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Essential and toxic minerals content and fatty acid profile of colostrum in dairy sheep

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Simple Summary: Colostrum is gain attention of the scientific community thanks to its nutritional and therapeutic capabilities. The aims of this study were to characterize the macro and micro composition of colostrum from Sarda dairy sheep, and to compare it with the composition of the mature milk from the same breed.

Abstract: Colostrum is the primary source for the acquisition of immunity in ruminant. It provides the transfer of antibodies from the mother to the fetus, and it is the exclusive nutrient source of newborn. The objectives of this study were i) to characterize the macro e micro composition of colostrum, ii) to analyze the antioxidant capacity, the fatty acid (FA) profile and the content of essential and toxic element in colostrum, iii) and to compare FA profile of colostrum with that of mature milk. For these purposes, colostrum and milk samples were collected from 10 animals arising from 8 sheep dairy farms distributed in North Sardinia (Italy). All colostrum samples were analyzed for chemical composition, essential and toxic elements and FA profile. The comparison between milk and colostrum FAs were assessed. The average of fat and protein (TP) concentration in colostrum were 7.8% and 16%, respectively. Also, an average of 40 ± 20 g dm-3 was found for Immunoglobulin G (IgG). As regard antioxidant capacity of colostrum, a high variation among samples from different farms was found for the 2, 2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) assay which was 30 ± 10% (Mean ± SD). A high content of selenium (Se), zinc (Zn) and copper (Cu) was found in colostrum (respectively 200, 2,5000 and 1,200 μg kg-1). A positive strong correlation between TP and IgG was found (r = 91%). The colostrum IgG are correlated positively with Se and Zn, because essential mineral for immune system. The FA profile evidenced, a higher content of medium- and long-chain fatty acids in the colostrum than mature milk, especially of ARA, EPA, DPA, and DHA. This study provided new information about the colostrum quality of Sarda dairy sheep, and it allowed to highlight the different fatty acid composition of fat in colostrum and mature milk.

Keywords: colostrum; essential minerals; fatty acid; immunoglobulins; antioxidant capacity; dairy ewe

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1. Introduction

Colostrum in sheep provides immunoglobulins (Ig) that confer passive immunity to the newborn lambs [1-3] because the syndesmocorial placenta prevents the transfer of antibodies from the mother ewe to the fetus. Colostrum is also the exclusive nutrient source of the newborn, as it is rich in fats, carbohydrates, and proteins. In addition, its rather complex composition resulting in a vital source of micronutrients (vitamins and minerals), antimicrobial (e.g., lactoferrin and lysozymes) and growth factors. Essential

microelement in colostrum has also crucial role to avoid nutritional pathologies in suckling lambs as the myodegeneration disease known as white muscle disease due to selenium (Se) deficiency [4]. Beyond Se, other essential minerals like copper (Cu), manganese (Mn) and zinc (Zn) have important antioxidant functions that are crucial in protecting the integrity of cell membrane against oxidative stress. On the other hand, toxic minerals like lead (Pb) and cadmium (Cd) could be found in colostrum as consequence of environmental pollution or dietary contaminants.

The ruminant colostrum has recently received considerable interest because of their potential nutritional and therapeutic effects also in humans [5-7], especially against inflammatory intestinal diseases [6, 8]. Beyond its classical use, e.g. a farm colostrum bank for lambs that have not been suckled from their mothers, aimed to reduce the use of antibiotics in newborns [9], sheep colostrum can be utilized in human nutrition to make beverages or immunoglobulin-rich dietary supplements. Sheep colostrum has also been an important resource for the nutrition of Mediterranean peoples; in some areas of Italy it was used for the preparation of a fresh cream or a semihard cheese (Casada) a particular ricotta recognized as a traditional agri-food product [10]. Currently, few data are available on the nutritional components of sheep colostrum, such as trace elements content and nutritional quality of fats. An adequate supply of microminerals to transitioning ewes could significantly improve the composition and biological value of colostrum, which could affect the health of newborn lambs. Moreover, it is known that organic supplements of trace elements such as Zn, Cu, Mn, Se, and Fe fed in transitioning period significantly improve immunity and reproduction in dairy animals.

The objective of this study was to characterize, through its variability at the farm level, the gross composition, the Ig content, the amounts of essential trace elements as Se, Cu, Mn, Zn, of toxic elements like Pb and Cd, of an allergenic oligoelement like Ni, of the fatty acid profile and of the antioxidant potential of colostrum in Sarda dairy sheep. Furthermore, the last two parameters were compared with those measured in mature milk.

2. Materials and Methods

2.1. Ethical practices

The experiment was approved by the Ethics committee of the University of Sassari (Prot. n. 139652 03/11/2021 with the authorization of Ministero della Salute n° 676/2021-PR based on art. 31 D.lgs. 26/2014).

2.2. Animals and Experimental Design

The survey was carried out in eight sheep dairy farms distributed in North Sardinia, Italy, representative by size and breeding technique of the situation of dairy sheep industry in Sardinia and central Italy where the most important Italian sheep cheese, Pecorino Romano PDO, is produced [11]. Twelve animals per farm, homogenous for age (3 years) were randomly chosen for a total of 96 samples. Each ewe was identified with a medal and was maintained within the flock. The lambing periods were concentrated in November.

2.3. Colostrum sampling

A colostrum sample was collected from each ewe, by manual milking, within 24 hours after lambing. Each colostrum sample has been divided in aliquots and stored for the analysis.

2.4. Determination of IGg, protein, fat content and fatty acid profile

The Gamma-Globulin (IgG) content has been determined by using electrophoresis MP (test method 13/023).

The total nitrogen (TN) was measured using Kjeldhal method [12], and the total protein (TP) was calculated as TN x 6.38. Fat content was determined according to the Rose-Gottlieb [13].

Total antioxidant capacity was spectrophotometrically measured with the ferric ion reducing antioxidant power (FRAP) and the 2, 2'-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) radical scavenging as described by Tsiplakou at al. [14].

The fatty acid profile was determined in 6 samples for each farm, by gas-chromatography as detailed by Correddu et al. [15]. A gas-chromatograph Agilent model 7890 (Agilent Technologies, Santa Clara, CA, USA), equipped with a 7693 Autosampler (Agilent Technologies, Santa Clara, CA, USA) and a flame ionization detector (FID) operating to 225°C was used. The stationary phase was a CP-Sil 88 capillary column (100 m × 0.250 μm i.d., 0.25 μn film thickness, Agilent Technologies, Santa Clara, CA, USA). Briefly, 1g of colostrum was added 0.4 cm^3 of 25% of ammonia, 5 cm^3 of hexane and 1 cm^3 of ethyl alcohol. The mixture was first vortexed for 2 min, and then centrifuged at 3000 rpm for 1 min, hence, after phase separation, the organic upper layer was separated by the aqueous one. The whole extraction procedure was repeated again for two times, where the only change being the nature of the extracting solution (i.e., 5 cm^3 of hexane and 1 cm^3 of ethyl alcohol 95% in the second extraction, and 5 cm^3 of hexane in the third extraction). The three organic extracts were combined and evaporated at 40°C at a reduced pressure until the complete evaporation of the solvent. According to the FIL-IDF 1999 [16] standard procedure, the fatty acid methyl esters (FAME) were prepared by means a base-catalyzed transesterification. Hence, 25 mg of the lipid residue from evaporation was mixed with 1 cm^3 of hexane (containing 0.5 mg of internal standard) and 1 cm^3 of 2 mol dm^{-3} methanolic solution of KOH. The solution was vortexed for 2 minutes and centrifuged for 1 minutes at 3000 rpm, hence 0.08 g of sodium hydrogensulfate monohydrate were added. Hence, the supernatant used for the gas chromatographic analysis was obtained by the last centrifugation at 3000 rpm for 3 minutes. Individual FAMEs were identified by comparison of the retention time of each analyte with that of a standard mixture of 37 components FAME Mix (Supelco, Bellefonte, PA). The nonadecanoic acid (C19:0) methyl ester Sigma Chemical Co., St. Louis, MO) was used as internal standard for FAME quantification.

The concentration of each fatty acid was expressed as g/100 g of FAME and the groups of FA were also calculated. The nutritional properties were valuated as the ratio between n-6 and n-3 and three indices, that are the atherogenic index (AI) and thrombogenic index (TI) were calculated as reported [17]: AI = [12:0 + (4 × 14:0) + 16:0] / [(PUFA) + (MUFA)]; TI = (14:0 + 16:0) / [(0.5 × MUFA) + (0.5 × n-6) + (3 × n-3) + (n-3: n-6)]; the hypocholesterolemic to hypercholesterolemic ratio (h:H), calculated as [(sum of 18:1cis-9, 18:1cis-11, 18:2 n-6, 18:3 n-6,18:3 n-3, 20:3 n-6, 20:4 n-6, 20:5 n-3, 22:4 n-6, 22:5 n-3 and 22:6 n-3)/(14:0 + 16:0)].

The Δ9-desaturase indices (DI) were calculated according to Schennink et al. [18] to evaluate the effect of the different diets on the capacity of desaturating SFA to Δ9- UFA: C10 index = [C10:1/(C10:0 + C10:1)] × 100; C14 index = [C14:1 cis-9/(C14:0 + C14:1 cis-9)] × 100; C16 index = [C16:1 cis-9/(C16:0 + C16:1 cis-9)] × 100; C18 index = [C18:1 cis-9/(C18:0 + C18:1 cis-9)] × 100; CLA index = [CLA cis-9,trans-11/(C18:1 trans-11 + CLA cis-9,trans-11)] × 100; total index = [(C10:1 + C14:1 cis-9 + C16:1 cis-9 + C18:1 cis-9 + CLA cis-9,trans-11)/(C10:0 + C14:0 + C16:0 + C18:0 + C18:1 trans-11+ C10:1 + C14:1 cis-9 + C16:1 cis-9 + C18:1 cis-9 + CLA cis-9,trans-11)] × 100.

2.5. Determination of oligoelements and toxic elements in colostrum

The determination of the total amount of Cd, Cu, Mn, Se, Ni, Pb, and Zn in sheep's colostrum samples has been accomplished by means of a validated ICP-MS method. Samples have been mineralized by means a Milestone Ethos Easy Labstation microwave oven (Milestone, Sorisole, Italy) and mineralized solutions have been analyzed by means an inductively coupled plasma mass spectrometry (ICP-MS) spectrometer model NexION 300X equipped with an autosampler model S10 (Perkin Elmer, Monza, Italy), running under the Windows 7 operating system. Ultrapure (Type 1) water (specific resistance ≥ 18 MΩ) was used throughout the analytical procedure. The elemental standard solutions were by Carlo Erba (Milan, Italy) for Cd, Cu, Mn, Pb, Ni, Se and Zn, (100 mg dm^{-3} in 2% aqueous HNO_3. The 67% aqueous solution of HNO_3 and the 30% aqueous solution of H_2O_2

were both Ultrapure Normatom reagents (VWR International, Milan, Italy). The ERM-BD151 (Skimmed milk powder) and the IAEA-A-13 (Animal Blood) Certified Reference Materials were by Merck, Milan, Italy and by IAEA, Vienna, Austria, respectively. The NexION ICP-MS tuning solution (2% HNO_3 solution in water containing 1 μg dm^{-3} each of Be, Ce, Fe, In, Li, Mg, Pb, and U, code N8145051) and the NexION ICP-MS KED tuning solution (1% HCI solution in water containing Co, 10 μg dm^{-3} and Ce, 1 μg dm^{-3}, code N8145052) were both purchased from Perkin Elmer Italia (Monza, Italy). The mineralization procedure (Table S1), the instrumental settings (Table S2) and the validation parameters (Table S3) have been reported in the Supplementary Material.

2.6. Statistical Analysis

Differences in concentrations of the colostrum components, IgG, fatty acid profile and minerals among the farms were analyzed with one-way ANOVA and compared by Tukey test (SAS® software). Relationship among minerals, total protein, fatty acids and immunoglobulin were also computed. The statistical model for the FA profile included the fixed effects of type of secretion and farm, and the day of partum as random factor.

3. Results and Discussion

The TP content in the colostrum (from 7.1% to 29%, mean 14%) was not different among farms (P=0.511). The high amounts of TP measured are due to the constant presence of IgG (from 7.9 g dm^{-3} to 105 g dm^{-3}, mean 40 g dm^{-3}). Also the concentration of IgG does not differ among farms (P = 0.379). The amounts of IgG here measured are consistent with those previously measured in the same breed (unpublished data), and higher than that reported in others dairy sheep as Lacaune and Friesian, 28.9 and 28.8 g dm^{-3} [19-20]. Some research evidenced that lambs should intake an average of about 30 g of IgG in the first 24 h from birth to acquire the proper passive immunity [20-22]. Applying this principle, the lambs of this study should ingest 0.75 dm^{-3} of colostrum containing 40 g of IgG dm^{-3} to meet the immunity requirements. The antioxidant capacity of colostrum, measured by ABTS evidenced a high variation among farms, probably related to the different feeding techniques which may have determined passage of specific antioxidant substances, as phenolic compounds, from feeds to colostrum. However, the FRAP assay was not different among farms. The different results are likely because antioxidant assays can target a specific compound (as FRAP), or the total antioxidant capacity (as ABTS) given by the combined antioxidant capacities of all substances in a sample.

Table 1. Total protein, fat and Immunoglobulin (IgG) contents and antioxidant properties of colostrum sampled in 8 farms. .

	Colostrum composition				
Farm	**TP (%)**	**IgG (g dm-3)**	**Fat (%)**	**FRAP (μmol ascorbic acid/mL)**	**ABTS (% inhibition)**
A	17	40	5.3c	3.5	20b
B	16	40	7.6abc	3.4	20b
C	14	30	7.7abc	nd	nd
D	15	40	9.6a	2.3	20b
E	15	40	6.9abc	2.4	20b
F	19	50	5.5bc	3.1	20b
G	14.5	40	9.1ab	2.2	40a
H	16	40	10a	3.4	50a
Mean of all samples	16	40	7.8	2.9	30
SD	5	20	3.2	1.4	10

Min	7.1	7.9	2.5	0.7	10
Max	29	105	18	8.5	58
Pvalue	0.511	0.379	<0.001	0.120	<0.001
SEM	0.54	2.20	0.36	0.15	1.53

Average amounts reported are rounded according to the number of significant digits of the relevant standard deviation, while statistical tests have been accomplished on unrounded data. A-H = the farms used in the survey; TP = Total Protein (TN x 6.38); IgG = immunoglobulin G; FRAP = Ferric Reducing Antioxidant Power; ABTS = 2, 2'-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid); nd =not determined.

The contents of essential and toxic trace elements in colostrum are reported table 2, whereas the correlation matrix of colostrum components was reported in Table 3. A wide variation of minerals levels was found in colostrum collected from different farms. Mean concentration of Se in sheep colostrum (from 100 μg kg^{-1} to 350 μg kg^{-1}, mean 200 μg kg^{-1}) is greater than that found in colostrum of dairy cows [23] and goats [24] and markedly higher than values observed in milk of the same bred (76.1±40.6 μg kg^{-1} [25]) and other sheep breeds (28.4±1.0 μg kg^{-1} [26]). Selenium deficiency and the consequent risk of WMD can be corrected by parenteral dosage of 0.1 mg of Se kg-1 BW, or by oral supplements, ensuring a concentration of 0.3 μg kg^{-1} [4]. This recommended Se level for lambs could be reached in our study by suckling 1.28 kg day^{-1} of colostrum containing 234 μg kg^{-1} of Se. On the other hand, the dosage of 0.4 μg kg^{-1} of Se can be too high and cause acute symptomatology characterized by sialorrhea, prostration, and dyspnea [27]. It is reported that Se has an important role in regulation the immunoglobulin and antioxidant capacity of colostrum [28, 29]. This was also confirmed in this study where a significant positive correlation of Se and IgG has been observed (Table 3).

Also, the Zn content in sheep colostrum (from 5000 μg kg^{-1} to 57000 μg kg^{-1}, mean 25000 μg kg^{-1}) is higher than reported in goats [24] and human [30] colostrum, and markedly higher than reported in sheep milk [9, 31]. Because of the role of Zn in immune function and in teat keratin synthesis, it could reduce the susceptibility of the mammary gland to mastitis, which is generally greatest exposed around the parturition [9]. However, the correct concentration of Zn in colostrum and milk is crucial for lambs' growth as weight gain is dramatically reduced in lambs when Zn supplements provided only 0.05 mg Zn kg^{1} BW day^{-1}, whereas providing 0.2 mg Zn kg^{1} BW day^{-1}, a good rate of growth is ensured [32].

The Cu content in sheep's colostrum (from 130 μg kg^{-1} to 2800 μg kg^{-1}, mean 1200 μg kg^{-1}) is almost 3 times higher than the Cu content reported in goat colostrum [24] and in sheep milk (410 ppb [31]). Cu levels in sheep milk below 10 μg kg^{-1} has been reported to favor occurrence of swayback disease in newborn lambs [33], but values in colostrum measured in this study are over 100fold higher than this critical limit. Like Se, also Mn, Zn and Cu has been reported to improve immunoglobulins and antioxidant status of dairy animals [34]. However, in our study IgG correlate positively only with Zn, whereas a weaker negative relationship has been observed with Cu. No similar information has been found, however the increase of Ig in blood of lambs supplemented with has been reported [35].

The mean concentrations of Pb and Cd heavy metals in colostrum are markedly lower than the maximum limits indicated by the European Union for raw drinking milk and baby foods which is set at 20 μg kg^{-1} and 10 μg kg^{-1}, respectively [36]. The intake by ewes of toxic heavy metals could be thought contaminated feeds or soil in which animal graze on pasture, with the consequent exposition of suckling lambs.

The concentration of nickel in sheep colostrum was below the value reported in milk [37, 38] and below the permissible limit (0.43 mg dm^{-3}) set by World Health Organization (WHO).

Table 2. Concentration (μg kg^{-1}) of essential and toxic elements in colostrum sampled in 8 farms.
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	Elements						
Farm	**Cd**	**Cu**	**Mn**	**Ni**	**Pb**	**Se**	**Zn**
A	0.4^{ab}	660^{d}	140^{b}	90^{ab}	10	300^{ab}	26000
B	0.8^{a}	1200^{abc}	70^{c}	110^{ab}	12	200^{ab}	32000
C	0.5^{ab}	1600^{a}	240^{a}	80^{b}	7	200^{ab}	23000
D	0.6^{ab}	880^{bcd}	250^{a}	120^{a}	11	300^{ab}	23000
E	0.4^{ab}	1400^{ab}	74^{bc}	80^{b}	7	200^{ab}	18000
F	0.6^{ab}	670^{cd}	74^{bc}	80^{b}	7	100^{b}	27000
G	0.6^{ab}	1300^{abc}	100^{bc}	110^{ab}	9	350^{a}	25000
H	0.3^{b}	1600^{a}	60^{c}	100^{ab}	11	200^{ab}	22000
mean	0.5	1200	130	100	9	200	25000
SD	0.3	600	90	30	5	200	11000
Min	0.1	130	33	39	3	20	5000
Max	1.5	2800	400	190	32	1000	57000
Pvalue	0.0083	<.0001	<.0001	0.0016	0.0417	0.0282	0.217

Average amounts reported are rounded according to the number of significant digits of the relevant standard deviation, while statistical tests have been accomplished on unrounded data. Cd = Cadmium; Cu= Copper; Mn =Manganese; Ni= Nickel; Pb = Lead; Se= Selenium; Zn =Zinc.

The correlation matrix (Table 3) shown a positive strong correlation between immunoglobulin and TP. It is therefore evident that TP can be used as a reliable parameter to estimate the IgG content of colostrum in samples collected on the day of parturition. IgG significantly correlate with Se and Zn, because these two elements are essential for the immune system [39] but, even slightly, also with Ni. Conversely, negative correlations are observed between IgG and fat and, in a minor amount, between IgG and Cu.

A positive and significant correlation of ABTS and fat content and of FRAP and protein and Ig contents. The ABTS assay measures the electron- or H-donating properties of antioxidants, both hydrophilic and lipophilic. In accordance with our findings, whole milk had the highest total antioxidant capacity measured by ABTS assays [40]. More specifically, skimmed milk has a 6 % (ABTS) lower total antioxidant capacity than whole milk. A significant higher total antioxidant capacity, as determined by ABTS assay, was also found in cows' milk with 3% fat than cows' milk with 0,5–1,5 % fat and skimmed milk [41]. These findings indicate that interference with lipids and lipophilic reactivity antioxidants and lipid globule membrane proteins can affect the overall antioxidant capacity and explains why the whole milk has a higher antioxidant potential rather than skimmed milk [42].

Table 3. - Correlation matrix between trace elements and immunoglobulins, protein and fat content, and antioxidant power of colostrum.

	Se	Cu	Mn	Zn	Ni	Pb	Cd	TP	IgG	Fat	FRAP
Cu	0.053	1									
Mn	0.220	-0.124	1								
Zn	0.469**	-0.115	0.114	1							
Ni	0.428**	-0.087	0.336**	0.486**	1						
Pb	0.127	-0.020	-0.003	0.135	0.433**	1					
Cd	0.041	0.017	-0.035	0.154	0.263*	0.059	1				
NT	0.492**	-0.208	0.113	0.680**	0.359**	0.039	0.051	1			
IgG	0.447**	-0.254*	-0.005	0.555**	0.250*	0.015	0.107	0.912**	1		
Fat	-177	0.247*	0.029	-0.063	0.058	0.014	-0.021	-0.331*	-0.412**	1	
FRAP	0.135	-0.111	-0.038	0.310**	-0.028	-0.126	-0.058	0.285*	0.256*	-0.035	1
ABTS	0.051	0.39**	-0.219	-0.072	-0.048	0.087	-0.099	-0.063	-0.182	0.44**	-0.025

The fatty acid profile of colostrum is reported in Table 5. The FA of colostrum evidenced that C16:0, C18:1c9, C14:0, and C18:0 are the most abundant fatty acids. The medium-chain fatty acids (MCFA) and the long chain fatty acids (LCFA) were higher, whereas the short-chain FA (from C4:0 to C10:0) were markedly lower in colostrum than in mature milk. The same pattern has been reported in colostrum of dairy cows compared with mature milk [43]. The odd and branched-chain FAs were lower in colostrum than in milk, and the same is observed for the content of C18:1 t11 and conjugated linoleic acid, CLAc9t11 [44, 45]. This behavior is not in agreement with that observed in dairy cows, where no differences (e.g., for C18.1 trans11) or a decrease of concentration (e.g., for C17:0; CLAc9t11) passing from milk to colostrum has been observed [43].

The long chain PUFA both n-6 and the n-3 family as ARA, EPA, DPA, and DHA were higher in colostrum than in mature milk, probably because the specific higher requirements for newborn lambs. In fact, arachidonic acid (AA) and DHA are essential and structural constituents of cellular membranes and are mainly required for the growth and function of the brain and nervous system [46, 47]. The ARA and DHA contents in colostrum were 2-fold higher than that in the mature milk. This is important, as in newborn the ability to elongate LA to ARA and ALA to DHA is very low; therefore, the high amounts of LC-PUFA in colostrum could be of crucial advantage to lambs.

The fatty acid profile of colostrum compared to that of the mature milk indicates the specific metabolism of ewe and udder during the transition period. In particular, the higher content of FAs derived from body fat, the lower D9desaturase activity, and the lower OBCFA due to reduced ruminal activity in the peripartum period are evidence of the metabolism of animals after parturition.

Table 4. Fat content and fatty acid profile of colostrum (g/100 g of FA) and mature milk sampled in 8 farms. .

	Type			P value	
	Colostrum	**Milk**	**SEM**	**Type**	**Farm**
Fat, %	8	5.8	0.4922	0.0081	0.0021
FA (% on Total FAs)					
C4:0	1.8	2.4	0.0656	<.0001	0.0017
C6:0	0.8	2.0	0.0417	<.0001	0.0006
C7:0	0.05	0.08	0.0048	0.0005	<.0001
C8:0	0.6	2.1	0.0464	<.0001	0.0063
C9:0	0.10	0.15	0.0095	0.0441	<.0001
C10:0	1.8	7	0.1744	<.0001	0.0031
C10:1	0.06	0.09	0.0052	0.0001	0.0226
C11:0	0.12	0.32	0.0126	<.0001	0.0041
C12:0	2.0	4.2	0.1112	<.0001	0.0097

isoC13:0	0.01	0.02	0.0008	<.0001	0.0441
anteisoC13:0	0.03	0.04	0.0023	0.0064	0.0009
isoC14:0	0.06	0.12	0.0039	<.0001	0.3183
C14:0	11	11	0.4014	0.9561	0.0001
isoC15:0	0.18	0.31	0.0071	<.0001	0.0398
anteisoC15:0	0.20	0.54	0.0116	<.0001	0.1539
C14:1c9	0.4	0.17	0.0353	<.0001	<.0001
C15:0	0.6	1.1	0.0251	<.0001	0.0002
C15:1	0.03	0.08	0.003	<.0001	<.0001
isoC16:0	0.20	0.35	0.0083	<.0001	0.1687
C16:0	29	24	0.8182	<.0001	<.0001
C16:1t4	0.06	0.03	0.0031	<.0001	0.0182
C16:1t5	0.06	0.03	0.0032	<.0001	0.0144
C16:1t6-7	0.04	0.06	0.0016	<.0001	0.0776
isoC17:0	0.42	0.51	0.0132	<.0001	<.0001
C16:1t9	0.07	0.07	0.0055	0.3189	0.0002
C16:1t10	0.02	0.03	0.001	0.0005	<.0001
C16:1t11-t12	0.07	0.10	0.0046	<.0001	<.0001
C16:1c7	0.28	0.29	0.006	0.1557	0.0103
anteisoC17:0	0.47	0.48	0.0155	0.7088	<.0001
C16:1c9	1.6	0.8	0.1189	<.0001	0.0001
C16:1c10	0.04	0.05	0.002	<.0001	<.0001
C16:1c11	0.05	0.01	0.0047	<.0001	0.0053
3, 7, 11, 15-Tetramethyl-16:0	0.04	0.04	0.0015	0.7496	0.0004
C17:0	0.8	0.72	0.0264	0.0002	0.0004
7-methyl-hexadecyl-7-enoate	0.01	0.01	0.0008	0.0044	0.1594
isoC18:0	0.12	0.07	0.005	<.0001	0.0012
C17:1 c6-7	0.03	0.02	0.0016	0.2206	0.0314
C17:1c8	0.04	0.04	0.0023	0.3876	<.0001
C17:1c9	0.4	0.19	0.0148	<.0001	0.0006
C18:0	7	10	0.3547	<.0001	0.0162
C18:1t4	0.01	0.02	0.0008	<.0001	0.0029
C18:1t5	0.01	0.02	0.0011	<.0001	0.019
C18:1t6-8	0.19	0.24	0.0085	<.0001	0.0001
C18:1t9	0.21	0.25	0.009	0.0004	<.0001
C18:1t10	0.3	0.4	0.0273	<.0001	0.0367
C18:1t11	0.7	1.6	0.0752	<.0001	0.0059
C18:1t12	0.23	0.4	0.0162	<.0001	0.008
C18:1t13:t14	0.3	1.1	0.0391	<.0001	0.0306
C18:1c9	30	17	1.0669	<.0001	<.0001
C18:1c11	0.7	0.47	0.0181	<.0001	<.0001
C18:1c12	0.28	0.3	0.0156	0.0577	0.0022
C18:1c13	0.11	0.10	0.0042	0.1224	0.0086
C18:1t16:c14	0.24	0.53	0.0193	<.0001	0.0011
C19:0/C18:1c15	0.22	0.4	0.0139	<.0001	<.0001
C18:2t10t14	0.05	0.05	0.0022	0.0063	0.042
C18:2t11t15	0.02	0.06	0.0042	<.0001	0.0007
C18:2t9t12	0.02	0.02	0.0016	0.0577	0.0407
C18:2c9t13	0.4	0.5	0.0225	0.0062	<.0001
C17cyclo	0.10	0.12	0.0037	<.0001	0.0012
C18:2t8c13	0.17	0.22	0.0102	0.0034	<.0001
C18:2c9t12	0.12	0.13	0.0057	0.3376	0.0002
C18:1c16	0.03	0.04	0.0022	0.0163	0.0294
C18:2t9c12	0.03	0.03	0.0014	0.0095	0.1745
C18:2t11c15	0.11	0.3	0.0201	<.0001	<.0001
C18:2n6	2.5	2.1	0.1102	0.0001	<.0001
C18:2t12c15	0.07	0.06	0.0026	0.2436	0.5655
C18:2c12c15	0.02	0.04	0.0025	<.0001	0.0008
C20:0	0.22	0.26	0.0078	<.0001	<.0001

Δ 7, 9 17:2	0.04	0.04	0.0019	0.3819	<.0001
C18:3n6	0.05	0.05	0.0037	0.0631	0.0044
C20:1c9	0.03	0.02	0.0012	<.0001	0.0002
C20:1c11	0.09	0.05	0.0032	<.0001	0.0022
C18:3n3	0.4	0.7	0.0349	<.0001	<.0001
CLAc9t11	0.7	0.8	0.0422	0.0043	<.0001
C20:1c15	0.03	0.03	0.0014	<.0001	<.0001
CLAt9c11/C21:0	0.05	0.10	0.0028	<.0001	0.0653
CLAt10c12	0.03	0.05	0.0031	<.0001	0.0003
CLAt12t14	0.01	0.04	0.0021	<.0001	0.0065
CLAt11t13	0.03	0.06	0.0034	<.0001	0.042
C20:2n9	0.01	0.04	0.002	<.0001	0.3913
CLAt9t11	0.02	0.03	0.002	<.0001	0.0098
C18:4n3	0.01	0.01	0.0005	0.0002	0.0229
C20:2n6	0.03	0.02	0.0011	<.0001	0.3811
C20:3n9	0.07	0.10	0.0051	<.0001	0.4713
C22:0	0.07	0.15	0.0048	<.0001	0.0035
C20:3n6	0.04	0.03	0.0014	<.0001	0.0006
10,14,17 C20:3	0.01	0.02	0.0007	<.0001	0.0035
C22:1n9	0.03	0.03	0.0027	0.0509	<.0001
C20:3n3	0.01	0.01	0.0007	0.4803	<.0001
C20:4n6 (ARA)	0.31	0.14	0.0116	<.0001	<.0001
C23:0	0.02	0.08	0.0025	<.0001	0.0252
C20:4n3	0.01	0.02	0.001	<.0001	0.0053
C22:2n6	0.02	0.10	0.0043	<.0001	0.0022
EPA	0.07	0.05	0.0033	<.0001	<.0001
C24:0	0.03	0.07	0.0024	<.0001	0.0004
C22:3n6	0.01	0.01	0.001	0.0004	<.0001
C24:1c15	0.02	0.02	0.001	<.0001	<.0001
C22:4n6	0.05	0.02	0.0025	<.0001	<.0001
C25:0	0.01	0.02	0.0009	<.0001	0.3763
C26:0	0.02	0.07	0.0025	<.0001	0.0561
DPA	0.17	0.09	0.0084	<.0001	<.0001
DHA	0.06	0.03	0.0034	<.0001	<.0001
SCFA	5	14	0.2799	<.0001	0.0015
MCFA	48	46	1.3171	0.25	<.0001
LCFA	47	40	1.4586	0.0003	<.0001
SFA	58	69	1.1462	<.0001	<.0001
MUFA	37	25	1.0343	<.0001	<.0001
PUFA	6	6.1	0.1953	0.152	0.0103
UFA	42	31	1.1463	<.0001	<.0001
OCFA	1.7	2.4	0.0455	<.0001	0.0014
BCFA	1.7	2.4	0.0458	<.0001	0.0034
OBCFA	3.4	4.9	0.0769	<.0001	0.0023
PUFA6	3.0	2.5	0.1208	<.0001	<.0001
PUFA3	0.8	0.9	0.0464	0.0078	<.0001
n6/n3	4	3	0.3021	<.0001	<.0001
n3/n6	0.27	0.4	0.0213	<.0001	<.0001
CLA	0.8	1.1	0.0479	<.0001	<.0001
TFA	3.4	6	0.2146	<.0001	0.0012
TFA no VA	2.7	5	0.1519	<.0001	0.0013
AI	1.9	2.3	0.1329	0.0071	<.0001
TI	1.9	2.1	0.1237	0.1187	<.0001
h/H	0.9	0.60	0.049	<.0001	<.0001
DI C10:1	4	1.3	0.2513	<.0001	<.0001
DI C14:1	3	1.5	0.178	<.0001	0.0018
DI C16:1	5	2.9	0.2219	<.0001	0.0081
DI C18:1	80	63	0.7329	<.0001	0.1824
DI CLA	51	35	0.9838	<.0001	0.5566

Average amounts reported are rounded according to the number of significant digits of the relevant standard deviation. SD = standard deviation; ΣFAs = sim of all FAs; FAME = fatty acid methyl ester; SA = stearic acid; LA = linoleic acid; LNA = linolenic acid; ARA=arachidonic acid; EPA = eicosapentaenoic acid; DPA = docosapentaenoic acid; DHA = docosahexaenoic acid; SFA = sum of the individual saturated fatty acids; UFA = sum of the individual unsaturated fatty acids; MUFA = sum of the individual monounsaturated fatty acids; PUFA = sum of the individual polyunsaturated fatty acids; OCFA = odd-chain fatty acids; BCFA = branched-chain fatty acids, sum of iso- and anteiso-FA; OBCFA = odd- and branched-chain fatty acids, sum of odd-, iso-, and anteiso-FA; SCFA, short-chain fatty acids (sum of individual fatty acids from C4:0 to C10:0); MCFA = medium-chain fatty acids, sum of the individual fatty acids from C11:0 to C17:0; LCFA = long-chain fatty acids, sum of the individual fatty acids from C18:0 to DHA; PUFA n-3 and PUFA n-6 = sum of individual n-3 and n-6 fatty acids, respectively; CLA = sum of individual conjugated linoleic acids; TI = thrombogenic index; AI = atherogenic index; h:H = hypocholesterolemic to hypercholesterolemic ratio; in the same row indicate the significant differences ($p < 0.05$).

5. Conclusions

This survey permitted to characterize the colostrum composition of Sarda dairy ewes in terms of macrocomposition (i.e., total proteins and fat), antioxidant properties (measured in terms of FRAP and ABTS), seven trace elements (Cd, Cu, Mn, Ni, Pb, Se and Zn) and IgG concentration. The high correlation between IgG and total protein evidenced that the latter can be used to estimate immunoglobulin content of colostrum in sheep farm. The colostrum antibodies are correlated positively with Se and Zn, both "well known" as essential for stimulating the animal's immune system. The average amounts of toxic elements were always below the established EU level. The fatty acid profile of colostrum highlights a high variability in fatty acid groups between farms but evidenced meaningful differences with the fatty acid profile observed in the mature milk. The amounts of trace elements could be an important marker of nutritional and healthy quality of colostrum, but also of environmental contamination of an area in which animals are breed. In conclusion, this survey provides new data about the fatty acid profile of colostrum. Further investigations are necessary to evaluate the factors of variation associated with the quality of ewe colostrum, especially those associated with the variability of the IgG concentration.

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