

Effect of lambing season on ewe's colostrum composition

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ABSTRACT

Colostrum provides newborns with nutrients and immunoglobulins that play a major role in the immune system. In this survey, the immunoglobulin G (IgG) content, gross composition, mineral content, and fatty acid composition were determined in the colostrum of Valle del Belice ewes with the aim of evaluating the effect of lambing of season. In total, we analysed 60 bulk tank colostrum samples taken after lambing during two seasons (summer and winter). The IgG content and Brix mean values were 40.35 g/L and 21.02%, respectively. The colostrum fat, protein, casein, and lactose percentages were 8.01, 12.10, 8.51, and 3.13%, respectively. The lambing season significantly influenced the pH and somatic cell count, with higher values observed in winter than in summer. The most common fatty acids were palmitic (27.75 vs. 24.84 g/100 g), oleic (24.57 vs. 18.15 g/100 g), myristic (12.55 vs. 12.16 g/100 g) and stearic (7.02 vs. 6.16 g/100 g) detected in the summer and winter seasons, respectively. The winter season significantly increased the polyunsaturated fatty acid values (11.18 vs. 6.41). Additionally, the lambing season determined different mineral composition levels in the colostrum, particularly copper (8.50 vs. 5.35 $\mu\text{mol L}^{-1}$) and manganese (3.35 vs. 0.80 $\mu\text{mol L}^{-1}$), which were higher in the summer. Based on IgG content, the quality of the colostrum was excellent.

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Introduction

Despite seasonal fluctuations in pasture feeding resources in some Sicilian environments, the distribution of births is less seasonal. This is the case for Valle del Belice breed ewes reared in the origin area, which presents two principal, but not exclusive, lambing seasons (Todaro et al. 2015). The summer season of lambing (SSL) ranges from the end of August to the beginning of October, and the winter season of lambing (WSL) extends from the end of December to February. In sheep farming in Sicily during the summer season, 20–30 days before the expected date of lambing, ewes are housed in fences with water available and fed hay and concentrate. In the WSL, pregnant ewes are fed pasture during the day and only housed in fences in the evening; concentrates are typically not provided.

In the Mediterranean area, the farming systems of small ruminants are based on grazing pastures and milk production, which frequently depend on climatic conditions that influence the quantity and quality of the pasture (Pulina et al. 2015). Accordingly, in Sicily,

milk production varies greatly throughout the year and is essentially linked to the seasonality of grazed forage (Todaro et al. 2015). In these environments, pasture forages are green from October to mid-May, with maximum vegetative growth in spring corresponding to more intense grazing activity. This green period is followed by a drying period in summer, from June to September, where crop residues, especially the stubble of threshed cereals, are the only grazed resources. When the available forage cannot meet ewes' need for fibre, the ewes receive a supplement of hay and/or straw.

In sheep production systems based on extensive grazing, neonatal mortality often impacts 15–20% of lambs born; this mortality rate can be doubled in the case of multiple births (Banchero et al. 2015). An important factor that influences neonatal mortality is the colostrum production of mothers, which depends on their nutritional state at the end of pregnancy (Banchero et al. 2015). Ewes carrying twin lambs have higher energy requirements than ewes carrying a single lamb. In addition, voluntary feed intake is limited by the gravid

uterus, which compresses the rumen so that energy requirements cannot be fulfilled through the supply of pasture alone. This problem can be overcome via supplementation with concentrates during the last period of pregnancy. Higher energy intake can increase colostrum production and reduce colostrum viscosity, making it easier for the lamb to suckle (Banchero et al. 2015).

Colostrum, the first food consumed by newborns, is generated in the periods immediately before and after lambing and represents a source of passive immunity due to its concentration of immunoglobulins; these do not enter the embryo's bloodstream in cattle, sheep, goats, and horses (Hernández-Castellano et al. 2015). The only means of providing newborns with adequate immunity is feeding them appropriate amounts of colostrum. Colostrum stimulates the digestive system and, by reducing the chance of infection, has a positive influence on the metabolism of young mammals (Nowak, Mikula, Zachwieja, et al. 2012). The quality of colostrum is an important factor in determining the normal growth and development of offspring in all farm animals (McGrath et al. 2016).

Fats and fatty acids are the main dietary components in colostrum that fuel lambs' metabolic processes and health (Pecka-Kielb et al. 2018). Different proportions of volatile fatty acids produced in the rumen affect the fat content and fatty acid profile of milk (Van Burgel et al. 2011). Acetic and butyric acids are the main precursors of milk fat, while propionic acid is the main precursor for glucose and, consequently, lactose in milk and colostrum (Trigg 1979). Unsaturated fatty acids, such as linoleic and linolenic acids, play a critical role in the metabolic functions and general performance of newborns (Hernández-Castellano et al. 2015).

The mineral composition of colostrum also plays an important role in the growth and health of lambs. The mineral components of colostrum include citrates, phosphates, and chlorides of H^+ , K^+ , Na^+ , Mg^{2+} , and Ca^{2+} , which are present either as ions in solution or as colloidal species complexed with caseins (Lucey and Horne 2009). The mineral concentrations of first-milking colostrum are higher than those of subsequent milkings, suggesting their importance for newborns (Tsioulpas et al. 2007). The involvement of minerals in immune and antioxidant responses is key to preserving calf health; there is interest in trace mineral supplementation to maximise these positive effects in calves (Teixeira et al. 2014).

The physicochemical characteristics of colostrum differ significantly from those of milk (Martini et al. 2012). Colostrum is richer in biologically active

elements, such as nucleic acids and amino acid derivatives, whose concentrations change considerably in the hours and days after lambing (Pecka-Kielb et al. 2018). The composition and quality of colostrum depend on many genetic and nongenetic factors (Campion et al. 2019), such as health and bodily maintenance, but predominantly depend on nutrition (Nowak, Mikula, Kasprócz-Potocka, et al. 2012; Banchero et al. 2015; Pecka-Kielb et al. 2018). To achieve the desired results in terms of colostrum yield and quality, the feed ratio must fulfil the ewes' nutritional requirements. Failure to provide the necessary nutrients reduces the synthesis of colostrum and milk and may influence their quality (Balbin et al. 2020).

A study on the Valle del Belice breed was carried out with the aim of evaluating the effect of season of lambing (SSL or WSL) on ewe colostrum composition.

Materials and methods

Animal management and feeding

The study was carried out on a dairy farm that commonly raises 500 Valle del Belice ewes. This farm is located in the territory of Santa Margherita di Belice in the province of Agrigento (Sicily, Italy). We carried out our study during the summer season of lambing (SSL), with sampling from the end of August to the beginning of October, and during the winter season of lambing (WSL), with sampling from the end of December to the beginning of February. The summer and winter seasons of lambing are very different in terms of feeding and management of the pregnant ewes. During the SSL, the forages at pasture are dry; therefore, pregnant ewes are confined in fences near the sheepfold and fed with hay *ad libitum* as well as concentrate (300 g/head/d of barley grain). In the WSL, pregnant ewes graze at pasture with nonlactating ewes mainly on the meadows of *sulla* (*Sulla coronarium* L.). Given the good availability of pasture, no hay or concentrates are utilised. The forage biomass of pasture was sampled by cutting four areas of 1 m²; feeds utilised (fresh forage in WSL, hay, and barley grain in SSL) were sampled and analysed as reported by Gannuscio et al. (2022). The feeding intake of pregnant ewes was not detected. As shown in Table 1, the quality of forage administered in SSL was lower than WSL, particularly in terms of protein percentages.

Sampling

In both seasons of lambing, pregnant ewes were confined in the fold in the evening. Every morning, when

Table 1. Chemical composition (% DM) of forages and concentrate feed received by pregnant ewes.

	SSL		WSL
	Mixed hay	Barley grain	Fresh sulla forage
Dry matter (DM), %	91.31	88.83	18.46
Crude protein (CP)	6.09	7.00	14.82
Ether extract (EE)	1.39	1.90	2.11
Ash	9.00	3.64	11.20
aNDFom	66.24	43.09	42.30
ADFom	62.08	13.23	36.52
ADL	8.23	1.48	7.65
Cellulose	53.85	11.75	28.87
Hemicellulose	4.16	29.86	5.78
NSC	17.28	44.37	29.57

SSL: summer season of lambing; WSL: winter season of lambing; aNDFom: neutral detergent fibre using heat-stable amylase and exclusive of residual ash; ADFom: ash free acid detergent fibre; ADL: acid detergent lignin; Non-structural carbohydrates, NSC % = 100 – (CP % + EE % + ash % + aNDFom %).

lambing more than two pluriparous (≥ 2 lambing), the colostrum was hand-milked completely, filtered, and mixed, in the same quantity, in the same container. After this, 50 mL of colostrum was placed in each of 6 sterile bottles and immediately frozen at -20°C . The residual colostrum was immediately given to the lambs with a baby bottle. For each season of lambing (SSL and WSL), 30 pooled samples of colostrum were collected.

Physicochemical analyses

All colostrum samples were thawed at room temperature ($20\text{--}25^{\circ}\text{C}$) and vortexed for 10 s to ensure adequate homogeneity. Colostrum samples were diluted with deionised water (1:1), warmed at 42°C in a water bath and analysed for their lactose, fat, protein, casein, urea, and somatic cell count concentration (SCC) *via* the infra-red method (Combi-Foss 6000, Foss Electric, Hillerød, Denmark). The obtained results were recalculated taking into account the dilution factor.

In the undiluted samples, we measured the pH and colour parameters. The pH was measured using an HI 9025 pH metre (Hanna Instruments, Ann Arbor, MI). The colour parameters were measured using the CIE LAB colour space and its cylindrical representation (CIE 1986). Variables included lightness (L^* , from 0 = black to 100 = white), redness (a^* , from green = $-a$ to red = $+a$), and yellowness (b^* , from blue = $-b$ to yellow = $+b$), which were measured using a Minolta Chroma Metre CR-300 using illuminant C (Minolta, Osaka, Japan) by placing the lens directly over a capsule containing the colostrum sample. In addition to these attributes, the a^* and b^* values were used to determine the hue angle and chroma. The hue angle $\tan^{-1}(b^*/a^*)$ gives the predominant wavelength

responsible for the colour, while the chroma or saturation [$\sqrt{(a^2 + b^2)}$] accounts for vividness or colour purity. The chromameter was standardised using a white standard plate. Colour was assessed in triplicate, so the results reported are the averages of three measurements of the same sample. The intra-assay coefficients of variation (CVs) were 2.22, 1.08, and 1.31% for L^* , a^* , and b^* , respectively.

Immunoglobulin determination

Colostrum samples were thawed at room temperature ($20\text{--}25^{\circ}\text{C}$) and gently mixed to ensure good homogeneity. Then, the samples were diluted with deionised water (1:1), and 500 μL of acetic acid at 10% was added to precipitate the casein. Then, the samples were centrifuged at 5,000 rpm $\times$ g for 10 min at 4°C , and 25 μL of whey was collected for electrophoresis analysis (SAS1-SAS2, Helena Bioscience, Gateshead, UK). Total whey protein (TWP) was quantified *via* spectrophotometry using the commercial reagent 'Total Protein Plus' on an automatic analyser (KoneLab T 60I, Thermo Electron Corporation, Rodano, Milan, Italy) according to the manufacturer's instructions.

The total Ig fraction area on the electrophoretogram was calculated *via* the instrument's software, and the percentage of total IgG area with respect to the total curve area was determined. Once the TWP value (g/L) of the sample was inserted, the instrument software provided the value of the total Ig concentration (g/L) by applying the following formula: total IgG (g/L) = Ig area (%) $\times$ TWP (g/L). The results obtained on diluted samples were doubled.

After all colostrum samples were thawed to room temperature ($20\text{--}25^{\circ}\text{C}$), the refractive index was measured in duplicate with an optical Brix refractometer (Manual Refractometer MHRB-40 ATC, Mueller Optronic, Erfurt, Germany). The refractometer was equipped with a Brix scale ranging from 0 to 40% Brix. The accuracy of the instrument was $\pm 0.2\%$ Brix at 20°C .

Fatty acid composition

The colostrum samples were subjected to a freeze-drying process (lyophilization) upon arrival and kept at -20°C . The fatty acids (FAs) in freeze-dried colostrum samples (100 mg) were directly methylated in 1 mL hexane with 2 mL 0.5 M NaOCH_3 at 50°C for 15 min, followed by 1 mL 5% HCl in methanol at 50°C for 15 min based on the bimethylation procedure (Lee and Tweed 2008). Fatty acid methyl esters (FAMES)

were recovered in 1.5 mL hexane. Using an auto sampler, 1 µL of each sample was injected into an HP 6890 gas chromatography system equipped with a flame-ionization detector (Agilent Technologies, Santa Clara, CA, USA). The FAMES were separated using a CP-Sil 88 capillary column (100 m long, 0.25 mm internal diameter, 0.25 µm film thickness; Chrompack, Middelburg, the Netherlands). The injector temperature was kept at 255 °C, and the detector temperature was kept at 250 °C, with a hydrogen flow of 40 mL/min, an air flow of 400 mL/min, and a constant helium flow of 45 mL/min. The initial oven temperature was held at 70 °C for 1 min, increased by 5 °C/min until reaching 100 °C, held for 2 min, increased by 10 °C/min to 175 °C, held for 40 min, and finally increased by 5 °C/min to a final temperature of 225 °C and held for 45 min. Helium, with a pressure of 158.6 kPa and a flow rate of 0.7 mL/min (linear velocity 14 cm/s), was used as a carrier gas. A FAME hexane mix solution (Nu-Check-Prep, Elysian, MN, USA) was used to identify each FA. To identify some branched FAs, such as C15:0 iso, C15:0 anteiso, C17:0 iso, and C17:0 anteiso, individual standards (Larodan Fine Chemicals AB, Malmö, Sweden) were used. Isomers of conjugated linoleic acid (CLA) were identified using a standard mixture of C18:2 c9 t11 (rumenic acid, RA) and C18:2 c10 t12 methyl esters (Sigma-Aldrich, Milano, Italy) along with published isomeric profiles (Kramer et al. 2004). To quantify the total FA, one millilitre of C23:0 solution (20 mg/50 mL of hexane, Sigma-Aldrich) was used as the internal standard.

Mineral composition

Elements in the colostrum samples were determined using a microwave plasma atomic emission spectrometer (Agilent 4200 MP AES; Agilent Technologies, Santa Clara, CA, USA) after acid digestion carried out using a CEM MARS XPRESS 230/60 Microwave Accelerated Reaction System. Briefly, 1 mL of each fresh colostrum sample was transferred to a 15 mL Teflon digestion vial. Before capping the vials, 3 mL of nitric acid and 1 mL of hydrogen peroxide were added to each sample. We also prepared a blank solution containing 3 mL of nitric acid and 1 mL of hydrogen peroxide. Analytical grade concentrated nitric acid (HNO₃ 67–69%) and hydrogen peroxide (H₂O₂ 30%) were used for sample digestion. Each colostrum sample and blank solution were detected in triplicate, and the averages of three measurements of the same sample were utilised. The intra-assay coefficients of variation (CVs) were 0.90, 0.57, 0.79, 0.78, 0.79, 4.84, 20.97, 4.19,

and 28.51% for Ca, Mg, Na, K, P, Zn, Fe, Mn, and Cu, respectively. Microwave digestion of the samples was carried out at a power of 1200 W and at a temperature of 200 °C, which was reached in 10 min. These values were maintained for 30 min (the duration of the digestion). Upon completion of the program, each digested sample was diluted to a final volume of 12 mL with 18.2 MΩ deionised water and then diluted another 10 times with a solution of 2% nitric acid.

Statistical analysis

Data were checked for unlikely values. For each detected colostrum parameter, Student's *t* for skewness and kurtosis and Chi-square for heterogeneity of variance were calculated, and they had a normal distribution, with the exception of SCC. Colostrum somatic cell count was transformed in Log10 to normalise this variable before the analysis. The chemical and physical parameters were analysed using the generalised linear model (GLM) procedure (SAS 9.1.2 software), which included the seasons of lambing as a fixed effect. Comparisons among the least-square means were carried out using a *t*-test. Differences were considered significant at *p* < 0.05.

Results

Physicochemical parameters and immunoglobulin

The physicochemical parameters of the colostrum samples are reported in Table 2. The gross composition of colostrum from Valle del Belice ewes presented fat, protein, casein, and lactose percentages equal to 8.01, 12.10, 8.51, and 3.13%, respectively. The urea content, which was rather high, presented a

Table 2. Physico-chemical parameters of colostrum sampled in two lambing seasons.

Parameters	Season of lambing		SEM	<i>p</i> -Value
	SSL	WSL		
Fat, %	7.69	8.34	0.272	0.098
Protein, %	12.16	12.04	0.318	0.781
Casein, %	8.57	8.45	0.250	0.735
Urea, mg/dL	49.81	46.07	2.636	0.320
Lactose, %	3.21	3.05	0.082	0.176
Somatic cell count (Log)	5.43	6.18	0.113	0.001
pH	6.26	6.46	0.027	0.001
IgG, g/L	40.78	39.91	2.023	0.762
Brix values, %	21.15	20.89	0.364	0.610
Lightness (L*)	84.05	84.14	0.440	0.892
Redness (a*)	−8.14	−7.62	0.178	0.043
Yellowness (b*)	18.83	19.24	0.516	0.572
Chroma	20.54	20.71	0.511	0.814
Hue angle	1.15	1.60	0.188	0.096

SSL: summer season of lambing; WSL: winter season of lambing; SEM: standard error of mean.

mean of 47.94 mg/dl, while the IgG and Brix mean values were 40.35 g/L and 21.02%, respectively. The abovementioned parameters were not statistically influenced by the lambing season. Significant differences were found only for pH and SCC, which presented higher values in the colostrum samples obtained during the WSL than SSL.

Across the two lambing seasons, the average colour values were 84.05, −8.14, 18.83 and 84.14, −7.62, 19.24 for L*, a*, and b* in SSL and WSL, respectively. The season of lambing significantly influenced redness of the colostrum; it was less red in SSL than WSL (−8.14 vs. −7.62; $p < 0.05$).

Fatty acid profile

The composition of fatty acids (FAs) in the ewe colostrum is reported in Table 3. The most characteristic fatty acids in the colostrum were palmitic and oleic acids, followed by myristic and stearic acids. The season of lambing significantly influenced most of the

fatty acids detected in the colostrum. The concentration of short-chain FAs, from C4 to C11, was statistically higher in colostrum milked during WSL than in colostrum obtained during SSL. Palmitic, oleic, and stearic acids, which were found in high overall concentrations in the colostrum, presented higher values in the SSL than in the WSL samples. Conversely, the total PUFA content was higher in the WSL than in the SSL samples (11.18 vs. 6.41; $p < 0.01$). MUFA and SFA were higher in the SSL than in the WSL samples ($p < 0.01$).

Higher concentrations of FAs with favourable properties were found in the WSL colostrum than in the SSL colostrum: alpha linolenic acid (ALA, 1.74 vs. 0.70; $p < 0.01$), rumenic acid (RA, 2.83 vs. 0.96; $p < 0.01$) and trans vaccenic acid (TVA, 4.32 vs. 1.45; $p < 0.01$). Moreover, other FAs of health interest, such as eicosapentaenoic acid (EPA, 0.16 vs. 0.11; $p < 0.01$) and total omega-3 (1.90 vs. 0.98; $p < 0.01$), were statistically higher in WSL colostrum than in SSL colostrum. The omega-6/omega-3 ratio was significantly lower in the WSL colostrum (4.32 vs. 1.45; $p < 0.01$).

Table 3. Fatty acid composition (g/100g FA) of colostrum sampled in two lambing seasons.

Parameters	Season of lambing		SEM	p-Value
	SSL	WSL		
C4	2.31	2.50	0.058	0.025
C6	1.56	1.77	0.055	0.007
C8	1.26	1.47	0.054	0.007
C10	3.39	3.83	0.141	0.034
C11	0.22	0.25	0.070	0.008
C12	3.01	2.99	0.062	0.757
C14	12.55	12.16	0.249	0.279
C15	0.34	0.38	0.018	0.525
C16	27.75	24.84	0.322	0.001
C16:1cis9	0.45	0.84	0.017	0.001
C17	0.75	0.77	0.011	0.081
C18	7.02	6.16	0.191	0.003
C18:1trans11 (TVA)	1.45	4.32	0.109	0.001
C18:1cis9	24.57	18.15	0.409	0.001
Other C18:1	2.86	3.97	0.017	0.001
C18:2 n-6 (LA)	2.63	1.87	0.051	0.001
C18:2cis9trans11 (RA)	0.96	2.83	0.084	0.001
C18:2cis9trans12	0.52	0.95	0.023	0.001
C18:2cis12trans9	0.39	0.58	0.009	0.001
C18:3 n-3 (ALA)	0.70	1.74	0.038	0.001
C20:3 n-3	0.17	0.01	0.009	0.001
C20:4 n-6	0.21	0.17	0.003	0.001
C20:5 n-3 (EPA)	0.11	0.16	0.009	0.001
C22:1	0.12	0.008	0.005	0.001
C22:4 n-6	0.18	0.25	0.010	0.001
Other CLA	0.00	0.48	0.017	0.001
Total SFA	60.94	57.93	0.527	0.001
Total MUFA	32.64	30.89	0.432	0.006
Total PUFA	6.41	11.18	0.210	0.001
Total n-3	0.98	1.90	0.045	0.001
Total n-6	3.33	2.69	0.059	0.001
n-6/n-3	3.46	1.49	0.104	0.001

SSL: summer season of lambing; WSL: winter season of lambing; SEM: standard error of mean; TVA: trans vaccenic acid; LA: linoleic acid; RA: rumenic acid or CLA; ALA: alpha linolenic acid; EPA: eicosapentaenoic acid; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Mineral composition

The macro- and microelements of the colostrum samples are reported in Table 4. Phosphorus was the most common macroelement in the sheep colostrum, followed by calcium, potassium, sodium, and magnesium. Among the microelements, copper and manganese had the highest levels, while heavy metals (cadmium, lead, nickel, and chromium) were not detected in our colostrum samples. Differences were found among seasons of lambing in the macroelement magnesium (5.43 vs. 4.70 mmol L^{−1}; $p < 0.05$), as well as the microelements copper (8.50 vs. 5.35 µmol L^{−1}; $p < 0.01$) and manganese (3.35 vs. 0.80 µmol L^{−1}; $p < 0.01$). All values in the SSL samples were numerically higher than those detected in the WSL samples.

Table 4. Macro (mmol/L) and microelements (µmol/L) in sheep's colostrum in two lambing seasons.

Parameters	Season of lambing		SEM	p-Value
	SSL	WSL		
Ca, mmol/L	26.03	26.49	1.156	0.779
Mg, mmol/L	5.43	4.70	0.263	0.053
Na, mmol/L	13.29	13.54	1.016	0.859
K, mmol/L	15.84	14.37	0.609	0.091
P, mmol/L	87.76	82.53	3.829	0.338
Zn, µmol/L	130.38	151.85	11.120	0.177
Fe, µmol/L	24.35	20.70	8.160	0.753
Mn, µmol/L	3.35	0.80	0.629	0.001
Cu, µmol/L	8.50	5.35	0.659	0.001

SSL: summer season of lambing; WSL: winter season of lambing; SEM: standard error of mean.

Discussion

Physicochemical parameters and immunoglobulin

This study reports, for the first time, the chemical composition of colostrum from Valle del Belice ewes, a specialised dairy breed reared in southern Italy, particularly in Sicily. Colostrum composition differs from the milk of this breed (Todaro et al. 2015), particularly in casein, urea, and lactose content. The colostrum fat and lactose percentages were similar to the data in several studies of other breeds (Martini et al. 2012; Abecia et al. 2020; Kessler et al. 2021); the protein content was similar to that reported by Martini et al. (2012) and Alobre et al. (2021) but lower than the values reported by other authors (Abecia et al. 2020; Kessler et al. 2021; Spina et al. 2021).

To establish passive immunity against disease, newborn ruminants need to quickly ingest colostrum that contains enough IgG to ensure protection in early life (Beam et al. 2009). The IgG mean value of our colostrum samples was found to be in line with that reported in the literature (Abecia et al. 2020; Kessler et al. 2021; Spina et al. 2021; Averós et al. 2022). Overall, the IgG value obtained in our study can be considered excellent from a quality point of view, based on the threshold value reported by Kessler et al. (2021) for ewe colostrum equal to 20 mg/mL.

The Brix refractometer enables rapid on-farm estimation of colostrum quality. This method has been intensively studied in bovines and was validated for sheep colostrum by Kessler et al. (2021), demonstrating a high correlation coefficient (0.75) between the IgG and Brix values. The season of lambing did not influence IgG and Brix values, and significant differences were found only for the SCC and pH, which were higher in the WSL colostrum than SSL. Analogous values for SCC were found by other authors in ewe colostrum (Martini et al. 2012; Averós et al. 2022; Silva et al. 2022), but no data on pH were found in the literature. It is well known that milk SCC and pH are positively correlated (Pellegrini et al. 1997). Therefore, the lambing season could be the cause of this because pregnant ewes graze until lambing in WSL, causing more udder rubbing, which would lead to an increase in SCC value due to increased flaking of epithelial cells. In fact, compositional changes in the milk reflect the degree of physical damage to the udder tissue; through this damage, the blood–milk barrier is damaged, and mammary epithelial tight junctions become leaky, leading to the escape of blood and components into the lumen of the alveoli, which produces a different composition and an increase in milk pH (Kandeel et al. 2019).

Colostrum has a reddish-yellow colour largely due to the presence of carotenoids, particularly in bovine species, while goat and ewe colostrum do not contain β -carotene, only retinol, and xanthophyll (Madsen et al. 2004). Goats and ewes convert β -carotene from plants into vitamin A, which lacks colour (Chudy et al. 2020). Therefore, the yellow colour in ewe colostrum is probably due to the high presence of fat (Madsen et al. 2004). The reddish colour of colostrum is due to the presence of red blood cells; in fact, during pregnancy, an increase in the permeability of mammary gland membranes occurs, and more blood constituents gain access to the colostrum (McGrath et al. 2016). No studies have reported L^* , a^* , and b^* values for sheep colostrum. Our values are in accordance with those reported by Saipriya et al. (2021) for goat colostrum, particularly for lightness, while redness and yellowness detected in our samples were higher than those in goat colostrum. Regarding the effect of season of lambing on colostrum colour, significant differences were found for redness, with a higher value found in WSL, probably for the presence of traces of blood due to greater udder rubbing of grazing pregnant ewes. In this case, the possible damage to the mammary glands could increase the presence of blood in colostrum, which significantly affected its colour and caused the sample to be redder (Madsen et al. 2004).

Fatty acid profile

The fatty acid profile analyses showed that the ewe colostrum samples were rich in saturated fatty acids, as previously reported in sheep (Or-Rashid et al. 2010; Alobre et al. 2021) and cow colostrum (Zaitsev and Makarova 2011; Mann et al. 2016). The effect of lambing season on colostrum FAs in this study was probably linked to the forages utilised for feeding the pregnant ewes. Ewes received dry feed during the SSL, with hay and concentrate, while they consumed fresh forage at pasture in the WSL. The higher presence of short-chain FA detected in the WSL is likely due to more intense *de novo* synthesis in the mammary gland due to the high availability of acetate and beta hydroxyl butyrate, which are precursors formed in the rumen by the microbial fermentation of cellulose. The significant presence of these precursors in the WSL colostrum could be related to the higher digestible fibre that characterises ewe feed during this season (Todaro et al. 2015). The higher percentages of palmitic (C16), oleic (C18:1 cis 9), and stearic acids (C18) detected in the SSL colostrum could be due to

their greater availability at the udder level as a result of the greater mobilisation of long-chain FAs, particularly oleic acid, from the body fat deposits of pregnant ewes (Chilliard et al. 2003). The purpose of this mobilisation is to balance the energy deficits that pregnant ewes incur more frequently in the summer season when the feeding regime may not be sufficient to satisfy their energy needs (Todaro et al. 2015). Moreover, as suggested by Ponte et al. (2022), the higher presence of oleic acid (C18:1 *cis* 9), the main component of MUFA in the SSL colostrum, could be attributed to the lower content of CT in dry feed (hay) compared to that in fresh forage, where sulla is the most abundant forage type. Indeed, oleic acid also derives from the rumen biohydrogenation of PUFAs (Maia et al. 2007). Additionally, the increase in oleic acid together with branched chain FA could be attributed to the low content of CT in the hay being unable to limit the activity of microflora in the rumen, which presumably occurred in the fresh sulla forage.

The exclusive presence of fresh forage in the diets of pregnant ewes during WSL improved the colostrum FA profile, indicating more favourable PUFA/SFA and n-6/n-3 ratios. In terms of the effects of green forage on healthy milk fatty acids, it is well known that RA, and generally CLA, increase with the intake of fresh forage (Cabiddu et al. 2005; Nudda et al. 2005). In general, when the amount of green forage increases in the diets of ruminants, the high α -linolenic acid (ALA, C18:3 n-3) content is partly biohydrogenated into vaccenic acid (TVA, C18:1 *t*11), partly absorbed by the intestine and successively secreted into the milk or colostrum. Furthermore, TVA is partly converted into RA in the mammary glands by the Δ -9 desaturase enzyme (Antongiovanni et al. 2003; Bauman et al. 2006). These changes in the FA profile of colostrum fat can be attributed to the high presence of PUFAs in WSL forage, as well as to the inhibitory effect of sulla CT on the rumen biohydrogenation of PUFAs.

The higher percentage of eicosapentaenoic acid (EPA, C20:5 n-3) in the WSL colostrum was likely due to the higher presence of ALA, the precursor of EPA. Clarke (2001) reported that EPA and docosahexaenoic acid (DHA) are particularly bioactive and can alter the physiology and metabolism of lambs by increasing the transcription of lipolytic genes and decreasing the transcription of lipogenic genes, potentially increasing the utilisation of fatty acids for energy, as fatty acids yield more energy than other metabolisable nutrients. Moreover, Cooper et al. (2004) demonstrated that feeding diets high in EPA and C22:6 n-3 FA to growing lambs substantially increased the concentrations of

these fatty acids within muscle phosphatidylglycerols and triacylglycerols with positive effects on the lambs.

Overall, in this study, the lambing season significantly influenced the fatty acid profiles of ewe colostrum, indicating the production of a higher-quality FA profile colostrum during the winter season when green forage represents the most prevalent, if not the only, component in the pregnant ewe's diet.

Mineral composition

The mineral composition detected in the ewe colostrum was found to be comparable to the data provided by Kráčmar et al. (2005) for ewes reared on an organic farm in the Czech Republic, and was lower than those found for cow colostrum (Valldcabres and Silva-del-Río 2022). Phosphorus was the most abundant mineral in ewe colostrum, contrary to the data from bovine colostrum in California (Valldcabres and Silva-del-Río 2022), which reported that calcium is the most abundant mineral. However, a different analytical treatment was employed on the cow colostrum samples, which were pre-treated to favour the precipitation of caseins that contain phosphorus (Lucey and Horne 2009); therefore, the lower presence of phosphorus than calcium reported by Valldcabres and Silva-del-Río (2022) may be attributable to the laboratory method used.

Moreover, it is well known that mineral nutrition, diet composition, soil conditions in individual areas, season or month of lactation, parity, etc., are variable factors that can influence the mineral composition in milk or colostrum (Kráčmar et al. 2005). An analysis of microelements, particularly heavy metals, showed the absence of the latter in our colostrum samples. Controlling milk composition is an increasingly important factor for consumers due to the novel applications of foods as tools for disease prevention and health (Domingo 2021). A previous study reported the presence of lead, cadmium, and chromium in the milk of ewes during pasture was likely due to the accumulation of these substances in the grass and other types of forage (Póti et al. 2021). However, the grazing of the pregnant ewes in our study took place on mountain soils outside inhabited areas, which could explain the absence of heavy metals detected.

Considering the effect of the season of lambing on mineral content, the higher presence of Mg and Cu in SSL colostrum was likely due to the concentrate's supplementation with barley grain. In fact, the content of these two microelements in barley grains is higher than that in oat and wheat grains (Jordan-Meille et al.

2021) and considerably higher than that in sulla forage (Labidi et al. 2015). The greater presence of manganese in SSL colostrum seems less readily explainable, as this microelement is very abundant in sulla forage according to data reported by Labidi et al. (2015).

Conclusions

This study presented a survey on colostrum quality in the Valle del Belice breed ewe in two different seasons of lambing. The colostrum composition was strongly influenced by season, probably because the feeding and management practises differed between seasons. Indeed, the differences between the two seasons were particularly evident in the fatty acid composition of the colostrum fat, which was more favourable to the health of lambs in WSL than SSL. Additionally, the mineral composition of colostrum samples was different between seasons, probably based on the effects of feeding supplementation. The type of breeding among pregnant ewes reared in paddocks in SSL and at pasture in WSL likely influenced the SCC and pH of the colostrum, suggesting greater maltreatment of the udders in WSL pregnant ewes. Overall, the quality of the colostrum was found to be excellent in terms of its immunoglobulin content even if the lamb nutrition should be cared for more in the SSL.

Disclosure statement

No potential conflict of interest was reported by the author(s). The authors alone are responsible for the content and writing of this article.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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