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Research Article

Cookies Enriched with Maqui (*Aristotelia chilensis* (Mol.) Stuntz) Flour: Good Source of Dietary Fiber and Antioxidant Capacity

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Byproducts derived from the agricultural industry and food processing, such as seeds and skin or husks, have become important due to environmental sustainability and their value-added potential. Maqui (*Aristotelia chilensis* (Mol.) Stuntz) is a native Chilean wild tree that has several beneficial properties due to its high content of anthocyanins, anthocyanidins, phenolic acids, tannins, and fiber. The present study involved flour derived from maqui byproducts (seeds and skin) to produce cookies with a higher content of nutrients, dietary fiber, and antioxidants. Maqui bagasse was converted into flour and mixed with wheat flour to prepare the cookies. The control consisted of wheat flour cookies with no added maqui flour. Results indicated that the cookies with the added maqui flour were preferred more than the control and had a higher percentage of fiber. Compared with the control, the amount of anthocyanins increased 3.5 times, and the amount of antioxidants, measured via the DPPH (2,2′-diphenyl-1-picrylhydrazyl radical) assay, increased approximately 10 times. Our results show that the incorporation of maqui byproducts, in the form of maqui flour, into the cookie formulation is an effective way to add nutritional value to cookies by increasing dietary fiber, total polyphenols, and total anthocyanins.

1. Introduction

Many companies are now concerned about environmental sustainability and security; they are interested in adding value to the byproducts generated in both food processing and the agricultural industry [1–4]. These byproducts, which are mainly husks and seeds, can contain considerable amounts of fiber, proteins, and antioxidants that can be used in the pharmaceutical, cosmetics, and food industries [5–7]. Maqui (*Aristotelia chilensis* (Mol.) Stuntz) is a native Chilean wild tree whose fruit weight is approximately 65% seeds and skin [8]. Different studies have shown that consuming maqui provides some benefits to people because of its high anthocyanin, anthocyanidin, phenolic acid, and tannin content [9–11]. Maqui significantly contributes natural antioxidants of plant origin to the diet of consumers, thus providing health benefits [12]. In addition to its antioxidant potential, maqui has antidiarrheal, anti-inflammatory, antipyretic [9, 13], and antidiabetic effects [14, 15]. It prevents cardiac disorders [16], and there are now studies indicating that regular consumption of this fruit would reduce the risk of suffering or delay the onset of neurodegenerative diseases such as Alzheimer's disease [17]. It has been demonstrated that anthocyanins, which are phenolic metabolites belonging to the flavonoid family, have high antioxidant potential with recognized health benefits [18–21]. This characteristic is related to the fact that they can act as free radical scavengers, thus decreasing oxidative stress [22]. In addition, maqui has the highest proportion of fiber compared with other berries such as murtilla, blueberry, raspberry, and blackberry [23]. This characteristic, coupled with the high antioxidant content of the fruit, has prompted interest in studying a way to reuse maqui byproducts, such as skin and seeds, obtained after juice production. These byproducts could contain important nutritional compounds to produce food products with potential benefits for today's consumers who have focused their interest on healthier foods that are free of synthetic preservatives, have antioxidant properties, and generally provide health benefits [24].

Several studies have been conducted recently with the aim of using part of these byproducts as ingredients in mass consumption foods such as cookies. Given that wheat flour per se has a low nutritional composition, the amount of nutrients it provides in this type of product is low [25]. Other authors have substituted part of the wheat flour in cookies with banana flour, dry grape marc, and chestnut shells, to obtain a product with physical and organoleptic properties that are satisfying for the consumer [26–28]. Research has also been conducted to evaluate cookies fortified with mango flour; functional properties derived from dietary fiber were expected, which led to promising results [29]. There is an interesting review of food industry byproducts that have been used or could be used as a source of dietary fiber in a variety of foods such as bakery and confectionery products, sauces, ice cream, juices, beverages, meat products, and different packaging, thus providing them with a number of benefits [30]. However, despite the properties and benefits of maqui consumption, there is no precedent to date for the development of applications or foods formulated with maqui derivatives; thus, the present study used maqui byproduct flour (seeds and skin) to produce cookies with a higher content of nutrients, dietary fiber, and antioxidants.

2. Materials and Methods

2.1. Raw Material. The maqui (*Aristotelia Chilensis* (Mol.) Stuntz) fruits used for the study were collected from domesticated maqui trees located in the Fundo las Pataguas in the commune of Coihueco near Chillán, Ñuble Region, Chile. The maqui fruits were cleaned and sorted to discard stalks, leaves, and damaged fruits.

2.2. Description of Process to Produce Maqui Flour (MF) from Bagasse. Bagasse was obtained from fresh residue-free (sanitized) maqui fruits. The raw material was placed in a juicer (HR-1832, Phillips, Montrouge, France) to separate the juice from the seeds and skin (bagasse). The bagasse was transferred to a 1.5 L plastic container with a lid (previously protected from light) with distilled water at 1 : 0.5 *w*/*v* ratio. The first soluble compound extraction was performed by shaking the sample in a shaker (SK-018-Pro, SCILOGEX, Rocky Hill, CT, USA) at 500 rpm for 30 min. The mixture was placed again in the juicer (HR-1832, Phillips, Montrouge, France) to extract the remaining bagasse pulp. This procedure was repeated at 500 rpm for 20 min (total extraction time of 50 min). The bagasse/water mixture was manually filtered using a cloth to obtain the final bagasse with seeds.

The bagasse was dried in a conventional oven (1375 FX, Shel Lab, Cornelius, OR, USA) at 70°C for 48 h. The dried bagasse was ground in a hammer mill at 40 mesh to produce maqui flour (MF) (0.400 mm). The MF was stored in polyethylene bags, protected from light, and vacuum-sealed until further analysis and used for cookie production.

2.3. Formulation and Production of Cookies with Added Maqui Flour (MF). Wheat flour cookies (control) and cookies with added MF were formulated and produced according to Cruzat and Barrios [23]. The MF was added at rates of 5%, 7.5%, and 10% as a replacement for wheat flour in the formulation.

The production of cookies with MF at 5% consisted of weighing 950 g of wheat flour and adding 50 g of MF. The formulation also included 150 g sugar, 200 g vegetable fat (100 g margarine and 100 g vegetable oil), 120 g egg white, 4 g baking soda, and 260 g water. These ingredients were mixed until the batter was homogeneous. Portions of 50 g were kneaded, molded into a disk shape (9.5 cm diameter and 1.2 cm thickness), and baked at 180°C for 20 min.

The formulation and production of cookies added with MF at rates of 7.5% and 10% were carried out as mentioned above by substituting the MF rate in the preparation.

2.4. Sensory Evaluation

2.4.1. Sensory Evaluation of Preference for Cookies with Maqui Flour (MF) and Control Cookies. A semitrained panel (35 panelists from the Universidad del Bío-Bío, Chillán campus, Chile) participated in the sensory evaluation; panelists used the preference test, which refers to the choice between several products on the basis of like or dislike. This was based on the person's choice between a set of alternatives (two or more products). When two products are used, it is a paired test, and when more than two samples are used, it is a ranking test [31].

The sensory evaluation was conducted in two stages. The first stage consisted of the preference test for cookies with added MF at 5%, 7.5%, and 10%. The second stage was a preference test between the control cookies and the most acceptable cookies with MF from the first stage.

The data were evaluated using the Friedman analysis of variance via the ranking test using the following equation.

$$x^2 = \left(\frac{12}{(k) * (J) * (J+1)} * \sum Tj^2\right) - 3k * (J+1), \qquad (1)$$

where $\sum Tj^2$ is the column sum of squared ranks, J is the number of columns or products, and k is the number of panelists or rows.

2.4.2. Descriptive Sensory Analysis of Control Cookies and Cookies with Maqui Flour (MF). Once the sensory evaluation of preference was concluded, a second sensory analysis was performed [26]. The semitrained panelists were asked to evaluate using a scale from 1 to 7 with scores of 1 (very poor), 2 (poor), 3 (fair), 4 (acceptable), 5 (good), 6 (very good), and 7 (excellent).

2.5. Analyses Performed on Maqui Flour, Control Cookies, and Cookies with Added Maqui Flour

2.5.1. Proximate Analysis. Moisture (AOAC method 934.06 for sugar-rich fruits) [32], lipid (AOAC method 954.02) [33], ash (AOAC method 923.03) [34], and protein (AOAC method 991.20) [33] content was determined. The total carbohydrate content was calculated based on difference [35] and the caloric content via the Atwater coefficient [36]. Each analysis was performed in triplicate with two replicates.

2.5.2. Determination of Soluble, Insoluble, and Total Dietary Fibers. Soluble, insoluble, and total dietary fibers were determined via the enzymatic-gravimetric method (AOAC method 991.43) [33] in triplicate. The principle for total dietary fiber is to perform enzymatic digestion that is treated in alcohol to precipitate the soluble dietary fiber before filtration. The residue is washed with alcohol and acetone, dried, and weighed. A duplicate is analyzed for protein, and another is incinerated to determine the amount of ash.

2.5.3. Determination of Total Polyphenols via the Folin-Ciocalteu Method. Total polyphenols were determined by adding a 250 μL aliquot of sample, 1250 μL Folin-Ciocalteu reagent (2 N), and 2500 μL 20% sodium carbonate in 50 mL Falcon tubes (previously protected from light with an aluminum foil) to a 25 mL volume with distilled water. The tubes were closed and maintained in the dark at ambient temperature for 30 min [37]. The absorbance of the samples was read at a 765 nm wavelength using a UV-visible spectrophotometer (T-70 UV-VIS, PG Instruments Limited, Wibtoft, Lutterworth, UK). All samples were analyzed in triplicate. Total polyphenols were expressed as mg of gallic acid equivalents (GAE) per 100 g of sample [38].

2.5.4. Determination of Total Anthocyanins. Total anthocyanins were determined using the pH differential method [39] which was modified [40]. A 0.2 mL aliquot of the extract was placed in two test tubes previously protected from light. A buffer (1.8 mL) at pH 1 and pH 4.5 was placed in the first and second tubes, respectively, and both tubes were then homogenized. Finally, the absorbance of the samples was read at 510 and 70 nm wavelengths using a UV-visible spectrophotometer (T-70 UV-VIS, PG Instruments Limited, Wibtoft, Lutterworth, UK). All analyses were realized in triplicate [41]. Total anthocyanins were calculated based on the variation in the absorbance at pH 1 and pH 4.5 at 510 and 700 nm wavelengths using the following equation.

$$\Delta A = \left[(A_{510}–A_{700})_{\mathrm{pH}\,1.0} - (A_{510} - A_{700})_{\mathrm{pH}\,4.5} \right]. \quad (2)$$

The total anthocyanin concentration, expressed as 7-cyanidin 3-glucoside and delphinidin 3-glucoside per 100 g of sample, was calculated using the molar extinction coefficient and molecular weight of each monomeric anthocyanin, respectively, as in the following equation.

$$\text{Anthocyanins (mg/100 g)} = \left(\frac{\Delta A \times \mathrm{Pm} \times 1000}{\mathrm{CE} \times 1}\right) \times \left(\frac{2}{0.2}\right) \times \mathrm{FD} \times \left(\frac{V_{\mathrm{extract}}}{\text{sample weight}}\right) \times \left(\frac{1}{1000}\right), \quad (3)$$

where Pm is the molecular mass of 7-cyanidin 3-glucoside (449.2 g/mol), CE is the molar extinction coefficient of 7-cyanidin 3-glucoside (26,900), FD is the dilution factor applied to the sample, and V is the volume in mL of extract obtained.

2.5.5. Determination of Decolorization Percentage of DPPH Radical. The antioxidant capacity was determined via the decolorization percentage of the DPPH radical. A 0.1 mL aliquot of the extract and 3.9 mL of the DPPH radical (0.1 mM) were placed in a test tube, which was previously protected from light, and the mixture was shaken. The mixture was closed and maintained in the dark at ambient temperature for 30 min. Afterward, the color change from dark violet to yellow was determined via UV-Vis spectroscopy with measurements at the 515 nm wavelength [42]. Analyses were performed in triplicate, and Equation (4) was used to calculate the decolorization percentage of DPPH in the samples.

$$\text{DPPH decolorization}(\%) = \frac{A_0 - A_f}{A_0} * 100, \quad (4)$$

where A_0 is the initial absorbance of DPPH and A_f is the absorbance of the DPPH sample after 30 min.

2.5.6. Water Activity (a_w). Water activity (a_w) was determined using AQUALAB 4TE equipment (Meter Group Inc., Pullman, WA, USA). Values were recorded at constant temperature (20°C).

2.6. Statistical Analysis. The statistical analyses were performed using STATGRAPHICS Centurion XVI software at $\alpha = 0.05$ (95% confidence level). Analysis of variance (ANOVA) was conducted and Tukey's test was applied to compare the means and identify the pairs of groups that showed significant differences. All the assays were carried out in triplicate with two replicates, and data were expressed as the mean and standard deviation.

3. Results and Discussion

3.1. Process Parameters Associated with Maqui Flour (MF) Production. The maqui juice extraction process provided 32.73% juice and 67.27% bagasse. Table 1 shows the processing losses in the production of bagasse and MF and their respective yield percentages. The bagasse yield was 50.7% at the drying stage, while the MF yield was 28.1% for the initial weight of the bagasse in the milling and sieving process. The MF yield was 18.9% for the fresh fruit.

There is limited information available on MF-processing yields. This is mainly because most research focuses on the use of flour from different fruits to produce or improve bakery products, but does not provide data on their processing yields. Bagasse yield from fresh fruit has been reported in

Table 1: Maqui flour (MF) yield (%) compared to bagasse yield obtained in maqui juice extraction.

Bagasse obtained (%)	Dried bagasse yield (%)	MF yield (%)
100.0	50.7	28.1

Table 2: Percentage of preferences and data for analysis of the preference test (Friedman test) for each type of cookie.

Panelists (total)	Sample A (5%)	Sample B (7.5%)	Sample C (10%)
35	31.43% (11)	17.14% (6)	51.43% (18)
Sum total	72	81	57
Sum^2	5184	6561	3249
X^2			8.40

which there was a physical evaluation of the maqui fruits; fruits were processed to obtain pulp resulting in pulp yields that ranged from 28% to 57%, while bagasse yields ranged from 40% to 72% [43]. These authors explained that values depended on the amount of fruit used because a lower amount of fruit led to a higher percentage loss due to pulp adhesion to the filtration mesh and pulping equipment. Other studies have been conducted on fresh maqui berries with 50.2% pulp yield [44] and 41.6 ± 16.8% pulp yield [45]. Data reported by these authors differ from our results, which could be due to the variability of the maqui fruit related to plant origin, collection area, and fruit size (pulp/seed variation).

3.2. Sensory Evaluation. Table 2 shows the results for the preference evaluation of cookies with added MF at 5% (sample A), 7.5% (sample B), and 10% (sample C). The panelists preferred sample C with 10% MF. They indicated that their preference was based on the sensory attributes of this sample, especially its palatability, texture, and flavor.

The Friedman method was used to corroborate that there were differences between samples (Table 2). The panelists found significant differences between cookies prepared with MF with a value of 8.40, which was much higher than the tabulated critical value of 5.99 [31]. Given that sample C (with 10% MF) was preferred in the first sensory evaluation, the second descriptive sensory test for each attribute of control cookies and MF-added cookies was performed only on cookies with 10%-added MF together with a preference evaluation between the two samples. The semitrained panelists were asked to evaluate the attributes (appearance, color, flavor, texture, and aroma) with a score of 1 to 7 [26] where 7 was the highest score (excellent) and 1 was the lowest (very poor). They were also asked to choose their preferred cookie (between the control and cookies with MF).

Table 3 displays the data provided by the semitrained panelists according to the sensory evaluation of the attributes performed on the control and cookies with MF. The aroma, flavor, and texture attributes of the cookies with MF had higher acceptability than the control. Meanwhile, the appearance and color attributes had higher acceptability in the control sample. Cookies with MF acquired a dark color (brownish-purple),

Table 3: Sensory analysis for each attribute of control cookies and cookies with maqui flour (MF).

Sensory parameter	Control cookie	Cookie with MF
Appearance	6.17 ± 0.791^a	5.59 ± 1.001^b
Color	6.17 ± 0.912^a	5.66 ± 1.092^a
Aroma	5.55 ± 1.162^a	5.86 ± 1.224^a
Flavor	5.52 ± 1.221^a	6.00 ± 1.083^a
Texture	5.66 ± 1.183^a	5.52 ± 1.163^a

Different letters in the same row indicate significant differences between samples at 95% confidence level according to Tukey's test.

which was attributed to the MF color (dark purple) and the thermal treatment (baking); this directly affected the appearance and color of the final product. Figure 1 shows images of the control cookies and cookies with MF obtained in this study; clearly, the appearance and color of the cookies with MF differ from those of the control cookies and were therefore evaluated with a lower score by the sensory panel.

For the evaluated sensory attributes, cookies with MF only had significant differences for appearance compared with the control. According to Table 4, the panelists observed that the color, aroma, flavor, and texture attributes showed no significant differences; however, they pointed out that the cookies with MF exhibited slight differences in texture and flavor (mealy texture, palatability, and lack of sweetness). The same is observed in Figures 2 and 3, where the values of the sensory attributes obtained for each type of cookie studied are plotted.

The panelists were also asked to choose which of the two types of cookies they preferred. Of the 35 semitrained panelists, 9 (25.8%) chose the control, while 26 preferred the cookies with MF (74.2%). As for acceptability, our results were similar to those obtained in studies conducted to increase crude fiber, amount of antioxidants, and organoleptic and physical characteristics of cookies with added flour obtained from other fruits [26, 29].

3.3. Proximate Analysis of Maqui Flour, Control Cookies, and Cookies with Maqui Flour. Table 4 shows the results of the proximate analysis for MF, control cookies, and cookies with MF. Both the control cookies and cookies with MF had similar moisture content, 11.15% and 11.27%, respectively; there were no significant differences between the two samples.

Most microorganisms cease to be active when the water content decreases below 10% [46]; we can therefore infer that the moisture content levels of MF, control cookies, and cookies with MF were within the limit required to prevent any proliferation of microorganisms.

The MF exhibited a higher value (2.91%) for ash content than the control cookies and cookies with MF. This is directly related to the mineral content of the soil in which the maqui fruit orchards are located and their agronomic management; both factors are important for the proportion of minerals found in the fruits [47]. Other authors have indicated that maqui fruits are characterized by high percentages of minerals such as K (3.683 mg/kg) and Ca (1.558 mg/kg), which directly affect ash content [44]. Ash percentages in the control cookies and cookies with MF showed no significant differences between

(a) (b)

Figure 1: Images of control cookies (a) and cookies with MF (b) obtained in this study.

Table 4: Proximate analysis of maqui flour, control cookies, and cookies with maqui flour (MF).

Parameters (%)	MF	Control cookies	Cookies with MF
Moisture	3.59 ± 0.06	11.15 ± 0.27[a]	11.27 ± 0.05[a]
Ashes	2.91 ± 0.94	0.88 ± 0.013[a]	0.92 ± 0.020[b]
Proteins	7.44 ± 0.04	9.26 ± 0.21[a]	8.53 ± 0.76[a,b]
Lipids	11.02 ± 0.13	11.18 ± 0.10[a]	12.91 ± 0.02[a,b]
Fiber	33.47 ± 0.19	0.26 ± 0.027[a]	1.80 ± 0.262[b]
Carbohydrates*	41.57	67.27	64.57
Calories (kcal/100 g)**	295.18	406.74	408.59

*Value calculated via difference. **Value calculated using the Atwater method. Different letters in the same row indicate significant differences between samples at 95% confidence level according to Tukey's test.

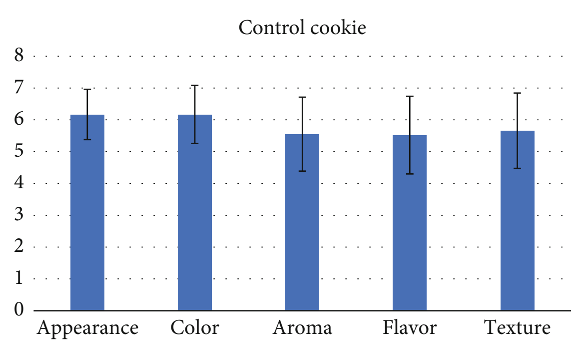

Figure 2: Bar chart of sensory attributes of control cookies.

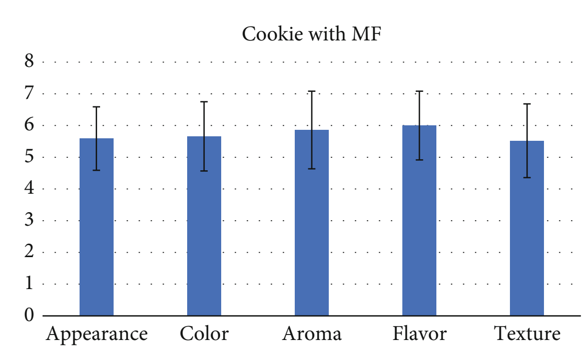

Figure 3: Bar chart of sensory attributes of cookies with MF.

them, although cookies with MF had a higher ash percentage (0.92%) than the control cookies (0.88%). Table 4 also shows the protein content for MF, control cookies, and cookies enriched with MF. The control cookies and cookies with MF exhibited a higher percentage of proteins than MF. There was no difference between the control cookies and cookies with MF; however, the control had a higher percentage of proteins (9.26%) than the cookies with MF (8.56%). Lipid content (Table 4) showed significant differences between the control and the cookies with MF, 11.18% and 12.91%, respectively. This could be explained by the fact that MF largely consists of maqui seeds, which tend to store lipids [44]. In addition, Table 4 shows that the fiber content in cookies with MF (1.8%) was 6 times higher than that in the control (0.26%). The MF had a high fiber percentage (33.4%) because it mostly consists of seeds and husks. It should be highlighted that the caloric content for the control and cookies with MF had a similar value (Table 4).

3.4. Dietary Fiber Content in Maqui Flour, Control Cookies, and Cookies with Maqui Flour. Dietary fiber can be defined as a substance of plant origin that cannot be digested by the enzymes of the human digestive tract. These are structural polysaccharides of plants, including cellulose, hemicellulose, β-glucans, pectins, mucilages, gum, and lignin. The latter does not have polysaccharide structures because it consists of phenylpropane polymers. The structural differences of each of these determine the different physical and chemical properties. This results in diverse physiological behaviors [48–50] that

Table 5: Dietary fiber in maqui flour, control cookies, and cookies with maqui flour (MF).

Dietary fiber	MF	Control cookies	Cookies with MF
Soluble (g/100 g)	8.3 ± 0.13	1.2 ± 0.09[a]	1.7 ± 0.11[b]
Insoluble (g/100 g)	54.3 ± 0.21	2.0 ± 0.10[a]	5.3 ± 0.10[b]
Total (g/100 g)	62.6 ± 0.18	3.2 ± 0.09[a]	7.0 ± 0.11[b]

Different letters in the row indicate significant differences between samples at 95% confidence level according to Tukey's test.

contribute to the proper functioning of the digestive tract; it is therefore necessary to include these values in nutritional information tables.

The results for the different types of dietary fiber in MF, control cookies, and cookies with MF are shown in Table 5. The MF has a high total dietary content and both soluble and insoluble dietary fiber content. The high insoluble dietary fiber content in MF, 54.3 g/100 g, should be highlighted. Table 5 also includes values for soluble and insoluble dietary fibers for control cookies and cookies with MF. Adding MF to the cookies produced a significant increase in the percentage of the total dietary fiber, which was more than twice (7.0 g/100 g) compared with the control (3.2 g/100 g). Insoluble dietary fiber in the cookies with MF increased more than 2.5 times compared with that in the control. Goswami et al. [51] developed functional cookies using carabeef and 10% orange pulp fiber waste, obtained after removing the juice, along with sodium caseinate and guar gum. The cookies showed significantly ($P < 0.05$) higher fiber content, with IDF, SDF, and TDF levels being 6.13, 5.47, and 4.47 times higher, respectively, than those of the control cookies made with refined wheat flour.

The recommended daily allowance of fiber for women is 28 g/d and 38 g/d for men [52]. A food must contain at least 10% or more of the recommended daily allowance per typical serving to be fortified. Likewise, the FAO has indicated that 25 to 30 g/d is the daily intake of dietary fiber per person. Based on the results of the present study, it can be pointed out that consuming one serving of cookies with MF (approximately 40 g) provides 0.72 g of dietary fiber; this value is therefore not sufficient for cookies with MF to be classified as being fortified with dietary fiber. However, it has been mentioned that the daily fiber requirement is between 5 and 18 g/d for children under 8 yr of age [53]; therefore, the dietary fiber value of the serving of cookies with MF would be within the 10% recommended daily allowance for this particular group.

3.5. Total Polyphenol Content in Maqui Flour, Control Cookies, and Cookies with Maqui Flour via the Folin-Ciocalteu Method. Polyphenols are known to be secondary metabolites of plants that have been shown to provide positive effects on human health. However, a decrease in polyphenols has been detected due to the different applied treatments, particularly to fruits and their derivatives, which alter their quality characteristics [54, 55]. Phenolic components are oxidized by the mixture of phosphotungstic and phosphomolybdic acids known as the Folin-Ciocalteu reagent, which are reduced to blue oxides of tungsten and molybdenum. Maximum absorbance occurred at 765 nm, which indicated that the sample has a higher phenol concentration, expressed in this case as mg of gallic acid equivalents (GAE) per 100 g of sample [56]. Table 6 shows the total polyphenol content of the samples of MF, control cookies, and cookies with MF. Incorporating MF into the cookies increased the value of polyphenols by approximately 3.5 times.

The polyphenol content of the MF was 303.84 mg GAE/100 g, which was lower than values between 1014 and 2584 mg GAE/100 g reported by other authors for fresh fruits [57]. This is because the polyphenols are found in the whole fruit and in the fleshy parts of maqui. Therefore, the total polyphenol content is greatly reduced when the maqui juice and pulp are extracted and the bagasse is used to produce flour. Nonetheless, approximately 30% of the polyphenol content remains; we therefore believe that it is important to use maqui bagasse as a byproduct. Some researchers have reported the ability of maqui bagasse polyphenols to protect the body against LDL (low-density lipoprotein) oxidation and oxidative damage to vascular endothelial cells, thus suggesting antiatherogenic potential [10]. Recent studies have shown that maqui bagasse possesses significant antimicrobial and antioxidant activity [58]. Ortiz et al. demonstrated that the polyphenolic extract of maqui has therapeutic effects on acute inflammation in Crohn's disease, by modulating inflammatory proteins and the Nrf2/HO-1 antioxidant pathway [59]. Our findings indicate that maqui bagasse flour is capable of retaining polyphenols even after the extraction of the juice and pulp. Consequently, the inclusion of maqui bagasse flour in cookies can augment their antioxidant content. This suggests that maqui flour has the potential to impart both antioxidant and anti-inflammatory benefits to cookies, while simultaneously enhancing their physicochemical and sensory properties.

3.6. Total Anthocyanin Content in Maqui Flour, Control Cookies, and Cookies with Maqui Flour. Total anthocyanin results are shown in Table 6 for MF, control cookies, and cookies with MF; values are expressed as mg cyanidin 3-glucoside/100 g dry matter. The amount of total anthocyanins in the cookies with MF (0.0993 mg/g) was 3.6 times the amount of total anthocyanins in the control cookies (0.027 mg/g). However, the value in cookies with MF is much lower than that in MF (1.21 mg/g). This difference in anthocyanin content between MF and cookies with MR can be due to the typical degradation of macromolecules that occurs during the thermal treatment, which mainly depends on the time and temperature involved [60].

3.7. DPPH Antioxidant Content in Maqui Flour, Control Cookies, and Cookies with Maqui Flour. The high level of consumer interest in products containing components that are beneficial to health has generated considerable attention in the food and pharmaceutical industries to develop new and innovative products with high antioxidant capacity. This potential is created by the high content of anthocyanins and phenolic compounds in some dark-colored fruits such as maqui [61].

The bioactivities of MF, control cookies, and cookies with MF determined via the DPPH assay are shown in Table 6. The MF sample had a value of 2360.69 (μg TE/mL), an antioxidant

Table 6: Total polyphenol content, total anthocyanins, and DPPH in MF, control cookies, and cookies with MF.

Parameters	MF	Control cookies	Cookies with MF
Polyphenols (mg GAE/100 g)	303.84 ± 30.78	18.11 ± 0.85[a]	63.14 ± 3.24[b]
Total anthocyanins (mg/g)	1.21 ± 0.023	0.027 ± 0.0052[a]	0.0993 ± 0.096[b]
DPPH (μg TE/mL)	2360.69 ± 6.36	118.03 ± 0.32[a]	1213.86 ± 3.27[b]

Different letters in the row indicate significant differences between samples at 95% confidence level according to Tukey's test.

capacity value directly related to the total polyphenol content according to other studies [62]. It has been indicated that these bioactivity percentages can vary because of the high heterogeneity of maqui plants [63].

As for the antioxidant capacity of the control cookies and cookies with MF, there were significant differences between them, 118.03 and 1213.86 (μg TE/mL), respectively. Our results indicated that adding MF to the cookie formulation increased the antioxidant capacity of the cookies by approximately 10 times, which was expressed as the percentage of decolorization of the DPPH. This is evidence that adding MF is a good way to incorporate antioxidants in cookies.

4. Conclusions

Our study showed that the wheat flour cookie formulations with added maqui flour (MF) at 5%, 7.5%, and 10% were evaluated by a semitrained panel, and the cookies with 10% MF were the most preferred. The incorporation of up to 10% MF in the cookie formulation was well accepted by the panelists compared to the control cookies without added MF. It can also be concluded that adding byproducts derived from maqui, such as MF, to the cookie formulation is a good way to incorporate nutritional value to cookies. The amount of dietary fiber increased up to values that can be considered as enriched if the cookies are consumed by children under 8 years of age. The antioxidant capacity of the cookies also increased by having a higher amount of total polyphenols and anthocyanins. But, although the results of the study are promising, there are some important limitations that should be taken into consideration. For example, the study was conducted using a single cookie formulation and a specific concentration of maqui flour (up to 10%); therefore, the results may not be generalizable to other cookie formulations or levels of maqui flour concentration. And although the study indicates that the amount of dietary fiber increased with the addition of maqui flour, the actual amount of dietary fiber that children consumed when eating the cookies was not measured.

Data Availability

The data are available on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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