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Sardinian dietary analysis for longevity: a review of the literature

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Abstract

Sardinia is one of the five Longevity Blue Zones (LBZs) in the world. Compared to other LBZs, the percentage of male centenarians in Sardinia is much higher. Due to the island's isolation, the genetic traits of Sardinian people have shown that they are direct descendants of their Nuragic ancestors from the Neolithic era. To survive during times of food scarcity, many "famine foods" are created; acorn bread containing clay, cheese ripened in goat abomasum, and soft cheese with worms are examples of these uncommon foods. Although considered food taboo by the outside world, they are cherished as cultural heritage and local delicacy. Studies have shown that Sardinian longevity is closely related to their special famine foods. They are not only nutritious; the production of these foods resulted in low stress and increased lifespan. Moreover, local food production practices have resulted in a strong cultural bond and helped the Sardinian people to survive cultural erosion from industrialization and modernization.

Keywords: Sardinia, Blue zone, Traditional food, Food anthropology, Food taboos, Longevity

Introduction

Longevity Blue Zone (LBZ), also known as Blue Zone, describes places in the world where people consistently live for over a century [1]. There are currently five LBZs in the world: Loma Linda, USA; Okinawa, Japan; Nicoya, Costa Rica; Ikaria, Greece; and Sardinia, Italy. Studies have found several similarities among people originating from these LBZs. They live in a community and family-centered environment, which is aided by a low-stress and relaxing lifestyle. Moreover, they also live in geographically and/or histologically isolated areas. As such, they have maintained a traditional lifestyle, and their activity level is above average throughout their life. Lastly, they produce and consume locally produced food using traditional methods [2].

Sardinia, a large Italian island located in the Mediterranean Sea, has been inhabited by ancient civilizations [3]. Nuraghi stone structures, dating from the Early Bronze Age, are proof of the ingenuity of the ancestors of the Sardinian people. Due to isolation from the European mainland, the study has revealed that the current local population is a descendant of the Nuragic people from the Neolithic era [4]. The specific LBZ in Sardinia is located in the mountainous regions in the Ogliastra province, where they typically work in farms [5]. Isolated by the mountains (Fig. 1), the people of this LBZ have maintained a traditional, pastoral lifestyle and consume locally produced food products. Although modernization has led to cultural erosion and nutritional transition, most Sardinian populations in the LBZ have maintained their traditional practice and diet, eating a combination of garden vegetables and fruits when they are in season, and dried or pickled the surplus to use off-season [6].

Throughout the ages, many difficult times of scarcity have struck ancient civilizations. To survive such harsh times, old civilizations developed many methods to process and preserve foods. These foods are referred to as fallback food or "famine food" [7]. A few of the famine foods utilized in Sardinia include acorn bread, a bitter-tasting black-colored bread made with acorn and clay;

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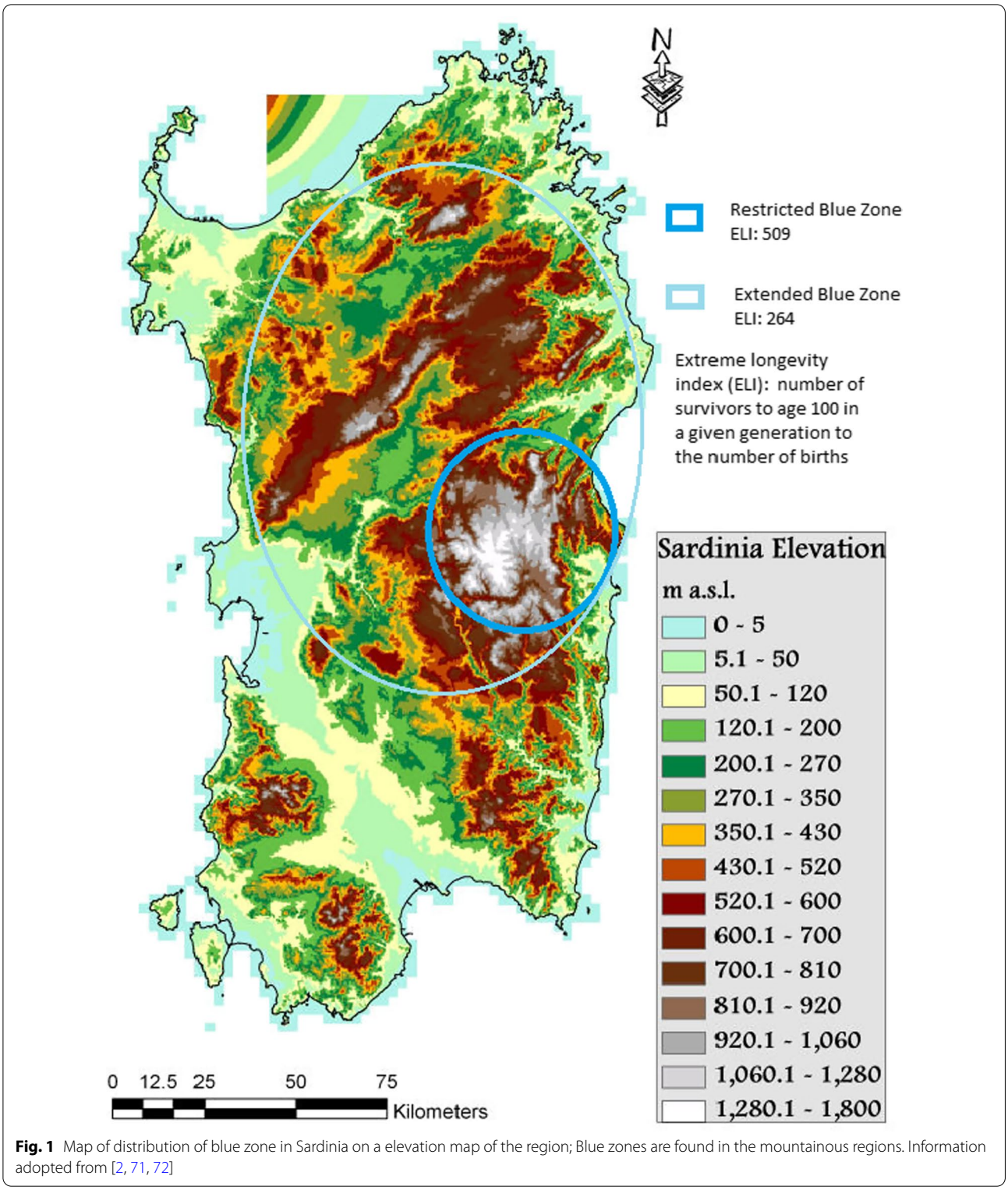

Fig. 1 Map of distribution of blue zone in Sardinia on a elevation map of the region; Blue zones are found in the mountainous regions. Information adopted from [2, 71, 72]

caggiu de crabittu, a cheese ripen in the abomasum of a young goat; and casu marzu, the infamous soft cheese with live worms inside. These foods are considered cultural heritage by the locals, while they are deemed to be food taboo by the outside world [8].

Compared to other LBZs, it is noteworthy that the percentage of male centennials is much higher in Sardinia

[9]. It has also been revealed that the longevity of these people in Sardinia has a causal link with their dietary factors. This review paper aims to evaluate how the unusual famine food is linked to the longevity of Sardinian people by promoting a different diet, lifestyle, and the maintenance of their tradition.

Difference between the Sardinian diet and the general diets of Western Europe and North America

To better understand the secrets of Sardinian longevity, it is pertinent to learn about their lifestyle and diet. Differences between compositions of different diets could be one of the key factors which underlie the health pattern and lifespan in different populations of the world. In this chapter, the Sardinian diet will be compared to the average diet of the western world.

The average American diet in North America, also known as the standard American diet (SAD), differs vastly from the Mediterranean and, in particular, the Sardinian diet from the eastern mountainous region. A National Health and Nutrition Examination Survey from the US department of agriculture showed that in SADs, approximately 47.3% of total calories come from carbohydrates, 34.9% from total fat, and 16.1% from protein [10].

European countries have different eating patterns. For example, a study in France [11] found that the average French consumer consumes on average 75.5 g of fat, 205.6 g of carbohydrates, 81.2 g of protein, and 11.8 g of alcohol per day which equates to a total energy intake of 2252 kilocalories. As such, this translates to approximately 34% of energy intake from fat, 36.5% from carbohydrates, 14.4% from protein, and 3.6% from alcohol. In Italy, 9.4% of daily calorie intake comes from meat protein, 12.8% from dairy products, and 38.2% from grains [12]. In contrast, the paper showed that in the Czech Republic, the daily calorie intake of 2000 kcal consists of 13.5% of energy intake coming from meat, 38.5% from grains, and only 7.5% from dairy products.

There are several differences between the Sardinian diet and the rest of the western world. For instance, the Sardinian diet consists of very little animal protein, consuming meat sparingly, using it as a celebratory food, or a way to flavor dishes (5% instead of 10 ~ 16% from European countries or American). Instead, Sardinians blue zone people rely heavily on the consumption of dairy products, particularly goat's and sheep's milk products, for their calorie intake. In the SAD, 47.3% are composed of carbohydrates and only 13.7% of the total grain intake amount for adults in the USA consists of whole grains [13]. In comparison, 47% of the calories in the traditional Sardinian diet are obtained from whole grains. Moreover, USDA [14] has estimated that one-third of total grain consumption by the average American citizen occurred in restaurants. Those products were highly refined and processed to emphasize the taste rather than nutrients. The paper also estimated that a standard restaurant meal of 1000 kilocalories contains less than 9 g of whole grains on average. Conversely, 47% of the total calories intake in the Sardinian diet is composed of whole grains.

Aside from providing more micronutrients, the consumption of whole-grain also has other benefits to promote longevity. Sardinian people consumed daily a handful of nuts, particularly almonds (high in vitamin E and magnesium), pistachios, and walnuts (high in alpha-linolenic acid-omega-3 fat). A recently published systematic review [15] noted that long-term consumption of whole grains instead of refined grains improved total cholesterol, triglycerides, and hemoglobin levels, which are factors closely related to healthy body function and a lowered risk of chronic or cardiovascular diseases. It has also been shown that whole-grain consumption instead of refined grains, which are balanced for the same number of kilocalories, resulted in a greater feeling of fullness 3 h after breakfast, 2 h after lunch, and 1 h after dinner [16]. An increased feeling of fullness post-meal consumption has helped Sardinians to maintain a calorie-restricted diet of approximately 2000kcals, which has been linked to their longevity. In comparison, the average calorie intake in the rest of Italy, the Czech Republic, and the USA was 2149 kcal, 2572 kcal, and 2200 kcal, respectively [12, 17].

This feeling of prolonged fullness occurs due to whole grains having a much lower glycemic index than highly refined grains. Foods with a higher glycemic index result in higher fluctuations in the level of insulin [18]. The long-term effect of high fluctuations of insulin has been associated with an increase in the risk of diabetes.

Grotto et al. [19] also highlighted that 480 kcal, almost 23% of the daily calories in the SAD, came from added sugar. Some of the sources of added sugars include sweetened carbonated beverages, candy, cakes, and cookies. Those foods are dense in calories, high in glycemic index, but also very low in nutrients. They are proven to increase the risk of chronic diseases such as cardiovascular diseases or diabetes. The Sardinian diet, in contrast, contained only 3% of calories from added sugar.

Vegetables have a much higher nutrient density than meat and grain [20]. Therefore, even when consuming the same amount of calories, vegetables are much more nutritious and provide a greater breadth of micronutrients such as antioxidants and vitamins, well known for beneficial properties promoting good health. The Sardinian diet has a much higher consumption of vegetables than the rest of the European countries; roughly 12% of

total calorie intake compared to 6%, 2.5%, and 1.3% from the average person in France, the rest of Italy, and the Czech Republic, respectively [12]. Comparably, a study about Namul, a traditional Korean vegetable-focused diet based on foraging wild plants in fields or mountains traced back to a time of food shortages, concluded that such diet is rich in micronutrients and is related to the longevity of the local Korean population [21]. It is noteworthy that because vegetables are less dense calories compared to grains, dairy, and meat, a difference of 6 ~ 10% in calorie intake from vegetables represents a much larger vegetable consumption than the number implies at first glance.

Overall, the Sardinian diet differs from the western diet of other European countries or American diets in terms of the macronutrient content. The difference in composition of those macronutrients may have also played a significant role in the Sardinian population's longevity. For example, although similar in number, 47% of daily calories from carbohydrates in the Sardinian diet are from whole grains compared to 6.5% in the American diet. Higher consumption of whole grains has resulted in a lowered risk of chronic diseases such as cardiovascular disease and diabetes. A much lower amount of added sugar in the Sardinian diet further lowers the risk of obesity and diabetes by lowering the spikes in insulin levels. Lastly, higher consumption of vegetables provides an increased amount of micronutrients and antioxidants, which are known to lower the incidence of cancer, Alzheimer's disease, and slows cellular aging, factors which are closely related to longevity [22]. Therefore, it is essential to look at how the unique food of the Sardinian people helps them to achieve such a healthy diet.

The unique famine foods from the traditional Sardinian diet

Fallback food or traditional vegetables are terms describing the groups of secondary food resources of people from a particular geographical region or a particular culture [7]. During difficult times where resources were scarce, unusual foods were consumed to fight hunger and provide the crucial nutrients required for survival. These foods were referred to as "famine food." Over time, famine foods were no longer consumed by necessity but as an integral part of food culture [23]. Snails, rotten cheese with maggots, and bread with clay are still commonly consumed in Sardinia and are considered to be delicacies passed down from their ancestors [8]. Due to the unusual nature of these foods, they are often viewed as food taboo by the outside world while being cherished as intangible cultural heritage and treasures from ancestors [24]. "Neglected foods" around the world are similar in that although they are unappealing to modern consumers, they are proven to be rich in nutrients, sustainable, and benefit health in the long term [25]. Traditional and famine foods in Sardinia include abbamele, acorn bread, pane carasau, caggiu de crabittu (Callu de Cabreddu), casu marzu, snails, bottarga, and many more.

Abbamele

Abbamele is one of the oldest honey-based products recorded in Sardinia and consists of honey, pollen, water, and honeycomb [26]. To make the abbamele, honey is first extracted from the honeycombs. Subsequently, the honeycombs are crushed and dipped into warm water to separate the wax from pollens and residual honey. Lastly, orange peel or lemon rinds are then added while boiling the concoction until a brownish product with water content between 17.7 to 27.7% is obtained. This is vastly different compared to conventional honey, which is produced in several steps. The first step is to filter out the beeswax, pollen, and other particles [27]. Following filtration, the honey is heated to between 60 and 65 °C to concentrate the honey to around 17% moisture content while maintaining the color and flavor by minimizing caramelization. Lastly, a high-temperature treatment is applied for a short duration to destroy microorganisms. Compared to conventional honey, abbamele features a richer flavor and more micronutrients. Polyphenols in honey products are known to prevent heart diseases [28], while pollens collected by honeybee are known to have antimutagenic, antioxidant, and anti-inflammatory effects that are attributable to its phenolic compounds, particularly to the flavonoids [29]. A similar production method is also performed by natives from southern Portugal to produce the nutrient-rich Água-mel [30]. Currently, handcrafted abbamele is one of the most sought-after Sardinian foods and is sold at prices that are up to tenfold greater than traditional honey [26].

Acorn bread

Acorn is the nut produced by oak trees, and although widely available, it is rarely consumed on a daily basis. Acorn contains a high amount of tannin, which is known to be toxic to humans and many mammals [31]. To prepare Pan' Ispeli, the acorn bread, acorns are crushed and soaked in water to leach out some of the tannins and reduce the toxicity [32, 33]. Clay is then mixed with the acorn meal to further counter the toxicity of tannin and the bitter taste. The clay also provides the pitch black color of the Pan' Ispeli. Geophagy, a term describing the consumption of soil, is still practiced in the poorer countries of Africa.

Currently, acorn bread is no longer a part of the traditional Sardinian diet. However, the bread is still prepared and consumed during celebrations and festivities

[33]. Locals who still possess the skill to prepare Pan' Ispeli take pride as they pass down this knowledge, tradition, and wisdom from their ancestors, who were able to survive the harshest times of extreme hunger.

Pane carasau

Pane carasau is a traditional Sardinian sourdough flatbread made with durum wheat flour, yeast, water, and salt [34]. The bread is prepared using a double baking technique which is designed to lower the water content much further than common flatbreads. As a result, Carasau can be stored for several months without losing its sensory characteristics [35]. The long shelf life was also essential to the shepherds as their lifestyle is nomadic, and they often did not have access to perishable food [36]. Studies have revealed that the strains of lactic acid bacteria in the sourdough used by the locals produce special sets of peptides and γ-aminobutyric acid with antihypertensive effects [34]. Moreover, pane carasau has a low glycemic index, which helps to reduce the risk of chronic diseases such as diabetes. Therefore, pane carasau not only nourished Sardinia's ancestors during difficult times, the healthy composition of this food might have played a crucial role in their longevity.

Caggiu de crabittu or Callu de Cabreddu

Caggiu de crabittu, also known as Callu de Cabreddu in some regions, is a traditional Sardinian food consisting of edible goat rennet (EGR) with soft cheese inside [37]. The word "Caggiu de crabittu" is translated to as a kid's rennet in the Sardinian language. This unusual cheese is produced by ripening goat milk inside the abomasum of a young goat for between 30 and 60 days. The abomasum is shown to be free of pathogenic bacteria also contains a significant number of mesophilic lactic acid bacteria species (i.e., Lactococcus lactis, Lactobacillus plantarum, Lactobacillus paracasei, to name a few). Rennet contains special proteases and lipase enzymes that release short- and medium-chain free fatty acids (FFA), contributing to this cheese's flavor [38]. The raw milk, diversity of the lactic acid bacteria, and abundance of FFA provide many health benefits compared to modern cheese, such as improving protection against allergic or atopic diseases, promoting gut health, and improving anti-inflammatory activities [39]. Initially, Sardinian shepherds used the abomasum as a pouch to carry food. This spreadable soft cheese is often consumed with pane carasau to provide a nutritious, healthy, and sustainable meal. Nowadays, caggiu de crabittu has become a signature Sardinian cheese due to its unusual production method and flavor.

Casu marzu

Casu marzu is another unusual cheese of Sardinia. The word casu marzu translates to "rotten cheese" in the Sardinian language [40]. To make this cheese, goat milk is first curdled with rennet and then placed in brine for a day. During the following 15 days of ripening, the cheese is exposed to *piophila casei* flies. After fermentation, countless worms are placed inside the cheese. Currently, some producers are using specially reared flies in captivity to ensure food safety [41]. This creamy cheese is meant to be consumed with living worms, which is often unaccepted and considered to be distasteful by the outside world (Fig. 2). Despite efforts to control food safety and documentation related to the history of this food, it is not recognized by the European Union Database as a traditional food product [42]. Therefore, the food is not known or appreciated outside of the region, and the sale of it is banned in many countries, including Italy, as the living worms are considered to be carriers of parasites. Studies have revealed that edible insects have countless health benefits [43]. According to this study, edible insects may contain up to 30% of essential amino acids, given that they are very high in protein content, and they could improve human gut microbiota. Another study also highlighted the vast amount of vitamins, minerals, and polysaccharides that aid in enhancing human immune functions [44]. Although rejected by most of the world, it is shown that this specialty cheese offers a vast amount of health benefits, while controlled production could guarantee food safety and hygiene. Without any doubt, Case Marzu plays an important role in the longevity of

Fig. 2 Casu marzu cheese; a traditional Sardinian sheep milk cheese containing live insect larvae (retrieved from https://en.wikipedia.org/wiki/Casu_martzu)

Sardinian people both as a symbol and thanks to its rich nutrients.

Snails

Snails have been consumed as famine food since the Palaeolithic era in the Mediterranean region [45]. Snails are considered taboo in most parts of the world as the mollusk is believed to be unhygienic. However, studies have shown that pathogens such as E. coli 157, the Hepatitis A virus, and Norovirus are not detected on farmed land snails, and they are therefore as safe as other reared animals [46]. Similar to the worms found in Case Marzu, the snail is very nutrient-dense. They are also known to have a very high percentage of polyunsaturated fat-to-saturated fat ratio (44.06% to 20.39%), which is healthier than red meat [47]. Snail meat is also known to prevent diseases linked to mineral deficiencies such as night blindness, osteoporosis, postpartum hemorrhage, and hypophosphatemia [48]. Therefore, the snail is, in fact, not only safer than most have imagined, but the food also provides much-needed vitamins and minerals, which are crucial to healthy during harsh times.

Bottarga

Bottarga is a traditional Sardinian food product made by salting and drying the ovaries of mullet fish [49]. Bottarga is different from most other fish roe products, given that this roe is directly cured inside the ovary as opposed to being extracted first. The ancient production method has been recorded since the seventeenth century [50]. Bottarga can be stored for up to 3 years thanks to its low moisture and high salt content, as well as the protection provided by the dry ovary. Bottarga is known to contain a high percentage of proteins, minerals, vitamins, and most importantly, n-3 polyunsaturated fatty acids (PUFAs), better known as omega-3 fatty acids [51]. PUFAs are known to be beneficial to the human body and are able to lower blood cholesterol and prevent other diseases and disorders. However, PUFAs are known to oxidize when exposed to light, air, or heat rapidly. It has been revealed that thanks to the preparation of bottarga with the original ovaries, less ideal storage conditions result in much lower damage to the lipid components and color of bottarga [52]. Currently, Sardinia is famous for the production of bottarga and other roe with ovaries [53]. The ancestors of Sardinia produced this cured roe in order to preserve food during famine times. Unknowingly, this preservation technique also helped to maintain the quality of PUFAs as well as many other beneficial but difficult to preserve nutrients linked to longevity. Nowadays, bottarga is recognized as a gourmet delicacy, while it was previously considered to be a hunger food and consumed during difficult times when fresh foods were scarce.

There are many other ancient Sardinian foods, such as Treccia, a roasted lamb intestine dish, horse steak, pigeon, sea urchin roe, and seeds from Boraginaceae plants [54]. Some have been recognized as a delicacy, such as a sea urchin roe [55], while other foods, such as Boraginaceae seeds, are now gaining popularity due to their nutritional value [56]. However, most of the ancient Sardinian foods are still considered taboo by the outside world. The resourcefulness and ingenious preparation methods allowed the ancestors to prepare and preserve foods other civilizations had to discard. These unusual foods not only helped Sardinian people to survive during famine time, but their surprisingly nutritious properties also improved the health and longevity of the locals. Moreover, the preparation of the famine food also acted as a guide of lifestyle, which, in turn, promoted a longer lifespan.

Traditional food: beyond nutrition

Studies have shown many similarities in terms of habits and practices among the five LBZs [57]. Some of the critical habits related to longevity include moving naturally, controlled diet intake, a less stressful life, and commitment to family and loved ones. Traditionally, Sardinians place great emphasis on local development and a self-sufficient living style [58]. This ideology focuses on the quality, rather than quantity, of the food products. This is the opposite of the current food trend where globalized mass production, focusing on production cost and efficiency while maximizing profit from exportation, is targeted. Sardinia's local food production, especially in the mountainous region, focuses on a pastoral lifestyle with some low-density agriculture defined as shepherds herding livestock in open lands; the key mentality is following and respecting natural factors such as the changing seasons as well as water availability and pasture. This mode of production generates minimal environmental impact and produces food to suffice instead of seeking profits through quantity. Compared to the traditional agricultural lifestyle, the lives of shepherds are notably less stressful and allow more time for cultural and family activities.

According to an interview with D. Buettner [57], moving naturally is a key habit of the people living in LBZs. Sardinian shepherds do not go to the gym or practice specific sports training. In most parts of the world, this would lead to a higher rate of obesity due to lack of exercise. However, according to reports, the shepherd style of living combined with the steep, mountainous landscape results in the equivalent of low to medium-intensity exercise evenly spread out throughout the day [59]. Increased average energy expenditure from low-to-moderate-intensity physical exercise is known to have beneficial

effects such as reducing excess fat, high blood pressure, as well as other cardiovascular risk factors and, therefore, a lower early mortality rate [60]. Studies have also reported that performing a moderate amount of exercise throughout life provides health benefits and increases cardiorespiratory fitness, and thus increases the average health at old age [22]. Studies have also suggested that it is strongly associated with the extreme male longevity observed in Sardinia's mountainous region [61]. It has also been noted that men in LBZs are mostly living the shepherd style of life, whereas outside of LBZs, the agriculture lifestyle, which is more wearing and intense, is more common. According to Mr. Buettner, an expert on longevity and LBZs, the foods consumed by LBZs consist of beans, greens, and whole grains. He summarized them as "peasant foods" [59]. Mattalia et al. [62] reported that the consumption of wild plants was also common among Sardinians living in pastoralism. According to the study, 73 taxa from 35 families of plants were consumed and used. One-third of those plants were consumed as a raw snack, while 56% were also used in different food preparations. Consumption of a large variety of wild plants provides good coverage of the various micronutrients. It is known that restriction of dietary intake plays a vital role in the longevity observed in LBZs [1]. The paper suggested that most people in LBZs ate until they were 80% full. Lowered food intake resulted in a lower caloric intake, which, naturally, can be beneficial. However, there might be a higher risk of malnutrition should the diet be insufficient or contain an unbalanced composition of nutrients. In Sardinia, famine foods provided balanced nutrition and compensated for the risk caused by lower food intake. Overall, the production and consumption of "famine food" in the mountainous region helped the people maintain a low-stress life and keep them healthy by providing a good amount of daily exercise.

Cultural food heritage: preservation against modernization and cultural erosion

Modernization, often associated with increased efficiency and production, leads to an overall faster pace of living [63]. The digital age has further accelerated this speed of daily routine by providing easier access to media, information, and faster access to services that would require in-person service before the informatics evolution. As such, a culture of "immediacy" has developed among the population exposed to this lifestyle. Everything needs to be fast and efficient. For instance, studies have shown a significant increase in the consumption of purchased food compared to foods cooked at home since the 1960s [64]. People have less interest in spending time to perform traditional activities and practices, which are often slower in pace. Cultural erosion is a term to describe the loss of knowledge about traditional practices and methods of living. Associated with this term, the loss of knowledge regarding food and nutraceutical plants is one of the damages caused by cultural erosion due to modernization [65]. A study on food transition from a traditional diet to a modern diet in East Asia found an increase in the prevalence of non-communicable diseases in countries including Indonesia, Malaysia, Nepal, and Thailand [25]. Therefore, the modernization of Sardinia could threaten the loss of this traditional lifestyle and result in the loss of knowledge and practice over generations. Modernization has led to a nutritional transition in several parts of Sardinia, which has resulted in a shift in consumption from cereal, pulses, and potatoes to meat products, fat, and sugar [66]. As a result, Sardinian cities known to consume this modernized diet, similar to that of the western diet, are no longer considered an LBZ as their longevity is now similar to the rest of the Mediterranean countries. Furthermore, a recent study on the transition from eating behaviors from traditional food to nontraditional food in China concluded that the change to nontraditional eating behaviors is associated with many chronic non-communicable diseases and an increase in mortality rates [67].

To resist this cultural erosion, Sardinians have relied on their strong belief in localism and traditional practices. In turn, their practice constantly reminds them about their identity and culture. Local food activists such as the Slow Food movement were created to protect local small-scale food production, add value to traditional regional food, and promote cultural heritage [68]. Heatherington [69] has noted that food preparation and consumption in highland Sardinia are engaged with discourses of authenticity and cultural heritage. As such, attributes such as texture and flavor are associated and interpreted very strictly with traditional, local production. Authenticity has also become an important factor for local consumers. The notion of local authenticity describes more than the economy of self-sustain or home-produced food; it has also become an organizing force of symbolic practices. The local government has established different regulations and promoted different food activism groups to ensure the safety of this heritage. For example, the Cagliari chapter of the Slow Food movement has helped to reestablish local caper production, previously on the verge of disappearance due to overseas competition [58]. The local government also banned the sale of fast food or food from other cultures in the historic center or beachfront of Tuscan in 2010.

Food previously eaten by the mass population of the past, often called "peasant cuisine," is what defined the living condition and habits of a local civilization throughout the ages [70]. Monuments and artifacts

have been constantly listed in the World Heritage List and are used as a vehicle for economic development. The world has recently started to pay attention to ethnic food as a part of the culture and intangible heritage. In Sardinia, many of the peasant foods have become an important part of the cultural heritage of the locals. For instance, bread, an important staple of the Sardinian diet, is also highly valued based on authenticity. Bread made using wood fire in a traditional oven by a household member whose knowledge has been passed down throughout the different generations via apprenticeship is considered to be authentic and of the highest quality. In contrast, the locals often consider the commercially bought ones to be "good for nothing" [69].

Festivals are also often associated with cultural practices and accompanied by traditional food. For example, S'arrostu, a local festival, is known to have open-fire roasted meat. For the meat to be deemed suitable for the festival, it has to come from animals raised on the natural pastures of the communal territory using the traditional method.

Overall, although modernization has caused cultural erosion and nutritional transition in some parts of Sardinia, Sardinians resorted to their strong cultural practice and tradition to maintain their practices and ancestors' way of living.

Conclusion

In conclusion, many of the unusual foods consumed in Sardinia originated from ancient times and were created by the ancestors of the local population to survive extreme food scarcity. These "famine foods" are considered food taboo due to their unique appearance, flavor, or content by the outside world. For example, acorn bread tastes bitter and contains; caggiu de crabittu is a cheese ripened in goat abomasum; and casu marzu is a spreadable cheese with living worms. Although avoided by the outside world, they are cherished by the local people and are considered as cultural heritage. It has been underlined that the famine foods are, in fact, not only very nutritious, but their proper preparation and careful control could also guarantee that the food is about as safe and hygienic as conventional food products. Moreover, the "famine foods" of Sardinia also significantly benefit in dictating the food production and lifestyle of the people while helping them maintain the ways of their ancestors by providing cultural reference and solidarity. Therefore, the "famine foods" of Sardinia undoubtfully play a crucial role in the longevity of Sardinian residents of the LBZ.

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Author contributions
CW is the main author of this review paper; drafted the work; and interpreted the literature. MAM verified the accuracy of the information and provided insight on the subject and revised the work. JB verified the accuracy of the information and provided insight on the subject and revised the work. MM designed the concept of this work, verified the accuracy of the information, and revised the work. All authors read and approved the final manuscript.

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Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

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Competing interests
The authors declare that they have no competing interests.

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