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Comparison of nutritional value of different ruminant milks in human nutrition

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Abstract. The present study was conducted on milk samples from 30 Italian Mediterranean buffaloes, and as many goats, sheep and cattle. Milk samples were subjected to chemical-nutritional analysis and compared with commercially available milk samples. In the experiments, the management conditions could have influenced this parameter, determining the observed values. The higher fat content in sheep's milk differed significantly from that in the milk of the other animals analyzed. A higher lactose content was found in the milk of buffaloes and sheep, than in cows and goats. The highest cholesterol content was observed in cow and buffalo milk. These differences were statistically significant. To avoid excessive cholesterol intake, it is necessary to pay attention to both the quantity and quality of fats contained in food, bearing in mind that the introduction of large quantities of dairy products in the diet can cause a significant intake in cholesterol levels. Furthermore, when selecting the type of milk to be consumed, it is necessary to consider that the amount of total cholesterol is dependent on both the animal of origin and on the integrity of the lipid fraction. To complete the study, a chemical-nutritional analysis of milk samples normally marketed, both of vegetable and animal origin, was also included. Observing the results, some differences appear evident in the chemical-nutritional composition of goat and cow milk compared to the raw milk analyzed. In particular, goat's milk has a higher percentage of lipids. However, the differences observed herein were not significant and could be explained by the manufacturing process the samples were subjected to from the stable to the packaging industry. From the results obtained in the present study in the compositional analyses performed, and as also obtained from previous studies, it was found that sheep and goat milk, in particular, may be a valid substitute for cow's milk.

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Introduction

Currently, global milk production is dominated by different animal species: Dairy cattle, buffalo, goat and sheep. Cow's milk accounts for >80% of the world's milk production. The consumption of cow-derived dairy products prevails in numerous cultures globally. Sheep and buffalo milk, due to their high protein content, including casein and fats, is an excellent raw material for processing, particularly dairy. The composition of goat milk allows it to be used as a raw material for milk processing (1).

The average values of the basic components of milk (proteins, fats and lactose) also appear to be influenced by factors, such as the breed, the feeding system, the stage of lactation and the climatic conditions in which the animals are reared. The energy value of milk from various animal species is closely related to the concentration of certain compounds in the dry matter, in particular the amount of fat (2).

In recent years, the use of milk from different mammals in human nutrition is gaining increasing popularity (3), mainly owing to a cholesterol-lowering action, better bioavailability, therapeutic properties (used in gastro-intestinal disorders) and the absence of allergies following consumption. Milk fat is also one of the few dietary sources of butyric acid, a potent inhibitor of cancer cell proliferation, as well as an inducer of differentiation and apoptosis in a number of cancer cell lines (4).

There is some evidence from epidemiological studies and systematic reviews alike that dairy intake is inversely associated with the risk of developing metabolic syndrome (5,6). Recently, a greater preference for the vegan diet, as well as increasing attention to health in general, has influenced the selection of the type of milk consumed.

Milk is one of the foods that help maintain a healthy nutritional state, providing energy, calcium, proteins and vitamins, particularly during early childhood, as well as a greater attention to one's health. Recently, the increase in allergies and intolerances to cow's milk proteins and a growth in the vegan population have influenced parents to frequently select cow's milk substitutes for children, including other types of mammalian milk and beverages with a vegetable milk base.

Marked differences have been documented in the macronutrient composition between multiple milk sources, particularly in terms of the protein and lipid content. For instance, 100 g sheep milk provides a markedly greater amount of protein (P: 5.5 g) and fat (F: 5.9 g) compared to cow (P: 3.4 g; F: 3.3 g), goat (P: 3.7 g; F: 3.8 g) and camel (P: 3.3 g; F: 4.0 g) milk (7). Buffalo and reindeer milks also have a notably high lipid content (7.4 g/100 g and 16.1 g/100 g, respectively) (8). In addition, the mean lactose content varies modestly across ruminant milks at 4.51, 4.75, 4.79 and 4.82% for 100 g goat, sheep, buffalo and cow milk, respectively (1).

The main component of milk, which has a major impact on its nutritional value and technological suitability, is protein (9). It has been reported that the content of whey proteins in human milk is in the range of 0.68 to 0.83 g/100 g, and in cow's milk, this range is 0.55 to 0.70. Sheep's milk is the richest in whey proteins (1.02 g/100 g) (10) and contains the highest concentration of casein (4.18 g/100 g) (10), similar to buffalo milk, which contains 4.0 g casein in 100 g (11). Almost half the amount of casein is found in cow's milk (2.46 to 2.80 g/100 g) (9) and goat's milk (2.81 g/100 g) (12). Human milk also contains casein; however, in small amounts -0.32 to 0.42 g/100 g (9); therefore, the ratio between whey proteins and casein is very high (2.08), as previously mentioned (13).

The protein fraction can be broken down into soluble and insoluble proteins. Soluble proteins, termed whey proteins, represent 20% of the total amount, while insoluble proteins, or caseins, account for 80% (14). The main role attributed to caseins is the binding of minerals and their capacity as carriers, mainly calcium and phosphorus. Furthermore, caseins give rise to numerous bioactive peptides that have certain benefits for human health. These include antioxidants (15), cytomodulators, immunomodulators (16), antihypertensives (17) and antithrombotic factors (18) in the cardiovascular, nervous and immune and digestive systems. Certain peptides, such as b-casomorphins have opioid-like actions, functioning similar to an analgesic and tranquilizer affecting the central nervous system (19). Experimental studies have also demonstrated that some peptides interfere with the gastrointestinal tract, favoring the production of mucin, thus preventing the adhesion of the pathogen to the intestinal surface, exerting effects on intestinal motility that may justify a possible role in weight control through the regulation of food intake (20).

Fat is the main substance that defines the energy value of milk and significantly contributes to its nutritional properties, as well as to its technological suitability. Cholesterol is present in the milk fat globule membrane and accounts for 95% of milk fat sterols (6).

The cardio-metabolic risk is linked to several factors, including obesity, abnormal glucose homeostasis, dyslipidemia and hypertension (21). A positive association has been established between these groups of risk factors, cardiovascular disease and type 2 diabetes, and a similar association has been described in children and adolescents (21,22). In addition to genetic factors, lifestyle and eating habits also significantly contribute to this risk (5).

In this context, scientific research has focused on understanding the role of diet in the development of cardiometabolic risk. Previous studies have report that the intake of dairy products protects against this risk rather than representing a problem (23,24). The data reported in some studies have demonstrated that, mostly in adults, the higher dairy intake may decrease the risk of developing increased blood pressure, obesity and hyperinsulinemia (22,25).

Some components contained in dairy products, such as calcium, medium-chain fats and bioactive peptides, have been found to play a crucial role in the prevention of cardio-metabolic risk and its complications, through mechanisms that include the sense of satiety and the regulation of insulin levels (26). While some researchers have reported a positive association between the intake of dairy products and the increased cardio-metabolic risk (27), others have reported conflicting data, particularly in adolescents (26,28). Furthermore, it has not yet been clarified whether different types of dairy products exert the same effects on the cardio-metabolic risk.

It should be emphasized that the introduction of a large number of dairy products in the diet also increases the ingestion of fats, which are particularly rich in these products, particularly saturated fatty (29) and cholesterol. The effects of the increased intake of these two nutritional components are mainly two: i) An increase in low density lipoprotein (LDL) levels, and therefore in the onset of cardiovascular issues; and ii) an increase in the levels of circulating estrogens.

In 1958, an American scientist (Ansel Keys) began the project termed 'Seven Countries Study', a comparative analysis of the diet of 14 groups of subjects, aged between 40 and 59 years, for a total of 12,000 cases, in seven countries from three continents (Finland, Japan, Greece, Italy, Holland, the United States and Yugoslavia) (30). The data collected demonstrated that, among the Mediterranean populations, who consumed mainly pasta, fish, fruit and vegetables, and used exclusively olive oil as a condiment, the percentage of mortality from ischemic heart disease was much lower than that in the subjects of countries, such as Finland, where the daily diet included a notable amount of saturated fat (butter, lard, milk and red meat).

Previous research has also suggested that high levels of cholesterol that appear in milk have a protective role in infants and program the metabolism of cholesterol in later life. Therefore, mothers are advised to avoid the use of infant formulas, which are considered to have low cholesterol levels (31). It has been reported that saturated acids, such as myristic and palmitic acid, tend to increase plasma cholesterol and LDL levels, concluding that their partial replacement in the diet with polyunsaturated fat is able to lower cholesterol and coronary risk (27). A summary of the main benefits of consuming milk is presented in Fig. 1.

Although there are increasing data on the health benefits of cow's milk, whether milk from alternative (non-bovine) sources could provide cardio metabolic protection has not yet been reviewed, at least to the best of our knowledge. Considering that the differences in the nutritional value of milk can be used as a marker milk, helping to select the optimal food for human nutrition, the aim of the present study was to compare different components and parameters of milk (total lipids, density, lactose, total solids, proteins, casein, freezing point, pH, electrical conductivity and cholesterol) from different mammals.

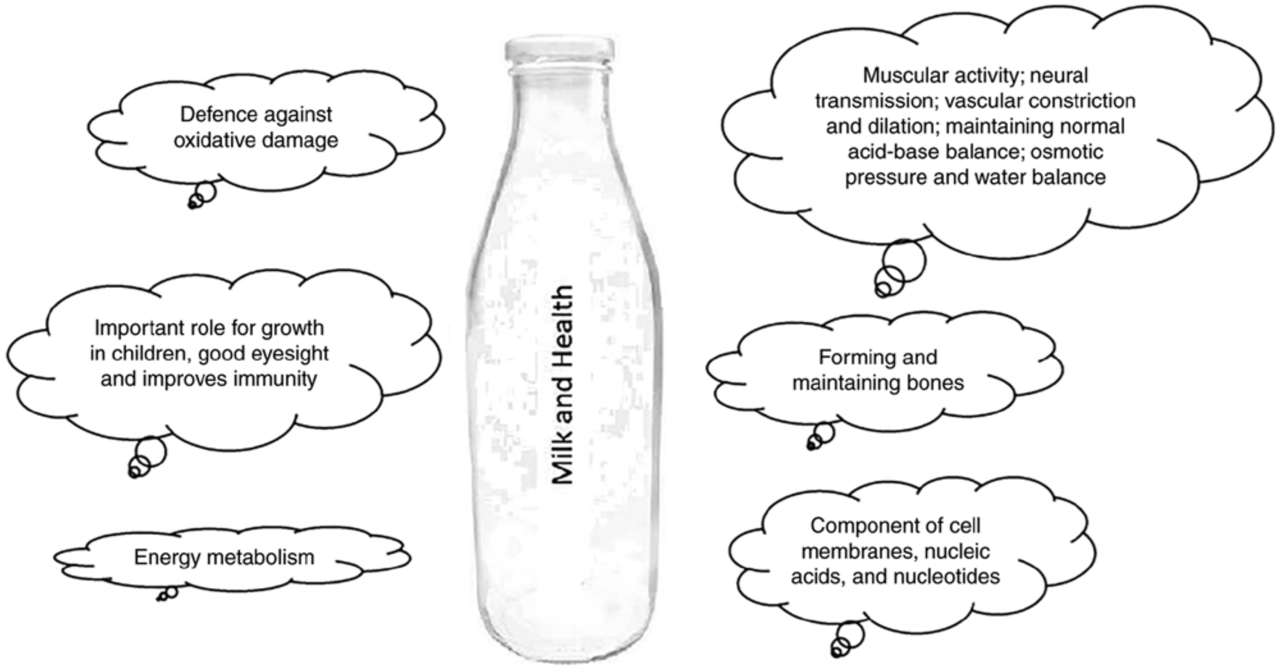

Figure 1. Schematic illustration summarizing the main benefits of consuming milk.

Data and methods

Criteria for selecting the cited articles. The cited articles were selected according to their relevance for the purpose of the study in order to assess the state of the milk and to compare the data obtained in the study.

Milk samples and analyses. The study was conducted on milk samples from 30 Italian Mediterranean buffaloes, 30 goats, 30 sheep and 30 cattle at different stages of lactation and different parity levels. The selected farms were all intensively managed. In total, of the selected animals, 10 animals were in second lactation, 10 were in third lactation and 10 were in fourth lactation. The milk samples (50 ml), obtained by weighing the milk produced by milking twice daily, were analyzed for the chemical-nutritional composition on the same day of collection. The farms were all located in the same region, in southern Italy and the samples were obtained during the same period.

Milk samples from these species of zootechnical interest were subjected to chemical-nutritional analysis and compared with commercially available milk samples and a sample of soymilk. These are samples of packaged milk normally present in supermarkets, from various manufacturing companies that have been sampled and analyzed, both for milk of animal origin and for those of vegetable origin.

All samples were analyzed in triplicate. The aliquots, analyzed the day after harvesting from the farm and obtained by weighing the productions of the two-daily milking, were subjected to the following determinations: Total lipids, density, lactose, total solids, total proteins, casein, freezing point, salts, pH, electrical conductivity and cholesterol.

When milking, all hygiene actions were followed, and the samples were placed into sterile bottles. Prior to the analysis, the milk samples were stored at a temperature of ±5˚C. The quantitative determination of cholesterol was carried out using a method previously described in 1995 (32). The cholesterol content was analyzed using a HP Series 1100 chromatograph (Hewlett Packard 1100 Series HPLC System) equipped with a flame ionization detector (FID). The analysis was performed on a glass column (C18 5 μl x ID 25 cm x 1,6). Helium was used as a carrier gas, the flow rate was 1 ml/min, and the detector and the injector temperatures were 300 and 290˚C, respectively.

Statistical analyses. Statistical analyses were performed using SPSS software (2017, IBM Corp.). Data are presented as the mean ± SD. One-way ANOVA was used to assess the differences in the milk characteristic values from the different species. Tukey's test was used as a post hoc test to identify the mean values that differed significantly from each other. Values of $P<0.01$ and $P<0.05$ were considered to indicate statistically significant differences.

Results and discussion

The chemical-nutritional characteristics of the milk from the different mammals are presented in Table IA, and the results of statistical analysis with the Tukey's test are presented in Table IB. The mean values of all parameters reported in the study were like those reported in the literature. The highest fat content (%) was found in sheep's milk (13.72±2.51) and this differed significantly from the milk of the other animals analyzed (cow milk, 3.40±0.55; buffalo milk, 9.86±1.80; and goat milk, 9.63±0.45). In particular, a significant difference ($P<0.01$) was found for buffaloes and goats vs. sheep and vs. cow milk. These results were similar to those reported in previous studies (8,33).

In the present study, a higher lactose content (%) was found in buffalo (5.27±0.33) and sheep (5.70±0.28) milk compared with cow (3.40±0.35) and goat (4.56±0.21) milk. A significant

Table I. Chemical and nutritional composition of raw milk from different species and statistical analyses of the differences.

A, Chemical and nutritional composition of the milk

Parameter	Cow milk	Buffalo milk	Goat milk	Sheep milk
Fat (%)				
Mean	3.40[c]	9.86[b]	9.63[b]	13.72[a]
SD	0.55	1.80	0.45	2.51
Density (˚SH)				
Mean	1.031[a]	1.038[b]	1.032[a]	1.039[b]
SD	0.017	0.02	0.015	0.015
Lactose (%)				
Mean	3.40[e]	5.27[f]	4.56[e]	5.70[d]
SD	0.35	0.33	0.21	0.28
RDM (g/l)				
Mean	8.99[f]	10.76[e]	9.29[f]	11.67[d]
SD	1.01	0.61	0.40	0.74
Protein (%)				
Mean	4.07	4.53	3.99	4.02
SD	0.18	0.85	0.24	0.41
FP (˚C)				
Mean	-0.528[e,f]	-0.629[d,e]	-0.46[f]	-0.740[d]
SD	0.089	0.155	0.31	0.063
Salts (%)				
Mean	0.77[c]	0.92[b]	0.79[c]	1.01[a]
SD	0.09	0.05	0.03	0.07
Casein (%)				
Mean	2.91	3.48	3.07	3.10
SD	0.90	0.99	0.23	0.38
pH				
Mean	6.85[b]	7.00[a]	6.79[b]	6.85[b]
SD	0.05	0.13	0.12	0.10
EC (ohm 25˚C)				
Mean	11.94[d]	5.39[e]	13.54[d]	3.70[e]
SD	1.19	2.24	2.03	0.75
Cholesterol (mg/100 ml)				
Mean	20.67[a]	20.49[a]	6.02[c]	6.07[b]
SD	9.07	10.89	2.08	8.77

B, Results of statistical analysis with (ANOVA with Tukey's post hoc test)

	Subset for alpha=0.05		
Parameter	1	2	3
Fat			
Cow	3.40		
Goat		9.63	
Buffalo		9.86	
Sheep			13.72
Density			
Cow	1.031		
Goat	1.032		
Buffalo		1.038	
Sheep		1.039	

Table I. Continued.

	Subset for alpha=0.05		
Parameter	1	2	3
Lactose			
Cow	3.40		
Goat	4.56		
Buffalo		5.27	
Sheep			5.70
RDM			
Cow	8.99		
Goat	9.29		
Buffalo		10.76	
Sheep			11.67
Protein			
Cow	4.07		
Goat	3.99		
Buffalo	4.53		
Sheep	4.02		
FP			
Cow		-.528	-.528
Goat			-.460
Buffalo	-.629	-.629	
Sheep	-.740		
Salts			
Cow	.77		
Goat	.79		
Buffalo		.92	
Sheep			1.01
Casein			
Cow	2.91		
Goat	3.07		
Buffalo	3.48		
Sheep	3.10		
pH			
Cow	6.85		
Goat	6.79		
Buffalo		7.00	
Sheep	6.85		
EC			
Cow	11.94		
Goat	13.54		
Buffalo		5.39	
Sheep		3.70	
Cholesterol			
Cow	20.67		
Goat			6.02
Buffalo	20.49		
Sheep		6.07	

RDM, residual dry matter; FP, freezing point; EC, electrical conductivity. Values with different letters are statistically significantly different, whereas values with the same letters are not ($^{a,b,c}P<0.01$ and $^{d,e,f}P<0.05$).

Table II. Chemical and nutritional composition of the normally marketed milk, for direct consumption and statistical analyses.

A, Chemical and nutritional composition of the normally marketed milk

Parameter	Goat	Oat	Rice	Soy	Cow
Lipids (%)					
Mean	2.85[a]	1.36[b]	1.06[b]	1.62[b]	3.36[a]
SD	0.47	0.04	0.06	0.05	0.37
Density (˚SH)					
Mean	1.03	1.04	1.03	1.02	1.03
SD	0.02	0.02	0.01	0.03	0.02
Lactose (%)					
Mean	4.18	4.94	4.55	3.09	4.38
SD	2.85	1.36	1.06	1.62	3.36
RDM (g/l)					
Mean	8.52	9.92	9.11	6.26	8.97
SD	0.27	0.31	0.21	0.30	0.25
Protein (%)					
Mean	3.01	4.04	3.76	3.04	3.07
SD	0.89	1.02	0.94	0.57	0.69
FP (˚C)					
Mean	-0.49	-0.58	-0.53	-0.34	-0.52
SD	0.21	0.19	0.25	0.15	0.21
Salts (%)					
Mean	0.72	0.84	0.77	0.53	0.76
SD	0.08	0.07	0.08	0.05	0.07
Casein (%)					
Mean	2.81	3.77	3.51	2.84	2.87
SD	0.8	0.7	0.8	0.8	0.8
pH					
Mean	6.81	6.05	7.20	7.55	6.87
SD	0.04	0.04	0.05	0.04	0.03
EC (ohm 25˚C)					
Mean	5.34	6.21	5.55	4.64	4.3
SD	1.25	1.16	1.18	1.15	1.18
Cholesterol (mg/100 ml)					
Mean	12.3	5.24	2.11	0	29.84
SD	1.16	0.87	0.75	0	2.89

B, Results of statistical analysis with (ANOVA with Tukey's post hoc test)

	Subset for alpha=0.05	
Parameter	1	2
Fat		
Goat		2.85
Milk from oats	1.36	
Milk from rice	1.06	
Milk from soy	1.62	
Cow		3.36
Density		
Goat	1.03	
Milk from oats	1.04	
Milk from rice	1.03	
Milk from soy	1.02	
Cow	1.03	

Table II. Continued.

	Subset for alpha=0.05	
Parameter	1	2
Lactose		
Goat	4.18	
Milk from oats	4.94	
Milk from rice	4.55	
Milk from soy	3.09	
Cow	4.38	
RDM		
Goat	8.52	
Milk from oats	9.92	
Milk from rice	9.11	
Milk from soy	6.26	
Cow	8.97	
Protein		
Goat	3.01	
Milk from oats	4.04	
Milk from rice	3.76	
Milk from soy	3.04	
Cow	3.07	
FP		
Goat	-.490	
Milk from oats	-.580	
Milk from rice	-.530	
Milk from soy	-.340	
Cow	-.520	
Salts		
Goat	.08	
Milk from oats	.07	
Milk from rice	.08	
Milk from soy	.05	
Cow	.07	
Casein		
Goat	2.81	
Milk from oats	3.77	
Milk from rice	3.51	
Milk from soy	2.84	
Cow	2.87	
pH		
Goat	6.81	
Milk from oats	6.05	
Milk from rice	7.20	
Milk from soy	7.55	
Cow	6.87	
EC		
Goat	5.34	
Milk from oats	6.21	
Milk from rice	5.55	
Milk from soy	4.64	
Cow	4.30	

Table II. Continued.

	Subset for alpha=0.05	
Parameter	1	2
Cholesterol		
Goat	12.3	
Milk from oats	5.24	
Milk from rice	2.11	
Milk from soy	0	
Cow	29.84	

RDM, residual dry matter; FP, freezing point; EC, electrical conductivity. Values with different letters are statistically significantly different, whereas values with the same letters are not ([a,b]P<0.01).

difference was found (P<0.05) of cows and goats vs. buffalo vs. sheep. This finding could be justified by the rusticity characteristics maintained by these species, as they are not subjected to very strict selection regimes. Lactose is the main milk sugar, and it is involved in the intestinal absorption of minerals (calcium, magnesium and phosphorus), in the use of vitamin D, and is a source of energy.

The highest cholesterol content (mg/100 ml) was observed in bovine and buffalo milk (20.67±9.07 and 20.49±10.89, respectively), and was markedly higher than that found in goat and sheep milk. These differences were significant (P<0.01) between cows and buffalo vs. goat and sheep. Cholesterol levels in buffalo and cow milk were found to differ significantly compared to those in sheep and goat milk. Similar results were observed in previous studies (33). This peculiarity could be justified by the of characteristics milk that are influenced by factors endogenous and exogenous to the animal, including ambient temperature, feeding (fibrous component of the diet, presence of fodder, starch content of the ration, high protein degradability), and the method of administration of the ration (unifeed or separate administration of forages and concentrates). Among all the factors, nutrition has a greater weight, due both to the effects it induces at the hormonal level, and as it allows the animal's organism to make available, for the udder, the precursors necessary for the synthesis of the lipid component (34). In the present study, the managerial conditions could have influenced this parameter, determining the observed values.

Another significant difference found, as shown in Table IA, is related to the electrical conductivity. This was significantly higher in cattle and goat milk, than in buffalo and sheep milk. The conductivity of milk is closely related to the presence of mineral electrolytes, such as chlorides, phosphates and citrates. As shown in Table IA, when comparing the values of electrical conductivity with the content of salts, it can be noted that as the latter increase, the electrical transmission capacity decreases. This is due to the fact that the content of mineral electrolytes and colloidal ions decreases the resistance to the passage of electric current in the water, the main constituent of milk.

Among the peculiarities of buffalo milk there is also a greater suitability for infant feeding, compared to cow's milk, owing to the better ratio of calcium and phosphate contents, compared to those of sodium and potassium (33). The density of the milk is not a constant parameter and is strictly related to the lean residue and the quantity of fat; with respect to the latter, there is an inversely proportional association; moreover, it is also linked to the temperature of the milk itself; thus, the data reported in the literature are not always comparable with each other. In the buffalo, where the fat content varies considerably during lactation, this parameter is even more variable.

The proteins are the most noteworthy from an allergological point of view, being, roughly, comprised of 80% casein, the remainder being of whey proteins (β-lactoglobulin, α-lactalbumin, etc. The majority of dairy-related allergies are caused by immunoglobulins as they bind to particular amino acid sequences, causing the allergic reaction. Yet, this allergenic capacity is not strictly linked to the total protein content. Indeed, from the analysis in the present study, it may seem that buffalo milk, exhibiting a higher total protein content, is more likely to cause allergic reactions; in reality, if the total protein data are compared with the casein content, it can be seen that this is higher in buffalo milk than in milk from other species (Table IA).

Milk normally has a pH value close to neutral and is a buffered solution, as there are acid or basic molecules that neutralize any added bases or acids, mainly proteins carrying ionic groups with positive or negative charges. As pH highlights the 'current' acidity that is an indication of the 'state of freshness', in all the milk samples examined and in the different species, the characteristics of freshness are clearly represented, as the sampling was carried out immediately after milking. As demonstrated in Table IA, by comparing the electrical conductivity values with the salt content, it is noted that the latter affect the electrical transmission capacity.

For the completeness of the study, a chemical-nutritional analysis of milk samples normally marketed, of both vegetable and animal origin, was also included. The results obtained are presented in Table IIA.

The differences between the chemical and nutritional characteristics between the different types of commercial milk were analyzed. The samples were examined in triplicate, and only the average values found are reported. From the results, some differences in the chemical-nutritional composition of goat and cow's milk with respect to the raw milk analyzed appear evident. In particular, there was a higher percentage of lipids in goat's milk. This peculiarity may be justified by the fact that the milk characteristics are influenced by factors endogenous and exogenous to the animal, including ambient temperature, feeding (fibrous component of the diet, presence of fodder, starch content of the ration, high protein degradability) and the method of administration of the ration (unifeed or separate administration of forages and concentrates).

Among all the factors, nutrition has a greater weight, both for the effects it induces at the hormonal level, and as it allows the animal's organism to make available, for the udder, the precursors necessary for the synthesis of the lipid component (34). In the present study, the managerial conditions could have influenced this parameter, determining the observed values.

Cow's milk had the highest cholesterol content. However, these differences were not statistically significant, and this may be explained by the manufacturing process the samples undergo from the stable to the packaging industry. In this regard, it is important to note that raw milk, compared to whole milk, at the time of purchase has all the 'original' nutritional qualities (thermolabile components, including enzymes and vitamin D) and the protein fraction is slightly more digestible; however, the fat micelles remain totally intact, considerably prolonging the digestibility of the food. On the contrary, whole milk is proportionally depleted with respect to the type of heat treatment most commonly applied: Rapid pasteurization, or high temperature short time (HTST, termed 'fresh milk', less conservable), and ultra-high temperature treatment (UHT), termed 'long-life' milk; however, owing to the homogenization of lipids, this type of milk boasts an absolutely greater digestibility than raw milk.

From the aforementioned findings, it appears that raw milk, in addition to having a greater palatability, is nutritionally more integral, even if less digestible; however, this statement is only partially acceptable. Raw milk, being only macro-filtered, is a potentially polluted food; thus, it cannot or should not be consumed as it is; statistically, ~1/5 of the analyzed samples contain pathogens, and evidently, such a condition requires the sanitation of the product (35).

In conclusion, cow's milk is the most universal raw material for processing, resulting in the widest spectrum of manufactured products. However, it should be emphasized that in some regions of the world (with conditions that preclude the use of dairy cattle), the milk obtained from these species is a valuable source of nutrients providing an important food source. Sheep and buffalo milk, due to its high protein and fat content, is an excellent raw material for dairy processing.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

AA performed all the fieldwork, undertook primary data analysis and interpretation, prepared the draft manuscripts, and completed the revisions. GA performed all the fieldwork and undertook primary data analysis. FS was involved in the conception and design of the study, technical input into the manuscript, and the overall scientific management. AA and GA confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable, as the milk samples were collected in an automated milking parlor.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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