Acta Scientific Veterinary Sciences (ISSN: 2582-3183)

Volume 3 Issue 12 December 2021

Research Article

Husbandry and Cheese Manufacturing Practices in Small Ruminants' Farmhouse Dairies in Central Italy

Ziad Mezher[1]*, Evgeniya Titarenko[1], Valeria Morena[1], Gilberto Giangolini[2] and Roberto Condoleo[1]

[1]Istituto Zooprofilattico Sperimentale del Lazio e della Toscana "M. Aleandri", Italy

[2]Istituto Zooprofilattico Sperimentale del Lazio e della Toscana "M. Aleandri", Centro di Referenza Nazionale per la Qualità del Latte e dei Prodotti Derivati degli Ovini e dei Caprini (CReLDOC), Italy

***Corresponding Author:** Ziad Mezher, Istituto Zooprofilattico Sperimentale del Lazio e della Toscana "M. Aleandri", Italy.

Received: September 28, 2021

Published: November 11, 2021

Abstract

Farmhouse cheeses made from raw ovine or caprine milk are very popular among the consumers not only in Italy but also overseas because of their unique organoleptic properties. These cheeses are usually manufactured, according to traditional methods, in small rudimental facilities adjacent to the farm where the achievement of satisfactory hygienic standards can be challenging. However, the lack of systematic data about farm management and the cheese manufacturing processes hampers the conduction of specific risk assessment studies. In order to fill the knowledge gaps, we collected relevant data, through a questionnaire - based survey, from 125 farmhouse dairies spread in Lazio. Results showed that 1.1% of small ruminant's registered farms process their own milk for the production of raw milk cheeses. Hand milking is still applied in almost half of them and most products are subject to a short - to - medium ripening period which might not be sufficient to reduce eventual pathogen load. Products are mainly sold directly to consumers on the farm premises. Our results suggest the need to support these artisan cheese producers in order to improve the production standards without altering however, the traditional cheesemaking practices. The reported data are useful for risk assessors as well as food technologists and might be employed in future risk assessment studies.

Keywords: Small Ruminants; Raw Milk; Farming Practices; Cheese Production

Abbreviations

MT: Million Tons; PDO: Protected Designation of Origin; EU: European Union; RTE: Ready-To-Eat; Kt: Kilo Tons

Introduction

Dairy goat and sheep farming has been traditionally practiced by the population inhabiting the Mediterranean basin [1]. Nowadays small ruminant dairy production continues to represent one of the most important sources of sustenance and revenue for the communities of the Area. According to FAOSTAT 2019 [2], the countries surrounding the Mediterranean produce 3.77 Million tons (MT) of sheep milk and 2.31 MT of goat milk, which constitute 41% and 15.8% of worldwide sheep and goat milk production, respectively.

Unlike cow's milk, which is consumed primarily as pasteurized fresh milk, the main destination of small ruminant's milk is the production of cheeses and yogurts [3]. Approximately 60% of the world's sheep milk cheeses and 33% of the world's goat milk cheeses are manufactured in the Mediterranean Area [2]. The largest quantities are mainly produced in Greece, Italy, France, Spain, Syria (as of 2014) and Turkey.

Despite a relatively small livestock size, which accounts only 4.7% of the total number of sheep reared in the Mediterranean

Area, Italy is considered the third largest producer of sheep milk cheeses in the world and the leading export country [2].

This phenomenon is explained by the presence of advanced dairy sheep systems, involving high-yield specialized dairy breeds, farms, milking facilities and processing plants equipped with modern technology, without excluding however the application of local and traditional approaches [3]. In contrast, goat milk production in Italy is among the lowest in the Mediterranean Area [2] and amounts to just 8% of the total dairy small ruminants' milk production in the country [4].

Dairy sheep herds are commonly found throughout the Italian territory, but are mainly concentrated in Sardinia (47%), Sicily (11.3%) followed by the Central Regions of Lazio (10%) and Tuscany (6%). Dairy goats are mostly reared in Sardinia (20%), followed by Lombardy (13.1%), Sicily (12.4%), Calabria (12%) and Piedmont (7.5%) [4]. Dairy sheep and goat sectors in Italy are characterized by semi-extensive farming where sheep and goats are often reared together in mixed flocks and where pasture constitutes the main food source. The average sheep flock size varies between 50 and 250 heads, with a mean value of 140 heads [5].

Around 86% of milk produced in Italy is transformed by industry, and the rest (14%) is processed on farm [5] into a high number of different cheese types, some of which have a Protected Designation of Origin (PDO) status under Regulation (EU) 1151/2012 while others are regulated by only national or local set of rules and recognized as Traditional Agri-food Products [6]. The latter status permits to obtain a series of derogation provisions from European specific hygiene rules and aims at preserving the traditional systems of farmhouse cheesemaking. In fact, such category of cheeses is traditionally produced in small processing facilities annexed to animal farms, which use raw milk regularly collected from their own herds. These artisanal cheeses are very popular among national and international consumers for their unique organoleptic and nutritional values, for their perception as healthy and genuine food as well as for their contribution in preserving local traditions and activities. At the same time, this category of cheeses may pose additional problems compared to conventional production in terms of maintaining hygienic standards, thus raising concerns regarding some aspects of food safety [7].

Cheeses belong to the category of ready-to-eat (RTE) products that do not require further treatment before consumption; hence, more strict hygienic measures are necessary to avoid contamination with foodborne pathogens. Hygienic standards must be even more elevated when it comes to raw milk cheeses that skip the fundamental technological step - pasteurization. The occurrence of foodborne pathogens in goat, sheep and cow soft and semi-soft cheeses made from raw or low-heat-treated milk, in general, is significantly higher compared with cheeses made from pasteurized milk [8]. The following microbiological hazards are associated with raw milk consumption: *Listeria monocytogenes, Campylobacter spp., Escherichia coli* (STEC*), Bacillus cereus, Staphilococcus aureus, Mycobacterium bovis, M. avium subsp. paratuberculosis, Salmonella spp., Brucella spp., Coxiella burnetti*, tick-borne encephalitis virus and others [8-10]. Apart from the endogenous contamination route, a vast variety of exogenous factors are involved in milk and final product contamination: herd size, production per head, farming system, milking system, milk storage modalities, the conditions under which the flocks are reared, climatic conditions, geographic area, cheesemaking practices, cheese storage etc.

Several quantitative risk assessments have been conducted to investigate about the microbiological risks for the population connected with raw milk cheese consumption [11-17], however just a few of them regarded exclusively raw ovine or caprine milk cheeses [18-20]. Such a scarce scientific production could be ascribed to the unavailability of systematic data on a wide variety of factors that influence the hygienic quality of small ruminant's milk and its derivatives, thus making the risk assessment procedure extremely challenging.

The main scope of the present paper is to provide information on ovine and caprine farming methods and artisanal cheesemaking practices in the most detailed manner possible, hence contributing to eventual risk assessment studies regarding a wide range of traditional cheeses. For this purpose, data were collected, through the administration of a questionnaire survey within the context of one of the regional monitoring programs, from several ovine and caprine farms spread in all the provinces of the region of Lazio, Central Italy.

The further scope of the present study is the identification of eventual risky practices related to animal rearing, milking and cheesemaking, which could compromise the safety and hygienic quality of final products and increase the risks for consumers. The collected data, although being limited to a relatively small geographic area, could be representative, with due precautions, of different realities within the Mediterranean Region.

Materials and Methods

Study population

The present descriptive observational study has been conducted between 2016 and 2018 in Lazio. With its almost 5.9 million inhabitants, Lazio is the second most populated region of the country. It includes Rome, the capital, which attracts millions of visitors every year driven not only by its famous historical heritage but also by its culinary traditions. Tourism is not exclusively limited to Rome, but it is also widespread throughout the five provinces, were travelers have the opportunity to reach the most remote sites, to learn about customs and traditions and to savor local foods and specialties that often comprise raw-milk cheeses. Lazio constitutes a land area of 17,242 km^2 and is predominantly hilly (53.9%) with mountains (26.1%) in the most eastern and southern districts and plains (20%) located mainly along the Tyrrhenian coast. There are 7681 sheep farms and 2722 goat farms in Lazio unevenly distributed throughout the territory; 74.9% of sheep farms are in fact concentrated in the provinces of Roma, Rieti and Frosinone whereas most of the goat farms (94%) are distributed in the provinces of Roma, Rieti, Latina and Frosinone (data retrieved from the National Livestock Registration System - reference date 30/06/2019). They rear approximately 633,000 dairy ewes and 27,000 dairy goats producing in total 24.8 kilo tons (kt) and 0.49 kt of sheep and goat milk respectively [4].

A questionnaire-based survey has been chosen as a research technique for gathering and analyzing data on small ruminants' farms possessing farmhouse dairies registered in accordance with Regulation (EC) 852/2004 [21]. The data collection was performed by Official Veterinarians from the Local Health Authorities within the framework of a regional monitoring program. According to the program, veterinarians had to include in the survey all the farmhouse dairies that met the following selection criteria:

- They mainly raised sheep, goats, or both species;
- They directly transformed their own produced milk;
- They utilized unpasteurized milk for cheese manufacture.

Data collection

The official veterinarians administered two different questionnaires to the operators of the selected farmhouse dairies during their inspection visits.

The first one, titled "Farmhouse Registration Data Sheet", regarded the farm and dairy management, and was subdivided into three different sections: general registration information, information about the dairy production and about the farm. It contained dichotomous and multiple choice close-ended questions that aimed to acquire data regarding the characteristics of the farm (e.g. number of animals, species and breeds, etc.) and dairy production (e.g. milk processing periodicity, types of produced sheep and goat cheeses, marketing context of finished products, etc.).

The second questionnaire, "Data Sheet for a Single Cheese Type", investigated about the technological characteristics and parameters of the cheesemaking process. It had to be filled in for each type of cheese listed in the first questionnaire.

Data analysis

Excel spreadsheets (Microsoft Corporation, Redmond, WA, USA, v. 2016) and SPSS software (IBM, Armonk, NY, USA, v. 21) were employed to record the collected data and carry out the descriptive statistics.

Qualitative data were described using percentages whereas mean values and percentiles were used in case of quantitative data.

Results

In total, information was collected from 125 farmhouse dairies that met the selection criteria (Figure 1) and the main results are illustrated in table 1.

More than 90% of the dairies were distributed in the central and southern provinces of Lazio and raised mainly sheep and/or goat breeds. The mean duration of the business activity was almost 11 years (Median 10 years).

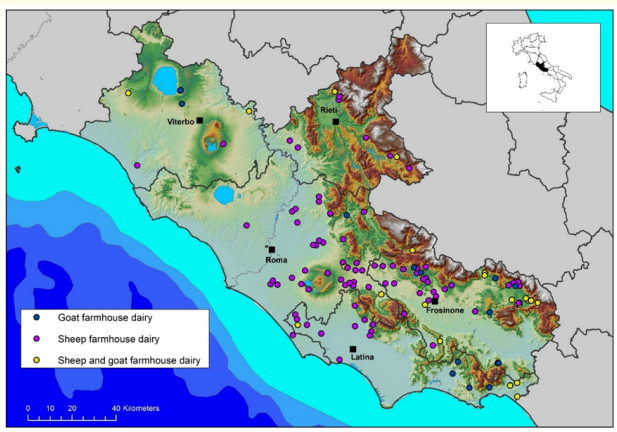

Figure 1: Distribution map of the surveyed farmhouse dairies.

Question	Answer		N (%)
Registration information			
Reared dairy species (from which milk is collected and processed)	Sheep		84 (67.2)
	Goat		15 (12)
	Sheep and Goat		23 (18.4)
	Sheep/Goat/large ruminants[A]		2 (1.6)
	Sheep/large ruminants[A]		1 (0.8)
Amount of estimated processed milk (Litres/week)	Sheep	Min	18
		Mean	567
		Max	4200
	Goat	Min	35
		Mean	419
		Max	4580
Number of employees	1		51 (48.1)
	2-3		52 (49)
	4-6		2 (1.8)
	>6		1 (0.9)
Duration of the dairy's business activity	1-2 years		11 (10.1)
	3-5 years		20 (18.3)
	6-10 years		29 (26.6)
	> 10 years		49 (45)
Information about cheese production			
Marketing channels of finished products: Direct/retail (D)[B] Local (L)[C] Provincial (P)[D]	D		49 (39.8)
	D + L		49 (39.8)
	D + L + P		13 (10.6)
	L		5 (4.1)
	D + P		4 (3.3)
	P		2 (1.6)
	L + P		1 (0.8)
Period of the year during which the dairy processes sheep and/or goat milk	1-3 months		7 (5.6)
	4-6 months		12 (9.7)
	7-9 months		46 (37.1)
	10-12 months		59 (47.6)
Milk processing periodicity (on a weekly basis)	Every day		57 (45.6)
	Every 2 days		47 (37.6)
	Every 3 days		13 (10.4)
	Not every day and with undefined frequency		8 (6.4)

Types of cheeses manufactured by the farmhouse dairy	1		58 (46.4)
	2		32 (25.6)
	3		23 (18.4)
	>3		12 (9.6)
Information about the farm annexed to the dairy			
Number of reared animals	Sheep	Min	12
		Mean	365
		Max	4000
	Goat	Min	15
		Mean	177
		Max	620
Number of animals in the lactation phase	Sheep	Min	4
		Mean	163
		Max	2500
	Goat	Min	4
		Mean	61
		Max	350
Number of reared sheep breeds	1		91 (85.8)
	2		11 (10.4)
	>3		4 (3.8)
Number of reared goat breeds	1		36 (90)
	2		3 (7.5)
	>3		1 (2.5)
Grazing period	3-6 months		5 (4.7)
	7-9 months		4 (3.8)
	10-11 months		5 (4.7)
	12 months		92 (86.8)
Milking system	Hand milking		55 (45.1)
	Machine (pipeline milking)		39 (32)
	Machine (bucket milker)		25 (20.5)
	Mixed (hand and machine milking)		3 (2.5)
Milking frequency	Once a day		5 (4.2)
	Twice a day		115 (95.8)
Use of pre-dipping and/or post-dipping	No		58 (53.7)
	Yes		48 (44.4)
	Not on a regular basis		2 (1.9)
Milk conservation method	Milk tank		76 (63.3)
	Insulated milk bin		42 (35)
	None		2 (1.7)

Milk transportation mode to the dairy	Insulated milk bin		59 (48.8)
	Refrigerated vehicle		3 (2.5)
	None (e.g. Farm annexed to the dairy)		59 (48.8)

Table 1: Information regarding the farm and dairy management.

[A] Cow and/or buffalo

[B] Direct/retail: Cheese is sold directly to the customers through a shop annexed to the dairy

[C] Local: Cheese is marketed through shops or supermarkets distributed within the farmhouse's municipality or the neighboring municipalities

[D] Provincial: Cheese is marketed through shops or supermarkets distributed within the farmhouse's province or the neighboring provinces.

Farm management and husbandry practices

Most farms were small to medium sized, rearing less than 200 lactating animals (200 sheep and 70 goats at 75°P) and employing between 1 and 3 permanent workers. Moreover, in most cases animals were kept to graze on pasture at least 10 months per year (91.5% of farms).

The ratio between the number of lactating ewes and sheep among the different farms varied between 0.20 and 0.88. When considering seasonality, the mean ratio ranged from 0.40 during fall up until 0.55 during summer. The mean ratio between the number of lactating does and goats was 0.63. One third of the farmhouses dairies reared goats alone or mixed with sheep (38/125; 30.4%).

In relation to the sheep and goat breeds, the most raised animals were crossbreeds (51.2% and 73.3% respectively) followed by the "Sarda" (18.4%) and "Comisana" (10.4%) for sheep, and "Saanen" (8.9%) for goats.

Lactating animals are mainly milked twice a day and farmers either resort to hand milking (45.1%) or machine milking (52.5%) for the collection of milk. Regarding the hygienic practices, the use of pre/post-dipping, a procedure that consists of disinfecting the udder before and/or after milking, is applied regularly by 44.4% of farmers. The freshly collected milk is then conserved in a cooling tank or an insulated milk bin prior to processing; nonetheless, about 1.6% of the farms process the milk immediately after collection and therefore do not require any conservation systems.

Milk is collected and processed all year round in just 36.3% of farms however the weekly volumes of processed milk and frequency of cheesemaking varied greatly among the surveyed dairies and was based mainly on the period of the year as well as the number of lactating animals and the processing capacities.

90.4% of farmhouse dairies produce up to three different kinds of sheep and/or goat milk cheeses and finished products are mostly sold directly to consumers (93.4%) and/or marketed through local retailers and shops (55.2%).

Cheese manufacturing practices

We collected information about the cheesemaking process of 130 types of cheeses (Table 2) although the surveyed farmhouse dairies declared to produce more than 250 different types. The reason is that, in many cases, the cheeses from a given dairy differed slightly (e.g. for the presence of additional ingredients or various ripening periods) but basically underwent the same manufacturing process.

After collecting the milk, most farmhouse dairies keep it refrigerated at 4 °C for a certain amount of time prior to cheese manufacturing (12 h at the 50°P). The process of cheesemaking is initiated by heating the milk and adding the starter culture. The average temperature and duration for the heating step is 39.8°C and 17.4 minutes respectively. The most used starters are commercial (n = 18; 21.2%) followed by whey-starters (n = 5; 5.8%) and milk-starters (n = 2; 2.3%), however 70.5% (n = 60) of dairies do not

Phase of the process	Activity (unit)	Mean	Min	Max	25°P	50°P	75°P	Number of observations (n)[A]
Milk reception and collection	Storage temperature(°C)	4.78	0	40	4	4	4	115
	Estimated average duration (hours)	19	0	72	12	12	24	92
Milk thermization/ heating	Treatment temperature (°C)	38.9	20	70	35	37	39	111
	Duration (min)	17.4	0.03	90	10	16.3	20	94
Coagulation (curd formation)	Temperature (°C)	37.3	20	60	35	37	38	121
	Duration (min)	26.5	4	100	15	20	30	98
Curd setting	Temperature (°C)	36	18	60	34	36	40	75
	Duration (min)	27.5	2	180	10	20	30	77
Extraction and moulding	Wheel/block diameter (cm)	14.3	3	35	10	15	20	123
	Heel height (cm)	11.2	4	30	8	10	12	117
	Wheel/block weight (g)	1156	150	4000	500	1000	1500	110
Salting	Mean duration of dry surface rubbing (hrs)	4.9	0.5	70	1	1	2	56
	Mean duration of brining (hrs)	6.6	0.5	24	1	2.75	10	18
	Salt quantity (g/kg)	57	2	200	25	30	100	62
	Salt concentration in brine (%)	18	3	40	12.5	20	25	19
Ripening	Temperature (°C)	11	2	25	8	10	15	90
	Duration (days)	54	1	180	24	41	89	88
	Humidity (%)	69	40	88	60	70	77	28
Storage	Temperature (°C)	11.1	3	25	7.25	10	15	83
	Duration (days)	22	1	90	4.5	15	30	49
Packaging	Established storage temperature (°C)	7.2	2	20	4	5	9.5	45
	Stated shelf-life (days)	65.5	2	180	10	60	90	37

Table 2: Information associated with the cheese production process.

[A]The number of observations for each phase of the process varied either because some steps were optional and were not applied during the manufacturing of all cheese types or because the farmers do not possess the information.

employ any starter cultures for milk acidification and therefore rely on the native microflora already present in the milk. Rennet or coagulants are added afterwards in order to start the coagulation process. 80.6% of dairies use commercial rennet (n = 75), 17.2% use their own-produced ones and 2.1% use both types alternatively. The main source of rennet (n = 69; 90.8%) is the one obtained from the stomach of young animals (44.9% calves, 27.5% lambs, 16% kids, and 11.6% from mixed young animals); the remaining dairies employ microbial/artificial (n = 6; 7.9%) or vegetable (n = 1; 1.3%) coagulants.

Coagulation of milk occurs at temperatures between 20 and 60 degrees (Median 37°C) and heating is usually maintained for 25 - 30 minutes in order to allow the complete formation of curd. Once it is formed, curd is left to set for another 25 - 30 minutes while maintaining the same heating temperature. Afterwards, curd is cut to the appropriate measure based on the type of cheese. Curd used to produce soft cheeses (rich in moist) is usually cut into large pieces whereas dryer cheeses require small curd pieces that provide more surface area for continued drainage of the whey. Among the investigated cheeses, 84.5% had the curd grain size ≤ 8mm (n

= 109); in addition, pressing or stewing the curd was applied to 88.7% of the cheeses in order to expel any extra whey and create the shape of the final product. In the subsequent step curd is left for a certain amount of time to mature (55.3% of farmhouse dairies) before it is extracted and put into molds that varied either in shape or dimension depending on the type of cheese that is being manufactured (Table 2).

This step is followed by salting which can be implemented in three different ways: dry salting, brining or dry surface rubbing. The main purpose is to extend the shelf life of cheese and enhance its flavor. Based on the results of the survey the most adopted approach was rubbing the salt on the cheese surface (77%) followed by immersion in brine (23%).

Some types of cheeses are subject to additional intermediate steps along the cheese manufacturing process such as smoking but their adoption was very low among the surveyed farmhouse dairies (less than 0.5%).

The ripening period is short to medium in most cheeses (less than 89 days at the 75°P). The temperature in the ripening environments varies between 2 and 20 degrees with the median temperature being at 10 degrees while humidity varies between 40 and 88% (70% at the 50°P) but many cheesemakers were unable to provide such technical information.

43.3% of the produced artisanal cheeses are soft, 46.2% are semi-soft and just 10.3% are hard cheeses.

The mean storage temperature and duration of final products is 11°C and 22 days respectively.

Most products are sold unpackaged (68.4%), 15.3% are vacuumed and only 0.76% are conserved under modified atmosphere.

Few producers (n= 37, 28.4%) established a shelf life for their products since the provision of food information to consumers is mandatory, under EU regulation 1169/2011, only for prepacked products and does not include foods packed on the farmhouse premises at the consumer's request.

In most cheeses (n= 29; 78,3%) the shelf life is below 90 days; the maximum declared duration is 180 days in 13.5% of cheeses.

Discussion

The survey revealed that 1.1% of small ruminants' farms in Lazio process their own milk for the production of raw milk cheeses (125/10453). Most probably, such quantity is an underestimate of the actual number of farmhouse dairies in Lazio. Unfortunately, official data are missing and often it is quite difficult to distinguish between different production systems due to the absence of a clear categorization of farms. In any case, despite an apparently small number, we decided to focus the investigation on such dairies because of their potentially higher microbiological risk in comparison with the "industrial" ones. This assumption could be explained by the presence of several risk factors such as the limited use of modern equipment (e.g. mechanical milking systems) and/or the application of less stringent hygienic procedures; moreover the lack of the dilution effect might play an additional role in case of a contamination event since the own-produced milk is used for cheese making without a prior mixing with milk from other farms [15,20].

As predicted, most of the farmhouse dairies were small to medium, subsistence-oriented family type farms that relied on selling their own produce at local level as one of the main sources of income. They roughly raised 5% and 16% of the estimated total number of dairy sheep and goats present in Lazio, respectively, but some of them are able to produce remarkable amounts of milk and its derivatives, which might represent a significant source of exposure to consumers. The activity usually involves few workers that are probably family members but most of the dairies operate since many years and presumably have acquired considerable experience in the management of the cheese making process and in the respect of the food safety procedures.

In many parts of Italy, like in other Mediterranean countries, small ruminants are usually raised on marginal land areas where animals are kept outdoors almost all year round and confined just in case of adverse climate conditions; the data collected in the present study confirm that even the farmhouse dairies adopt such extensive farming systems. In fact, small ruminants' husbandry is still considered a rural reality and is often conducted in hilly or mountainous areas where it is difficult to build modern facilities such as milking parlors even though, in recent years, there has been an increase in the number of farms that adopt technologically advanced farming and cheese making systems.

In general, extensive rearing entails a higher probability of exposure of sheep and goats to animal and zoonotic pathogens due to the limited application of biosecurity measures. In relation to milking, disinfecting the udder prior to milk harvest is relevant for reducing contamination but was adopted by less than half of famers. It is also important to notice that a considerable number of them still rely on hand milking to extract the milk. It is well known that milk harvesting is a delicate phase during which the contamination with pathogens is more likely to occur [22]. Respect to other methods, hand milking increases the probability of contamination for several reasons: teats are completely exposed during the process; the milker's hands can carry germs (and represent a source of contamination), but above all, milk is not immediately conveyed into a closed container and therefore might be subject to further microbial contamination caused by fecal material, fleece, soil etc.

Many farmers use isolated bins to collect and transport the milk to the dairy. The transportation time and temperature are two important parameters that might influence the hygienic quality of milk. In fact, Regulation (EC) 853/2004 specifies that milk must be immediately cooled to a temperature not exceeding 8°C in the case of daily collection and not more than 6°C if the collection is not carried out daily (23). In addition, the cold chain must be maintained during transport and the temperature of milk must not exceed 10 °C upon arrival to the processing plant. However, the operators are not required to comply with these thermal requirements if milk is processed within two hours after milking. We did not investigate further in detail these aspects but some concerns arise about the duration of the storage prior to processing and the respect of the cold chain especially during summer.

In this study we also collected information about small ruminants' raw milk cheeses produced in the region of Lazio. The aim is to fill the knowledge gaps and provide useful data for risk assessors and food technologists regarding the manufacturing techniques of such unique products.

Although any step of the cheesemaking process might bear important food safety implications, the collected data revealed that the most crucial ones are represented, in particular, by the heating step and the duration of the ripening phase.

It is recognized that pasteurization is able to eliminate most pathogens eventually present in milk destined for human consumption. The standard procedure consists of heating the milk for 15 seconds at 72°C at least but any combination of time and temperature that allows obtaining an equivalent effect is also permitted [23]. Our data confirm that such temperature was not reached, during the heating step, in all of the surveyed cheesemaking processes but remained predominantly below 40°C for less than 20 minutes (75°P), thus pathogens eventually present in the milk are expected to survive [24]. In addition, most cheeses (81%) underwent a short-to-medium ripening period (less than 90 days) which might not be sufficient to reduce the presence of harmful microorganisms and as such might represent a potential source of infection to consumers [25-28].

Conclusion

Considering all the above mentioned hygienic and food safety concerns, particular attention must be addressed towards the small-scale artisan cheese makers of these popular raw milk cheese products. It would be desirable to provide them with appropriate economic, technical and training support in order to modernize their facilities and improve the hygienic quality of their produce without affecting however the traditional cheesemaking process.

Acknowledgment

This research did not receive any specific funding. We thank Dr. Pasquale Rombolà for the creation of the map, the veterinarians from the local health units who administered the questionnaires as well as the veterinary authorities from the region of Lazio for allowing the use of the data.

Disclosure Statement

The authors declare no conflict of interest regarding the publication of this article.

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