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PAPER

Effects of season on the quality of Garfagnina goat milk

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ABSTRACT

The Garfagnina goat is an endangered native goat population from Italy. This study aims to give a contribution to the milk quality assessment of the native goat during the two productive seasons, spring and summer, and to verify the relationships between some meteorological data and physiological and milk quality parameters. Individual milk samples were taken in the two seasons. Physiological parameters and meteorological data were also registered. All the milk samples were measured for volume and analysed for: dry matter, total nitrogen, casein, ash, lactose, fat, milk fatty acid (FA) composition, number and diameter of the fat globules, and rheological parameters. There were not differences in the average diameter of the milk fat globules ($2.27 \pm 0.28\,\mu m$) and in milk gross composition between the two seasons, except for lactose which was significantly lower in summer. During summer a significant increase in some long-chain FAs such as CLA c9,t11, C18:1 t11, C18:0, C18:3 n3, C20:0, C22:0, C22:2 was observed, whereas short-chain FAs (C6:0, C8:0, C10:0), which are responsible for the development of unpleasant aromas, as well as monounsaturated C16:1, C17:1 c9, C20:1, C22:1 and polyunsaturated FAs C20:2, C20:3 n3 decreased. The average PUFA n6/PUFA n3 ratio was 1.7 and the lowest values were recorded in summer. In summer a worsening of the clot, which was less firm, was found. Environmental parameters were found to be linked to the milk FAs, while heart rate and skin temperature were negatively linked to milk yield and lactose, respectively.

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Introduction

In marginal hilly and mountainous areas, sheep and goats are reared in pasture-based production systems. In these types of farming systems, milk production is highly seasonal and the quality of milk is positively influenced by fresh grass-based diets. In fact, grazing improves the milk's characteristics, also due to the increased concentrations of polyunsaturated fatty acids (PUFA) in milk (e.g. omega-3 FA and conjugated linoleic acid), which are known to have many beneficial effects on human health (Biondi et al. 2008; Renna et al. 2012; Albenzio et al. 2016). Omega-3 (n-3) fatty acids (FAs) are involved in the development of brain and retinal tissues and in the progression and prevention of human pathologies, including heart disease and some cancers (Blondeau 2016). Conjugated linoleic acid (CLA) has been reported to reduce the risk of cancer, cardiovascular diseases, diabetes, and obesity, as well as boosting the immune system (Wang & Lee 2015; Hennessy et al. 2016).

The enhanced milk quality provided by the pasture could also be interesting for the economy of the livestock sector, since the market is oriented to foods with health benefits. In addition, although weather and climate affect both grazing and animal productive performances, local breeds have experienced low selection pressure and still have physiological characteristics which contribute to a better adaptation to their native environment. These characteristics favour the welfare, as well as the productive and reproductive efficiency of the animals (Bernabucci et al. 2010).

Although in recent years there has been an increasing interest in the safeguard of biodiversity, in the preservation of marginal areas and in the nutritional quality of food, most local European breeds have been still suffering of critical decrease in numbers, mainly as

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a consequence of agriculture industrialisation and the introduction of more productive selected breeds. The Garfagnina goat is an endangered native goat population from Italy with about 800 individuals and fewer than 700 breeding females reared (Data Asso.Na.Pa. 2013); the first zootechnical overview of this goat was carried out by Martini et al. (2010). The breed is reared in mountainous areas, and the farming systems are based on the exploitation of native pasture; the breeding is mainly intended to milk production for local cheeses manufacturing.

This study aims to give a contribution to the milk quality assessment of native Garfagnina goat during the two productive seasons, spring and summer, and to verify the relationships between some meteorological data and physiological and milk quality parameters.

Materials and methods

Animals and sampling

A total of 48 individual milk samples from 24 multiparous Garfagnina goats were taken from the morning milking during two seasons: spring (the end of March 2014) and summer (the beginning of July 2014). The animal were reared in a farm using semi-extensive farming practices and located in Central Italy at an altitude of ∼634 metres above sea level (latitude: 44° 05′ 25″; longitude: 10° 37′ 41″).

During the whole year the goats grazed in the same pasture area, mainly consisting of woodland pasture. It was a natural pasture characterised by deciduous forests of *Fagus* spp. and *Castanea* spp. with ground cover mainly of Graminaceae (*Bromus* spp, *Festuca arundinacea, Dactylis glomerata*) and Asteraceae (*Helichrysum stoechas*). Leguminosae were present in small quantity and were mainly annual medicks (*Medicago* spp) and clovers (*Trifolium* spp). In addition, shrubs of *Arbutus unedo* and *Juniperus communis L*. were present. The goats were in the pasture between morning and evening milking, whereas they were confined overnight. Few feed integration with hay was given during unfavourable periods of the year (winter). The lambing period took place once generally in January and February. The suckling period was about 60 days. At the time of the first sampling the goats were about 60 days in milk (DIM), while at the second one they were about 150 DIM. The animals were hand-milked. On the sampling day, physiological parameters and meteorological data were registered twice (in the morning and in the afternoon) and the daily mean of the registrations was calculated.

Milk analysis

All the milk samples were measured for volume and analysed for dry matter (DM), total nitrogen, casein, ash (AOAC 1990), lactose (Foss Electric, MilkoScan Foss Electric), gravimetric fat determination and milk FA analysis after fat extraction by Rose–Gottlieb's method (IDF-FIL IDF Standard 1D 1996) followed by methylation according to Christie (1982).

Milk FA analysis was performed using a Perkin Elmer Auto System (Perkin Elmer, Norwolk, CT) equipped with a flame ionisation detector and a capillary column (60 m × 0.25 mm; film thickness 0.25 mm; ThermoScientific (Thermo Fisher Scientific Inc., Waltham, MA) The helium carrier gas flow rate was 1 mL min^{-1}. The oven temperature programme was as follows: level 1, 50 °C held for 2 min; level 2, 50–180 °C at 2 °C·min^{-1} and then held for 20 min; level 3, 180–200 °C at 1 °C·min^{-1} and then held for 15 min and finally level 4, 200–220 °C at 1 °C·min^{-1} and then held for 30 min. The injector and detector temperatures were set at 270 °C and 300 °C, respectively. Individual FAs were identified by comparing their retention times with those of an authenticated standard FA FIM_FAME mix (Restek Corporation, 110 Benner Circle, Bellefonte, PA) and quantified as a percentage of total detected FA.

Morphometric analysis of milk fat globules

Diameter (μm) and the number of fat globules per mL of milk were determined directly in each sample of fresh milk as described by Martini et al. (2013). In brief, each sample of fresh milk was diluted 1:100 in distilled water, and was stained by adding a 0.1% solution of Acridine Orange (Sigma-Aldrich, Milan, Italy) in a 0.1 M Phosphate buffer (pH 6.8); the ratio of milk and staining solution was 10% (v/v). The analysis was performed by a fluorescence microscope Leica Ortomat Microsystem (Leika SPA, Milan, Italy) equipped with a camera (TiEsseLab, Milan, Italy) and an Image software TS view 2.0 (C & A Scientific, Manassas, VA).

The globules were grouped into three size categories: small globules (SG) with a diameter <2 μm, medium-sized globules (MG) with a diameter of 2–5 μm, and large globules (LG) with a diameter >5 μm.

Lactodinamographic analysis

The milk's rheological parameters were analysed by Formagraph (Italian Foss Electric, Padova, Italy) without pH standardisation. As reported by Martini et al. (2008), samples were tested at 35 °C using 0.2 mL of an 8% aqueous solution of Hansen rennet for 10 mL of milk.

The following parameters were recorded:

a. r = clotting time: the time (min) from the addition of rennet to the beginning of coagulation;
b. k20 = curd firming time: the time (min) needed until the curd is firm enough to be cut, i.e. the width of the diagram equals 20 mm;
c. a30 = curd firmness (mm): measured 30 minutes after the addition of the rennet.

Meteorological measurements

Climatic data regarding the relative humidity and air temperature were obtained by thermal microclimate data loggers HD32.1 (DeltaOhm Srl, Padua, Italy) equipped with probes to detect dry bulb, wet bulb and black globe temperatures. The loggers were located close to the animals and the following meteorological data were recorded:

a. Dry bulb temperature (DBT): air temperature measured by a thermometer freely exposed to the air, but shielded from radiation and moisture;
b. Wet bulb temperature (WBT): humid temperature measured by a natural ventilation wet bulb probe;
c. Mean radiant temperature (MRT): globe thermometer temperature measured by a globe thermometer probe;
d. Relative humidity (RH): relative humidity measured by a combined humidity/temperature probe;
e. Temperature–humidity index (THI): obtained using the formula: $THI = (0.8 \times AT + (RH\ \%/100) \times (AT - 14.4) + 46.4)$ (Thom 1959). THI is a single value representing the combined effects of air temperature and humidity. This index was developed as a weather safety index to monitor and reduce heat-stress-related losses (Bohmanova et al. 2007)
f. Wet bulb globe temperature index (WBGTI): represents the heat stress at which an animal is exposed and combines three measurements (WBT–MRT–DBT) in the following formula $WBGT = 0.7\ WBT + 0.2\ MRT + 0.1\ DBT$.

Physiological parameters

After each milking, once the animals had been moved into the shade, the following parameters were recorded:

1. Heart rate (HR): estimated by observing thoracic-abdominal movements for 1 min and expressed in beats per minute;
2. Respiratory rate (RR): estimated by observing thoracic-abdominal movements for 1 min and expressed in movements per minute;
3. Skin temperature (ST): measured with a digital infra-red thermometer Minipa MT-350 (São Paulo, Brazil) at a minimum of 10 cm and a maximum distance of 50 cm from the surface at three different points on the animal's body: thorax, left flank, and udder, ST was determined by the average of these three values. The skin of the animals was dry;
4. Rectal temperature (RT): estimated using a veterinary digital thermometer, with a range up to 44 °C, and obtained directly from the rectal wall.

Measurements were made twice a day at morning (9:00 h) and at afternoon (15:00 h).

Statistical analysis

Milk and physiological data were analysed with the Statistical Analysis System (SAS 2004) using GLM procedures, and the Tukey test for significant variables was applied. The following mathematical model was used: $y_{ij} = \mu + S_i + e_{ij}$ in which: y_{ij} is the dependent variable; μ is the overall mean; S_i is the fixed effect of season (i = summer or spring) and e_{ij} is the random error with mean 0 and variance o'^2. Pearson's correlations among milk and climate data were calculated using the CORR procedure of the Statistical Analysis System (SAS 2004).

Results

Descriptive statistics of meteorological measurements are shown in Table 1. The average morning milk yield of Garfagnina goats was 441.55 ± 118.74 mL, and the average composition was as follows: DM 10.86 ± 1.12%;

Table 1. Descriptive statistics of meteorological measurements.

Item	Mean ± SD	
	Spring	Summer
DBT, °C	13.46 ± 4.53	21.87 ± 1.03
WBT, °C	8.70 ± 1.63	14.97 ± 0.34
RH, %	58.7 ± 18.8	73.3 ± 5.0
THI	56.58 ± 4.09	58.44 ± 0.91

SD: standard deviation; DBT: dry bulb temperature; WBT: wet bulb temperature; RH: relative humidity; THI: Temperature Humidity Index.

total nitrogen 2.82 ± 0.40%; casein 71.58 ± 8.00% of total nitrogen, fat 2.90 ± 0.83, lactose 4.41 ± 0.21%, ash 0.73 ± 0.04%.

Statistically significant differences of milk qualitative characteristics, FA profile, lactodinamographic and physiological parameters between seasons are reported in Table 2. Milk yield and gross composition showed no significant differences between the two seasons considered, except for lactose, which was significantly lower in the summer. As regards the morphometric analysis of the fat, the average diameter of milk fat globules (2.27 ± 0.28 μm) remained constant in both the periods considered.

Saturated fatty acids (SFA) from C6 to C12 decreased significantly during the summer, as well as monounsaturated (MUFA) C16:1, C17:1 c9, C20:1, and C22:1 and PUFA C20:2, C20:3 n3, whereas the following long-chain FAs increased significantly: C18:0, C18:1 t9, C18:1 t11, CLA c9,t11, C18:2 t9t12, C18:3 n3, C20:0, C22:0, C22:2.

The average PUFA n6/PUFA n3 ratio was 1.7 with higher values in spring. Lactodinamographic studies highlighted better cheese-making characteristics in spring, due to a greater consistency of the clot (a30), however in spring there was less reactivity to rennet, as proved by the significantly longer clot formation time (r) registered. Significant lower HR and slightly higher RT in summer were registered, whereas no differences in the other physiological parameters were observed.

As reported on Table 3, the milk parameters related with environmental parameters were lactose, fat and LG. In particular, there were negative correlations between DBT, WBT, THI and lactose and between DBT, THI and LG, whereas positive correlations were highlighted between WBT, THI, WBGTI and fat percentage. As regards the physiological parameters, negative correlations were observed between HR and milk yield (Table 3). At the same time, ST was negatively correlated with the lactose content.

We also found negative correlations between meteorological data (DTB, WBT, THI, WBGTI) and lactodinamographic parameters (r and a30). Climate parameters were related to some FAs, and negative correlations were recorded between DBT, WBT, THI, WBGTI and SFA with a shorter length chain than C13:0 as well as with C20:2 and C22:1 and also between DBT, WBT, THI and C16:1 and C17:1 c9 (Table 4).

The table of correlations shows the positive relationships among the FAs with a chain length equal or greater than 18 (C18:1 t9, C18:1 c9, C18:2 n6t, C20:0 C20:1, C22:0 and C22:2), and the climate parameters (WBT, DBT, THI) and between RH and some short-chain FAs (C6:0, C8:0 and C10:0). THI and WBGTI were found to be positively related to C15:0.

Discussion

The detected temperature values and RH indicate a temperate microclimate and as a whole hygrothermal comfort conditions of the animals (Ohnstad 2016). These are confirmed by the calculated THI values. In fact, as reported by Silanikove (2000), THI values lower of 70 indicates a thermal comfort condition.

Garfagnina milk yield was lower compared to other breeds such as Alpine and Saanen, but similar to a Sicilian autochthonous breed, the Nebrodi goats (Zumbo et al. 2004). In addition, our total nitrogen values were similar to the Grey goat, whereas fat was lower (Cornale et al. 2014).

The lack of differences in milk yield and gross composition between the two seasons are in agreement with another study carried out on native goats in the Mediterranean area (Kondyli et al. 2012).

The average size of the globules was lower than other dairy species (Martini et al. 2016). So far, the studies carried out on the effect of the season on the average diameter of MFGs are few and related to other species (sheep and buffalo) (Asker et al. 1978; Martini et al. 2008). A larger average diameter was measured in bulk ewe milk in spring–summer compared to autumn–winter (Martini et al. 2008), in any case this feature should be further investigated.

As far as FA profile, it was more similar to some cosmopolite (Alpine and Saneen) goats and an Italian local goat (Grey goat of Lanzo Valleys) (Cornale et al. 2014; Maroteau et al. 2014), than Asian breeds (Kamori and Pateri goat) (Talpur et al. 2009). In particular, FA profile showed similar average SFA, MUFA, PUFA to the Grey goat of Lanzo Valleys (Cornale et al. 2014).

The observed FA trends could be in part linked to the changes in the pasture in the two seasons. In fact, the changes in milk fat composition is dependent on complex interactions between the composition of basal diet (forages, starchy concentrates), the FA profile of the diet and the lactation phase (Chilliard et al. 2014).

In addition, with respect to human health, the trends in FAs highlighted a better FA profile in the summer, particularly in terms of CLA c9,t11 and the CLA-precursor C18:1 t11. These two FAs have benefits in terms of their functional properties and the role they play in preventing atherosclerosis (Hennessy et al. 2016). CLA are healthy component of milk fat, predominantly found in ruminant milk, and CLA c9,t11

Table 2. Mean and mean square error of milk quality, cheese making aptitude, milk fatty acids, and physiological parameters in spring and summer.

	Seasons			
	Spring ($n = 24$)	Summer ($n = 24$)	Mean square error	Significance
Dry Matter, %	11.59	11.58	1.24	
Fat, %	2.85	3.30	0.67	
Protein, %	2.96	2.76	0.14	
Casein, % of protein	81.34	85.17	48.67	
Ash, %	0.74	0.73	0.001	
Lactose, %	4.52	4.15	0.04	*
r, min	10.26	7.73	2.85	*
k20, min	2.20	1.79	3.05	
a30, mm	13.92	9.68	4.74	*
MFG diameter, μm	2.30	2.25	0.27	
Number*10^9, mL	5.03	4.21	1.39	*
SG, %	47.92	47.33	181.2	
MG, %	48.90	49.74	160.9	
LG, %	3.12	1.69	4.78	*
C4:0, % of the total detected FAs	2.26	2.05	0.33	
C6:0	2.52	2.23	0.26	*
C8:0	3.15	2.59	0.43	*
C10:0	10.33	8.64	1.39	*
C11:0	0.11	0.07	0.07	*
C12:0	3.85	3.18	0.63	*
C13:0	0.11	0.09	0.04	
C14:0	9.00	9.17	1.03	
C14:1c9	0.29	0.32	0.07	
C15:0	0.97	1.13	0.12	*
C15:1c10	0.22	0.22	0.05	
C16:0	24.98	25.91	2.67	
C16:1c9	0.46	0.33	0.09	*
C17:0	0.84	0.92	0.18	
C17:1c9	0.33	0.24	0.08	*
C18:0	14.54	16.35	3.19	*
C18:1t9	0.17	0.24	0.06	*
C18:1t11	1.26	1.76	0.44	*
C18:1c9	19.15	18.09	2.70	
CLAc9,t11	0.35	0.53	0.17	*
C18:2t9,t12	0.42	0.53	0.12	*
C18:2c9,c12	1.86	2.1	0.09	
C18:3n3	1.11	1.39	0.04	*
C18:3n6	0.16	0.13	0.22	
C20:0	0.21	0.41	0.10	*
C20:1c11	0.06	0.03	0.22	*
C21:0	0.19	0.17	0.18	
C20:2c11,c14	0.04	0.02	0.02	*
C20:3 n3	0.04	0.03	0.03	*
C20:3 n6	0.05	0.02	0.09	
C20:4n6	0.01	0.01	0.01	
C22:0	0.13	0.25	0.08	*
C22:1c13	0.15	0.10	0.05	*
C20:5n3	0.02	0.006	0.04	
C23:0	0.10	0.08	0.03	
C22:2c13,c16	0.06	0.10	0.03	*
C24:0	0.11	0.15	0.08	
C24:1c15	0.02	0.02	0.01	
C22:5n3	0.17	0.18	0.04	
C22:6n3	0.12	0.13	0.04	
SFA	73.40	73.39	2.94	
MUFA	22.12	21.36	2.89	
PUFA	4.41	5.18	0.48	
n6 PUFA/n3 PUFA	1.74	1.66	0.72	*
HR, beat/min	88.9	73.9	13.2	*
RR, mov/min	28.2	32.4	9.70	
ST, °C	27.5	28.5	3.14	
RT, °C	38.2	38.4	0.33	*

r: clotting time, the time (min) from the addition of rennet to the beginning of coagulation; k20: curd firming time, the time (min) needed until the curd is firm enough to be cut, i.e. the width of the diagram equals 20 mm; a30: curd firmness (mm), measured 30 minutes after the addition of rennet; MFG: milk fat globules; SG: small globules (diameter <2 μm); MG: medium globules (diameter from 2 to 5 μm); LG: large globules (diameter >5 μm); SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; HR: heart rate; RR: respiratory rate; ST: skin temperature; RT: rectal temperature.
*$p \leq .05$.

average content in Garfagnina goat milk is 0.4%, as reported by Cossignani et al. (2014) in goat milk.

CLA c9,t11 synthesis depends on the concentration of its precursor C18:1 t11 and on Δ9-desaturase activity within the mammary gland. The grazing season as well as lactation stage affects the Δ9-desaturase expression in goat. Diets containing PUFA induce changes in Δ9 desaturase gene expression in goats and these changes are greater in goats compared with cows (Chilliard et al. 2014; Tudisco et al. 2014).

Our results about CLA c9,t11 are also in agreement with Tudisco et al. (2014) who reported highest levels of total CLA in goat milk in summer (June and July) compared to spring (April), as consequence of the highest levels of pasture C18:2 and C18:3.

Other studies on grazing goats in Mediterranean pastures are not in complete agreement regarding the isomers CLA content in different seasons. Some authors have not observed significant variations in CLA isomers according to the season (Ataşoğlu et al. 2009), whereas others found decrease in summer compared to spring (La Terra et al. 2013). The differences between the studies are probably due to the different rearing environments and to the diversity of pastures.

Regarding C18:3 n3 (α-linolenic acid, ALA), the average value is similar to the findings of Cornale et al. (2014) on another Italian native goat. Furthermore, there are different results in the literature about ALA content in goat milk depending chemical parameters of ingested plants (lignine, crude protein, FAs, concentration of ALA on the pasture) (Park et al. 2007; Iussig et al. 2015). A higher ruminal bypass of dietary ALA has been suggested in goats compared to cow (Cornale et al. 2014) and ALA was also found positively correlated with the type and relative abundance of dietary polyphenols (Kälber et al. 2011).

The average PUFA n6/PUFA n3 ratio was similar to the results shown by Pajor et al. (2014) for extensively grazing goat. In the past different values of PUFA n6/PUFA n3 for a healthy diet have been proposed. However, the most recent literature only sets reference values just for the intake of some essential FAs (EFSA (NDA) 2010; Vannice & Rasmussen 2014). Although this issue is not yet fully clarified, a recent review reports that high PUFA n6/PUFA n3 ratio in human might be associated with weight gain, and recommends a balanced ratio of 1–2/1 in food (Simopoulos 2016).

In addition, with regard to the content of short-chain FA in the analysed milk, the lower content of C6:0, C8:0, C10:0 during the summer months could result in a modification in the organoleptic characteristics of milk. In fact, short-chain free FAs play a role in the 'goaty flavours' in goat dairy products (Park 2001).

The clot consistency decreased in the summer, suggesting worse coagulation properties. Physiological parameters were generally within the reference values.

Table 3. Correlations among milk yield, quality, cheese making aptitude, physiological and environmental parameters (n = 48)[a].

Variable	Milk Yield	Fat	Lactose	LG, %	r	a30
DBT	–	–	−0.688**	−0.303*	−0.382**	−0.310*
WBT	–	0.315*	−0.673**	–	–	−0.306*
THI	–	0.345	−0.680**	−0.319*	–	−0.319*
WBGTI	–	0.306*	–	–	−0.281*	−0.310*
ST	–	–	−0.417*	–	–	–
HR	−0.443**	–	–	–	–	–

DBT: dry bulb temperature; WBT: wet bulb temperature; THI: temperature–humidity index; WBGTI: wet bulb globe temperature index; ST: skin temperature; HR: heart rate; LG: large globules (diameter >5 μm); r: clotting time, the time (min) from the addition of rennet to the beginning of coagulation; a30: curd firmness (mm), measured 30 minutes after the addition of rennet.
[a]Only significant correlations are reported in the table.
*$p \leq .05$; **$p \leq .01$.

Table 4. Correlations among milk fatty acid profile, physiological and environmental parameters[a].

Variable	C6:0	C8:0	C10:0	C11:0	C12:0	C13:0	C15:0	C16:1	C17:1c9
WBT	−0.424**	−0.464**	−0.439**	−0.391**	−0.450**	−0.445*	–	−0.617**	−0.539**
DBT	−0.403**	−0.403**	−0.404**	−0.348*	−0.400**	−0.318*	–	−0.540**	−0.492**
RH	0.350*	0.320*	0.291*	–	–	–	–	–	–
THI	−0.421**	−0.450**	−0.429**	−0.371*	−0.428**	−0.428**	0.481**	−0.583**	−0.520**
WBGTI	−0.397**	−0.420**	−0.415**	−0.385**	−0.429**	−0.356*	0.460**	–	–

Variable	C18:0	C18:1t9	C18:1c9	C18:2 n6t	C20:0	C20:1	C20:2	C22:0	C22:1	C22:2
WBT	–	0.491**	0.500**	0.410**	0.656**	0.571**	−0.460**	0.589**	−0.518**	0.526**
DBT	–	0.424**	0.438**	0.369*	0.584**	0.531**	−0.496**	0.518**	−0.528**	0.467**
RH	–	–	–	–	−0.311*	–	0.455**	–	0.388**	–
THI	0.305*	0.462**	0.473**	0.391**	0.627**	0.560**	−0.487**	0.558**	−0.532**	0.502**
WBGTI	–	–	–	0.350*	0.602**	0.527**	−0.472**	0.523*	−0.516**	0.473**

WBT: wet bulb temperature; DBT: dry bulb temperature; RH: relative humidity; THI: temperature humidity index; WBGTI: wet bulb globe temperature index.
[a]Only significant correlations are reported in the table.
*$p \leq .05$; **$p \leq .01$.

The general homeostatic responses may explain the reduced heart rates in summer, in fact as reported by Silanikove (2000), the reduction of heart rates and the increase respiration rates contribute to heat dissipation and to maintain a normal rectal temperature.

Also, the negative correlations between meteorological data (DTB, WBT, THI, WBGTI) and lactodinamographic parameters (r and a30) confirmed the general worsening of clot firmness (a30) observed in the summer as reported also in sheep by Todaro et al. (2014); these results could be due to the effect of both the advancing of lactation and of thermal adaptation.

The negative correlations between temperature and some short-chain FAs are in agreement with studies showing the reduction in the FAs synthesised from the breast (*de novo*) as a result of the increase of temperatures, usually combined with a reduced intake of feed (Hamzaoui et al. 2013). Some authors have suggested that, to cope with the lack of energy due to decreased feeding, goats do not mobilise body fat, but change the rumen fermentation and rumen volatile FA profile (Salama et al. 2014).

A negative action of the neuro-endocrine system on milk ejection may be responsible for the inverse relationship observed between HR and the quantity of milk released. HR depends on several factors (Brosh 2007), and gives an idea of the energy balance of the animal. HR affects milk production because of the negative effect on the animal's energy balance, but also to the activation of the sympathetic-adrenomedullary system. The latter has an effect on the hormonal mechanisms through milk ejection (Gutkowska et al. 2000).

The negative correlation between ST and lactose could be explained by the fact that ST increases with increasing in temperatures and solar radiation, which are generally related to a decreased intake of food (Bernabucci et al. 2010). The exposure of the animal to higher environmental temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus and thereby causing a decrease in feed intake. The decrease in feed intake could be the adaptive mechanism to produce less body heat (Marai et al. 2007). Since in lactating animals most of the blood glucose is used by the breast for the lactose synthesis, it could be speculated, according to Hamzaoui et al. (2013), that the reduction in lactose secretion is a strategy to maintain stable glycaemia.

Conclusions

The two seasons considered affected above all the milk rheological parameters and FA composition. In the summer, an increase in CLA c9,t11 and its precursor was observed, whereas short-chain FAs (C6:0, C8:0, C10:0), which are responsible for the development of unpleasant aromas, decreased. The clot was also less firm in summer, whereas PUFA n6/PUFA n3 ratio was better in summer. Environmental parameters were found to be linked to the milk FAs, while heart rate and skin temperature were negatively linked to milk yield and lactose respectively.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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