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Fatty Acid Profile in Creole Goat Milk in Grazing and French-Alpine and Saanen Confined Goats in Three Seasons of the Year

Research Article

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ABSTRACT

The composition of goat milk varies depending on the diet, breed, production system, weather conditions, gestation stage, among other factors. The objective was to determine the fatty acid profile in the milk of extensive grazing Creole and French Alpine and Saanen goats confined in three seasons. The experiment was carried out using a factorial design with two factors, the season of the year (fixed effects) with three levels (rainy, transition and dry) and the breeds (fixed effects) with three levels (Creole, Saanen and French Alpine) with measurements repeated over time. Five Creole, Saanen and French Alpine goats were randomly selected in the extensive grazing and in the confined system, respectively. The results showed that the most abundant fatty acid content in milk was palmitic acid in the three seasons, as well as in three goat breeds. From the total acids in the milk profile, only six showed significant differences between seasons and between goat breeds, while nine showed significant differences in the interaction of seasons × breeds. The content of caprylic, capric and lauric acid was higher in milk collected in the transition season, while stearic and oleic acids showed an increase in the dry season and only alpha linolenic acid was abundant in rainy season. The fatty acid showed differences between breeds, especially unsaturated fatty acids, being more abundant in Creole, which suggests that the species from the extensive grazing in the rangeland shows good nutritional contribution, both in the rainy and in dry seasons.

KEY WORDS confined goats, extensive grazing, fatty acids in goat milk, goat production systems.

INTRODUCTION

In peasant farming production, especially goats (*Capra hircus*), an absecence to provide added-value products exists. Furthermore, their traditional cultivation lies in preferring a higher number of animals whose production is unknown instead of having a lower number of smaller animals but with higher production (López-García *et al.* 2011). The goat milk quality not only depends on breed but is also influenced by the type of food the animals ingest: fiber quantity, protein level, additional supplements and the relationship forage-concentrate (Bedoya *et al.* 2011). The feed patterns in grazing goats show a selection that has seasonal availability and relative palatability. However, the mechanism by which goats detect changes in nutritional forage content and adjust their value in different phenologial status requires more investigation (Mellado, 2016).

The goat fatty acid (6:0), caprylic acid -found naturally in coconut oil and plam kern (8:0) and capric acid -found in saturated fats (10:0) derive from the word "caper" (goat in latin) and are more prevalent in specific ruminant species found in greater proptortion in goat milk (Vieitez *et al.* 2017).

The presence of these fatty acids (geometrical and positional isomers, cis and trans, of oleic, linoleic and α-linolenic acid) in milk fat is associated with unsaturated fatty acids ingested in animal diet (Martínez-Marín *et al.* 2015). The linoleic acid conyugated C18:2 cis9-trans11 (ALC c9t11), trans-vaccenic acid and some long-chain n-3 fatty acids of ruminant milk have beneficial effects on human health. The fatty acid content shown in goat milk is due to animal diet composition (Palmquist, 2007).

The goat genotypes have a notably influence on fatty acid profile in goat milk, with emphasis on linoleic and alpha-linoleic acids, which are considered beneficial for human health (Idamokoro *et al.* 2019). Therefore, the objective of the present study was to determine fatty acid profiles in Creole extensive grazing and confined system (French-Alpine and Saanen) goats in three seasons of the year (dry, rainy, and transition).

MATERIALS AND METHODS

Study sites

The present study was performed in two sites, Site 1, located in the farmer denominated El Mezquitillo at 23° 27' 33.264" LN and 110° 5' 18.7794" LW in the Sierra de la Laguna Biosphere Reserve buffer zone, Baja California Sur, México; Site 2, located at 24° 5' 45.19" LN, 110° 20' 20.36" LW in the Municipality of La Paz, Baja California Sur, México.

Exploitation systems

Site 1 was used for goats whose exploitation was performed by extensive grazing system. At night, goats were kept confined in corrals (without food and only water *ad-libitum*); during the day, they were set free in the rangeland to consume (*ad libitum*) plant species that according to Leon de la Luz *et al.* (2012), low deciduous forest vegetation predominates, characterized by the presence of *Lysiloma microphylla*, *Fouquieria diguetii*, *Tecoma stans*, *Jatropha vernicosa*, *Jatropha cinerea*, *Chloroleucon mangense*, *Bursera epinnata*, *Colubrina viridis*, *Lysiloma candidum*, *Mimosa distachya*. Site 2 was used for confined Saanen and French-Alpine breed goats and the system of exploitation is confind and consists of keeping the goats confined 24 hours (h) a day (d) in appropriate corrals and feeding them with alfalfa (*Medicago sativa*) hay and commercial milk concentrate (sorghum in grain, buckwheat’s husk, molasses, wheat bran and soybean meal) with 16% protein made by a local enterprise (Forrajera San Joaquín).

Animals in study

The site 1 (extensive grazing system) collected milk samples from Creole goats, since the breed allows and adapts to the grazeland conditions. The goats were selected with a corporal condition of 3/5, live weight average of 35 kg. The weight was registered using a spring balance (Nuevo Leon® model jogua din 100, made in Mexico). The site 2 (confined system), milking both breeds, Saanen and French-Alpine. The animals were selected with a corporal condition of 3/5, live weight average of 37 kg. The milk samples in the two sites were collected manually in the three seasons of the year. The study started in September (rainy) and by that date all goats in the study were 80 ± 10 d in lactation. Subsequently, goats were dried and started another lactation period. In March (transition), all goats were found in 60 ± 10 lactation d and (dry) in 150 ± 10 days by June. The females used in both production systems were roughly in their fourth lactation.

Ethical aspects

The present study did not implement any experimental practice with goats in the two production systems; only raw milk samples were considered since they are routine practice in both production systems. The goats were not subjected to any treatment provoking stress or distinct conditions that could attempt against their well-being.

Season of the year

Three distinct seasons rainy (September), rainy-dry transition (March), and dry (June) were used for the study.

Milk samplings

The milk samples were collected every season by duplicate in both sites from five Creole goats in extensive grazing system for five days (replications in time); five Saanen and five French-Alpine goats in the confined system were also sampled for five days (replications in time). The milk was manually collected at both locations and then stored in 100-mL bottles and frozen at -20°C in a ultrafreezeer (Westinghouse® model FC095SEW0, made in USA) for further analyses.

Fatty acid profile

The milk samples were processed according to Bligh and Dyer (1959). The equipment used to determine fatty acids was a chromatographer (Agilent Technologies® 7000 GC/MS Triple Quad, Santa Clara, CA, USA) with a 30-m column, using helium as carrier gas. The fatty acid profiles were performed in the Instrumental Analysis Department of the Pharmaceutical Chemistry Faculty at Universidad of Concepción, Chile.

Experimental design

The experiment was carried out using a factorial design with two factors, the season of the year (fixed effects) with three levels (rainy, transition and dry) and the breeds (fixed effects) with three levels (Creole, Saanen and French Alpine) with measurements repeated over time. The creole goats were in extensive grazing system, while Saanen and French-Alpine were placed in a confined system. Five goats of each breed and season represented one replication per goat; milk samplings (replications in time) were performe in each season for five consecutive days representing one subsample for five consecutive days per season; milk sampling (replications in time) and each sampling per day represented one subsample.

Statistical analysis

The variables that were expressed in percentage were arcsine transformed (Little and Hills, 1989; Steel and Torrie, 1985) to comply with normality. The analysis of variance (ANOVA) was performed considering a factorial design with two factors, the season of the year (fixed effects) with three levels (rainy, transition and dry) and the breeds (fixed effects) with three levels (Creole, Saanen and French Alpine) with measurements repeated over time. The differences within the variable (fatty acid content) were determined by Tukey's Honestly Signicant Differences (HSD) ($P \leq 0.05$) test. The analyses were performed in GLM (General Linear Model and Nested Anova Design) with Statistica v. 13. program (TIBCO, 2018).

RESULTS AND DISCUSSION

The results of the effect of seasons of the year on fatty acid profiles in goat milk is shown in Table 1. The seasonal variations in caproic acid content were not discernible; nevertheless, the content was greater in collected milk in the transition season. The capryllic acid content also showed differences between seasons of the year with a higher collected milk content in transition season, followed by rainy season. The capric content also showed significant differences between season and higher values on collected milk in the transition season followed by rainy season.

On the one hand, lauric acid content showed significant difference between season with a greater contren in transition, followed by rainy. The myristic and pentadecanoic acid contents did not show differences between seasons. In contrast, palmitic, margaric, and linoleic acids did not show significant differences between seasons. Nevertheless, they showed greater contents in rainy season followed by transition or dry season (palmitic acid). The stearic, oleic, and alfa linoleic acids showed significant differences between seasons. The stearic and oleic acids were higher in milk collected in the dryt season, followed by the rainy season, wherase alpha linoleic acid was greater in the rainy season followed by dry season.

The results of the effect of breeds on the fatty acid profiles in goat milk are shown in Table 2. The interbreed variations in the content of caproic, capric, myristic, palmitic, margaric and linoleic acids were not significant among goats breeds; however, milk from Saanen goats showed a moderate increase in the content of caproic and capric acids; milk from Alpine-French goats showed a slight increase in the content of myristic and palmitic acids, while milk from Creole goats showed an increase in the content of margaric and linoleic acids. The content of capryllic, lauric, pentadecanoic, stearic, oleic and alpha-linolenic acids showed significant differences among goat breeds. Milk from Saanen goats showed the highest content of capryllic and lauric acids, while milk from Creole goats showed the highest content of pentadecanoic, stearic, oleic and alpha-linolenic acids.

The results of the effects of seasons of the year and goat breeds on fatty acid contents are shown in Table 3. The caproic acid constent did not show significant differences between seasons and breeds, but its content was numerically greater in the rainy season in Saanen goat milk and decreased in French-Alpine goat milk in the rainy season. The palmitic acid content did not show significant differences between season and breeds, but its content was greater in the transition season in French-Alpine goat milk rainy season French-Alpine goat milk, decreasing in milk in the same breed but in dry season.

The capryllic, caproic, lauric, myristic, pentadecanoic, stearic, oleic, linoleic, and alpha-linoleic acids showed significant differences between seasons and breeds. The capryllic acid content was higher in Saanen goat milk collected in transition, showing the opposite in Creole goat milk collected in dry season. The capric acid stands out for being greater in Saanen goat milk collected in transition, whereas Creole goats showed a lower content in dryt. The Creole goat milk stood out in the rainy season showing a greater lauric acid content, but it decreased significantly in the same breed in the dry season. The myristic acid content showed increase in the three breeds but higher in Saanen in transition, followed by Creole in rainy season and French-Alpine in dry season.

The Creole goat milk collected in transition showed a high pentadecanoic acid content, where Saanen goats showed the opposite collected in the same season. The stearic acid content was greate in Creole goats collected in dryt and decreased significantly in French-Alpine goats in transition season. The Creole goat milk showed a greater oleic acid and decreased significantly in Saanen goats both in transition and dry seasons.

Table 1 Effect of season in Creole goat milk fatty acid (%) content in an extensive grazing system and two Saanen and French-Alpine goats in a confined production system

Season of the year	Caproic acid	Caprylic acid	Capric acid	Lauric acid	Myristic acid	Pentadecanoic acid
Rainy	2.31±0.53^{a}	2.34±0.17^{ab}	8.39±0.56^{b}	4.21±0.36^{a}	9.60±0.47^{a}	0.99±0.04^{a}
Transition	2.76±0.37^{a}	2.67±0.21^{a}	10.80±0.55^{a}	4.55±0.30^{a}	9.85±0.58^{a}	1.04±0.10^{a}
Dry	2.48±0.72^{a}	2.02±0.17^{b}	7.12±0.72^{b}	3.00±0.34^{b}	8.35±0.67^{a}	0.89±0.04^{a}
	Palmitic acid	**Margaric acid**	**Stearic acid**	**Oleic acid**	**Linoleic acid**	**Alpha-linolenic acid**
Rainy	26.98±1.20^{a}	0.75±0.08^{a}	7.93±0.56^{b}	21.60±1.32^{a}	3.07±0.18^{a}	0.78±0.10^{a}
Transition	23.38±0.91^{a}	0.71±0.09^{a}	6.16±0.92^{b}	15.85±1.34^{b}	2.97±0.20^{a}	0.46±0.05^{b}
Dry	24.93±1.37^{a}	0.68±0.10^{a}	11.50±1.43^{a}	23.71±2.06^{a}	2.90±0.25^{a}	0.57±0.07^{ab}

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Table 2 Effect of goat breeds in milk fatty acid (%) content in an extensive grazing system (Creole goats) and a confined production system (Saanen and French-Alpine goats)

Goat breeds	Caproic acid	Caprylic acid	Capric acid	Lauric acid	Myristic acid	Pentadecanoic acid
Creole	2.07±0.23^{a}	2.05±0.15^{b}	8.29±0.59^{a}	3.91±0.35^{a}	8.89±0.48^{a}	1.11±0.06^{a}
Saanen	3.60±0.99^{a}	2.90±0.23^{a}	9.83±0.84^{a}	4.06±0.36^{a}	9.38±0.73^{a}	0.77±0.04^{b}
French-Alpine	2.32±0.63^{a}	2.37±0.16^{ab}	8.68±0.64^{a}	3.81±0.31^{b}	9.92±0.63^{a}	0.88±0.05^{b}
	Palmitic acid	**Margaric acid**	**Stearic acid**	**Oleic acid**	**Linoleic acid**	**Alpha-linolenic acid**
Creole	25.75±0.80^{a}	0.79±0.08^{a}	10.18±1.09^{a}	22.25±1.32^{a}	3.27±0.16^{a}	0.77±0.07^{a}
Saanen	23.05±1.29^{a}	0.56±0.04^{a}	6.89±0.87^{b}	17.42±1.34^{b}	2.72±0.24^{a}	0.39±0.04^{b}
French-Alpine	25.89±1.79^{a}	0.68±0.11^{a}	6.88±0.85^{b}	19.62±2.06^{ab}	2.66±0.22^{a}	0.46±0.05^{b}

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Table 3 Effect of the interaction season × goats breeds on fatty acid milk content (%), Creole in a traditional extensive grazing system and Saanen and French-Alpine in a confined production system

Season of the year	Breeds	Caproic acid	Caprylic acid	Capric acid	Laureic acid	Myristic acid	Penta de-canoic acid
Rainy	Creole	1.86±0.25^{a}	2.40±0.18^{ab}	9.84±0.68^{abc}	5.47±0.41^{a}	10.94±0.43^{a}	1.10±0.04^{ab}
Rainy	Alpine	0.97±0.16^{a}	1.80±0.19^{b}	6.31±0.65^{cd}	2.77±0.32^{bc}	9.10±1.02^{ab}	0.94±0.06^{ab}
Rainy	Saanen	4.57±1.82^{a}	2.75±0.52^{ab}	7.59±1.02^{bcd}	3.10±0.24^{bc}	7.44±0.55^{ab}	0.81±0.06^{b}
Transition	Creole	2.90±0.55^{a}	2.26±0.32^{ab}	10.36±0.63^{ab}	4.41±0.39^{ab}	9.30±0.64^{ab}	1.35±0.15^{a}
Transition	Alpine	2.98±0.92^{a}	2.78±0.31^{ab}	10.19±1.20^{abc}	4.32±0.70^{ab}	9.80±1.55^{ab}	0.78±0.11^{b}
Transition	Saanen	2.27±0.64^{a}	3.38±0.35^{a}	12.31±1.36^{a}	5.07±0.68^{ab}	11.02±1.30^{a}	0.68±0.06^{b}
Dry	Creole	1.47±0.25^{a}	1.48±0.19^{b}	4.66±0.60^{d}	1.82±0.27^{c}	6.43±0.74^{b}	0.90±0.05^{b}
Dry	Alpine	3.03±1.63^{a}	2.54±0.15^{ab}	9.56±0.59^{abc}	4.34±0.23^{ab}	10.85±0.56^{a}	0.92±0.08^{ab}
Dry	Saanen	3.97±2.42^{a}	2.59±0.33^{ab}	9.60±1.35^{abc}	4.01±0.64^{ab}	9.69±1.39^{ab}	0.83±0.10^{b}
		Palmitic acid	**Margaric acid**	**Stearic acid**	**Oleic acid**	**Linoleic acid**	**Alpha-linolenic acid**
Rainy	Creole	28.40±1.25^{a}	0.86±0.15^{a}	6.73±0.81^{b}	17.39±0.55^{bcd}	2.77±0.24^{ab}	1.08±0.14a
Rainy	Alpine	29.30±3.10^{a}	0.63±0.06^{a}	9.24±0.52^{b}	25.40±1.73^{abc}	3.26±0.37^{ab}	0.54±0.08b
Rainy	Saanen	21.83±1.31^{a}	0.64±0.09^{a}	9.03±1.11^{b}	26.21±3.32^{ab}	3.48±0.37^{ab}	0.41±0.04b
Transition	Creole	23.90±0.95^{a}	0.70±0.10^{a}	7.18±1.27^{b}	18.34±1.41^{bcd}	3.33±0.27^{ab}	0.55±0.08ab
Transition	Alpine	21.38±2.30^{a}	0.89±0.32^{a}	4.70±1.98^{b}	15.52±2.92^{cd}	2.55±0.44^{ab}	0.37±0.07b
Transition	Saanen	24.35±2.27^{a}	0.52±0.03^{a}	5.59±1.95^{b}	11.21±2.84^{d}	2.69±0.35^{ab}	0.33±0.03b
Dry	Creole	24.88±1.63^{a}	0.82±0.18^{a}	16.63±1.52^{a}	31.03±1.72^{a}	3.73±0.30^{a}	0.64±0.10ab
Dry	Alpine	26.98±3.28^{a}	0.49±0.10^{a}	6.90±0.89^{b}	17.95±1.90^{bcd}	2.17±0.19^{b}	0.46±0.11b
Dry	Saanen	22.94±3.16^{a}	0.52±0.06^{a}	6.05±1.14^{b}	14.84±3.00^{d}	1.99±0.31^{b}	0.47±0.25b

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

The linoleic acid increased its content in Creole goat milk collected in dryt and decreased in the same season but in Saanen goats. The alpha-linoleic acid content in milk was higher in Creole goats in rainy season and decreased in Saanen goats in transition.

The goat milk fatty acid content by season of the year was determined by Toyes-Vargas *et al.* (2013) reporting the total saturated fatty acids in palmitic acid in Creole goat milk with a greater content in the extensive system. This result agrees with those obtained in the present study, where palmitic acid did not show differences between seasons and was high both in rainy and transiton and dryt. In another study, Toyes-Vargas *et al.* (2014) reported tha only two of the saturated fatty acids found in goat milk showed significant differences in a semi-intensive system, one of them was lauric acid whose content was greater in milk collected in the rainy season in the arid region of the Baja California peninsula. The previous results differer from those reported in the present study, since greater lauric acid content was observed in transition followed by rainy and dryt, respectively. In this respect, Milewski *et al.* (2018) compared goat milk fatty acid profiles in two seasons of the year – summer and winter – finding higher values in summer season. The present study reports similar data, since higher values were found in fatty acid contents in dry/rainy seasons, attributed to forage in rangeland, which is more abundant and shows a nutritional value tha benfits grazing goats.

The goat milk composition may vary depending on factors, such as diet, climatological conditions, gestation stage, among others Kljajevic *et al.* (2018). When animal breeds and milk production systems are compared, López *et al.* (2019) demonstrated that goat milk in farms managed with three production systems (conventional organic, non-organic, and high inputs) showed differences in fatty acid composition, mainly between systems with low imputs (conventional organic and non-organic) were minimum with the conventional system and low imputs. The differences in goat milk composition were mainly odd-numbered and ramified chain fatty acids: linoleic, alpha-linoleic, elaidic acid, n6 total and n3 total. These results agree with those found in the present study, since both linoleic and alpha-linoleic showed differences between season of the year and breeds. In the present study, breeds associated with both production systems, Creole goats have an extensive grazing management called traditional and French-Alpine and Saanen goats have a confined management with medium and high inputs.

Inglingstad *et al.* (2017) evaluated the effect of concentrates supplemented with lipids in milk fat content, fatty acid compositon, lipoprotein lipase activity, sensorial properties, goat milk fat globule size, observing that palmitic and palmitoleic acid contents increase in goats with a diet based on concentrate with 8% (added air-dried) of hydrogenate palm oil enriched with palmitic acid, among other results, palmitic acid in Creole, French-Alpine and Saeen goat milk. These results also agree with the present study, since palmitic acid showed a concentration without significant differences between seasons of the year when milk was collected. Therefore, both diets in extensive grazing and confined systems demonstrated adequate nutritional quality for goats in the three seasons of the year.

Pajor *et al.* (2009) compared the effect on enclosed animals with commercial diets and animals in free grazing that showed higher values in fatty acid profiles. Similar data were obtained in the present study when milk samples were compared by breed; grazing goats in the three seasons of the year demonstrated higher values in alpha-linoenic acid, which is attributed to grazing animal feed. In this respect, Mellado (2016) mentioned that goats show a selection that expresses relative seasonal availability and palatability, associating sensorial forage properties with their nutritional value. On the one hand, Idamokoro *et al.* (2019) determined and compared fatty acid composition and aterogenicity index of milk fat in Nguni, Boer, and undescribed goat breeds in extensive breeding. The butritic, caproic, myristic, palmitic, stearic, vaccenic, linoleic, conjugated linoleic, alpha-linolenic, arachidic, eicosatrienoic, and docosapentaenoic acids, among other milk fats, were found to differ significantly amongst the three goat breeds. Additionally, the milk fat of Nguni goats had healthier and non-descriptive fatty acid content than Boer goats. In the present study, significant differences were observed between breeds and sesons for myristic, linoleic, and alpha-linolenic acids but not in caproic and palmitic acid content, which determine that goat milk is a significant source of fatty acids that support human health and the sustainable use of animal genetic resources to enhance the fat content of goat milk. This situation requires greater attention in research into local creole breeds mating with other breeds introduced to the area of study.

According to Yurchenko *et al.* (2018) goat milk demand, its products have increased, and quality is determined, in part, by the fatty acid profile, but little information exists of the effect on race in fatty acid profile of this species milk. The previously mentioned authors described and compared fatty acid profiles in Saanen and autoctonous Swedish breed goat milk and found differences in fatty acid profiles between breeds; Saanen goats showed greater saturated fatty acid profiles than Swedish breeds, which allows goat milk quality and derived product improvement. The present study analyzed fatty acid profiles only considering the breeds as variation source; only significant differences between breeds were observed in caprylic, pentadecanoic, stearic and alpha-linolenic acids. Creole goat milk had greater alpha-linolenic, stearic and pentadecanoic acids, whereas Saanen goat milk showed a greater caprylic content. These results, same as those reported by Yurchenko *et al.* (2018), determine the importance of performing fatty acid profile studies among the different breeds used as milk source and their derived products in study.

Djordjevic *et al.* (2019) point out that fatty acid compositon depends on many different factors, such as animal species, breed, seson, lactancy stage, geographic location, and diet, indicating that goat milk is rich in medium chain fatty acids, caproic (C6:0), caprylic (C8:0), and capric (C10:0) with more conyugated linoleic acid, in general, lower n-6/n-3 rations with greater alpha-linolenic acid quantities compared to cow milk. The present study determined caproic, capric, linoleic, and alpha-linolenic acid contents. Although forage has demonstrated that its addition, especially fresh grass in milking animals, unsaturated fatty acids increase in ration when compared to saturated fatty acids and conjugated linoleic content Djordjevic *et al.* (2019). The present study detected unsaturated fatty acids in goat milk, showing high Creole goat milk content in the extensive grazing system in dry season.

CONCLUSION

Significant differences were found in composition when comparing fatty acid profile in Creole (extensive grazing), French-Alpine and Saanen (confined system) goats' milk in three seasons of the year. The differences were observed in the profile between seasons of the year where milk collected during transition and rainy seasons showed greater fatty acid content, while four of the fatty acids were greater in Creole goats, followed by Saanen with two fatty acids. The unsaturated fatty acid content was greater in Creole goats in dry season. The breeds influence notably fatty acid profiles in milk with special referece to linoleic and alpha-linolenic acids considered beneficial for human health. The future research on fatty acid profile should include goat breeds as a factor, which as a last resource should conduct optimum requirements for human needs of milk products. The differences in fatty acid content in milk according to season (rainy, transiton, dry), breed (Creole, French-Alpine and Saanen) and production systems (extensive grazing and confined) provide the capacity to select breed. The diets or adequate breeding conditions are also important to get milk and milk products with improved nutritional quality and more valuable fat composition, which should positively influence consumers' health.

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