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Milk fatty acid composition from goats in a semiintensive production system in an arid region of the peninsula of Baja California, Mexico

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Abstract: The aim of this research was to study the effects of seasons (rainy and dry) on the composition of the fatty acids (FAs) in milk of Creole goats in a semiintensive production system. Milk sampling was carried out in the dry season (June) and just after the rainy season (November) in an arid region of Baja California Sur, Mexico. The goat diet was composed of native species it grazed on in the rangeland, as well as hayed forages with some supplements containing approximately equal amounts of sorghum and maize. The results for different types of FAs in goat milk showed that there were no significant differences in saturated, polyunsaturated, branched, and omega-6 FAs, with differences for monounsaturated and omega-3 FAs. In terms of individual FAs, the majority of changes were not significant. The FA constituents showed that significant differences existed for C12:0, C23:0, C14:1 n-5, C14:1 n-7, C18:1 n-9, C18:3 n-3 *cis*, C22:5 n-3, and C22:6 n-3, and 2 branched fatty acids, C12:0 *iso* and C15:0 *anteiso*. The rest showed a trend of higher quantities of FAs during the rainy season, but it was not significant. In conclusion, goat milk quality as measured by FAs is for the most part very similar year round, independent of seasons in this semiintensive production system.

Key words: Omega-3, omega-6, goat milk, fatty acids, production in arid areas, semiintensive

1. Introduction

Mexico has large arid and semiarid regions with rural populations that need to have sustainable development. In developing countries, such as Mexico and others, milk from goats has been touted as being able to provide some of the nutritional requirements of humans, as well as easier to digest for children due to smaller fat globules (1). The goat's robust constitution for living in dry and marginal areas has contributed to the emergence of many small goat farms dedicated to goat milk production (2). Moreover, nutritional guidelines for humans around the world have recognized the importance of maintaining a balanced diet to help reduce the incidence of diseases such as type 2 diabetes, obesity, cardiovascular disease, and even cancers (3). From this viewpoint, the fatty acid fraction of milk is particularly attractive for use by humans in their diet, since it is known to provide many health benefits (4).

Mexico is among the top 20 producers of goat milk worldwide, producing 161,712 t in 2011 (5). However, much of the goat milk production system in Mexico has historically been based on extensive systems, where animals roam the local rangeland for food, with different seasonal availability (6), which can affect the quality of the milk since fodder quality apparently is the most important factor (7). It is generally accepted that of the 2 common production systems, extensive and intensive feeding systems, the former pasture-based system has been found to provide healthier compounds in milk (8). However, the majority of these studies showing the advantages of pasture feeding were conducted in nonarid or temperate climates (9), and the impact of local vegetation resources from arid ecosystems on milk quality is still not completely resolved. Studies of changes in the gross composition in milk are also scarce (10).

It is generally accepted that the quality of diet affects the chemical composition of milk fat. Moreover, many goat milk production systems are in arid and marginal environments that have historically used extensive systems, where data have indicated that goat milk quality can vary due to the seasonal quality variation of the forage,

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as well as many other factors such as production systems, degree of mastitis, race of goat, or lactation period (11). The purpose of this study was to determine whether a semiintensive production system, where supplemental feeding is provided in addition to pasture feeding, provides a more uniform quality or composition of milk fat in Creole goats year round (both rainy and dry seasons) in an arid region of Baja California.

2. Materials and methods

2.1. Study area

The study was conducted in the municipality of Comondú, Baja California Sur, Mexico. This system is located at 24°57′09″N, 111°38′25″W near the town of Villa Morelos, at 48 m above sea level with an average annual rainfall of 98 mm and average temperature of 18.7 °C during the wet season and 22.1 °C during the dry (12).

2.2. Dry and rainy seasons

In this arid area, the dry season is from December to June, while the rainy season starts in July and ends in November, with peak rains usually occurring between July and November due to tropical storms and hurricanes present in the Pacific. In June, the dry season sampling of milk was carried out, while for the rainy season milk sampling was done in October, near the end of the rainy season.

2.3. Semiintensive system

This type of production system combines grazing, in this case of native species and plant species regarded as weeds, which are associated with agricultural areas, and stalks from the harvest. The diet is supplemented with hayed forages and supplements in small amounts. In this system, the animals are milked in the morning and released to pasture until noon. Upon return from grazing the goats receive supplementary feeding; the goats eat ad libitum.

2.4. Animals and sampling

Ten native goats (Creole) mating with indefinite Anglo-Nubia goats were selected at random per trip to the farm and were sampled for milk; this was repeated twice for each season for a total of 20 goat milk samples per season. A total of 25 mL of milk samples was obtained by hand milking; the udder was cleaned prior to taking the sample to avoid contamination. All animals were goats with only 2 to 5 deliveries and the milk was sampled after 60 days of lactation. The samples were placed in sterile Falcon tubes, sealed, and marked and were kept on ice for transportation to the laboratory.

2.5. Consumed species

In the rangeland the legumes species consumed by the goats were *Prosopis palmeri* S.Watson, *Pithecellobium confine* Standl., *Acacia farnesiana* (L.) Willd., *Acacia brandegeana*, *Acacia peninsularis* (Britton & Rose) Standl., *Cercidium* × *sonorae* Rose & I.M.Johnst., *Lysiloma candida* Brandegee, *Cercidium microphyllum* (Torr.) Rose & I.M.Johnst., and *Cercidium floridum* Benth. ex A.Gray subsp. *peninsulare* (Rose) Carter. Nonlegume species that goats consumed included *Lippia palmeri* L., *Bursera microphylla* A.Gray, *Jatropha cuneata* Wiggins & Rollins, *Fouquieria diguetii* (Tiegh.) I.M.Johnst., *Lycium brevipes* Benth., *Celtis reticulata* Torr., *Ruellia californica* (Rose) I.M.Johnst., *Ferocactus* spp., *Phrygilanthus sonorae* S.Watson, *Jatropha cinerea* (Ortega) Müll.Arg. in D.C., *Opuntia cholla* F.A.C.Weber, *Pachycereus pringlei* (S.Watson) Britton & Rose, and *Stenocereus thurberi* (Engelm.) Buxb.

2.6. Lipid analysis

To extract milk lipids, the method developed by Bligh and Dyer (13) was used. A total of 30 mg of lyophilized sample was placed in a test tube with a mixture of CH_3OH:$CHCl_3$:H_2O at a ratio of 1:2:0.5, left to stand for 24 h without light in order to extract all lipids. The mixture was sonicated a total of 3 times; then 1 mL of CH_3OH and 2 mL of distilled water was added and the mixture was centrifuged at 3700 rpm for 15 min. The fraction of lipid-CH_3OH was then recovered and then the entire process was repeated. The extract was used to quantify total lipids and for acid derivatization.

The Marsh and Weinstein (14) method was used to quantify total lipids. A part of the lipid-CH_3OH fraction was evaporated to dryness using nitrogen gas; subsequently, 2 mL of concentrated H_2SO_4 was added to the test tube, which was sealed with aluminum foil and closed with a lid to prevent contamination. This mixture was placed in a sealed test tube, which was calcinated at 200 ± 2 °C in an oven for 15 min and left to stand for 5 min. The tubes were then placed in an ice water bath for 5 minutes. Once cooled, 3 mL of distilled water was added and vortexed. Absorbance of the mixture was read in a quartz tube at 375 nm using a spectrophotometer. The control samples used to calibrate spectrophotometer consisted of concentrated H_2SO_4 that received the same treatment as the samples.

For acid derivatization, the remaining fraction of the lipid-CH_3OH was dried with liquid nitrogen and 2.5 mL of a solution of HCl/CH_3OH (5%, v/v) was added and later placed in an 85 °C water bath for 2.5 h. The methyl esters obtained from the reaction were extracted with 1.5 mL of hexane using Pasteur pipettes. The total volume of hexane was evaporated to dryness using liquid nitrogen and resuspended in 250 µL of hexane, placed in a vial sealed with Teflon, and then injected into the gas chromatograph.

2.7. Identification and quantification of fatty acids

A gas chromatograph-gas spectrometer quadrupole Varian CP3800-1200 was used to identify and quantify fatty acids. It was equipped with an injection port and an OmegaWax 250 capillary column, with inner diameter was 0.25 mm, 30 m of length of fused polyethylene glycol silica, film thickness of 0.25 μm, and flow rate of 1.2 mL/min with helium as the carrier gas. Wsearch32 (Ver. 1.6) was used to analyze fatty acids, and the sample peak retention times were compared with 37 standard commercially available methyl fatty acid esters.

2.8. Statistical analysis

The data were analyzed by univariate analysis of variance with seasons (rainy and dry) as the main study factor using Statistica 10.0. Bartlett's box-test was used to test for homogeneity of variance. For all cases, Tukey's honestly significant different (HSD) post-hoc test was used to test for seasonal fatty acid differences at 2 levels of significance ($P \leq 0.05$ and $P \leq 0.01$).

3. Results

3.1. Types of fatty acids

There was a trend of increasing concentration of types of total fatty acids in the rainy season in comparison to the dry season. However, there were no significant differences in types of total fatty acids for saturated, polyunsaturated, branching, omega-6, or ratio of omega-3 to omega-6. Significant differences were found for monounsaturated fatty acids ($P \leq 0.05$) as well as omega-3 ($P \leq 0.01$) with higher concentrations in the rainy season (Table 1).

3.2. Saturated fatty acids

The saturated fatty acid showed a trend of increasing concentrations in the raining season (Table 2); 2 fatty acids, lauric acid (C12:0) and tricosanoic acid (C23:0), showed significant differences ($P \leq 0.05$) in concentration, both being more abundant in the rainy season. It is important note that the majority of saturated fatty acid constituents showed no significant differences.

Table 1. Concentration of types of total fatty acid in goat milk fed in a semiintensive production system.

	Season		
Fatty acids	Rainy (μg/mg)	Dry (μg/mg)	Significance
Saturated	1010.2	898.5	NS
Monounsaturated	297.8[a]	174.9[b]	*
Polyunsaturated	89.2	71.4	NS
Branching	66.6	58.2	NS
Omega-3	32.8[a]	20.6[b]	**
Omega-6	57.6	51.4	NS
Omega-3/omega-6 ratio	0.57	0.40	NS

NS: $P > 0.05$; *: $P \leq 0.05$, **: $P \leq 0.01$. Averages with different letters in same rows are statistically different, n = 20 (Tukey HSD, P = 0.05).

Table 2. Saturated fatty acid concentrations in the milk of goats fed in a semiintensive production system.

	Season		
Fatty acids	Rainy (μg/mg)	Dry (μg/mg)	Significance
C12:0	159.62 [a]	96.23 [b]	*
C13:0	2.79	2.66	NS
C14:0	331.73	244.61	NS
C15:0	33.34	25.59	NS
C16:0	338.90	323.20	NS
C17:0	19.09	13.76	NS
C18:0	140.19	129.12	NS
C19:0	2.67	2.55	NS
C20:0	5.18	5.06	NS
C21:0	1.86	1.59	NS
C22:0	3.28	2.70	NS
C23:0	3.66 [a]	2.73 [b]	*

NS: $P > 0.05$; *: $P \leq 0.05$. Averages with different letters in same rows are statistically different, n = 20 (Tukey HSD, P = 0.05).

3.3. Monounsaturated fatty acids

The majority of monounsaturated fatty acids isomers showed no significant differences due to season, except for C14:1 n-5, which showed highly significant differences ($P \leq 0.01$), and C14:1 n-7 and oleic acid C18:1 n-9, which showed significant differences at a lower significance level ($P \leq 0.05$). However, in all cases, the concentrations were higher in the rainy season, although, as mentioned, most were not significant statistically (Table 3).

3.4. Polyunsaturated fatty acids

The trend of concentration of fatty acids, although not significant for most, was for higher concentrations of isomers in the rainy season. Acids alpha-linolenic acid (C18:3 n-3 *cis*, ALA) showed highly significant differences ($P \leq 0.01$), while docosapentaenoic acid (C22:5 n-3, DPA) and docosahexaenoic acid (C22:6 n-3, DHA) showed significant differences ($P \leq 0.05$), with higher concentrations occurring during the rainy season for all 3 (Table 4).

3.5. Branched fatty acids

The branched fatty acids' trend was for higher concentrations in the rainy season (Table 5), but only 2 fatty acids, C12:0 *iso* and C15:0 *anteiso*, showed significant differences between seasons ($P \leq 0.05$).

4. Discussion

The analysis of different types of fatty acids in goat milk according to season (rainy vs. dry) showed that the most

Table 3. Monounsaturated fatty acid concentrations in the milk of goats fed in a semiintensive production system.

	Season		
Fatty acids	Rainy (µg/mg)	Dry (µg/mg)	Significance
C14:1 n-5	6.34 [a]	3.45 [b]	**
C14:1 n-7	0.88 [a]	0.49 [b]	*
C15:1 n-7	3.85	3.06	NS
C16:1 n-1	0.87	0.77	NS
C16:1 n-3	1.23	0.99	NS
C16:1 n-5	1.56	1.49	NS
C16:1 n-7	21.49	16.17	NS
C16:1 n-9	6.14	6.05	NS
C17:1 n-3	8.78	8.73	NS
C17:1 n-5	0.37	0.31	NS
C18:1 n-3	3.21	2.58	NS
C18:1 n-5	1.87	1.49	NS
C18:1 n-6	5.24	4.68	NS
C18:1 n-7	1.69	1.34	NS
C18:1 n-9	214.85 [a]	147.05 [b]	*
C18:1 *trans*	13.07	9.79	NS
C19:1	2.09	2.00	NS
C20:1 n-11	2.72	2.32	NS
C20:1 n-3	0.79	0.46	NS
C20:1 n-9	0.99	0.96	NS
C22:1 n-9	0.20	0.04	NS
C24:1 n-9	2.77	2.45	NS

NS: $P > 0.05$; *: $P \leq 0.05$, **: $P \leq 0.01$. Averages with different letters in same rows are statistically different, n = 20 (Tukey HSD, P = 0.05).

Table 4. Polyunsaturated fatty acid concentrations in the milk of goats fed in a semiintensive production system.

	Season		
Fatty acids	Rainy (µg/mg)	Dry (µg/mg)	Significance
C18:2 n-5	1.04	0.63	NS
C18:2 n-6 *cis*	45.91	38.48	NS
C18:2 n-6 *trans*	1.14	1.01	NS
C18:3 n-3 *cis*	20.25 [a]	10.99 [b]	**
C18:3 n-3 *trans*	0.77	0.75	NS
C18:3 n-6	0.51	0.49	NS
C19:2	6.29	4.55	NS
C20:3 n-3	0.38	0.22	NS
C20:3 n-6	4.46	4.17	NS
C20:4 n-6	4.46	4.17	NS
C20:5 n-3	2.42	1.83	NS
C22:5 n-3	4.53 [a]	3.17 [b]	*
C22:6 n-3	2.33 [a]	1.34 [b]	*

NS: $P > 0.05$; *: $P \leq 0.05$, **: $P \leq 0.01$. Averages with different letters in same rows are statistically different, n = 20 (Tukey HSD, P = 0.05).

abundant as a percentage of total fatty acids in descending order of abundance was saturated (65% vs. 70%), followed by monounsaturated (19.1 % vs. 13.7%) and then polyunsaturated (5.7% vs. 5.5%) and omega-6 (3.7% vs. 4%), and the least abundant was omega-3 (2.1% vs. 1.6%). It should be pointed out that abundance of all types of fatty acids was always higher in terms of µg/mg in the rainy season, with a lower percentage of saturated in the rainy season compared to dry season (65% vs. 70%), simply because the total of other fatty acids decreased in the dry season, making its percentage contribution greater. This result is similar to that reported by others with saturated fatty acids of 70%–75%, monounsaturated fatty acids of 20%–25%, and 5% polyunsaturated fatty acids (15). The differences due to season for fatty acid types were not significant, in general, except for monounsaturated fatty acids and omega-3. The higher concentrations of n-3 fatty acids during the rainy season in this semiintensive system could be explained by the fact that goats grazed on greener fodder, which typically contains higher concentrations of n-3 fatty acids sources such as alpha-linolenic acid (15).

For saturated fatty acids, only 2, lauric acid (C12:0) and tricosanoic acid (C23:0), showed significant differences in concentration due to seasons, both being more abundant in the rainy season. The variation in C23:0 in this semiintensive system, although in low concentrations (<2%), is widely reported in milk, but its seasonal variation may be due to the presence of anaerobic fungi (16). The highest saturated fatty acids in order of abundance for rainy season were C16:0, C14:0, C12:0, and C18:0, respectively. In a study conducted in Australia, the most abundant saturated fatty acid was C18:0 (17), not C16:0 as in this study. This difference may be due to goats eating different plants in the rangeland. In Australia, the animals grazed on sea grass, so the presence of C18:0 could be due to biohydrogenation of alpha-linolenic acid (18).

The majority of monounsaturated isomers showed no significant differences due to season, except for C14:1 n-5, C14:1 n-7, and oleic acid C18:1 n-9, which showed significant differences. In all cases, additionally, the concentrations were higher in the rainy season, although not significant. Delgadillo-Puga et al. (19) evaluated the effect of seasonal variation (summer and winter) of 2

Table 5. Branched fatty acid concentrations in the milk of goats fed in a semiintensive production system.

	Season		
Fatty acids	Rainy (μg/mg)	Dry (μg/mg)	Significance
C12:0 *iso*	4.59 [a]	2.63 [b]	*
C130: *iso*	3.68	3.05	NS
C14:0 *iso*	7.70	6.03	NS
C14:0 *anteiso*	11.03	8.79	NS
C15:0 *iso*	18.87	17.75	NS
C15:0 *anteiso*	1.20 [a]	0.77 [b]	*
C16:0 *iso*	9.78	6.97	NS
C16:0 *anteiso*	10.12	8.99	NS
C17:0 *iso*	1.30	1.09	NS
C17:0 *anteiso*	0.34	0.23	NS
C18:0 *iso*	1.05	0.79	NS

NS: $P > 0.05$; *: $P \leq 0.05$. Averages with different letters in same rows are statistically different, n = 20 (Tukey HSD, P = 0.05).

feeding strategies, the first in semiarid rangeland grazing and the second consisting of confinement feeding of alfalfa as hay and grain concentrate. They reported that seasonal variation affected the fat content of cheese made from goat milk. The most abundant monounsaturated fatty acid turned out to be C18:1 isomer, which coincides with the findings of this study. Chilliard et al. (20) reported that oleic acid is the most prominent monounsaturated fatty acid, with concentrations of 15%–21%, which is similar to what was found in this study.

It was determined that polyunsaturated fatty acids was present in low concentrations in milk and the majority showed insignificant seasonal variation, except for 3 fatty acids, alpha-linolenic (C18:3 n-3 *cis*, ALA), docosapentaenoic (C22:5 n-3, DPA), and docosahexaenoic (C22:6 n-3, DHA). However, the trend due to seasons was always higher in the rainy season compared to dry season. This trend for higher amounts of polyunsaturated fatty acids in the rainy season could be due to the fact that the goats consumed fresher fodder during the rainy season, which is known to have higher amounts of polyunsaturated fatty acids (21).

For branched fatty acids, 11 different types were identified with carbon chains of between 12 and 18 carbon atoms. This result is similar to other studies that found only branched fatty acids with more than 11 carbon atoms (22). The most abundant branched fatty acids were those of 15 atoms in the carbon chain, similar to what was reported in previous works (23). Seasonal variation trends showed higher concentrations in the rainy season for all, but only 2 fatty acids showed significant differences, namely C12:0 *iso* and C15:0 *anteiso*. Most concentration differences of branched fatty acids due to season were not significant. Other studies have reported similar results, such that variations in the concentration of branched fatty acids may be affected by increases or decreases of the feed rate/management of the diet concentrate (23).

In all cases, in this semiintensive system for total fatty acids types and individual fatty acid constituents, the trend was that there was a higher quantity of fatty acids during the rainy season compared to the dry season. However, most differences were not significant. For example, the sampling seasons (rainy and dry) in this semiintensive production system showed no significant effect on the composition of total types of saturated, polyunsaturated, branched, or omega-6 fatty acids in goat milk, with significant effects for monounsaturated and omega-3. In terms of individual fatty acid constituents, a similar pattern emerges where there is a higher quantity of fatty acids during the rainy season; however, only a limited number of fatty acids show statistically significant seasonal effects. For instance, of the 12 saturated fatty acids evaluated, only 2 (C12:0 and C23:0) showed significant differences due to seasons. For monounsaturated and polyunsaturated fatty acids, only 3 showed significant differences in concentration: fatty acids C14:1 n-5 and n-7 and C18:1 n-9 for monounsaturated, and C18:3 n-3 *cis*, C22:5 n-3, and C22:6 n-3 for polyunsaturated. For branched fatty acids, only C12:0 and C15:0 *anteiso* showed significant differences.

In summary, seasons apparently do not significantly change the quality of goat milk in terms of most fatty acids as measured by the individual concentration of fatty acids constituents in this semiintensive production system, although there is a general trend of increasing fatty acids during the rainy season compared to the dry season. This probably is because supplementary feeding provided, in general, compensation for some of the reduction of range pasture quality during the dry season. However, this is not completely the case since significant differences in some fatty acids were found, although they were in the minority. The semiintensive systems tested herein may be a viable option for producing milk of similar quality throughout the year in arid and semiarid zones.

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