Survey on husbandry and cheese manufacturing practices in small ruminants' farmhouse dairies in Central Italy

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Small ruminants,
Raw milk,
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Cheese production.

Summary
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 small ruminants' farmhouse dairies spread in Lazio. Results showed that 1.1% of 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 the traditional cheesemaking practices. The reported data are also useful for specific risk assessment studies.

Introduction

Dairy goat and sheep farming has been traditionally practiced by the population inhabiting the Mediterranean basin (Caja 1990). 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), the countries surrounding the Mediterranean sea 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 liquid pasteurized or UHT milk, the main destination of small ruminant's milk is the production of cheeses and yogurts (Pulina *et al*. 2018). Approximately 60% of the world's sheep milk cheeses and 33% of the world's goat milk cheeses are manufactured in the Mediterranean area (FAOSTAT 2019). 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 (FAOSTAT 2019).

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

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the application of local and traditional approaches (Pulina *et al*. 2018). In contrast, goat milk production in Italy is among the lowest in the Mediterranean area (FAOSTAT 2019) and amounts to just 8% of the total dairy small ruminants' milk production in the country (ISTAT 2018).

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%) (ISTAT 2018).

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 (ISMEA 2018).

Around 86% of milk produced in Italy is transformed by industry and the rest (14%) is processed on farm into a high number of different cheese types (ISMEA 2018), some of which have a Protected Designation of Origin (PDO) status under Regulation (EU) 1151/2012 while many others are recognized as Traditional Agri-food Products (PATs). PATs are obtained with "methods of processing, preservation and aging consolidated over time, homogeneous for the whole territory concerned, according to traditional rules, for a period not less than twenty-five years".

In accordance with Regulation (CE) 2074/2005, the establishments manufacturing PATs might be granted with specific derogations from the hygiene requirements set out in Regulation (CE) 852/2004. The derogations refer mainly to the premises where such products are manufactured and exposed as well as the instruments and equipment used for their preparation.

There is also a significant variety of farmhouse cheeses without a specific designation that are manufactured locally in limited quantities, usually in small processing facilities annexed to animal farms, which use raw milk regularly collected from their own herds. These cheeses are commonly identified with generic names such as "Pecorino" or "Caciotta".

In the territory of Lazio three PDO raw sheep's milk or mixed sheep and goat's milk cheeses are produced (Pecorino di Picinisco, Pecorino Romano and Pecorino Toscano; and 45 cheeses with PAT status (e.g. Cacio di Genazzano, Cacio magno, Caciotta dei Monti della Laga) (MIPAAF, 2022a, b).

Farmhouse 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 (Gonzales-Baron *et al*. 2017). 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 (EFSA and ECDC 2021).

The following microbiological hazards are associated with raw milk consumption: *Listeria monocytogenes, Campylobacter spp.,* Shiga toxin-producing *E. coli* (STEC*), Bacillus cereus, Staphylococcus aureus, Mycobacterium bovis, Mycobacterium avium subspecies paratuberculosis, Salmonella spp., Brucella spp., Coxiella burnetti*, tick-borne encephalitis virus and others (Verraes *et al*. 2014,Verraes *et al*. 2015, EFSA and ECDC 2021). 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 (Bemrah *et al*. 1998, Lindqvist *et al*. 2002, Sanaa *et al*. 2004, FDA HC 2015, Perrin *et al*. 2015, Choi *et al*. 2016, Campagnollo *et al*. 2018), however just a few of them regarded exclusively raw sheep or goat milk cheeses (Delhalle . 2012, Valík and Medveďová 2013, Condoleo *et al*. 2017).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 study reported in this paper was conducted in Lazio, the second largest region of central Italy (after Tuscany).

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 travellers have the opportunity to reach the most remote sites, to learn about customs and traditions and to savour 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 (ISTAT 2018).

The aim of the paper is to provide information on sheep and goat 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.

Materials and methods

Study population

The present descriptive observational study was conducted between 2016 and 2018 and involved several sheep and goat farms spread in all the provinces of the region of Lazio, Central Italy.

A questionnaire-based survey was chosen as a research technique for gathering and analysing data on small ruminants' farms possessing farmhouse dairies registered in accordance with Regulation (EC) 852/2004.

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 (Supporting information, S1 and S2 data sheets).

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 spread sheets (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 or median 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 (Fig.1) and the main results are illustrated in Table I.

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).

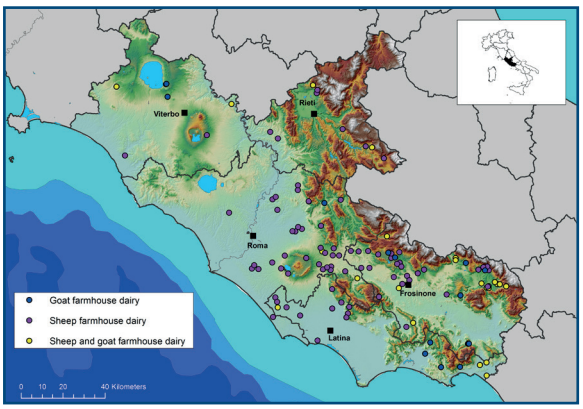

Figure 1. *Distribution map of the surveyed farmhouse dairies*

LOCAL HEALTH AUTHORITY
_____
Department of Prevention
Veterinary Services – District _____

FARMHOUSE REGISTRATION DATA SHEET

Filled in by Mr./Mrs. .....

REGISTRATION INFORMATION	
Business name of the dairy:	
Registered in accordance with Reg. 852/04 Dairy species from which milk is collected and processed on farm: □ Sheep □ Goat □ Bovine □ Buffalo	
Address: Str./Square	
Town:	Province:
Location:	
Amount of estimated processed milk: - Sheep: Mean value _____; Min Value: _____ liters; Max Value: _____ liters; - Goat: Mean value _____; Min Value: _____ liters; Max Value: _____ liters;	
Duration of the dairy's business activity:	Number of employees:
Marketing context of finished products	□ Direct/retail (e.g. shop attached to the dairy) □ Local (supply of small quantities to other business operators) □ Provincial

INFORMATION ON PRODUCTION		
Period of the year during which the dairy processes sheep and/or goat milk	□ all year round □ during some periods of the year (specify):	
	□ January □ February □ March □ April □ May □ June	□ July □ August □ September □ October □ November □ December
Milk processing periodicity (on a weekly basis)	□ Every day □ Every 2 days □ Every 3 days □ Not every day and with undefined frequency	
List the name of the sheep and/or goat cheeses produced by the dairy *: 1. Cheese: _____ 2. Cheese: _____ 3. Cheese: _____ 4. Cheese: _____		

1

Supporting information S1 data sheets

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FARMHOUSE REGISTRATION DATA SHEET

5. Cheese: _____
6. Cheese: _____
7. Cheese: _____
8. Cheese: _____
9. Cheese: _____
10. Cheese: _____

* For each type of cheese a technical data sheet must be filled

INFORMATION ABOUT THE ANIMAL FARM ANNEXED TO THE DAIRY	
Reared animal species: □ Sheep Total number of reared animals: _____ Number of animals in the lactation phase: _____ □ Goat Total number of reared animals: _____ Number of animals in the lactation phase _____	
Raised Sheep breeds: _____ Raised Goat breeds: _____	
Do animals graze on pasture?	□ No □ Yes: Number of months _____
Type of milking:	□ Hand milking □ Machine (bucket milker) □ Machine (milking parlor)
Frequency of daily milking	□ Once □ Twice
Use of pre-dipping and / or post-dipping	□ No □ Yes
Milk conservation method	□ Insulated milk bin □ Milk tank
Milk transportation mode to the dairy	□ None (e.g. farm annexed to the dairy) □ Insulated milk bin □ Refrigerated vehicle
Remarks	

Supporting information S1 data sheets

LOCAL HEALTH AUTHORITY

_____

Department of Prevention

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DATA SHEET FOR A SINGLE CHEESE TYPE

Name of farmhouse dairy:	
Denomination of cheese:	
The product is: □ Traditional Agro-Food Product (TAP) □ Protected Designation of Origin (PDO) □ Neither of these	
Dairy species from which milk is collected: □ Sheep □ Goat □ Sheep and goat (specify % of milk): % of sheep milk ....., % of goat milk.....	Production period (e.g. March - October):
Texture of finished product: □ soft □ semi-soft □ hard	Weight of cheese wheel/block ..... gr.
Length of ripening phase of the finished product: ..... days Minimum length ..... Maximum length	Ingredients (specify eventual use of food additives):

Flow chart*

Types of starters:
□ None (Native microbial flora)
□ Milk based starter
□ Whey based starter
□ Commercial starter

Rennet type
□ In-house
□ Commercial
Origin
□ Calf □ Lamb □ Kid
□ Artificial □ Vegetable

Salt addition
□ Dry form (Salt quantity..... g\Kg)
□ In brine (brine concentration..... % and replaced every ..... days)
□ In the mixture (Salt quantity.....g\Kg)

Packaging Type
□ None □ Vacuum
□ Protective atmosphere

□ Milk reception and collection	Storage temperature..... °C Estimated average duration..... hours
□ Milk thermisation/ heating	Treatment temperature:..... °C Duration:..... □ seconds □ minutes
□ Coagulation (Curd formation)	Temperature:..... °C Duration:..... minutes
□ Curd set	Temperature..... °C Duration:..... minutes
□ Curd breaking	Curd grain size: □2mm (rice) □ 4mm (wheat) □ 6mm (hemp seed) □ 8mm (corn) □ 10mm (hazelnut) □ 12mm (walnut)
□ Extraction and molding	Wheel/block size: Diameter..... cm Heel..... cm in height
□ Pressing	
□ Salting	Length of salting phase\brine..... hours
□ Smoking	Temperature:..... °C Duration:..... minutes
□ Ripening	Temperature:..... °C Duration:..... days Humidity:.....
□ Storage	Temperature:..... °C Average duration:.....days
□ Packaging	Established storage temperature: ..... °C Stated shelf life:.....days

*Tick the box for each step envisaged by the production process and report the process specifications in the dedicated spaces shown on both sides of the flowchart

Supporting information S2 data sheets

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Farm management and husbandry practices

Most farms were small to medium sized (Table I), 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 grazing 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.

Table I. *Information regarding the farm and dairy management*

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 (Liters/week)	Sheep	Min	18
		Mean	567
		Median	350
		Max	4200
	Goat	Min	35
		Mean	419
		Median	210
		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 (6.4)
	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 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)

[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

Lactating animals were mainly milked twice a day and farmers either resorted 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, was applied regularly by 44.4% of farmers. The freshly collected milk was then conserved in a cooling tank or an insulated milk bin prior to processing; nonetheless, about 1.6% of the farms processed the milk immediately after collection and therefore did not require any conservation systems.

Milk was 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 produced up to three different kinds of sheep and/or goat milk cheeses and finished products were mostly sold directly to consumers (93.4%) and/or marketed through local retailers and shops (55.2%).

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Cheese manufacturing practices

Information were collected about the cheesemaking process of 130 types of cheeses (Table II) 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.

Table II. *Information associated with the cheese production process*

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 thermisation/ 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 (min)	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 (min)	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

[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.

After collecting the milk, most farmhouse dairies kept 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 was initiated by heating the milk and adding the starter culture. The average temperature and duration for the heating step was 39.8°C and 17.4 minutes respectively. The most used starters were 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 did not employ any starter cultures for milk acidification and therefore relied on the native microflora already present in the milk. Rennet or coagulants were added afterwards in order to start the coagulation

process. 80.6% of dairies used commercial rennet (n=75), 17.3% used their own-produced ones and 2.1% used both types alternatively. The main source of rennet (n= 69; 90.8%) was 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 employed microbial/artificial (n=6; 7.9%) or vegetable (n=1; 1.3%) coagulants.

Coagulation of milk occurred at temperatures between 20 and 60°C (median 37°C) and heating was usually maintained for 25 – 30 minutes to allow the complete formation of curd. Once it was formed, curd was left to set for another 25 – 30 minutes while maintaining the same heating temperature. Afterwards, curd was 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 was left for a certain amount of time to mature (55.3% of farmhouse dairies) before it was extracted and put into moulds that varied either in shape or dimension depending on the type of cheese that was being manufactured (Table 2).

This step was 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 flavour. 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 were 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 was short to medium in most cheeses (less than 89 days at the 75°P). The temperature in the ripening environments varied between 2 and 20°C with the median temperature being at 10°C while relative humidity varied 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 were soft, 46.2% were semi-soft and just 10.3% were hard cheeses.

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

Most products were sold unpackaged (68.4%), 15.3% were vacuumed and only 0.76% were 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 was below 90 days; the maximum declared duration was 180 days in 13.5% of cheeses.

Discussion and Conclusion

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 underestimation 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 (van den Brom *et al*. 2020).

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 (FDA HC 2015, Condoleo *et al*. 2017).

As predicted, most of the farmhouse dairies were small to medium based on the size of the flock; they were mainly subsistence-oriented family type farms that relied on selling their own products 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 were able to produce remarkable amounts of milk and its derivatives, which might represent a significant source of exposure to consumers. The activity usually involved few workers that were probably family members and most of the dairies operated since many years.

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 parlours 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 relied 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 (Oliver *et al*. 2005). 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 faecal material, fleece, soil etc.

Many farmers used 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. 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 was 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 were 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, but it is important to underline that the contamination with harmful microorganisms such as *Listeria monocytogenes* might also occur after this production process, therefore cheeses made with pasteurized milk can still represent a risk to consumers (Gérard *et al*. 2018).

The standard pasteurization 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 (Regulation (EC) 853/2004).

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 (Pearce *et al*. 2012) .

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 (Maipa *et al*. 1993, Rey *et al*. 2006, Gameiro *et al*. 2007, Stephan *et al*. 2008).

The survival and growth of pathogens might also be influenced by the pH and water activity of cheeses but these parameters where not investigated in this study. Few studies from other Italian regions investigated about the farming practices of farmhouse dairies (Carloni *et al*. 2016, Sandrucci *et al*. 2019) and reported similar results but, unlike our study, did not collect data about the cheesemaking process. Some of the data were missing because the surveyed farmers were unable to supply all the requested information or were unaware of it since the production of farmhouse cheeses is not an officially standardized process.

Another critical issue was linked to the fact that the reported data were not based on analytical measurements but only on the farmers 'declaration. Nevertheless, the data suggest that a certain attention should be addressed towards the small-scale artisan cheese makers of these popular raw milk cheese products. Some non-optimal aspects linked to milk collection, storage and cheese manufacturing were reported but it is important to underline that further studies are needed to verify and evaluate their effects on the hygienic quality and safety of the final products.

The survey allowed to collect data in the most detailed manner and some of it was already employed in a recent risk assessment study that evaluated the risk

of acquiring STEC through the consumption of raw sheep's milk cheeses (Condoleo *et al*. 2022). The present study, although being limited to a relatively small geographic area, could be representative, with due precautions, of different realities within the Mediterranean Region.

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References

Bemrah N., Sanaa M., Cassin M. H., Griffiths M. W., & Cerf, O. 1998. Quantitative risk assessment of human listeriosis from consumption of soft cheese made from raw milk. Prev Vet Med, 37, 129-45. https://doi: 10.1016/s0167-5877(98)00112-3.

Caja G. 1990. L'évolution des systèmes de production ovin-lait dans le bassin méditerranéen. In Bougler, J.(Ed.), Tisserand, J.-L.(Ed.). Les petits ruminants et leurs productions laitières dans La Région Méditerranéenne : CIHEAM Options Méditerranéennes : Série A. Séminaires Méditerranéens, 12, 31-38.

Campagnollo F. B., Gonzales-Barron U., Pilão Cadavez V. A., Sant'Ana A. S. & Schaffner D. W. 2018. Quantitative risk assessment of Listeria monocytogenes in traditional Minas cheeses: The cases of artisanal semi-hard and fresh soft cheeses. Food Control, 92, 370-379.https://doi.org/10.1016/j.foodcont.2018.05.019

Carloni E., Petruzzelli A., Amagliani G., Brandi G., Caverni F., Mangili P., Tonucci F. 2016. Effect of farm characteristics and practices on hygienic quality of ovine raw milk used for artisan cheese production in central Italy. Anim Sci J, 87, 591–599.

Choi K., Lee H., Lee S., Kim S. & Yoon Y. 2016. Cheese microbial risk assessments - A review. Asian Australas J Anim Sci, 29, 307-314.https://doi.org/10.5713/ajas.15.0332.

Condoleo R., Mezher Z., Marozzi S., Guzzon A., Fischetti R., Senese M., Sette S. & Bucchini L. 2017. Risk assessment of human listeriosis from semi-soft cheeses made from raw sheep's milk in Lazio and Tuscany (Italy). Risk Anal, 37, 661-76. https://doi.org/10.1111/risa.12649

Condoleo R., Palumbo R., Mezher Z., Bucchini L., Taylor RA. 2022. Microbial risk assessment of Escherichia coli shiga-toxin producers (STEC) in raw sheep's milk cheeses in Italy. Food Control, 137, 108951. https://doi.org/10.1016/j.foodcont.2022.108951.

Delhalle L., Ellouze M., Yde M., Clinquart A., Daube G. & Korsak N. 2012. Retrospective analysis of a Listeria monocytogenes contamination episode in raw milk goat cheese using quantitative microbial risk assessment tools. J Food Prot, 15, 2122-2135.

ttps://doi.org/10.4315/0362-028X.JFP-12-074.

EFSA and ECDC (European Food Safety Authority and European Centre for Disease Prevention and Control). 2021. The European Union One Health 2020 Zoonoses Report. EFSA Journal,19.https://doi.org/10.2903/j.efsa.2021.6971.FAOSTAT. 2019. Food and agriculture statistic database.

[Accessed 2019 May 23]. Available from URL: http://www.fao.org/statistics/en/.

Food and Drug Administration (FDA), & Health Canada (HC). 2015. Joint FDA / Health Canada quantitative assessment of the risk of listeriosis from soft-ripened cheese consumption in the United States and Canada: Interpretive summary. Available from URL: https://www.fda.gov/media/90493/download.

Gameiro N., Ferreira-Dias S., Ferreira M. & Brito L. 2007. Evolution of listeria monocytogenes populations during the ripening of naturally contaminated raw ewe's milk cheese. Food Control, 18, 1258-62. https://doi.org/10.1016/j.foodcont.2006.08.002.

Gérard E., El-Hajjaji S., Niyonzima E., Daube G. & Sindic M. 2018. Prevalence and survival of Listeria monocytogenes in various types of cheese - A review. Int J Dairy Technol, 71, 825-843. https://doi.org/10.1111/1471-0307.12552

Gonzales-Barron U., Gonçalves-Tenòrio A., Rodrigues V. & Cadavez V. 2017. Foodborne pathogens in raw milk and cheese of sheep and goat origin: a meta-analysis approach. Curr Opin Food Sci, 18, 7–13. https://doi.org/10.1016/j.cofs.2017.10.002

Istituto di Servizi per il Mercato Agricolo Alimentare (ISMEA). 2018. La competitività della filiera ovina in Italia. Rete Rurale Nazionale 2014-2020. Available from URL: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/19086

Istituto Nazionale di Statistica (ISTAT). 2018. Agricoltura: Latte e prodotti lattiero caseari; consistenze degli allevamenti. [Accessed 2019 October 1]. Available from URL: iLindqvist R., Sylvén S. & Vågsholm I. 2002. Quantitative microbial risk assessment exemplified by Staphylococcus aureus in unripened cheese made from raw milk. Int J Food Microbiol, 78,155-70. https://doi.org/10.1016/s0168-1605(02)00237-4

Maipa V., Papadopoulou C., Pappas C., Dimitriou D., Voutsinas L. & Malatou H. 1993. Survival of Salmonella enteritidis during the manufacture of feta cheese made of pasteurized ewe's milk. Zentralbl Mikrobiol, 148, 66-73. https://doi.org/10.1016/S0232-4393(11)80082-X

Ministero delle politiche agricole alimentari e forestali (MIPAAF). 2022 (a) Ventiduesima revisione dell'elenco dei prodotti agroalimentari tradizionali. [Accessed 2022 June 28]. Available from URL: https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/17979

Ministero delle politiche agricole alimentari e forestali (MIPAAF). 2022 (b) Elenco dei Prodotti DOP, IGP e STG (aggiornato 21 Giugno 2022). [Accessed

2022 June 28]. Available from URL: https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/2090

Oliver S. P., Jayarao B. M. & Almeida R. A. 2005. Foodborne pathogens in milk and the dairy farm environment: Food safety and public health implications. Foodborne Pathog Dis, 2, 115-29. https://doi.org/10.1089/fpd.2005.2.115

Pearce L. E., Smythe B. W., Crawford R. A., Oakley E., Hathaway S. C. & Shepherd J. M. 2012. Pasteurization of milk: The heat inactivation kinetics of milkborne dairy pathogens under commercial-type conditions of turbulent flow. *J Dairy Sci*, 95, 20-35. https://doi.org/10.3168/jds.2011-4556

Perrin F., Tenenhaus-Aziza F., Michel V., Miszczycha S., Bel N. & Sanaa M. 2015. Quantitative risk assessment of haemolytic and uremic syndrome linked to O157:H7 and non-O157:H7 shiga-toxin producing Escherichia coli strains in raw milk soft cheeses. Risk Anal, 35, 109-28. https://doi.org/10.1111/risa.12267

Pulina G., Milán M. J., Lavín M. P., Theodoridis A., Morin E., Capote J., Thomas D.L., Francesconi A.H.D. & Caja G. 2018. Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *J Dairy Sci*, 101, 6715-29. https://doi.org/10.3168/jds.2017-14015

Rey J., Sanche S., Blanco J. E., de Mendoza J. H., de Mendoza M. H., Garcia A, Gil C., Tejero N., Rubio R. & Alonso J. M. 2006. Prevalence, serotypes and virulence genes of shiga toxin-producing Escherichia coli isolated from ovine and caprine milk and other dairy products in Spain. Int J Food Microbiol, 107, 212-7. https://doi.org/10.1016/j.ijfoodmicro.2005.08.025

Sanaa M., Coroller L. & Cerf, O. 2004. Risk assessment of listeriosis linked to the consumption of two soft cheeses made from raw milk: Camembert of Normandy and brie of Meaux. Risk Anal, 24, 389-99. https://doi.org/10.1111/j.0272-4332.2004.00440.x

Sandrucci A., Bava L., Tamburini A., Gislon G. & Zucali M. 2019. Management practices and milk quality in dairy goat farms in Northern Italy. Italian J Anim Sci, 18, 1–12.

Stephan R., Schumacher S., Corti S., Krause G., Danuser J. & Beutin, L. 2008. Prevalence and characteristics of shiga toxin-producing Escherichia coli in Swiss raw milk cheeses collected at producer level. *J Dairy Sci*91, 2561-5. https://doi.org/10.3168/jds.2008-1055

Valík Ľ. & Medveďová A. 2013. Exposure and risk assessment of Staphylococcus aureus in food chain in Slovakia. Potr S J F Sci, 7, 58-62. https://doi.org/10.5219/263

van den Brom R., de Jong A., van Engelen E., Heuvelink A. &Vellema P. 2020. Zoonotic risks of pathogens from sheep and their milk borne transmission. Small Rumin Res, 189, 106123.

Verraes C., Claeys W., Cardoen S., Daube G., De Zutter L., Imberechts H., Herman L. 2014. A review of the microbiological hazards of raw milk from animal species other than cows. Int Dairy J, 39, 121-30. https://doi.org/10.1016/j.idairyj.2014.05.010

Verraes C., Vlaemynck G., Van Weyenberg S., De Zutter L., Daube G., Sindic M. & Herman L. 2015. A review of the microbiological hazards of dairy products made from raw milk. Int Dairy J, 50, 32-44. https://doi.org/10.1016/j.idairyj.2015.05.011