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Potential of traditional Chilean blood-fleshed peach to support livelihood opportunities in local agriculture

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The blood-flesh peach or vineyard peach is an older heritage cultivar with juicy red-flesh and tart-sweet flavor. They are popular in France, where more than 200 years ago wine growers used to plant them on the vineyards as biological markers to detect the presence of powdery mildew. It is present in countries such as China, Italy, New Zealand, Australia and USA however, it remains a very rare variety worldwide. In Chile, the blood-flesh peach has a centenary presence in rural orchards where is called "Durazno Betarraga." Reproduced by seeds, it has pass through generations of family farmers and has been adapted to local environmental conditions. This red-flesh peach is a local variety considered part of their traditional diets, however, cultural changes in food consumption, short postharvest life and water scarcity due to climate change are threatening its conservation. One of the objectives of the International Year of Fruits and Vegetables, as defined by the FAO, is to integrate small holders and family farmers into value chains for sustainable production and consumption of fruits and vegetables recognizing the contributions of farmer's landraces to their food security, nutrition, livelihoods and income. To promote this objective, we present the work we have been carry out for several years with a farming community. We have conducted ethnographic research to provide a qualitative description of the agricultural value of the blood peach in a limited territory of the Maule Region defined as the study area. For the quantitative section of our research we analyzed the antioxidant capacity (ORAC) and total polyphenol content and compared them with those of other fruits. To gather information on the presence of the blood-fleshed peach in other regions of Chile, we used a citizen science approach through social networks. We propose that this local variety is an innovative raw material to develop healthy fruit-based food, thus encouraging its conservation and consumption with a positive social and economic impact for the community and the local food system.

KEYWORDS

blood-flesh peach, food innovation, Chile, antioxidant, peach [*Prunus perica* (L) Batsch], heritage, agrobiodiversity

Introduction

Peach [*Prunus persica* (L.) Batsch] is a fruit specie that belongs to the Rosaceae family. Is one of the most consumed fruit worldwide and economically important for temperate climate countries. Based on archaeological evidence, early peach selection and domestication began 7,500 years ago, in the Yangtze River valley, from an unknown wild ancestor (Zheng et al., 2014). Genomic analyses of 480 widely collected peach accession including wild relatives, landraces and improved cultivars, shows that two thirds of the genetic diversity have been lost during peach domestication. Fruit size was predominantly selected during domestication, and fruit-taste was associated with successive breeding processes. As a consequence, peach cultivars produced today in China, Europe and America harbor a very low level of genetic diversity (Li et al., 2019). The conservation of landraces and heirloom varieties are valuable resources for future breeding programs to introgressing genetic diversity to breed fruit cultivars more resilient to extreme weather conditions or other threats (Carrasco et al., 2013).

Flesh color is one of the most important selection attributes, related to consumption preferences and nutritional attributes. According to this character, peaches are classified as white, yellow and red-flesh. Red-flesh or blood-flesh peaches, as they are known worldwide, were cultivated in China by the TANG dynasty (618–917 ADC) in the vicinity of the Yangtze river where they are still being grown. The most cited Chinese cultivars are the "Dahongpao" (Zhou et al., 2015), Wujingzaobaifeng (Zhao et al., 2015), and the Wu Yue Xian (Wang and Zhuang, 2001).

The blood-flesh peach was first described in France during the 17th century by Friar Triquel as "Peche Beterave" or "Sanguinole" (Hedrick et al., 1917). The variety was described as a round and slightly elongated fruit, with thin skin and adherent to the pulp, dark red pulp, rather dry, sour and bitter, not a very pleasant taste. The pit separated from the pulp, small and ovoid. It ripens from the end of September and beginning of October. In temperate climates its flavor is sweeter. It is mainly used for canning since the flavor of the cooked fruit is better than the raw one [William Robert Prince, Pomological manual for the orchard and garden, New York, Prince and Prince (1831)]. In France's Bordeaux region the blood-flesh peaches are known as Pêche de Vigne. It is a generic designation for different varieties of peaches that were related to the practice from the 18th century of having them planted at the ends of the rows in the vineyards. The high susceptibility these peaches have to the oidium fungus was used as a biosensor to detect the presence of the fungus in the vineyard and to allow in advance the treatment of the vines. The Pèche de Vigne has been considered a heritage food from the Lyonnaise region (Coteaux du Lyonnais). Since 1980 a French plant breeder called René Monteux-Caillet has developed many new varieties of peaches and nectarines, now branded as "Les Sanguines" (PêcheVigne® and Nectavigne®) by Star Fruits company.

Historian have postulated that the peach trees were introduced into United States in 16th century by French explorers. The mild climate of the new world was favorable to fast growing, high productivity and delicious flavor development and the peaches were widespread in the American continent by seeds. The abundance of the peach trees from Pennsylvania trough Georgia and Alabama caused that most European explorers mistakenly though the peach was an indigenous American product (Thornton, 2015). In 1871 it was entered in the catalog of the American Society of Pomology under the name Indian Blood Cling (Hedrick et al., 1917).

Despite its presence in China, France and USA, Blood-flesh peaches are scarce and rare varieties worldwide. They also exist in Canada (Harrow blood), New Zealand (Black-boy peach) and Australia where they were probably introduced by French and Spanish explorers into colonial European Settlements.

Peach trees were introduced to Chile in the 16th century, along with orange, apple, quince, pomegranate and olive trees and were easily propagated in central and southern Chile due to the Mediterranean climate (González de Nájera, 1614; Muñoz, 2011). In the 18th century, and according to court records and rural and urban property inventories, more than 12 varieties of peaches were grown, some of which have disappeared. However, no mention is made of red-fleshed peaches (Lacoste et al., 2011). Today, the Chilean blood-flesh peach is found just in small orchards and home gardens in rural areas of the country. Commercial cultivars with longer shelf life, the standardization of agricultural products driven by globalization, cultural changes in food consumption, water decrease due to climate change and the rural to urban transition are transforming the local food systems and threatening its conservation.

Considering the cultural and genetic value of local plant resources and agrobiodiversity to ensure food security in communities, in 2015 we initiated a process of conservation of this variety of peach, with a community of farmers in the district of Constitución, Maule Region. We propose that the heritage blood-flesh peach is an innovative raw material for food innovation and can contribute positively to the economy and social welfare of the farming community.

Materials and methods

We have carried out both ethnographic research and laboratory analysis to provide a qualitative and quantitative description of the agricultural value of the blood peach. For the qualitative ethnographic research we interviewed farmers currently engaged in blood peach cultivation in a limited territory of the Maule Region defined as the study area.

For the quantitative section of our research we analyzed the antioxidant capacity (ORAC) and total polyphenol content and compared them with those of other fruits. To gather information on the presence of blood-fleshed peach in other regions of Chile, we used a citizen science approach through social networks.

Study area

Constitución commune (the smallest administrative subdivision in Chile) is situated in the eastern side of the Maule Region, covering an area of 1,344 km^2. Constitución is the capital district of the city of Constitución. The city is located on the 72° 25′ 00″ South longitudes and 35° 20′ 00″ South latitudes, about 14 m above sea level. Hosting over 50.000 habitants of which 50.06% are women and 49.93% are men. The population density is 44.3 inhabitants per km^2 and one third of the population is rural. It has an economy based mainly on exotic forestry industry and secondly agriculture, animal husbandry and fishing.

The geography of the commune is characterized by the predominance of the coastal mountain range with hills between 300 and 700 meters that form hills and valleys. Toward the ocean, the mountain range disappears abruptly forming the coastal plains with a width of ∼5 km, long beaches, and dunes. Only 17.7% of the area is covered by native forest, with 10% corresponding to deciduous forest, 5% to sclerophyllous forest and 2.7% correspond to dune and wetland vegetation. Most of the surface is covered by exotic tree plantation. The climate of the coastal zone of Constitución, is classified as coastal Mediterranean, with an annual rainfall of 809 mm, an average temperature of 9.6°C in the winter and 16.7°C in the summer (Santibáñez, 2016).

Thirty-three kilometers to the west of Constitución, in the coastal mountain, the village of Las Corrientes is located. It is a rural area formed by small farms and surrounded by extense forestry properties. The soil in this area is granitic and with a high percentage of clay, which originated the local clay handicrafts tradition. There is a high level of soil erosion, mainly due to deforestation, watershed management, and forest fires. There is basic electricity service, but no potable water or sewage system. The families obtain water from springs and streams and there is just one primary rural school.

Twenty-two kilometers to the North of Constitución city, by the coast, there is the small village of Putu, located between sand dunes and wetlands. It hosts over 2,000 inhabitants with many either working or studying in Constitución. The urban area of Putu has basic service, paved road, electricity, potable water and sewage system. There is a rural health service, a primary and scientific-humanistic secondary school, a police station as well as a fire station.

Ethnographic research

Based on public information provided by The Latin American Center for Rural Development—RIMISP—an international organizations dedicated to promoting sustainable and inclusive territorial policies among the rural populations of Latin America (Schejtman and Berdegué, 2004; Ranaboldo and Schejtman, 2009), we have defined the concept of Agrifood Heritage as: "The set of knowledge, rituals, traditions and symbols that have been historically built in the relationship between man and nature to satisfy basic subsistence needs such as food. It is related to the ways of producing, preserving, transforming, cooking, sharing, and consuming food." We will use this definition to analyze the Chilean blood-flesh peach as a symbol of the agri-food heritage in the coastal zone of the Maule Region food system and an ethnographic analysis based on fieldwork research and structured interviews. The fieldwork was based on an ethnographic approach in which qualitative techniques were applied to collect data and produce information. According to Geertz (1982), the ethnographic approach implies placing the focus of the narrative record on the point of view of the study participant in his or her real environment. In this sense, cultural facts are networks of meanings and senses, whose expression is textual and must be interpreted within this framework. In this study, the ethnographer interacts with the farmers for 2 weeks, recording the observations, testimonies and interviews. We selected 15 farmers that belong to the PRODESAL [Local Developmental Program from the Chilean Ministry of Agriculture (https://www.indap.gob.cl), to support technically and economically the family farming] who have at least one blood-flesh peach in their farms or home gardens. Prior to each interview, informed consent was obtained. The structured interview covered the following: (a) Information regarding age, educational level and economic activity, (b) number of blood-flesh peach trees, origin and management, the way blood-flesh peach is consumed, recipes, economic use and (c) cultural practices, traditions, social relationships and histories and memories related to the peach. The interviews were recorded, transcribed, and analyzed, and complemented with an ethnographic register.

The studies involving human participants were reviewed and approved by Marcela Celis and Claudio Contreras, members of CONVERSA ethics committee. The participants provided written informed consent to participate in this study.'

Fruit harvest

Five trees were selected. From each one, five peaches fruits were harvested and randomly selected for analyzes. The trees are located in Putu's orchard (35°12′51″S 72°17′01″O). The harvest was done in March 8th 2020, at 8 pound of pressure using a fruit

pressure tester (IMERI, Italy) and 10–12° Brix using a pocket refractometer (ATAGO, Japan). Immediately after harvest were transfer to cold chamber and store at 4°C until processing.

ORAC and total soluble phenolic analysis

The peaches from each tree were washed and milled with skin. The total soluble phenolic contents analysis was assayed by the Folin-Ciocalteu method, according to Coseteng and Lee (1987). The results were expressed as mg Gallic acid (GAE)/100 g of fresh material based on a standard calibration curve daily prepared using gallic acid (3,4,5-trihydroxybenzoic acid). The antioxidant capacity was determined by ORAC (Oxygen Radical Absorbance Capacity) methodology according to Huang et al. (2002) and Prior et al. (2003). The results were expressed in μmoles ET/100 g of fresh material, which corresponds to the number of micromoles of Trolox equivalents (TE) per 100 grams of fresh weight. For this purpose, a Biotek Synergy HT microplate reader for absorbance, fluorescence and luminescence was used.

Social media data collection and fieldwork research of Chilean blood-peach

The use of on-line technology and social media has expanded the opportunities for citizen science, that means "the involvement of volunteers in science" (Roy et al., 2012). Citizen scientists have made important contributions in conservation and surveillance of many species of animals, insects and plants, through the collection of data over extensive areas in long periods of time. The use of social-media such as facebook has provided positive experiences to support participants and encourages them to be active and create forums for learning and community of practice (Kampen et al., 2015; Liberatore et al., 2018). Based on that strategies we open a Facebook group to recruit participants who wants to share information and some history about the blood-flesh peach from their communities along Chilean territory. The Facebook group is public and all content is freely available online. There were no further exclusion criteria. We gathered 317 records which refer to having blood-flesh peach. One hundred and eighty-seven records are from people who have either 20 years-old or older trees or young trees propagated from seeds from older trees. The existence of 53 of them was confirmed personally or by a photographic register and mapped in Google maps. The fieldwork research was conducted between July 2015 and March 2019. Sixty percent of the participants were female and 40% were male. Seventy-two percent stated that the trees were planted on their own properties, while the rest (28%) stated that they were in a parent's or grandparent's house. Eighty-nine percent of the trees are distributed in the rural area and only 11% are in the urban area.

Results

Distribution of red-fleshed peaches in Chile

Using a citizen science approach and Facebook social media platform we gathered information about the presence and distribution of blood-flesh peaches in Chile. Fifty-three, 20 years-old blood-flesh peach trees were found distributed between O'Higgins and Los Lagos region.

Figure 1 shows a map of Chile (A), where box B points out O'Higgins, Maule and Ñuble regions, and box C Bio-Bio, Araucanía, Los Rios and the northern part of the Los Lagos region. The purple dots represent the presence of at least one 20 years-old or older blood-flesh peach. The place can be either a home garden in an urban sector (city or town) or an orchard in a rural sector. The purple stars represent the presence of a population of at least 10 trees older than 20 years of age. Our results show that the geographical distribution of blood-flesh peaches is wide, covering six regions of the country equivalent to 900 Kilometers in a north-south direction. It is observed that its distribution is wide in an east-west direction, being found in the foothills (east) in the intermediate valleys and in areas near the sea (west). These distributions suggest a great adaptability of the variety to different climatic zones and geographic conditions. The blood-flesh peach has different popular names depending on the territory being Beetroot peach (Durazno Betarraga) the most common. In the southern's regions (BioBio, Araucania, Los Rios, and Los Lagos region) it is also known as Purple peach (Durazno Morado) and in the central regions (O'Higgins and Maule) it is known as Wine peach (Durazno Vino o conchovino) and Strawberry peach (Durazno Frutilla).

In the Maule region there are two closed zones with abundance of red-flesh peach: Las Corrientes and Putu.

Traditional blood-peach as a valuable heritage fruit in local farming

The group of farmers selected for the qualitative research included fifteen people, five of them living in "Putu" and 10 living in "Las Corrientes" (Figure 1B). All of them declare to know the blood-flesh peach since childhood (named as "Durazno Betarraga") and to have at least one blood-flesh peach tree in their home gardens. The farmers age range is from 42 to 82 years. Seven of them are over 60 years. Most of the informants reported to live alone or with their partner ($n = 11$), and the remainder ($n = 4$) to live with more than two people either

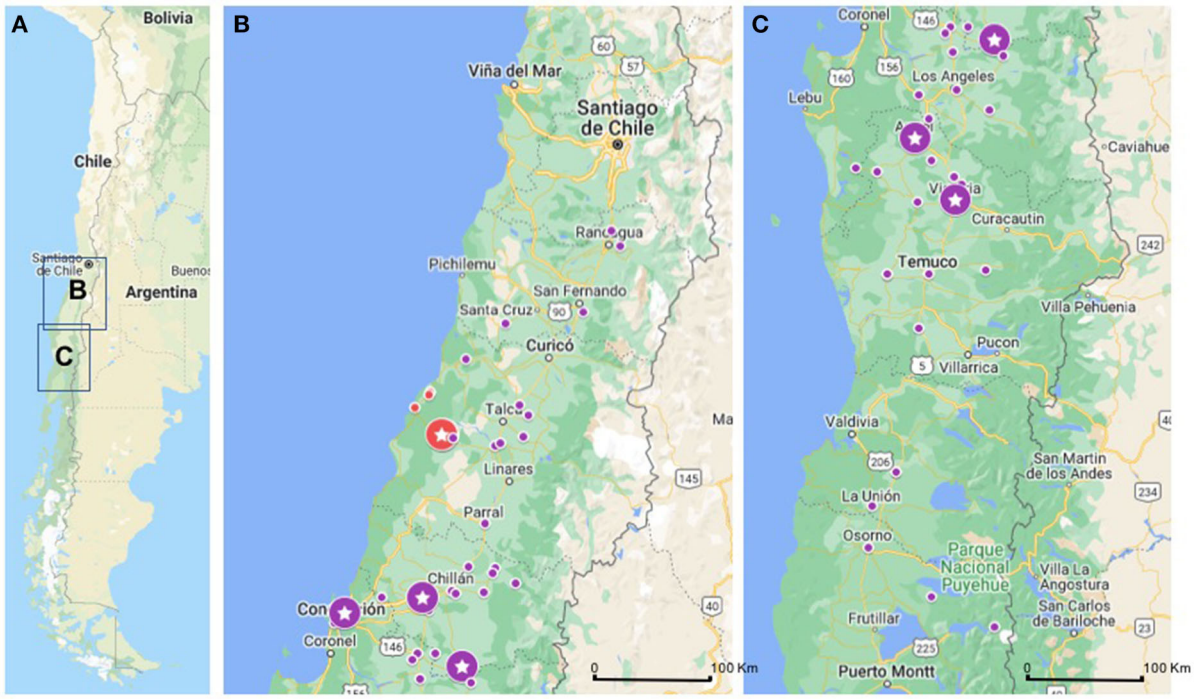

FIGURE 1
Chilean distribution of blood-flesh peach. **(A)** Chilean map, southern part of America continent. The squares indicate two selections areas. **(B)** O'Higgins, Maule and Ñuble regions, **(C)** Bio-Bio, Araucanía, Los Rios and Los Lagos regions. The purple dots represent the presence of at least one blood-flesh peach 20 years-old or older. The purple stars represent the presence of a population of at least 10 trees more than 20 years old. The red dots and start represent the population and territory under study.

children or parents. Nine of the farmers indicated that only one person in their household is engaged in agricultural work, and for the remaining ($n = 6$), there are two or more people who share these tasks. The fact that almost half of the farmers are over 60 years-old is a trend affecting all the countryside nationwide and threatens the survival of traditions and peasant wisdom. The young population is migrating to the city to pursue higher education or is being employed in logging operations that offer salary on a permanent basis. Fourteen of the 15 participants have children, and none of the children or grandchildren are engaged in farming. One of the farmers said: "*We wanted to educate our children. But we did not realize that the countryside was going to be left without people. The young people no longer want to work in the fields. I have 5 children and none of them work with me.*"

Regarding the educational level of the farmers, 11 of them did not complete primary education and only one has university education level. Data from CASEN (2011) (National Socioeconomic Characterization Survey by Social Development Ministry) reveal that just a 31% of the adult population of Constitución has completed secondary education and 39% of the adult population does not have formal education or has incomplete primary education. The average years of schooling (primary and secondary) in the region (9.8 years) is lower than the national average (11.0 years). The total is 12 (CASEN, 2015).

It is interesting to notice that for most of the interviewees, during the ethnographic research, the "Durazno Betarraga" evokes childhood past experiences and strong emotions: "*This is a very old peach, I used to eat it at my grandmother's house. I remember that it was dripping and it was all painted red…like beetroot.*" This quote is another example: "*I love them! they bring back memories of my dear godmother back in the countryside of Talca…she used to pass us a knife and let us go into the garden and eat as many as we could.*"

Participants expressed that more than 50 years ago the peach was abundant and together with a white-flesh variety called "blanquillo" were the only two peach varieties present in the orchards. Nowadays the blood-flesh peach is scarce and has been replaced by other varieties and fruits. Quoting some of them: "*When I was a child we only knew the beetroot peach. But this fruit was lost. The elders used to say that it was good for cancer, anemia and diabetes.*"

For some farmers the reasons for such a loss would be the low valuation by the community due to its short shelf life after harvest and the dark color of its skin compared to modern peach cultivars available at retail. Because of the scarcity of this variety

at present, it is unknown by the new generations, an additional factor that also has a negative impact on its commercialization. One of the farmers reported: "*The beet-peach is very delicate. You have to take it very carefully. That is why it is not marketable, the peach falls off the branch easily. The beet peach is not very popular. You take it to the local market and nobody buys it because they don't know it…and they find it ugly*."

Several interviewees appreciated the "Durazno Betarraga" because the trees are stronger than other fruit trees and does not need as much water. The majority of the farmers do not take special care of their trees, just pruning during winter season and some watering in summer. This is especially important for farmers in the Las Corrientes sector, which in recent years has suffered a severe water deficit and forces farmers to prioritize the use of water for human consumption and greenhouse horticulture.

Putu and Las Corrientes areas have a strong rural identity expressed in everyday life and peasant tradition, characterized by lifestyles linked to field work and attachment to the land, inherited from colonial times. The way they perceive the world and reality is marked by a syncretism between tradition and modernity, between Catholic religion and popular religiosity, which is revealed in various dimensions. The agricultural practices are highly influenced by tradition and popular beliefs. Knowledge has been passed down from generation to generation through oral tradition. Most commonly, farmers reported that the transplants and trees pruning have to be done during waning moon. To quote one of the farmers: "*I was taught that you never transplant before 12 o'clock noon. Always transplant in the waning of the moon and the sun. We wait for the waning of the moon because the plants grow better and more beautiful*." Most of them said they were obtained by spontaneous germination from an older tree that was on the same property or from seeds from their parent's home. Some of them said they were obtained *via* exchange or as a gift.

The farmer's interviewees consume the blood-flesh peach in different ways: fresh as a fruit during the summer season and cooked, dried, canned or processed as jam during the rest of the year (Figures 2A–C). The most popular preparations is sundried as "huesillo" (dry peaches) and jam, for two reasons: they allow for the fruit to be preserved for longer and, on the other hand, they have greater marketing possibilities. To dry peaches they are harvested green, peeled, and are exposed to the sun covered by a thin cloth. Once dried (Figure 2C), they are stored in a dry place. For consumption they are soaked overnight and boiled in hot sugary water. This preparation is served cold with "mote," which is peeled and cooked wheat. This is one of the most traditional Chilean preparations consumed on hot days and during the celebrations of Independence Day (September 18th). The sun-drying process is an ancient practice that was very important in 18th century for Chilean agribusiness to preserve peaches, pears, prunes, grapes and figs. The drying processes of peaches can be with or without stone and cut into slices, which are called "orejones" (Lacoste et al., 2011). The color of its flesh is a distinctive characteristic of this variety that is used as an advantage in many preparations. One female farmer that sells preserves and jam in Constitución said: "*The jam is very easy to make and it looks nice because it is red. I take advantage of the red color to dye for example cooked yellow-canned peaches with the color of the Durazno Betarraga*."

FIGURE 2
Traditional products based on Durazno Betarraga. **(A)** Fresh fruit from Putu farmers, **(B)** Peaches in preserves and jams prepared by farmers and packaged under their own brand name **(C)** dried blood-flesh peaches.

Fourteen farmers defined themselves as small farmers, and just one as a merchant. The range size of their land is from 0,5 hectare (ha) to 25 ha. All of them culture different kinds of crops and fresh vegetables on their properties like garlic, peppers, onions, potatoes, tomatoes, beans, coriander, peas, lettuce, etc. All the farmers cultivated outdoors and four of them also cultivated in greenhouses. In addition, they have orchards or home gardens with diverse fruit species like peach, lemon, orange, walnut, fig, avocado, apple, pear, and plum trees. Six of them have small vineyards from which they produce handmade wine for their own consumption. The majority of the farmers ($n = 10$) produce exclusively for their own consumption and five sell vegetables, flowers, dried fruit, fresh and dried herbs, jams and eggs, offering them to neighbors by cell phone, setting up a roadside stand or at the local market ("Feria Libre") in Constitución.

Potential of the traditional blood-peach for food innovation

The antioxidant activity and total polyphenols of blood-flesh peach was expressed as means of the five trees samples (Table 1). The antioxidant activity (ORAC) of the fresh blood-flesh peach is 1,1406 ± 671 (ET/100 g) of FW and the total phenolics, as determined by the Folin-Ciocalteau assay was 572 ± 18 mg GAE/100 g of FW. This value is higher than the range reported for commercial cultivar of white and yellow-flesh peaches and nectarines (14–77 mg of GAE /100 g of FW) and for blood-flesh varieties (83.75–108.19 mg of GAE/100 g of FW) (Cantin et al., 2009; Aubert and Chalot, 2020). Using the public fruit

TABLE 1 Comparison of ORAC and total polyphenol between blood-flesh peach and other peaches varieties and fruits.

Fruit sample	ORAC (umol ET/100 g FW)	SEM	PFT (mg GAE/100 g FW)	SEM
Calafate	25,662	3,322	1,201	104
Maqui	19,850	966	1,664	83
Murtilla	10,770	453	863	30
Peach (Blood-flesh)	11,406*	671	572**	18
Peach (Elegant -Lady)	3,127	441	123	24
Nectarine (Brite pearl)	3,063	1,441	170	42
Stawberry	3,775	273	231	17
Raspberry	6,903	1,019	380	32
Plum (black)	8,379	483	270	29
Cherry (Lapins)	3,847	87	152	6
Cherry (Rainier)	4,225	1,014	142	16
Cherry (Bing)	6,608	967	200	11
BlueBerry (Elliot)	8,869	334	529	5
Blueberry (Duke)	4,864	409	339	301
Blueberry (Legacy)	6,771	481	421	16

The graphics were made using the public fruit antioxidant database provided by INTA, University of Chile (www.portalantioxidantes.com).
All the data was obtained from the public fruit antioxidant database: www.portalantioxidante.com.
SEM: Standard error of the mean.
*95% CI [9,543, 13,269].
**95% CI [521, 622].

antioxidant database provided by INTA, University of Chile (www.portalantioxidante.com) we compared our results with commercial cultivars of blueberry, cherry, strawberry, raspberry and peaches. The antioxidant activity of the Chilean blood-flesh variety is higher than antioxidant activity of elegant-lady peach variety, Brite pearl Nectarine, cherries (Bing, Lapins and Regina varieties), raspberry and strawberry. Compared with blueberry, the ORAC value is similar to Elliot variety, but is higher than Legacy and Duke. A similar pattern is observed with the total phenolic content. Additionally, the graphic shows the antioxidant activity and total polyphenol of three native Chilean berries: murta (*Ugni molinae* Turez), maqui (*Aristotelia chilensis (Mol.)* Stuntz) and calafate (*Berberis buxifolia* Lam.). These fruits are a well-known source of a wide range of polyphenol compounds with high antioxidant capacity and a valuable raw material for functional foods and nutraceutical development (Fredes, 2009; Céspedes et al., 2010; Rubilar et al., 2011; Romero-Roman et al., 2021).

Discussion

Chile has a prominent position in the global fruit market and is the leading export country of contra-seasonal fresh-fruit to Asia and The United States. Out of the total fruit produced by Chile, nearly 75% is exported fresh and 18% processed (juice, canned, frozen and dried) (ODEPA, 2021). This large-scale agricultural production of fresh fruit is mainly based on modern varieties with longer-shelf life to support the long trip to distant markets. However, this globalization of fruit productivity driven by exportation has led to the standardization of food production with the consequent loss of the value of traditional varieties that are not players of the global market. Many traditional crop species and fruit varieties have been neglected and replaced for cultivar developed by modern genetic programs.

Using a citizen science strategy and Facebook as a social platform, the most widely used for citizen science projects (Oliveira et al., 2021), we collected information on the presence of the blood-flesh peach in Chile. Limited internet access and digital literacy can be considered a barrier to equitable access and, as a consequence, many citizens would be excluded. However, the popularity of Facebook use in rural areas is an opportunity to engage individuals or communities from different regions and obtain data that would otherwise be impossible to obtain in person. The fields related to agriculture and food science have not taken full advantage of the knowledge being generated in citizen science, and there are only a few citizen science projects focused on these topics. However, citizen science has the power to help democratize science and engage communities to address grand challenges in agriculture and food security (Ryan et al., 2018; Edmonson et al., 2019; Sykes et al., 2021). A recently published example of citizen science is the "Historic Fruit Tree Working Group of North America" whose mission is to facilitate the conservation of heirloom apples by collaborating on cultivar documentation and identification (Dunbar-Wallis et al., 2022).

The "Durazno Betarraga," as popularly is known, was found in rural orchards and homegardens of seven Chilean regions (central and southern) with different popular's names: "Durazno Vino," "Durazno Morado," "Durazno Conchovino" or "Durazno Frutilla." Reproduced by seeds and handled by local farmers who rely purely on local knowledge, it has pass through generations of smallholders family farmers and has adapted to different environmental and geographical conditions. For the farmers interviewed it is a valuable resource, part of their traditional diets, consumed fresh during summer season and dried or processed during the winter when the fresh fruit is scarce. Altogether, these results allow us to conclude that the "Durazno Betarraga" is considered part of the cultural heritage of the territory and is a patrimonial or heritage food for the community and requires to be protected, promoted and conserved for future generations. This blood-flesh peach has been also included into the Heritage Products and Preparations catalog from Bio-Bio Region (FIA, 2016).

There is no official bibliographic information about when the blood-flesh varieties arrived in Chile. Its early introduction during 16th century together with different fruit species is not

documented. In the text "The South American Agronomist" published in 1872, the existence of a small, strong-flavored hairy peach known as the Vineyard Peach is mentioned. Furthermore, the existence of purple varieties such as the cardinal of Furstenberg, described as medium size, low red on the outside and marbled on the inside are also described. The name Furstenberg cardinal is mentioned in the peach in New York (Hendrick, 1916) as one of the French sanguine varieties of the mid-17th century. It is described as fibrous flesh colored with deeper streaks of red and orange-yellow skin. One possible hypothesis about the appearance of the blood-fleshed varieties in Chile is that they arrived along with the French vignerons or European vineyard-owning families who brought with them the ancient practice of planting them at the ends of the rows in vine plantations. However, the predominance of the French influence in Chilean vitiviniculture and the introduction of old and rare French varieties was mainly during the second half of the 19th century in the central regions of Chile (Briones, 2006; Pszczolkowski et al., 2018). The fact that we have not found ancient trees or testimonies in the central zone, but we have in the southern regions (Maule, Ñuble, Bio Bio and Araucanía), makes this theory unlikely. However, the role of European or North American migrants in the introductions of rare and heritage fruit cultivars cannot be ruled out.

Our observations during the fieldwork reveal that even when it was very common more than 50 years ago, nowadays it is rarely found in local markets, it remains unknown for new generations and it is not commercially cultivated, converting it into an underutilized and neglected fruit crop variety (Williams and Haq, 2002; Kour et al., 2018). The farmers produce the blood-flesh peach among other fruits and a variety of vegetables for their own consumption and subsistence in their home gardens. The home gardens are small-scale agroforestry systems that play a vital role in household food self-sufficiency, providing fresh and quality food for better nutrition and are frequently a source of income generation (Ferdous et al., 2016; Castro et al., 2018). Homegardens also function as center of conservation of plant genetic resources such as traditional and indigenous crops along with medicinal plants and are places for the transmission of traditional knowledge and cultural practices. The disappearing of the blood-flesh peach is a loss that along with decreasing agrobiodiversity threatens cultural food heritage and local economy.

Locally adapted varieties with higher genetic diversity can provide useful genes to breed cultivars with enhanced resistance to abiotic stress or disease, improved fruit size, texture and quality or to increase bioactive compounds concentrations. Furthermore, as mentioned in a recent report by the FAO, entitled "The state of the World's Biodiversity for Food and Agriculture" (FAO, 2019), crop wild relatives and traditional landraces are important resources for future resilience breeding programs in a global climate crisis scenario. This is particularly important for peach (*Prunus persica* L.), one of the most economically important fruit crop in temperate region. Population genetic analysis of domesticated, landraces and wild peach reveal that nearly two thirds of the genetic diversity has been lost during peach domestication suggesting a narrow domestication bottleneck. During the domestication the fruit size has been mostly selected with the consequence of decline in genetic diversity at loci related with fruit taste (Yu et al., 2018; Li et al., 2019). In this sense the use of landrace and heirloom peach varieties in modern selection programs has the potential to introgressing relevant genetic diversity.

Some neglected and underutilized species have the potential to make an important contribution to food security in local communities and vulnerable social groups, to combat micronutrient deficiencies, protect against market disruptions and climate uncertainties (Kour et al., 2018). In addition to the role as a nutrient, traditional crops and vegetable species are part of the cultural heritage of rural communities. The human activities related to traditional knowledge to producing food, based mainly in agroecology, are one of the rural world's main assets (Espluga-Trenc et al., 2021). Our interview reveal that the agricultural practices are highly influenced by tradition and popular beliefs passed down from generation to generation through oral tradition. These are cultural heritage elements essential for the sustainable support of farmers because create collective identities around local agricultural production. However, the low education level of the farmers, the lack of trained technical stuff in fruit growing and the emigration of young people to the cities could act as threats to conservation of agrobiodiversity and cultural heritage. The Putu and Las Corrientes farmers are supported by PRODESAL (government program) in eight specific areas: vegetables, beekeeping, cattle, poultry, pastures and livestock. Fruit production is not included as a training area, which contrasts with the fact that the Maule region is the main export fruit producing region. Local educational programs for the community on ecology, biodiversity, sustainable food production, nutritional importance of agrobiodiversity and agroecological management of homegardens, among other related topics as innovation and entrepreneurship, are necessary to potentiate the community and increase the engagement of the young people. The involvement of elderly farmers in this learning community is crucial to ensure biodiversity-related traditional knowledge safekeeping.

Traditional varieties that are not cultivated extensively have considerable economic importance in local food system since they are used for the preparation of processed products that are highly valued by the community and traded in local markets. In the case of "Durazno Betarraga," although their fast-ripening is an obstacle for fresh sales therefore, dehydrated products, jams and preserves are alternatives highly valued by the community. In this sense, we encourage the local people to conserve and produce blood-flesh peaches in a way to support improvement of their economic wellbeing. After the ethnographic research

results were presented to the community we developed a series of workshops to promote collaborative work and associativity. As a result, the farmers formed a community association with the aim of protecting the "Durazno Betarraga" and promoting its use and care. They produce jams, preserves and "huesillos" which are sold in local markets under their own brand (Figure 2B).

Fruits contain a wide range of health-promoting compounds, including vitamins, fiber and antioxidants. All fruits high in polyphenols compounds have gained attention due to their antioxidant capacity and potential biological effects in human health (Lourenco et al., 2019). Polyphenols are plants-secondary metabolites wide family ranging from simple molecules such as phenolic acids to more complex like flavonoids. Flavonoids-family members like antocyanins, catechins and procyanidins are known as having a strong antioxidant activity, protective effect against coronary heart disease, and anti-inflammatory properties (Auger et al., 2004; Dragsted et al., 2006; Shin et al., 2006; Butelli et al., 2008; Garzón, 2008; Ottaviani et al., 2018). Fruits like blueberry, blackcurrant, cranberries, grapes and cherries, with high content of polyphenols and high antioxidant capacity have been very used for nutritious and functional food and beverage development (Sun-Waterhouse, 2011).

Our results show that total phenols concentration and antioxidant activity of "Durazno Betarraga" is comparatively elevated against selected fruits listed on the public fruit antioxidant database provided by INTA, University of Chile like cherries, plums, strawberries and raspberries. There are many published studies referring to antioxidants compounds presents in yellow and white-flesh commercial peaches and nectarines (Tomás-Barberán et al., 2001; Cantin et al., 2009; Zhao et al., 2015). Using spectrophotometrics methodologies it has been found that blood-flesh cultivars present high content of anthocyanins and polyphenols (Chaparro et al., 1995; Cevallos-Casals et al., 2006; Vizzoto et al., 2007). Quantitative analysis of individual phenolic compounds have been carried out in Chinese cultivars (Zhao et al., 2015; Yan et al., 2017) and more recently in French blood-flesh peach cultivars (Aubert and Chalot, 2020).

There is growing interest in peach breeding programs to select germplasm with a high content of bioactive compounds to develop new peach varieties with improved nutritional value. Variability in antioxidant capacity and bioactive compounds concentration within peach germplasm provides genetic opportunities for breeding programs (Abdelghafar et al., 2018; Ding et al., 2020). However, some production factors, such as ripening season, environmental conditions, such as temperature and precipitation, and management conditions, such as nitrogen fertilization, also introduce variability in the accumulation of bioactive compounds and antioxidant capacity (Heimler et al., 2016; Abdelghafar et al., 2018). Considering that polyphenol content is dependent on genetic and environment, and in order to evaluate the influence of environmental factor on variation of polyphenol content, we established three genetically identical orchards in different pedoclimates. Based on phenolic profiling by HPLC (Personal communication, H. Silva, 2021), six ecotypes with the highest levels of polyphenols (especially anthocyanins) were selected and propagated by grafting on two different rootstocks, establishing three identical orchards of 200 individuals in different soil and climates conditions. These orchards will enter the production phase in March 2023.

Considering that consumers today are seeking for healthy, functional and clean label foodstuff we propose that one strategy to incentivize the conservation and production of the blood-flesh peaches is through its use as a functional raw material for food innovation. This approach would be an alternative process to the traditional dried and cooked peach and responds to the farmers' concern about the short shelf-life- of the peach. Consumers today are more aware of the nutritional properties of their food and are actively seeking for healthy, functional and clean label foodstuffs. In general terms, functional food products are those who have physiological benefits beyond its basic nutritional function, for example food high in fiber, omega-3, probiotics or antioxidants. Research about food and beverage development has been actively pursued to incorporate natural bioactive ingredients and to conserve their health properties during its processing. A key issue is related to preservation of the biological properties and color of polyphenols after fruit harvesting and processing. The content and stability of polyphenols and other antioxidants and bioactive compounds, such as vitamins, are affected by food processing such as roasting, boiling, drying and pasteurization. Emerging processing technologies such as High-pressure processing (HPP) used for non-thermal pasteurization of foods (Al-juhaimi et al., 2018) offer preservation of the nutritional and functional properties of fruits and vegetables and longer shelf life (Sánchez-Moreno et al., 2005; Bisconsin-Junior et al., 2015). However, these new food processing technologies are expensive and not easily accessible for farmers.

To boost the Durazno betarraga production it is necessary to create a value chain that includes food innovation as a driving force. In this model some fundamental stakeholders are chefs, restaurants, food entrepreneurs and research centers that can build networks between small producers and urban customers and act as knowledge transfer agents of agrobiodiversity and gastronomic heritage. There are many case studies about restaurants and food festivals that have contributed to increase the demand for traditional and local products provided directly by local producers along with the rediscovery of neglected food (Lane, 2011; Pereira et al., 2019; Fontefrancesco and Zocchi, 2020; Zocchi and Fontefrancesco, 2020). On the other hand, the linkage with food enterprises and research centers in processed foods allows the adoption of technologies to add value to food

by transforming them into more complex ones that allow the opening of new markets.

One model to follow in the future is the productive arrangement based on the SYAL approach trough the integration of tangible elements like natural resources, production systems, manufacture and institutional organism, with intangible resources like tradition and cultural heritage that brings cohesion to its elements (Mascarenhas and Touzard, 2018). The SYAL approach emerges in France in the 90's and is defined as "production and services organizations -units of agricultural production, enterprise, local markets, restaurants and services- linked by their characteristics and by their relationship to a specific territory" (Muchnik et al., 2008). In this way, governance that emerges from the territory and involves all stakeholders can create a powerful value chain for the Durazno Betarraga that brings social and economic wealth to farmers in rural territories while promoting the conservation and revaluation of this heritage variety.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Consultora Conversa SPA. The participants provided their informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

Authors LM and CR were employed by Botania. Authors JC and JL were employed by Conversa.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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