Aristotelia chilensis (Maqui Berry)

Subjects: Nutrition & Dietetics

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The *Aristotelia chilensis* (Mol.) Stuntz, also known as Maqui, is an endemic berry native to southern Chile. It is a very popular berry for its nutritional attributes and health benefits, provided mainly by its polyphenols.

Keywords: Maqui ; Aristotelia chilensis ; functional food

1. Introduction

The *Aristotelia chilensis* (Mol.) Stuntz, also known as Maqui, is a plant native to Chile that is distributed in tropical and temperate Asia, Australia, the Pacific area, and South America [1][2]. It is an endemic tree present in Chile and in the adjacent regions of southern Argentina; it can be found in the north of Chile from the province of Limarí up to the province of Aysén in southern Chile. Maqui belongs to the *Elaeocarpaceae* family and is a plant that blooms from October to December, and it is harvested once a year, from December to February [3]. The Maqui is a thin tree whose girth measures from 30 to 35 cm and reaches a height of 10 m; it is a dioecious species; that is, it has male and female flowers of a pale-yellow color, with a diameter from 5 to 6 mm. Its fruit is an edible, round, dark purple berry whose diameter is 5 mm (**Figure 1**). Maqui berries contain a rich variety of anthocyanins, including delphinidins, powerful antioxidants found in abundance in the standardized Maqui berry extract [4].

According to research, Maqui has 19 polyphenolic compounds identified as anthocyanins (eight compounds), flavonols (10 compounds), and ellagic acid, with anthocyanins being the most predominant of the delphinidins, while quercetin derivatives were the most predominant flavonols [5]. These bioactive compounds have a strong antioxidant power, which is also associated with anticancer, antimicrobial, anti-inflammatory, and inhibitory activity on the enzymes that participate in metabolic syndrome [6][7], making Maqui a fruit of interest for health [4].

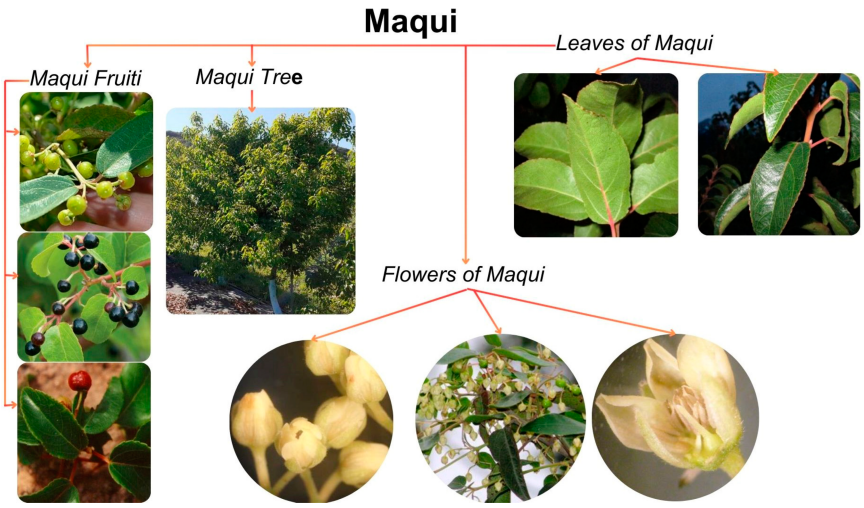

Figure 1. Maqui tree with its fruit, leaves, and flowers [4][8].

2. Nutritional Characteristics of Maqui Fruit

It is important to note that nutritional contributions will present variations depending on whether Maqui fruit is dried, fresh, or prepared as juice; it even shows differences according to the type of drying process, with freeze-dried Maqui being the most commonly sold [1][9].

According to Schmidt Hebbel [10], the nutritional composition of Maqui (**Table 1**) provides 150 calories per 100 g of edible portion. Its protein contribution is low, with 0.8 g/100 g; however, non-nitrogenous extractives, which correspond to

carbohydrates and other constituents such as gel and fiber are quite significant. Maqui stands out for having the highest fiber content when compared to other berries like murtilla, blueberry, raspberry, and blackberry.

In a study that assessed the nutritional composition of the Maqui seed, it was found that it had a crude protein contribution of 9.24%, much higher than that reported by Schmidt [10] for the Maqui fruit. Maqui juice has a low protein and total carbohydrate content, according to a study published by Araneda et al. [11].

In addition, it has been reported that it contains calcium, phosphorus, iron, and potassium (**Table 1**) [8]. Furthermore, it has a lower ash content, as its juice is made with the Maqui extract and does not include the whole fruit [11].

The Maqui seeds showed a 2.06% ash content [12], similar to what was found in grape seeds, where Elagamey et al. [13] obtained ash values ranging from 2.52% to 2.68%.

Issis Quispe et al. [1] found that dried Maqui has total levels of fiber levels that vary between 53.3 and 64.5 g/100 g depending on whether it is fresh or dried. Of these values, insoluble fiber accounts for 50.8 to 58.2 g/100 g, representing up to 90% of total dietary fiber. According to Quispe-Fuentes et al. [1], this is due to the high ratio between pulp and seeds in Maqui berries.

An interesting study analyzed the ether extract of Maqui and mainly indicated that its seed has a high oil content [12]. In the research by Quispe-Fuentes et al. [1], 11 different types of fatty acids were identified, including six SFAs (saturated fatty acids), two MUFAs (monounsaturated fatty acids), and three PUFAs (polyunsaturated fatty acids), in both fresh and dried Maqui (**Table 2**). The main fatty acid was C18:2 (n-6), which represented 45.41% of the total, followed by C18:1 (n-9) (34.2%), C16:0 (9.49%), C18:0 (2.92%), and C18:3 (n-3) (2.12%) (**Table 2**) [11]. Different results were obtained in a study by Brauch JE et al. [9], in which lipids vary in most of the fatty acids found.

Table 1. Nutritional composition of Maqui fruit.

Nutrient	100 g of Edible Portion	Ref.
Energy (kcal)	**150**	[8][10]
Proteins (g)	**0.8**	[8][10]
Lipids (g)	**2.9**	[9]
SFAs %	**13.6 ± 0.01**	[11]
MUFAs %	**35.25 ± 0.07**	[11]
PUFAs %	**47.78 ± 0.32**	[11]
PUFAs/SFAs %	**3.5**	[11]
NNEs (g)	**40.8**	[8][10]
Total dietary fiber (g)	**53.31**	[11]
Insoluble dietary fiber (g)	**50.85 ± 1.33**	[11]
Soluble dietary fiber (g)	**2.46 ± 0.60**	[11]
α-Tocopherols (µg/g)	**4.5 ± 0.1**	[11]
Ash (g)	**1.2**	[8][10]
Calcium (mg)	**87**	[8][10]
Phosphorus (mg)	**44**	[8][10]
Iron (mg)	**30.5**	[8][10]
Potassium (mg)	**296**	[8][10]

NEs: non-nitrogenous extractives (by difference), SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.

Table 2. Composition of fatty acids in dried Maqui.

Fatty Acid g/100 g	Araneda et al. [11]	Brauch et al. [9]
Lauric acid C12:0	0.27 ± 0.01	0.49 ± 0.01
Myristic acid C14:0	0.66 ± 0.01	1.075 ± 0.02
Pentadecanoic Acid C15:0	n/i	0.02 ± 0.00
Palmitic acid C16:0	9.49 ± 0.04	8.70 ± 0.04
Stearic acid C18:0	2.92 ± 0.01	3.29 ± 0.05
Arachidic acid C20:0	0.21 ± 0.01	0.13 ± 0.00
Behenic acid C22:0	0.12 ± 0.08	0.19 ± 0.00
Lignoceric Acid C24:0	n/i	0.13 ± 0.01
Total SFAs	13.66 ± 0.08	n/i
Palmitoleic acid C16:1 (n-7)	0.33 ± 0.01	0.37 ± 0.02
Oleic acid C18:1 (n-9)	34.92 ± 0.06	33.28 ± 0.24
Total MUFAs	35.25 ± 0.07	n/i
Linoleic acid C18:2 (n-6)	45.41 ± 0.05	46.31 ± 0.09
Alpha-linolenic acid C18:3 (n-3)	2.12 ± 0.03	2.09 ± 0.03
Eicosapentaenoic acid C20:5 (n-3)	0.26 ± 0.24	n/i
Total PUFAs	47.78 ± 0.32	n/i

n/i: no information. SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.

3. Applications of Maqui Fruit in the Food Industry

The health benefits associated with Maqui berry are often attributed to its abundance of bioactive compounds, particularly anthocyanins [14]. The interest in anthocyanins has risen significantly due to their association with a decreased risk of various chronic diseases. These compounds play a crucial role in promoting health by exhibiting antioxidant, anti-inflammatory, anti-cancer, and protective effects against metabolic, degenerative, and cardiovascular diseases [14]. Nonetheless, anthocyanins are inherently unstable and vulnerable to factors such as temperature, light, and pH conditions. Consequently, their bioavailability is recognized to be low, rendering their study complex [4]. To overcome this challenge, the intake of products rich in anthocyanins, incorporated into diverse food matrices, could provide protection against degradation caused by pH variations in different digestive stages. The structure and composition of the food matrix containing anthocyanins play a crucial role in either enhancing or hindering the release and stability of these compounds during digestion, thereby influencing their effectiveness. The bioactive compounds responsible for the claimed health benefits of Maqui berries must withstand the digestive process. In this sense, McDougall et al. [14] reported that when anthocyanin-rich raspberries are consumed alongside foods like bread, cereals, ice cream, or cooked meat, the anthocyanin content remains unaffected after gastric digestion.

Currently, the food industry has incorporated vegetable products into food composition, with the aim of providing a comprehensive product with benefits for consumers. In the case of Maqui fruit, it is mainly used in juices and in powdered, freeze-dried, and frozen forms, which are currently marketed both nationally and internationally. Various investigations have demonstrated that Maqui berry fruit was predominantly consumed in processed forms, such as dehydrated, jam, or juice. This preference can be attributed to distinct factors, including the fruit's limited harvesting window and its notably short shelf life. According to the report *"Perspectivas del mercado internacional para el desarrollo de la industria del Maqui: Un análisis de las empresas en Chile" [International market perspectives for the development of the Maqui industry: An analysis of Chilean companies]* [15], there are 21 exporting and marketing companies of Maqui, of which 4 are exclusively engaged in the manufacture of beverages, with these being the second most traded product in terms of dollars, followed by Maqui powder.

Maqui juice can be marketed as natural juice, that is, raw and pure fruit juice, but also mixed with or added to other natural components, as is the case of lemon juice enriched with Maqui berries [16]. A study that analyzed blends of lemon juice mixed with different berries found that the blend including Maqui was the most interesting in terms of antioxidant capacity, showing reduced effects on acetylcholinesterase and butyrylcholinesterase; moreover, lemon juice mixed with Maqui can

be useful to equilibrate redox balance in acute and intense exercise, it reduces glycemia levels in subjects of both sexes, and its composition has a lower glycemic index, with its properties remaining stable during preservation [16][17][18]. It is important to note the agent used to sweeten beverages or citrus-Maqui juices, since according to a study the use of non-caloric sweeteners could alter blood homocysteine levels when sucralose is used (p = 0.001); however, researchers observed a significant increase in IL-10 concentrations when the beverage was sweetened with Stevia [19]. Other research that analyzed the effect of a citrus-Maqui beverage with sweeteners on male and female consumers found that the use of Stevia regulated trans-ferulic acid levels in women, while sucrose regulated vanillic acid levels in men, concluding that sweeteners may influence the regulation of polyphenols in subjects who consume these drinks [20]. Along the same lines, a group of researchers designed an aniseed liquor-based beverage, which was originally produced in Navarra, incorporating Maqui berries. Results showed optimal organoleptic and sensory characteristics, with an attractive aroma and highlighting color; in addition, it exhibited a higher anthocyanin content during maceration and a higher antioxidant capacity [21].

Given the findings of earlier research indicating the potential utilization of bioactive compounds derived from herbs and plants in the development of innovative functional food products, Maqui emerges as a promising candidate for applications in functional foods and various industrial food sectors. Notably, Maqui offers health-promoting nutrients, positioning it as a crucial source of food security in economically challenged regions. This research aims to consolidate recent insights into the bioactive compounds derived from Maqui and explores their potential incorporation into food product formulations (**Table 3**).

In this sense, Maqui has also been used to improve the quality of beef patties. In a study where researchers compared control patties without antioxidants, patties added with synthetic antioxidants, and patties added with Maqui leaf powders in concentrations of 500, 1000, and 2000 ppm, it was found that the pH of the control beef patties increased during storage, while the pH of beef patties with synthetic and natural antioxidants decreased; furthermore, decreased lipid oxidation was observed in patties added with Maqui (at all doses) in comparison with the synthetic antioxidant. With respect to organoleptic characteristics, redness (a*) was affected at doses of 1000 ppm and 2000 ppm of Maqui powder; despite this, the incorporation of this product did not affect the general acceptability of the patties, concluding that this natural additive can be used in the formulation of beef patties [22][23].

Given the attractive color of the Maqui fruit, it has been tested as a natural colorant in yogurts. Researchers incorporated Maqui and murra (blackberry) to assess consumers' perceptions; it was found that Maqui samples had the highest acceptability means, with 74% of consumers reporting that they "like it" and "like it very much" when concentrations of 8% were used, while a 64% rejection was reported when a Maqui concentration of 12% was used. Purchase decision was mainly observed in relation to the products including Maqui when compared to products added with murra (blackberry), concluding that concentrations of 4% and 8% Maqui could be used as natural colorants [24].

Maqui fruit can be employed in a variety of ways; according to a publication, it can also be an excellent additive to enhance the functional and nutritional properties of a product, as well as to improve organoleptic and sensory characteristics, and has been tried as an enhancer for thermal stability of avocado oil. Researchers used Maqui leaf extracts and concluded that methanolic extract has a better protective effect on thermal oxidation when the oil is heated at 120 °C for 336 h in an oven. Natural extracts, which are by-products (leaves), can be an alternative to stabilize oils subjected to high temperatures [25].

Table 3. Maqui's application effect on product quality for bakery, meat, and milk products along with oils and juice.

Food	Parts Used	Maqui Application/Concentration Used	Main Results/Conclusions	Reference
Cookies	***Maqui* By-products (seeds and skin)**	**Substituting wheat flour in cookie formulations with the inclusion of Maqui flour (MF) at 5%, 7.5%, and 10%**	**Maqui improved the nutritional value, reporting a greater amount of nutrients, fiber, antioxidants, total polyphenolics, and total anthocyanins. In addition, cookies with Maqui flour were favored over the control ones, exhibiting a higher percentage of fiber. Compared with the control, anthocyanin content increased 3.5-fold and antioxidant levels increased approximately 10-fold.**	**[26]**

Food	Parts Used	Maqui Application/Concentration Used	Main Results/Conclusions	Reference
Yogurt	Maqui berry powders (MBP)	4% and 8%	The perception that the consumer has about yogurt with Maqui powder (at 4% and 8%) could serve as potential prototypes for future market launches, given that they have an attractive color and present high levels of bioactive compounds, which makes the Maqui in a favorable option as a functional ingredient or food coloring.	
Meat patties	*Maqui leaf powders (Ma)*	500, 1000, 2000 ppm	Patties with Ma at 500, 1000, and 2000 ppm treatments demonstrated the lowest rates of lipid oxidation (42.05%, 40.29%, and 43.14%, respectively) compared to the synthetic antioxidant (52.23%). This is attributed to the high total polyphenol content (148.76 mg GAE/g), predominantly characterized by significant amounts of hydroxybenzoic acids (82.5 mg GAE/g), flavonoids (7.1 mg QE/g), and hydroxycinnamic acids (3.7 mg CAE/g). Organoleptic analysis revealed that the inclusion of Maqui leaf powders did not impact the overall acceptability of the new formulations.	[23]
Cookies	Maqui berry powders (MBP)	2.5%, 5%, 7.5%, and 10%	The incorporation of Maqui berry powders (MBP) increased the antioxidant capacity of the cookies. Concerning the color of the cookie surface, there was a significant decrease in L* and b* values, while the a* value increased with the addition of MBP. The most favorable sensory attributes and acceptability were observed with 7.5% of MBP. The analysis suggests that cookies with desirable physical characteristics and enhanced antioxidant activities can be achieved by substituting a portion of wheat flour with MBP.	[27]
Pasta	Maqui berry powders (MBP)	Replacement of durum wheat semolina with Maqui berry powder at 0, 7.5, and 15 g 100 g^{-1}	Substitution of durum semolina with increasing levels of MBP resulted in shorter cooking time, increased firmness, and stickiness. The enriched pasta received a favorable acceptance score, surpassing the acceptability threshold. Pasta 7.5 (4.86 g/100 g) and pasta 15 (8.34 g/100 g) qualify for the “source of fiber” or “high fiber” claim, respectively. Predicted glycemic index values categorized pasta 7.5 and pasta 15 as low glycemic index pastas, indicating favorable outcomes in terms of starch digestibility for these products. Furthermore, the inclusion of MBP elevated the antioxidant capacity and total phenolic compound content, with pasta 15 showing particularly noteworthy results.	[28]
Drinks	Maqui berry powders (MBP)	Freeze-dried Maqui berries were incorporated into lemon juice to achieve final concentrations of 2.5% (*w*/*v*) and 5% (*w*/*v*) of ground fruit in the beverage.	Beverages formulated with Maqui berries and lemon juice exhibited protective interactions among bioactive phytochemicals and demonstrated good stability over time concerning the analyzed parameters. The presence of anthocyanins in Maqui berries played a crucial role in preserving vitamin C in lemon juice in these mixtures. Similarly, Maqui protected hesperidin and, consequently, the flavonoids present in lemon. Additionally, the newly developed beverages, enriched with bioactive phytochemicals, displayed substantial in vitro antioxidant activity and maintained an appealing and well-preserved color throughout the study period, particularly when stored at 4 °C.	[29]
Oil	Maqui leaf extract	Avocado oil was fortified with methanolic extract of Maqui leaves (OM) and ethyl ether extract of Maqui leaves (OE). The fortified oils were created with Maqui leaves (OE) at a concentration of 800 ppm.	Enhancing the thermo-oxidative stability of pure avocado oil is achieved through fortification with Maqui leaf extracts using two solvents. The methanolic extract exhibits a superior protective effect. This suggests that utilizing by-products of native plants, like leaves, could serve as an alternative to incorporating non-natural compounds into oils.	[25]

Food	Parts Used	Maqui Application/Concentration Used	Main Results/Conclusions	Reference
Cake	Maqui berry powders (MBP)	0.5, 1, 1.5, and 2.5%	The volume of the sponge cake decreased significantly with the increase in the substitution level of freeze-dried Maqui berry powder. Luminosity decreased significantly with the increase in freeze-dried Maqui berry powder in the crust and crumb of sponge cake. Hardness and stickiness increased, while gumminess tended to decrease with increasing Maqui berry powder. The consumer acceptability score of 0.5 and 2.5% freeze-dried Maqui berry powder obtained better acceptability results.	[30]

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