Milk Processing System in Barbasia of Sardinia (Italy), Mediterranean Area

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Abstract

The purpose of this paper is to 1) understand the cheesemaking process practiced in Sardinia, 2) analyze how the people utilized the ecology to mature cheeses in the summer heat, and 3) discuss the history of the development of matured cheeses in Sardinia, Italy. The matured hard cheese named \textit{Casu crudu} (S) /\textit{Fiore Sardo} (I) has processed in Sardinia by the \textit{pasta cruda} method. The transhumant pastoralists in Sardinia used to immediately sell or consume the freshly-made cheeses in the winter and spring when they resided in the lowland. It was also possible to mature cheeses in the lowland, because the temperature was low in the winter and spring. In the hot and dry summer, they migrated to the highland and made matured cheeses as they utilized the cold environment of the highland and their cool residence. They coated the cheese surfaces with olive oil to keep the cheeses from drying and succeeded in maturing the cheeses. They were able to mature cheeses and cope with the Mediterranean climate of hot and dry summer by skillfully utilizing the vertical migration from their year-round transhumance. The geography of Sardinia (comprising of lowland and highland of over 1,000 m above sea level), use of the environment (grazing in the lowland in the winter and fall and in the highland in the summer), and the transhumant lifestyle all contributed to the creation of matured hard cheeses unique to Sardinia.

Key words: Mediterranean climate, transhumance, highland, coolness, maturation

Introduction

One of Europe’s biggest contributions to the history of the world’s milk processing technology has been cheese maturation. The researchers have been examining how matured cheeses were developed in Europe\textsuperscript{1–5}. The ecological factor in the development of matured cheeses was notably the coolness, even if the humidity was not very high. It was also made possible by the existence of residential huts, which were capable of setting up a cold ecological environment. It is hot and dry in the summer in the Mediterranean region. People in West Asia, where they experience a Mediterranean climate, do not mature cheeses, but immediately sun-dry them to make dried cheeses\textsuperscript{6,7}. In northern Italy, located in the same Mediterranean region and on nearly the same latitude as the West Asian countries, they were able to mature cheeses using the cold temperature in the mountains or shaded rooms made of thick walls. Sardinia is an island in the Mediterranean Sea, where they produced matured hard cheeses like \textit{Fiore Sardo} and \textit{Pecorino Sardo}, which are certified D.O.P.\textsuperscript{8}. Honma\textsuperscript{8} describes that \textit{Fiore Sardo} is the hard cheese processed with whole raw ewe’s milk, by no cooking, smoking and more than 105 day’s maturation, and \textit{Pecorino Sardo} is also hard cheese processed with whole raw ewe’s milk, with semi-cooking, and maturation more than 20 days for short maturation type and more than 2 months for long maturation.
type. The research on the cheese maturing process in Sardinia, where the Mediterranean summers are hot and dry, is extremely important when discussing the history of cheese maturation as the matured cheeses in the European milk culture developed from the non-matured cheeses in the West Asian milk culture.

Although many articles discussed Fiore Sardo and Pecorino Sardo from the point of milk processing techniques and history, it is not studied how these cheeses have developed in the circumstances of Sardinia. The researchers conducted on-site research and interviews centering on a region called Barbasia in Sardinia as part of the study to discuss the history of the development of matured cheeses in the European milk culture. The purpose of this research is to 1) understand the cheesemaking process practiced in Sardinia, 2) analyze how the people utilized the ecology to mature cheeses in the summer heat, and 3) discuss the history of the development of matured cheeses in Sardinia. The region's name Barbasia comes from the word barbari, which means barbarian, named after the furious resistance of the inland islanders when the Romans attempted to conquer the island.

Barbasia is located in the highlands on the eastern part of central Sardinia (Region surrounding cases 2 to 6 in Fig. 1). Barbasia spreads along the highland located more than 1,000 meters above sea level.

**Research site and research method**

1. The natural environment of Sardinia

Cagliari, located along the coast of southern Sardinia, is hot in the summer with an average highest monthly temperature of over 30°C. The average monthly humidity gets down to 60%. The average monthly temperature is mild in the winter at about 0°C. The highest temperature from fall to spring is about 15°C, making it possible to mature cheeses in the lowland as well in this period. The temperature decreases relative to the rising altitude. The highest temperature is more or less 25°C in the summer and there is snow accumulation in the winter in Barbasia, where it is over 1,000 meters above sea level. The average highest monthly temperature in the summer in the highland is just about 25°C, but the average lowest monthly temperature is below 15°C. The rain falls mainly from fall to spring and almost never in the summer. The annual precipitation in Cagliari is 426 mm, which makes it possible to grow wheat and many varieties of vegetables with rainwater in the winter. The natural environment of Sardinia is

Fig. 1 Air temperature (°C), precipitation (mm), humidity (%), contour line, survey sites (①-⑦) in Sardinia.
found in the Mediterranean climate with dry summer and humid winter. Even though Barbasia is in the highland, the summer is around 25°C, which is too hot to mature cheese. It is important to figure out how to manage the temperature in the summer when maturing cheeses in Barbasia.

2. Research method and research household

The field survey was conducted from February 28 to March 4, 2017. The researchers visited cheesemakers (cases 1 and 2) and former transhumant households (cases 3, 4, 5, 6, and 7) for observations and interviews. Fig. 1 recorded the location of cases 1 to 7, and the name of the research sites. The former transhumant households have settled and were raising sheep or goats to supply their own milk to make cheese. The cheesemakers contracted with certain former transhumant households to purchase raw milk to make cheese. The interviews were conducted in Sardinian or Italian. The milk product words and their pronunciation were collected in Sardinian as well as in Italian. The milk product words referenced in this paper are recorded both in Sardinian and Italian. A word is noted with a (S) for Sardinian and (I) for Italian after its local name.

Case 1 and 2 are cheesemakers who contracted with former transhumant households to purchase raw milk to make cheese professionally. At case 1’s facility, they contracted with the 200 former transhumant households in the area and are making matured hard cheeses, fresh cheeses, and in recent years, sour milk and cream cheese. The former transhumant households under contract all raise sheep or goats. Case 2 has a contract with 18 neighboring households with sheep and 12 households with goats to process about 1,000 to 1,100 L of raw milk per day. They only use sheep milk and goat milk to make matured hard cheeses and fresh cheeses; they do not make sour milk or cream cheese.

Cases 3, 4, 5, 6, and 7 are former transhumant households. Case 3 raises about 30 goats, case 4 raises about 400 sheep, case 6 raises 500 sheep, and case 7 raises about 400 sheep. They all make matured hard cheeses. Case 5 used to raise 600 to 1,000 sheep, but they now run a hotel and only raises a small herd of sheep to produce just enough matured hard cheeses for personal consumption.

3. Transhumance

In the past, the pastoralists who practiced transhumance in Sardinia grazed their livestock in the highland at over 1,000 m above sea level in the summer and fall from May to November and in the lowland at below 500 m above sea level in the winter and spring from December to April14–16) (Fig. 2). They sought the warmer greener grassland in the lowland when it was cold, and sought grass resources in the cooler hills of the highland when it was hot. The sheep and goats were left to graze in the grassland year-round.

The transhumant pastoralists’ main village is located in the Barbasian highland, where the pastoralists grew barley, oats, and vegetables. It is
Fig. 3 The hut where a former transhumant household resided.
Cheese was also processed, smoked and matured within this hut.

symmetrical to the Alps region, located on a higher latitude, where the main villages are located at the base of the mountains\(^{17\cdots19}\). The women and the elders stayed in the highland all year to take care of children and agricultural crops, make hay, and manage the huts. Only the men descended to the lowland with the livestock in the winter and spring. The livestock was mainly made up of sheep, as well as goats, pigs, donkeys, and horses. The sheep was raised in a herd of 500 to 1,000. The pastoralists traveled on foot for about four or five days with a donkey carrying their tools and other essential goods to set up camp in the winter and spring. Two or three households, made up of relatives and close friends, typically collaborated and worked together to travel and manage the herds. Their destination was a hut (Fig. 3) and a stone enclosure for the livestock prepared by the affluent or the aristocrats of the region. The affluent and the aristocrats relied on the transhumant pastoralists to improve the condition of their cropland through livestock grazing and manure. The pastoralists bought pigs in the lowland when they arrived, raised them on discarded whey and human excrement, and sold them before they moved back to the highland.

The sheep and goats mate primarily from June to July, and the lambs and the kid goats are born mainly from November to January. The animals are milked primarily from November to about August. The animals are milked twice a day from November to end of June, but decreases to just once a day from end of June to about August, because the amount of milk decreases during this period. An average of 0.5 L of milk per animal was obtained each day. The cheeses processed in the lowland are not matured, but immediately exchanged for wheat and necessary goods with merchants and neighbors. For this reason, there was no need for a ripening chamber for maturing cheeses in the lowland.

The transhumant pastoralists started settling more around 1980. The affluent and the aristocrats lost interest in land improvement through livestock grazing and started selling their land and huts to the transhumant pastoralists. With land and a hut, the transhumant pastoralists stopped their year-round migration and settled in the lowland. Many settled, because it was more advantageous to cultivate agricultural crops and there were more business opportunities and better education for the children in the lowland. Permanent settlement meant that the livestock was taken to the grassland every day from their permanent home. They still basically left their sheep and goats out in the grassland to graze, but the pastoralists started feeding them oats and barley that they cultivated when feed resources tended to be low in the winter. Some of these former transhumant pastoralists stopped grazing their livestock in the grassland altogether and raised them in a barn. Since these animals no longer had to travel long distances and were fed concentrate feeds, the amount of milk production increased from 0.5 L per day to 2 L per day. Such increase in the milk yield and the extension of the milking period through feeding made it possible for the pastoralists to process hard cheeses nearly all year long.

One of the characteristics of transhumance in Sardinia is that the main village is located in the highland. The highland, with its expansive grassland and warm Mediterranean climate, became the base for the transhumant pastoralists. The milking animals, sheep and goats, were taken to the highland from May to November and milked until about August. This lifestyle is relevant to what made maturing cheeses possible in the hot Mediterranean summers.
Results

1. Milk processing system in Barbasia, Sardinia

The pastoralists do not make cream and butter in Sardinia, but process cheese exclusively. The Mediterranean climate makes olive cultivation possible in Sardinia. Olive oil is served at meals as a source of oil. There was no need to separate milk fat from raw milk and the practice of cooking with milk fat never developed. This is probably why cream separation from raw milk and churning of cream or sour milk was never developed. Therefore, it can be said that the milk processing technique of the transhumant pastoralists in Sardinia specializes in cheesemaking.

Two types of cheeses with a different process are made in Sardinia. The first type is unheated and whey separation from curdled milk is not facilitated after rennet is added to raw milk. The second type is heated slightly to separate whey from curdled milk after rennet is added. The former is called pasta cruda Note 2 and the latter is called pasta semi cotta Note 3 in Italian. A cheese made with the pasta cruda method includes Casu crudu (S)/Fiore Sardo (I), which is made with just sheep milk. Cheeses made with the pasta semi cotta method include Herbihinu (S)/Pecorino Sardo (I) made with sheep milk, and Hàaprìnu (S)/Caprino stagionato (I) made with goat milk. Also, the freshly-made cheeses are called Casu friscu (S) Note 4 and matured cheeses are collectively called Casu essu (S) Note 5 in Sardinia. The names of milk products differ depending on the region. Even within Barbasia, the names can differ between the villages. The milk product names reported below are based on the field survey collected from cases 1 to 7 from Fig. 1.

1–1. The cheeses made by the pasta cruda method

1–1–1. Casu crudu (S)/Fiore Sardo (I)

The cheesemaking starts at about 7 am after the animals are milked in the morning. The raw milk is called su latte (S) in Sardinian and latte (I) in Italian. Su (S) means water in Sardinian. As mentioned above, sheep milk is used to make matured hard cheese called Casu crudu (S)/Fiore Sardo (I). Casu means cheese and crudu means raw in Sardinian. The cheese is processed while the fresh raw milk is still warm. The raw milk is warmed to about 35°C if it has cooled after a certain time has passed since the milking, or if mixing previous night’s raw milk with the morning’s fresh raw milk (Fig. 4–1). The raw milk is never heated at a high temperature to be pasteurized. They also never intentionally add lactic acid bacteria to raw milk. They utilize the lactic acid bacteria that naturally gets incorporated into raw milk in the process of milking and handling raw milk.

Milk coagulating enzyme is added to raw milk of about 35°C. The milk coagulating enzyme is called Hàazzu (S)/Cagliata (I). They say that the cheesemakers used to use calf stomach, but now use store-bought liquid rennet. They add Hàazzu (S)/ Cagliata (I) and let it stand for about 30 minutes. The resulting curds are called Hàazzàu (S)/Cagliata (I). Hàazzàu (S)/Cagliata (I) is cut gently for about 5 minutes to separate the curds and the whey. They do not heat it to raise the temperature to promote further separation. This no cooking to strain whey from the curds is what makes Casu crudu (S)/Fiore Sardo (I) cheesemaking so characteristic. The name, Casu crudu comes from its use of raw milk and no cooking to promote whey separation from curds.

After cutting the curds, Hàazzàu (S)/Cagliata (I) is poured into a mold to separate whey. Whey is called Zotta (S), Soru (S), or Giotta (S)/Siero (I). The curds left in the mold is called Casu (S)/Formaggi (I), which means cheese. Some regions also call it Hàzu (S). The cheese contains a lot of whey, so the center of the cheese inside the mold falls when the whey is drained very quickly. The cheesemakers use a knife to cut off the relatively higher edges of the cheese around the mold and pile the trimmings at the center of the cheese a few minutes after the curdled milk is poured into the mold. Both hands are used to squeeze the cheese together to incorporate the sunken cheese and the piled cheese. Then the surface is thinly scraped and the cheese is turned over (Fig. 5). The cheese is left in the cheesemaking room and turned at the rate of about once an hour until the evening. The room is maintained at about 30°C. In the past, the cheesemakers left the cheese on top of a pot filled
with warm whey to keep it warm (Fig. 6). It is important to let the cheese stand for about half a day, so that the naturally-incorporated lactic acid bacteria are multiplied to increase the acidity of the cheese.

In the evening, the cheese is brined in saturated salt water. The exposed surface of the cheese when it floats in the brine is also sprinkled with coarse salt. A day and a half later, the cheese is removed from the brine and left to stand on a shelf for about a day to remove moisture from the
cheese. Then the cheese is transferred to a smoking room to be smoked (Fig. 7). The cheesemakers use oak wood for the smoking obtained from the oak trees growing naturally in the Barbasian highland at over 1,000 m above sea level. The cheese is placed on the floor of the smoking room at first, and then moved to a shelf installed above the smoking wood to apply the smoke directly. Then, it is placed on a shelf installed on the wall. The smoking room is maintained at about 25°C. The cheese loses moisture and turns dark brown and hard after about 20 days.

The cheese is moved to a ripening chamber after it is smoked-cured (Fig. 8). The rooms on the bottom floor of buildings are used as the ripening chamber. These rooms are relatively cool and very humid. In Barbasia, with the altitude of over 1,000 m, the ripening chambers can be maintained at about 15°C and about 85% humidity throughout the year without using an air conditioner. The windows are opened at night from 11 pm to 6 am during the hot summer season to let the cool outside air into the room. The windows of the ripening chamber typically face north where sunlight never reaches. They say that the cheese is turned every three days while it matures. The cheesemakers apply olive oil to the surface of the cheese when it gets too dry to prevent loss of moisture and cracking. White or blue mold covers the surface of the cheese while the cheese rests in the ripening chamber. The mold is rubbed into the surface to promote rind formation when the cheese is wiped with olive oil. The cheese surface is also wiped with a cloth to remove the mold before shipment. The women are in charge of turning the cheese, applying olive oil, and otherwise attending to the cheese inside the ripening chamber. The cheese is matured for a minimum of three months. They say that the cheese can be matured for many years, but it is usually consumed in about a year. The resulting cheese is Casu crudu (S)/Fiore Sardo (I). The final product is about 20 cm in diameter and about 12 cm tall. The weight of one lump of cheese reduces from 6 kg to 4 kg in the process of smoking and maturing. The young cheeses matured for about 3 months are used as an ingredient in cooking or eaten with honey. The fully matured cheeses of more than 6 months are grated before use.

The whey separated from curdled milk is used to make Hárehọto (S)/Ricotta (I). The whey is constantly stirred while it is slowly heated for about an hour until it reaches 79°C and small pieces of cheese float to the top. They are scooped up, poured into a mold, and separated from whey to make Hárehọto (S)/Ricotta (I). After making Hárehọto (S)/Ricotta (I), the leftover whey is fed to pigs and other livestock. The smoked Hárehọto (S)/Ricotta (I) keeps well and is called Mustia (S)/Ricotta Affumicata (I). Mold grows prolifically on the surface while it is stored, so the mold is removed if there are any on the surface before the cheese is eaten. These cheeses are often eaten with honey or used in cooking.

The cheesemakers also sometimes make fresh cheeses by adding rennet to raw milk and transferring a part to another container before the milk is...
After adding rennet coagulant to raw milk, subdivide some part into a container. The whey from the previous processing is also added to raw milk in the most case (left). Leave to stand the container beside of a warm fireplace and promote a lactic fermentation (right).

Fig. 9 Process of Fruhe (S).

Fig. 10 Casu modde (S)/Casu marzu (S) which were made use of cheese fly (Piophila casei) for maturation.

coagulated (Fig. 9). The container containing the raw milk with rennet is placed in a warm place, such as by the fireplace overnight. By next morning, it has turned into a well-fermented curdled milk. This fresh cheese is called Fruhe (S). Fruhe (S) is found at the bottom of the container after the lactic fermentation has advanced and caused the whey to separate. The cheesemakers often add whey from the previous processing, which contains lactic acid bacteria to promote lactic fermentation and whey separation from fresh cheese before setting aside the mixture overnight. Fruhe (S) is eaten with bread or with honey. It is stored, soaked in whey, but is consumed within a few days. The pastoralists cannot obtain enough milk to make hard cheeses after June when sheep starts producing less milk. They said that they used to only make Fruhe (S) after June. They remove the whey accumulated at the top and sprinkle coarse salt on top to preserve it for a long time. They say that it keeps for about two months when salted. When the whey is removed and the fresh cheese is exposed to air, it begins to dry while it is stored. The taste of the fresh cheese becomes milder during this time and improves the flavor. Therefore, this brined fresh cheese can be considered matured cheese. They sometimes differentiate between the unsalted and salted cheeses by calling them Casu agedu (S) Note 6 and Casu e filas (S) Note 7, respectively.

In summary, the matured hard cheese, Casu crudu (S)/Fiore Sardo (I), created through the pasta cruda method can be characterized by 1) its use of unpasteurized milk, 2) the no heating (cooking) to promote whey separation from curds, 3) smoking, 4) its use of cool and humid places, such as bottom floor rooms in a building to mature cheeses, and 5) the simultaneous processing of fresh cheeses and matured cheeses.

While Casu crudu (S)/Fiore Sardo (I) matures, cheese flies, Piophila casei swarm and lay eggs on the cheese, which sometimes hatch into white narrow worms just under 1 cm long20,21. The cheesemakers sometimes use this worm infestation to further the cheese maturation. The cheese utilizing these worms is called Casu modde (S)/Casu marzu (S) (Fig. 10). Modde means soft and marzu means rotten. They say that the only flies whose worms they use are these brownish green cheese flies.

When worms start to appear on a cheese, it is placed inside an unglazed clay pot. The cheesemakers add a small amount of raw milk and
covers the container with a fig leaf to maintain humidity. The pot is left in a warm room with a fireplace to intentionally let the worms breed. In several weeks, the inside of the cheese becomes very creamy. This creamy matured cheese is *Casu modde* (S)*/Casu marzu* (S) (Fig. 4–1).

*Casu modde* (S)*/Casu marzu* (S) is eaten with hardened bread, figs, or grapes. The sharp saltiness, the creaminess, and the richness of the cheese pair well with hard bread and sweet fruits. The pastoralists also eat the live worms that jump energetically from the cheese surface.

In the processing of *Casu modde* (S)*/Casu marzu* (S), it is not so much about the cheese becoming accidentally infested with worms, but rather, the cheesemakers intentionally use the worms to mature cheese. The flavor of cheese significantly improves when its milk protein is broken down or matured and this can be achieved by using lactic acid bacteria, yeast, mold, or worms. In Barbasia, the cheesemakers sometimes utilize worms to promote cheese maturation.

1–2. Cheese made by the *Pasta semi cotta* method

Raw milk is traditionally unpasteurized before it is used to make cheese. Currently, the cheese made by the *pasta semi cotta* method sometimes uses pasteurized milk. The milk is heated and pasteurized at a low temperature of 65°C. The cheesemakers add store-bought lactic acid bacteria when milk is pasteurized (Fig. 4–2).

The rennet is added when the pasteurized milk has cooled to about 35°C. The process of making the fresh cheese, *Fruhe* (S)*/Casu agedu* (S) and the matured cheese, *Casu e fitas* (S) is the same as the *pasta cruda* method. Rennet is added to the milk and left for about 10 to 30 minutes to form curdled milk, but the amount of time may differ depending on the cheesemaker. Then, they cut the curds as the temperature of the curds is heated to about 42 to 45°C over 10 to 15 minutes. This cheesemaking process is classified as *pasta semi cotta*, because the whey is drained by lightly cooking curdled milk at a somewhat low temperature of 42 to 45°C. The curds have become the size of a corn kernel after they are heated to 42 to 45°C.

The curds are poured into a mold to separate the whey, which is used to make *Hàarrehòto* (S)*/Ricotta* (I). The curds left in the mold are immediately formed inside the mold, just like in the *pasta cruda* process. The center of the cheese droops inside the mold, so the cheese around the side of the mold is cut with a knife and piled on the center of the cheese. The cheese is kneaded with both hands to incorporate the sunken cheese and the piled cheese. The surface is thinly sliced off and the cheese is turned before it is left in the room overnight. The cheese is turned every two to three hours. Next morning, it is soaked in saturated brine for about a day and a half to two days. It is left out to drain excess water after it is taken out of the brine. This salted cheese will not be smoked, but transferred and matured in a room maintained at about 15°C and 85% humidity. During this time, it is turned every other week for at least three months. The cheese is washed with water before shipping, because mold grows on the surface during maturation. This cheese is *Hërbihinu* (S)*/Pecorino Sardo* (I), *Hàaprìnu* (S)*/Caprino stagionato* (I). The household from case 2 calls it *Gorroppu* and the household from case 3 calls it *Casu ezzu*.

The characteristics of matured hard cheeses made by the *pasta semi cotta* method can be summarized as follows: 1) it mainly uses unpasteurized milk, 2) the whey is drained from curds by heating (cooking) it at a fairly low temperature of 42 to 45°C, 3) the cheeses are not smoked, 4) it can also lead to the simultaneous processing of fresh cheeses and matured cheeses.

Discussion

1. Maturation method adapted to the transhumance migration pattern and the ecological environment in the Mediterranean climate

It is very important for the discussion of cheese processing development how the pastoralists in Sardinia are utilizing the ecology in the hot and dry Mediterranean summers to mature cheeses. The pastoralists practicing transhumance in Sardinia used to graze their livestock in the Barbasian highland at over 1,000 m above sea level in the summer and fall from May to November, and in the lowland at below 500 m above sea level in the winter and spring from December to April. The
animals were milked from November until about August. This means that the pastoralists milked sheep and goats and also made cheese while staying in the lowland between December and April. The cheeses made in the lowland in the winter and spring were immediately sold to visiting merchants and neighbors. For this reason, they did not need to mature cheeses or need a ripening chamber. There were always some leftover cheeses, but these were eaten with their meals or taken back to the highland. It was also possible to mature cheeses in the hut, because the temperature never reached 20°C in the winter and spring. In the cool winter and spring seasons in the lowland, the cheeses could be preserved simply by keeping them inside the hut, which made it convenient to store them even without owning a ripening chamber. The transhumant pastoralists lived inside these huts (Fig. 3). They used logs as fuel to cook inside the hut, so the cheeses were naturally smoke-cured, which also made it convenient to preserve the cheeses.

It is hot in the summer and fall from May to November when the pastoralists return to the highland. The highest temperature surpasses 20°C. The animals are milked until the end of July, but the milk yield decreases after end of June, so the pastoralists rarely made cheese at this time. The hard cheeses were made in the highland primarily from May to end of June when the pastoralists could obtain substantial amount of milk. In the highland where the main village is located, the basement rooms in the pastoralists’ huts were used as storage or ripening chamber. The huts are made of concrete or thick stone structure, which provides shade and is relatively cool with high humidity. When it becomes hot in the summer, the pastoralists open the windows in the ripening chamber from 11 pm at night to 6 am in the morning to let the cool outside air into the room. If the cheeses become too dry and cracked, the surface is coated with olive oil to prevent them from drying. The transhumant pastoralists whose main village is in the lower area at about 500 m above sea level could not mature cheeses in the summer and fall, because it was too hot. These people living in the lower altitude carried the cheeses to villages located at about 1,000 m above sea level to have the cheeses matured for them. As described, the transhumant pastoralists used to utilize the cold temperature in the highland during the hot summer where they owned or used a residence, which provided a cool area or a way to take in the cool night air, to make cheese maturation possible in the hot Mediterranean summer climate.

In summary, the transhumant pastoralists in Sardinia used to immediately sell or consume the freshly-made cheeses in the winter and spring when they resided in the lowland. It was also possible to mature cheeses in the lowland, because the temperature was low in the winter and spring. In the hot and dry summer, they migrated to the highland and made matured cheeses as they utilized the cold environment of the highland and their cool residence. They coated the cheese surfaces with olive oil to keep the cheeses from drying and succeeded in maturing the cheeses. They were able to mature cheeses and cope with the Mediterranean climate of cold winter and hot and dry summer by skillfully utilizing the vertical migration from their year-round transhumance.

2. Developmental history of cheesemaking in Sardinia

Cheese maturation was made possible in the hot and dry summers in Sardinia by adapting to the natural environment of the Mediterranean climate and utilizing the year-round vertical migration of transhumance. In the past, there were residential huts for pastoralists in both the lowland and the highland. The floor was made of dirt, the foundation was made of stones, and the walls and ceiling were made of wood. The pastoralists slept, prepared and ate meals in these huts. There was an open hearth at the center of the hut, where firewood was used for cooking. Cheeses were also processed on the hearth, then stored, and matured inside the hut. The cheeses were first placed on the shelf installed on the wall for several days to drain excess moisture. Then, they were transferred to the shelf above the hearth to be smoked and dried. The cheeses are returned to the shelf on the wall and stored there after they have been cured. In the cool highland at 1,000 m above sea level, the cheeses only had to be left on the shelf to be cured, drained of extra moisture, and matured. The chee-
The cheesemakers only needed to apply olive oil on the surface if the cheese became too dry. This meant that ‘the coolness’ of the highland at 1,000 m above sea level was the factor, which made it possible for the pastoralists to make matured cheeses in the Mediterranean climate with its hot summer.

The origin of Casu crudu (S)/Fiore Sardo (I) is thought to date back to the Bronze Age\(^8\). There was a cheese called Rossi fini (I), Affumicati (I) in Italian, which is thought to be the predecessor of Casu crudu (S)/Fiore Sardo (I). At first, they used to use artichoke flowers as the milk coagulating enzyme to curdle Casu crudu (S)/Fiore Sardo (I). The wooden container they used to drain curdled milk was carved with flowers to make floral imprint on the cheese (Fig. 11). This wooden draining container is called pischeddu (S) in Sardinian. The pattern on the container tells us that the artichoke flowers were used as the milk coagulating enzyme. The origin of Herbihinu (S)/Pecorino Sardo (I) is not very well-known. The words, Herbihinu (S)/Pecorino Sardo (I) did not exist in Sardinia in the late 18th century. It is highly likely that the origin of Herbihinu (S)/Pecorino Sardo (I) in Sardinia is relatively recent. Pecorino romano, made in large quantity in Sardinia today, is a new cheese created at the beginning of the 20th century. Therefore, it means that the matured cheeses in Sardinia made with the pasta cruda method developed into the matured hard cheeses made with the pasta semi cotta method. The researchers would like to discuss the development of the matured cheese culture in Sardinia in light of the information above. The two types of cheeses, Härrehòto (S)/Ricotta (I) made from whey and Casu modde (S)/Casu marzu (S) made using cheese flies are excluded from the discussion, in order to simplify the developmental process when recreating the developmental history of the cheesemaking processes below. Härrehòto (S)/Ricotta (I) and Casu modde (S)/Casu marzu (S) are made with techniques individually developed or transmitted to Sardinia at some point in their cheesemaking history.

The cheesemakers in Sardinia started using plant-based milk coagulating enzyme to curdle raw milk (Fig. 12). Its evidence is found in the fresh cheese, Fruhe (S)/Casu agedu (S). Fruhe (S)/Casu agedu (S) can be made simply by adding milk coagulating enzyme to raw milk and leaving it in a warm place. The first cheese ever made was most likely a fresh cheese like Fruhe (S)/Casu agedu (S), because it is the most simple technique to process. To improve the flavor and the shelf life of the fresh cheese, the cheesemakers started adding whey, which contained lactic acid bacteria, from the previous processing to ensure lactic acid fermentation. The fresh cheese, Fruhe (S)/Casu agedu (S), can only be stored for a few days. To make the fresh cheese last longer, it is taken out of whey to dry and then salted. It can also be processed into matured cheese like Casu e filas (S). Through draining and salting, the matured cheese named Casu e filas (S) can be stored for two months. The cheese matures during this long-term storage, which also improves the flavor of the cheese.

The cheesemakers started using the fourth stomach chamber of livestock as the milk coagulating enzyme at some point. They transitioned from using plant-based milk coagulating enzyme to animal-based milk coagulating enzyme (rennet). As they realized that removing whey from cheese made the cheese last longer, they started actively removing whey from cheese. They started cutting curds and pouring them into a mold to rapidly drain whey. After salting the cheese, they also started to leave it on or near a fireplace to smoke-cure and actively remove moisture from the cheese. In the past, the cheesemakers slept and cooked in a small hut built for pastoralism. The cheeses were smoked only by leaving them in the hut, so the fact that their process started incorporating smoking
Fig. 12 Development of cheese processing in Sardinia.

- **Cheese processing by pasta cruda method**
  - **Raw milk**
  - (washing)
  - [mammalian enzyme (rennet)]
  - [lactic acid fermented whey]
  - (leave to stand)
  - Curd
  - (cutting)
  - Whey
  - [Cheese]
  - (shaping)
  - (leave to stand)
  - (turnover)
  - (salting)
  - (smoking)
  - (brushing)
  - Whey
  - [Matured cheese]

- **Cheese processing by pasta semi cotta method**
  - **Raw milk**
  - (washing)
  - [mammalian enzyme (rennet)]
  - [lactic acid fermented whey]
  - (leave to stand)
  - Curd
  - (cutting)
  - [Fresh cheese]
  - (cooking: semi-heating)
  - Whey
  - [Cheese]
  - (shaping)
  - (leave to stand)
  - (turnover)
  - (salting)
  - (smoking)
  - (brushing)
  - Whey
  - [Matured cheese]
was an inevitable consequence of the transhumant lifestyle. The cheeses could be stored for a long time and matured only by leaving them in a cool place even in the summer in the Sardinian highland. *Casu crudu* (S)/*Fiore Sardo* (I), the cheese unique to Sardinia, is made through this process of draining whey, salting, removing moisture through smoking, and storing and maturing cheeses in a cold place. This cheese can be stored for several years. According to case 1, the legend has it that *Casu crudu* (S)/*Fiore Sardo* (I) might have originated in the Barbassian highland of Gavoi. The fact that the cheesemaking method of just letting the fresh cheese rest. This *pasta cruda* style cheese is lightly heated to drain whey from curds to make the *pasta semiotta* style cheese called *Hirbhinu* (S)/*Pecorino Sardo* (I), *Hpârnu* (S)/*Caprino stagionato* (I). The *pasta semiotta* method was implemented relatively recently after the second half of the 18th century. By tracing the changes described above, all of the cheeses currently found in Sardinia will come out.

The cheeses found in Sardinia clearly illustrate the developmental history of cheeses from fresh cheese to matured cheese and to matured hard cheese. The switch from preserving curds in whey to preserving curds in air, cutting curds to rapidly remove whey, draining through smoking, salting cheese, and letting the cheese rest in a cold place can all be considered a discovery or development in the cheesemaking method. By employing the transhumant subsistence, which utilizes the vertical difference by season, the cheeses developed into matured hard cheeses even in the hot and dry Mediterranean summers by using the cold ecology of the highland. The geography of Sardinia (comprising of lowland and highland of over 1,000 m above sea level), use of the environment (grazing in the lowland in the winter and fall and in the highland in the summer), and the transhumant lifestyle all contributed to the creation of matured hard cheeses unique to Sardinia.

1) DOP stands for Protected designation of origin (Denominazione di Origine Protettain Italian).
2) *pasta cruda* in Italian means “raw pasta”.
3) *pasta semiotta* in Italian means “semi-heated pasta”.
4) *Casu friscu* in Sardinian means “fresh cheese”.
5) *Casu essu* in Sardinian means “aged cheese”.
6) *Casu agedu* in Sardinian means “soured cheese”.
7) *fitas* in Sardinian has no special meaning.

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地中海域サルデーニャ島・バルバージャ地域の乳加工体系

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本研究の目的は、ヨーロッパ乳文化の熟成チーズ発達史を考察する一環として、1）サルデーニャで実践されているチーズ加工を把握し、2）暑熱環境下においてどのように生態環境を利用してチーズの熟成を実現させているかを分析することを通じて、3）サルデーニャにおける熟成チーズの発達史を考察することにある。サルデーニャでは、凝乳からホエイを抜く際に加熱しないpasta cruda 法によりカズ・クルドゥ(S)/フィオレ・サルド(I)と呼ばれる熟成ハードチーズをつくるてきた。サルデーニャの移牧民はかつて、低地に滞在する冬・春期はつくりだすのチーズを主にすぐに売却したり食に供したりしていた。冬・春期は低地でも気温が低いため、チーズを熟成させることも可能であった。夏期には高地に移動して熟成チーズを加工していた。夏期の高温乾燥となる自然環境には、高地の涼しさとより涼しくできる住居を利用し、乾燥を防ぐにはオリーブオイルを表面に塗布し、チーズの熟成を実現させてきた。移牧という年間の高度差移動を巧みに利用し、冬期低温・夏期高温乾燥となる地中海性気候に対処してチーズの熟成を実現させてきた。それは、凝乳をホエイの中での保存から空気中への保存、凝乳のカッティングによる凝乳からの急速なホエイ排除、廃煙による脱水、加塩、涼しい場所を選んでの静置という加工法の発見・発達であったとも言える。サルデーニャの地形（低地から標高1000 m 以上の高地）、環境利用（冬・秋期間に低地、夏期に高地を放牧）、ライフスタイル（移牧）が、サルデーニャ独自の熟成ハードチーズを生み出していったといえる。