eaters were targeted. Four quinoa cookie samples were presented to the panelists on Unicel trays labeled with randomized 3-digit codes. Water was used to rinse the mouth before tasting each sample. The panelists were asked to rate the cookies in terms of color, aroma, texture, flavor/taste, and overall liking by assigning a score based on a seven-point hedonic scale ("I dislike it a lot" as 1 and "I like it a lot" as 7), with 4 as the neutral point. The evaluation was carried out in one session, and each panelist tasted the samples once. Additionally, the panelists responded to an acceptance/rejection test of the product by answering "Yes" (they would consume the product) or "No" (they would not consume the product).

2.11. Statistical analyses

The values are expressed as the mean ± standard error (SE) of three measurements. The data were analyzed using analysis of variance, and Tukey's test (significance of differences $P \leq 0.05$) was used to find significant differences between groups means. Statistical analyses were performed using the JMP 5.0.1 program (SAS Institute, Inc., USA).

3 Results and discussion

3.1 Total phenols, total flavonoids, and individual phenolics of heat-treated quinoa flours

The total phenols content of both the MQ and BQ was not affected by heat treatment, showing similar values to that of the RQ ($P > 0.05$). However, among the heat treatments, the MQ was found to have a higher total phenols content than the BQ ($P \leq 0.05$). Regarding total flavonoids content, the level was lower in both the BQ and MQ compared to the RQ, with a significant reduction of 34% and 26%, respectively. Ferulic acid was not detected in any of the samples. Rutin and quercetin and kaempferol glucosides were significantly affected by boiling of quinoa, with reductions close to 55%, 49%, and 52%, respectively ($P \leq 0.05$) (Table 1). Regarding the total phenols and total flavonoids content of raw quinoa, the results in this study were similar to those in previous studies (Vollmannová et al., 2013; Repo-Carrasco-Valencia et al., 2010a; Carrasco & Zelada, 2008; Paśko et al., 2009; Gorinstein et al., 2007). Other studies have shown some variability in individual phenolic compounds (Repo-Carrasco-Valencia et al., 2010b; Chlopicka et al., 2012). These variations are attributed mainly to the variety of quinoa used for the study, the type of extraction used for its quantification, and the reactivity of the Folin–Ciocalteu reagent with other non-phenolic compounds, such as amino acids and proteins. These situations can contribute to the over- or underestimation of phenolic compounds. Nickel et al. (2016) evaluated five different

Table 1. Total phenols, total flavonoids and individual phenolic compounds determined from the methanolic extract of quinoa flour.

Flour	Total phenols	Total flavonoids	Ferulic acid	Rutin	Quercetin 3-glucoside	Kaempferol 3-glucoside
	µgGAE/g	µgQE/g	µg/g			
RQ	620.7 ± 17.6^{ab}	1126.3 ± 25.7^{a}	ND	315.5 ± 25.9^{a}	168.3 ± 18.0^{a}	272.5 ± 20.5^{a}
BQ	580.6 ± 4.6^{b}	739.3 ± 33.2^{b}	ND	174.8 ± 17.5^{b}	84.1 ± 8.0^{b}	142.7 ± 14.7^{b}
MQ	679.2 ± 24.5^{a}	824.0 ± 17.4^{b}	ND	353.5 ± 1.1^{a}	159.7 ± 13.3^{a}	270.2 ± 10.7^{a}

Data were expressed as mean (n = 3) ± SE. Different superscript letters in each column indicate significant differences between the average values ($P \leq 0.05$). ND: not detected.

techniques for processing quinoa and placed them in order from best to worst for retention of phenolic compounds, as follows: washed and pressure-cooked quinoa > washed quinoa = washed and boiled quinoa > washed and hydrated quinoa > washed and roasted quinoa. The differences in the phenolic compounds content between treatments are related to the type of phenolic compounds present—free, conjugated, and linked—and their release depends on the type of treatment applied. In contrast, significant reductions in the content of phenolic compounds and flavonoids have been reported in sweet and sour quinoa after boiling in the cooking process. This effect has been attributed to the cooking water being discarded (Dini et al., 2010). Regarding the use of microwaves as a cooking treatment for quinoa to improve its biological potential, the shortage of reports prevents the comparison of our results.

Most studies that have used microwave radiation have evaluated cereals and pseudocereals that have been treated in combination with solvent extraction systems to improve the extraction of some components (Gianna et al., 2012). Additionally, microwaves have been used in seed-drying processes, that is, as heat treatment in the absence of moisture. Microwave radiation is also being used to improve the content of total phenols and flavonoids during the sorghum germination process (Hassan et al., 2019). The advantages of using microwaves lie in the speed at which samples can be heated, and in the avoidance of overheating and the degradation of heat-labile substances. Thus, good yields can be achieved in a short time.

3.2 Total phenols, total flavonoids, and individual phenolics of cookies made using heat-treated quinoa

The methanolic extract results show that before intestinal digestion, the total phenols and total flavonoids content of all heat-treated cookies was not affected compared to that of non-treated samples ($P > 0.05$) (Table 2). Ferulic acid was detected in all quinoa cookies; this result is relevant, considering that this phenolic acid was not detected in the respective flours. This result suggests that the baking process enhanced the ferulic acid content in all the samples. The rutin content was higher in the MQC than in the RQC and BQC ($P \leq 0.05$), while the quercetin 3-glucoside content was increased in both BQC and MQC compared with RQC. After intestinal digestion, the total phenols content increased significantly in all the samples evaluated compared to the original samples. The BQC and MQC digests exhibited higher values of total phenols (2,637.06 ± 88.22 μgGAE/g and 3,083.90 ± 86.7 μgGAE/g, respectively) than the RQC digest (2,070.7 ± 108.0 μgGAE/g). Similarly, for total flavonoids content, the highest values were found in the samples mentioned above, with 937.87 ± 36.49 μgQE/g and 1,096.55 ± 42.13 μgQE/g, respectively ($P > 0.05$). Regarding the content of ferulic acid, rutin, and quercetin and kaempferol glucosides in the intestinal digests, the results showed that none of these compounds was detected in any of the samples analyzed except in MQC. Since the food matrix had been exposed to digestive conditions, different reactions may have occurred than those that occur in a chemical extraction. This could have led to free phenolic compounds that were accessible in the food matrix before digestion no longer being detected, possibly due to their degradation, polymerization, or interaction with other components that inhibit their release. On the other hand, it is also possible that digestion conditions, such as enzymatic activity and changes in pH, significantly favored the release of phenolic compounds that were bound or conjugated in the sample before digestion or physically entrapped in the food matrix. In this study, it was observed that MQC had higher levels of total phenols in the intestinal digests compared to cookies made with boiled and untreated quinoa flours. It is feasible that microwave treatment modified the food matrix structure in such a way that it became more susceptible to digestion.

It may have promoted a greater association of digestive enzymes with the food components (i.e., proteins, carbohydrates, fats, etc.), resulting in the release and/or depolymerization of phenolic compounds. Consequently, the compounds could then have become part of the digest and thus been quantified. Importantly, when there are differences in the phenolic content of the samples before digestion, difficulties arise when determining the effect of the food matrix on digestibility and stability under the intestinal conditions. To normalize these results, we calculated the recovery rate for each variable analyzed. This is a valid procedure for determining the bioaccessibility of bioactive compounds in the food matrix. The intestinal recovery percentages of total phenols, total flavonoids, and individual components from the

Table 2. Levels of total phenols (TP), total flavonoids (TF), and individual phenolic compounds found in the non-digested cookies (methanolic extracts) and digested cookies made using heat-treated quinoa flours.

Cookies	Total phenols	Total flavonoids	Ferulic acid	Rutin	Quercetin 3-glucoside	Kaempferol 3-glucoside
	μgGAE/g	μgQE/g	μg/g			
Methanolic extracts						
RQC	446.4 ± 5.9^{a}	1029.8 ± 11.3^{a}	8.5 ± 0.1^{a}	40.3 ± 1.4^{b}	53.9 ± 1.5^{b}	76.9 ± 1.5^{a}
BQC	485.7 ± 21.2^{a}	1081.9 ± 41.8^{a}	9.4 ± 0.5^{a}	46.5 ± 2.1^{b}	1.7 ± 3.6^{a}	76.1 ± 4.4^{a}
MQC	476.5 ± 14.7^{a}	1118.8 ± 32.5^{a}	9.4 ± 0.1^{a}	66.5 ± 4.0^{a}	77.7 ± 0.7^{a}	88.8 ± 1.5^{a}
Intestinal digests						
RQC	2070.7 ± 108.0^{C}	821.8 ± 36.4^{B}	ND	ND	ND	ND
BQC	2637.0 ± 88.2^{B}	937.8 ± 36.4^{A}	ND	ND	ND	ND
MQC	3083.9 ± 86.7^{A}	1096.0 ± 54.1^{A}	13.6 ± 2.2	43.7 ± 5.9	66.3 ± 7.4	86.5 ± 2.5

Data were expressed as mean (n = 3) ± SE. Different lowercase and uppercase superscript letters in each column for methanolic extracts and intestinal digests, respectively, indicate significant differences between average values ($P \leq 0.05$). ND: not detected.

digestion of 1 g of cookies made using heat-treated quinoa flours are presented in Figure 1A. Only total phenols showed recovery percentages greater than 100% for all the samples evaluated. The MQC (647%) had the highest recovery percentage of total phenols, followed by the BQC (543%) and the RQC (456%). The total flavonoids showed recovery percentages of less than 100% for the RQC (79%), BQC (86%), and MQC (98%) digests. The recovery percentages of ferulic acid, rutin, quercetin, and kaempferol were observed only in the MQC digests. The intestinal recovery percentages of antioxidant activity were remarkably high for all cookie samples analyzed (greater than 100%). The digests of the BQC and MQC were found to have percentages of recovery of antioxidant activity below that of the RQC. However, of the two heat treatments, MQC showed higher intestinal antioxidant activity recovery (Figure 1B). Various studies have shown that GI digestion significantly increases the content of phenolic compounds; even when the digestion conditions of each stage are different, there is a predominance of high values in the intestinal stage. Pellegrini et al. (2017) evaluated the intestinal recovery rates of phenols and total flavonoids of six varieties of quinoa, obtaining total phenols values in the range of 250–320%. For total flavonoids, the range was 150–500% higher than those obtained in our study. Bouayed et al. (2011) determined the recovery rate of anthocyanins in different apple varieties and reported no recovery of this compound at the intestinal level, explaining that anthocyanins were degraded under the acidic conditions of gastric digestion. In their 2018 study, Hidalgo et al. (2018) showed that the content of total soluble phenols increased up to 300% in the intestinal digest of cookies enriched with 30% quinoa flour, slightly higher than that for breads enriched with buckwheat. The use of different types of cereals, pseudocereals, and mixtures thereof is suggested as a strategy for increasing the content of phenolic compounds in some food products. Although bioactive compounds have beneficial effects on human health, their effects depend not only on the content in their food matrix, but also on their absorption capacity and bioavailability in the body. Therefore, *in vitro* studies investigating the effects of different ingredients and preparation methods on the bioaccessibility and bioavailability of compounds are warranted. For example, as discussed here, the use of pseudocereals as alternatives to common cereals or applied heat treatments could improve phenolic content and increase the bioaccessibility and bioavailability of these compounds. The results presented here reinforce the fact that GI digestion significantly modifies the phenolic component content. GI digestion conditions (pH and enzymatic activity), the possible interactions that occur between the components during digestion, and the structure of the food matrix, among other factors, can significantly influence the reduction and/or increase in phenolic compounds.

3.3 Consumer test

The sensory attributes evaluated for the BQC, MQC, and WOC were more acceptable to consumers than those evaluated for the RQC (Figure 2A). Although no significant differences were found between the heat-treated quinoa cookies and the WOC, the consumers showed a slightly greater acceptance of the texture and flavor/taste and overall liking of the MQC. Because wholemeal oat flour is generally used for making cookies, the similarities in the overall liking of the MQC and WOC indicate the strong potential of quinoa flour for cookie making. Figure 2B shows that the acceptance/rejection percentage of each of the cookies yielded interesting results: 92% of the panelists responded that they would accept consuming MQC, 80% would accept consuming BQC, and 79% would accept consuming WOC. However, only 12% of the panelists responded that they would accept consuming RQC, suggesting that the evaluated sensory attributes influenced the panelists' decision to consume the cookies. Jan et al. (2018) optimized the process parameters and independent variables for the formulation of cookies using quinoa flour; the optimal baking temperature and time were 181 °C and 18 min, respectively. In this study, the response variables were an antioxidant activity of 20.66% (% DPPH inhibition) and an overall acceptability of 7.61. In our study, the baking temperature and time were 160 °C and 13 min, respectively, which were lower than those in previous studies. A similar study was carried out by Watanabe et al. (2014), who evaluated the

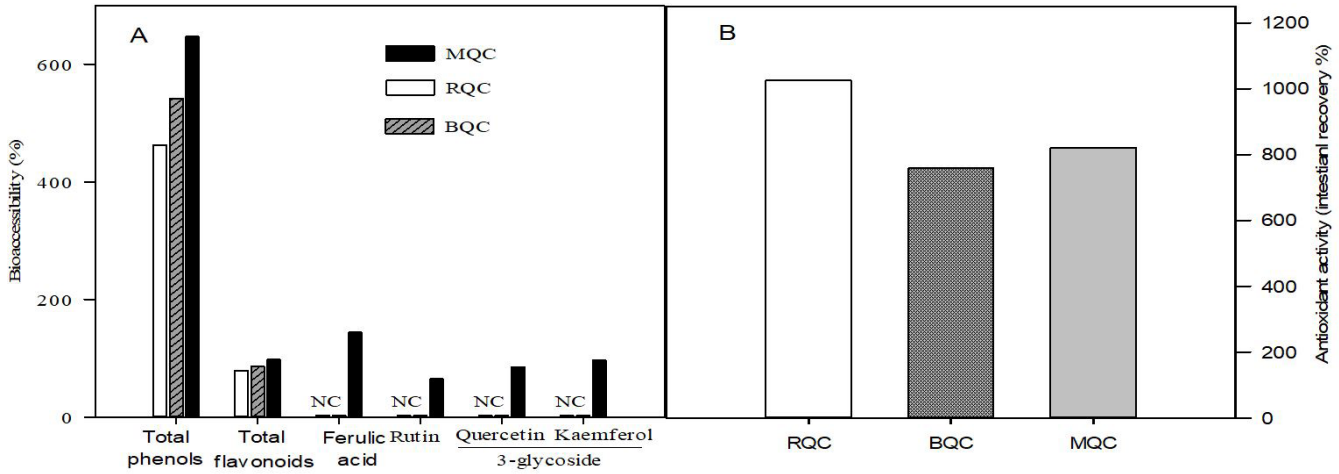

Figure 1. (A) Bioaccessibility (%) of total phenols, total flavonoids, and individual phenolic compounds (ferulic acid, rutin, and quercetin and kaempferol glycosides); (B) Intestinal recovery antioxidant activity of quinoa cookies (RQC, BQC, and MQC). NC: not calculated.

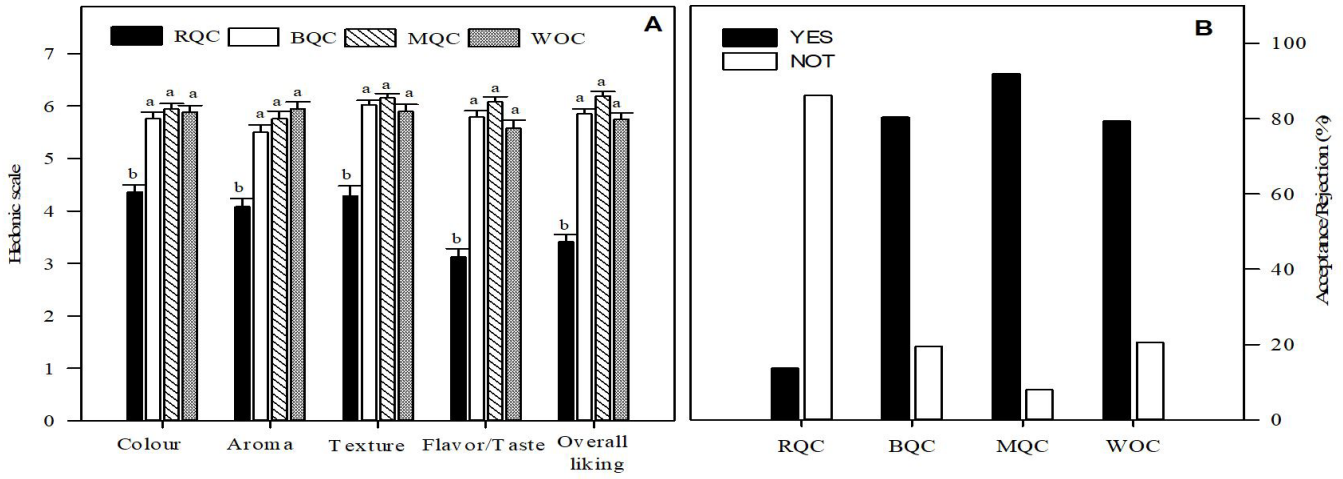

Figure 2. (A) Consumer acceptance of experimental cookies (RQC, BQC, MQC, and WOC) determined by a consumer sensory panel. Values correspond to the average (n = 87) ± standard error. Bars with different letters (per sensory attribute) are significantly different ($P \leq 0.05$).

storage stability of fat contained in cookies made with 7.5% and 15% quinoa flour instead of wheat flour. Their results showed that the antioxidants present in quinoa cookies could inhibit the oxidation of the fats contained in them. In our study, the cookies were not formulated by replacing a portion of the base flour—all the cookies were formulated with 45.5% quinoa flour (RQ, BQ, and MQ). This suggests that the heat treatment applied to the quinoa improved the sensory attributes of the cookies; the average values ranged between 6 and 7, which means that the panelists rated the cookies as "I like it moderately ".

Different formulations in cookies have been tested by adding various non-conventional food materials such as fruit bagasse, terebinth, green grain flour legume, among others, showing an increase in biological potential and improvement of sensory quality (Köten, 2021; Tarasevičienė et al., 2021; Maia et al., 2021).

On the other hand, many consumers remain neutral or positive regarding their opinion about unconventional technologies for food processing such as microwaves. However, many consumers still perceive the use of this technology negatively, mainly because they believe that microwaves promote a loss of nutritional food value and are hazardous for the health and nutrition of humans (Guzik et al., 2022). For the particular case of our study and subsequent works related to microwaves used as heat treatment in food, it could be necessary additional to consumer test, including consumers' perception tests. The preceding could help the consumer acquire a better acknowledgment regarding the proper use of microwave ovens. Another hand could help develop market strategies to permit consumers to make shopping choices with greater awareness.

4 Conclusions

The results of this study suggest that the digestion of 1 g of cookies made using microwave-treated quinoa flour favors the bioaccessibility of phenolic compounds compared to an untreated quinoa counterpart. These results are promising, suggesting that cookies made using microwave-treated quinoa flour could be incorporated as a ready-to-eat functional food into diets associated with health promotion and disease prevention.

Conflict of interest

The authors declare that there are no competing interests.

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