Turkish Journal of Veterinary & Animal Sciences

Volume 31 | Number 5 Article 10

1-1-2007

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ZEHRA GÜLER

MAHMUT KESKİN

TUĞRUL MASATÇIOĞLU

SABRİ GÜL

OSMAN BİÇER

Turk. J. Vet. Anim. Sci.
2007; 31(5): 347-354


**Research Article**

# Effects of Breed and Lactation Period on Some Characteristics and Free Fatty Acid Composition of Raw Milk from Damascus Goats and German Fawn × Hair Goat $B_1$ Crossbreds

Zehra GÜLER[1,*], Mahmut KESKİN[2], Tuğrul MASATÇIOĞLU[1], Sabri GÜL[2], Osman BİÇER[2]

[1]Department of Food Engineering, Faculty of Agriculture, Mustafa Kemal University, 31034 Hatay - TURKEY

[2]Department of Animal Science, Faculty of Agriculture, Mustafa Kemal University, 31034 Hatay - TURKEY

Received: 31.08.2006

**Abstract:** The effects of breed and period of lactation on milk composition were investigated. For this purpose, 8 crossbred ($^3/_4$ German fawn $^1/_4$ Hair goat) and 10 Damascus goats were kept under identical management conditions. Lactation period affected milk yield and milk composition in both goat breeds. Milk yield, lactation duration, and mean solid and fat values showed differences between the breeds. The mean values of total solid and fat of milk during lactation were 13.82 ± 0.294% and 4.55 ± 0.223% for the crossbreds, and 12.90 ± 0.179% and 4.02 ± 0.142% for Damascus goats, respectively. Although the percentages of short-chain free fatty acids (FFAs) ($C_4$ to $C_8$) in the milk of both breeds did not change during lactation, the other FFAs ($C_{10}$-$C_{18:3}$) significantly varied ($P \leq 0.05$, $P \leq 0.01$). The results showed that hexadecanoic ($C_{16}$), 9-octadecenoic ($C_{18:1}$), octadecanoic ($C_{18}$), tetradecanoic ($C_{14}$), decanoic ($C_{10}$), and decanoic ($C_{12}$) FFAs were the most predominant FFAs in the milk of both breeds from March through September, but octadecanoic acid and tetradecanoic acid shifted during the last 2 months of lactation.

Key Words: Damascus goat, German Fawn x hair goat $B_1$ crossbred, milk composition, free fatty acids, lactation period

## Damaskus (Şam) Keçileri ve Alman Alaca × Kıl Keçi (G1) Melezlerin Sütlerindeki Serbest Yağ Asitleri ve Bazı Nitelikler Üzerine Irkın ve Laktasyon Periyodunun Etkileri

**Özet:** Bu çalışmada, ırk ve laktasyon peryodunun süt kompozisyonu üzerine etkileri araştırılmıştır. Bu amaç için 8 Alman Alaca × Kıl keçi melezleri ve 10 Şam keçisi aynı şartlar altında yetiştirilmiştir. Laktasyon periyodu, her iki keçi ırkında süt verimi ve kompozisyonu etkiledi. Bunun yanı sıra süt verimi, laktasyon süresi, ortalama kurumadde ve yağ içeriği de ırklar arasında farklılıklar gösterdi. Melez ve Şam keçilerinin laktasyon süresince ortalama kurumadde ve yağ değerleri sırasıyla % 13,8 ± 0,294; % 4,55 ± 0,223 ve % 12,90 ± 0,179; % 4,02 ± 0,142 olarak belirlenmiştir. Laktasyon süresince her iki ırkın sütlerindeki kısa zincirli yağ asit ($C_4$ - $C_8$) yüzdeleri değişmemesine rağmen diğer yağ asitleri ($C_{10}$ - $C_{18:3}$) önemli düzeyde değişmiştir ($P \leq 0,05$, $P \leq 0,01$). Mart ayından Eylül'e kadar her iki ırkdaki en önemli yağ asitlerini yüzdelerini heksadekanoik ($C_{16}$), 9-oktadekenoik ($C_{18:1}$), oktadekanoik ($C_{18}$), tetradekanoik ($C_{14}$), dekanoik ($C_{10}$) ve dokenoik ($C_{12}$) oluşturmuştur. Fakat laktasyonun son iki ayında tetradekanoik asit yüzdesi oktadekanoik asitten daha fazla olmuştur.

Anahtar Sözcükler: Damaskus (Şam) keçisi, Alman Alaca x Kıl keçi melezleri, süt kompozisyonu, serbest yağ asitleri, laktasyon süresi

## Introduction

The importance of goat's milk not only arises from its impact on the national economy of many countries, but is also attributed to its role as a unique alternative to cow's milk in the survival of people, especially children and infants suffering from hypersensitivity to cow's milk (1,2). A well-known difference between the two is that goat's milk has much smaller fat globules, which has been credited as the reason why goat's milk is easier to digest (3). Another significant difference is the composition and structure of their lipids (1,4). Goat's milk is superior to cow's milk in most short- and medium-chain, mono-unsaturated, poly-unsaturated, and essential fatty acids, which are valuable to today's health conscious consumers

* E-mail: zguler@mku.edu.tr

(1). All short- and medium-chain fatty acids ($C_4$ to $C_{14}$), and half of the hexadecanoic acid ($C_{16}$) in milk fat are synthesized de novo in the mammary gland (4). The remaining half of the hexadecanoic acid ($C_{16}$), and the $C_{18}$ and longer fatty acids in milk fat are obtained directly from the blood supply to the mammary gland through dietary or adipose origin (4,5).

Damascus goats, which are known as Shami in Arabic, are considered the most important goat breed in some Arab countries (Egypt, Syria) due to their high milk and meat yield. This breed is more adaptable to the environmental conditions in the previously mentioned countries, compared to other exotic breeds (6). Hatay province in Turkey borders Syria and there are some Damascus goat flocks in the region. Keskin et al. (7) conducted a study in this region and reported that both Damascus goats and German Fawn × Hair goat $B_1$ crossbreds should be promoted in the Mediterranean region of Turkey because of their high milk yields. However, all studies on Damascus and different crossbreds in this region and Cyprus have focused only on milk yield and gross chemical composition (7,8). There are no reports in the literature on the free fatty acid (FFA) composition of Damascus and crossbred goat's milk during lactation.

The specific aims of this work were to obtain information on the lactation characteristics, gross chemical composition, and FFAs in milk from the 2 breeds during lactation; and to determine whether there are differences between the breeds in terms of milk composition and other lactation characteristics.

With respect to FFA composition, it is interesting to study the composition of milk fat in the Damascus and crossbred milks since variations in FFA content cause changes in the organoleptic and nutritional qualities of milk products.

## Materials and Methods

### Animals

This study was carried out with 10 head of Damascus (Shami) goat and 8 head of crossbred goat ($^3/_4$ German Fawn × $^1/_4$ Hair goat), kept at the Research and Training Farm of the Agriculture Faculty of Mustafa Kemal University in Hatay province, Turkey. The goats in both groups (second lactation) were randomly chosen from 3-year-old goats. The births were synchronized on the first week of March. All kids in each group were weaned at 60 days old. All goats were raised in the same flock and fed 250 g/day concentrate (16% crude protein and 2500 kcal metabolizable energy per kg dry matter) in addition to pasture. The concentrate consisted substantially of 25% cottonseed cake, 28% bran, 35% barley, 10% hay, 1% NaCl, and 1% feed additive.

Milk yields were recorded by means of the A4 method of ICAR (International Committee for Animal Recording) at 30-day intervals. Lactation milk yield and lactation duration were calculated using this method (9).

The goats were milked by hand twice a day (morning and evening). Milk samples were taken separately from the breed groups during the morning and evening milking on each recorded day to determine milk composition throughout lactation. Refrigerated raw milk samples (500 ml) were tempered at 20 °C for analysis.

### Milk Analysis

Milk samples were analyzed for fat content by the Gerber method and total solid by gravimetric method, according to the Turkish Standards Institution (10).

### Lipid Analysis

Extraction and quantification of FFAs were carried out as described by Salih et al. (11) and Deeth et al. (12), with slight modifications.

### Gas Chromatography (GC)/Mass Spectrometry (MS)

For GC/MS analysis of the milk solvent extracts, an Agilent 6890 N GC and 5972 N mass selective detectors (MSDs) (Agilent, USA) were used. Separations were performed on a fused silica capillary column (DB-FFAP, 30 m length × 0.25 mm i.d. × 0.25 µm $d_f$, J & W Scientific). Helium gas was used as a carrier at a constant flow of 1.4 ml/min. Oven temperature was programmed from 55 °C to 230 °C at a rate of 5 °C/min, with initial and final hold times of 5 and 20 min, respectively. MSD conditions were as follows: capillary direct interface temperature: 280 °C; ionization energy: 70 eV; mass range: 33-330 a.m.u; EM voltage: (Atune + 200 V); scan rate: 5 scans/s. Each extract (2 µl) was injected in the splitless mode using an 7683 B automatic injector (Agilent). Fatty acids were identified by comparing their mass-spectral data to the mass-spectral data base in the Wiley 275 L library. Identification was also made on the basis of the retention times of the standard of each individual FFA. The relative concentration of each FFA was expressed as a percentage of the corresponding peak area in the chromatogram.

### Statistical analysis

The following mathematical model was used in the experiment:

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

where $Y_{ij}$ = dependent variables (lactation milk yield, lactation duration, different milk components, an observation of $j^{th}$ animal under $i^{th}$ genotype)

$\mu$ = general mean common to all observations

$\alpha_i$ = the effect of $i^{th}$ genotype

$e_{ij}$ = residual effect.

Data were evaluated with SPSS using analysis of variance (one-way ANOVA). Duncan's multiple comparison test was used to compare the means of groups and months, in terms of milk yield and composition (13).

## Results

### Milk Yield, Lactation Duration, and Total Solid and Fat

Milk yield and lactation duration of the crossbred and Damascus goats in the second lactation under the same conditions were 380.94 ± 41.751 l and 257.6 ± 1.93 days, and 330.73 ± 51.121 l and 244.5 ± 0.48 days, respectively (Table 1). The effect of lactation stage was significant on milk yield ($P \le 0.001$), and total solid ($P \le 0.01$) and fat ($P < 0.01$) in crossbred milk; however, it affected only milk yield ($P \le 0.001$) in Damascus goats (Table 1). Milk yield from the crossbred and Damascus goats increased from March to June and July, respectively, and decreased towards the end of lactation. The total solid ($P \le 0.05$) and fat ($P \le 0.05$) of crossbred goat's milk varied significantly during lactation, with high values in the early and late lactation periods. Similar changes were observed in Damascus goat's milk.

Table 1. The gross composition of milk from crossbred and Damascus goats over the lactation period.

| Months of lactation | The crossbreds | | | Damascus goats | | |
|---|---|---|---|---|---|---|
| | Milk yield (l)*** | Total solid (g/100 g)** | Total fat (g/100 g)** | Milk yield (l)*** | Total solid (g/100 g) | Total fat (g/100 g) |
| March | 1.46 ± 0.239$^{cd}$ | 13.75 ± 0.615$^{abc}$ | 5.10 ± 0.200$^{bc}$ | 0.88 ± 0.084$^{bcd}$ | 13.81 ± 0.710 | 4.85 ± 0.250 |
| April | 1.51 ± 0.270$^{cd}$ | 14.84 ± 0.625$^{bc}$ | 5.45 ± 0.750$^{bc}$ | 0.90 ± 0.177$^{bcd}$ | 12.64 ± 1.060 | 4.40 ± 0.800 |
| May | 1.91 ± 0.286$^{de}$ | 12.68 ± 0.600$^{a}$ | 4.75 ± 0.050$^{bc}$ | 1.33 ± 0.167$^{de}$ | 13.19 ± 0.050 | 4.15 ± 0.050 |
| June | 2.15 ± 0.183$^{e}$ | 13.05 ± 0.685$^{abc}$ | 4.10 ± 0.700$^{ab}$ | 1.48 ± 0.234$^{e}$ | 12.43 ± 0.060 | 3.85 ± 0.050 |
| July | 1.88 ± 0.150$^{de}$ | 13.83 ± 0.365$^{abc}$ | 4.15 ± 0.450$^{ab}$ | 1.62 ± 0.204$^{e}$ | 13.13 ± 0.505 | 3.75 ± 0.450 |
| August | 1.13 ± 0.175$^{bc}$ | 12.64 ± 0.540$^{a}$ | 2.92 ± 0.120$^{a}$ | 0.98 ± 0.149$^{cd}$ | 11.87 ± 0.280 | 3.20 ± 0.300 |
| September | 0.79 ± 0.105$^{b}$ | 12.98 ± 0.520$^{ab}$ | 4.30 ± 0.500$^{ab}$ | 0.66 ± 0.069$^{bc}$ | 12.42 ± 0.135 | 3.95 ± 0.350 |
| October | 0.72 ± 0.170$^{b}$ | 14.58 ± 0.405$^{bcd}$ | 4.35 ± 0.250$^{abc}$ | 0.51 ± 0.103$^{ab}$ | 13.25 ± 0.095 | 3.58 ± 0.075 |
| November | 0.12 ± 0.041$^{a}$ | 16.10 ± 0.040$^{c}$ | 5.85 ± 0.250$^{c}$ | 0.19 ± 0.046$^{a}$ | 13.46 ± 0.135 | 4.40 ± 0.100 |

Mean values of different characteristics over the lactation period

| Parameters | The crossbreds | Damascus goats |
|---|---|---|
| Lactation milk yield (l)* | 308.94 ± 41.751 | 330.73 ± 51.121 |
| Lactation duration (days)*** | 257.6 ± 1.93 | 244.5 ± 0.48 |
| Total solid (g/100 g)* | 13.82 ± 0.294 | 12.90 ± 0.179 |
| Total fat (g/100 g)* | 4.55 ± 0.223 | 4.02 ± 0.142 |

Means in the same column followed by different letters are significantly different (*P < 0.05, **P < 0.01, ***P < 0.001)

### Free fatty acids (FFAs)

The mean FFAs proportions of morning and evening milk from both goat breeds during lactation are shown in Table 2. Lactation period affected the percentages of $C_{10}$ and longer chain fatty acids ($P \leq 0.05$). It did not affect C4 to $C_8$ FFAs (Table 2.). The $C_{10}$ to $C_{18:1}$ FFAs showed fluctuations from March through September. While the percentages of $C_{18}$ and $C_{18:1}$ FFAs significantly decreased during the last 2 months of lactation (October-November), $C_{10}$, $C_{12}$, $C_{14}$, and $C_{16}$ increased in milk from both breeds ($P < 0.05$). The total percentage of the 5 most important FFAs ($C_{16}$, $C_{18:1}$, $C_{18}$, $C_{14}$, and $C_{10}$) in the milk of both breeds during lactation accounted for > 75% of total FFAs (Table 2). In the present study, the first (March-May), second (June-August), and last (September-November) 3 months of lactation, that is, early, mid-, and late lactation, corresponded to spring, summer, and autumn. Therefore, the effects of these stages of lactation on short-, medium-, and long-chain fatty acids were evaluated. These changes are detailed in the Figure. Stages of lactation had an effect on medium- (MCFFA, $\geq C_{10}$, $\leq C_{14}$) and long-chain (LCFFA, $> C_{14}$) FFAs ($P \leq 0.05$, $P \leq 0.001$).

### Effects of breed on milk composition

The differences in mean values of milk yield ($P \leq 0.05$), lactation period ($P \leq 0.001$), and total solid ($P \leq 0.05$) and total fat ($P \leq 0.05$) were significant between the genotype groups (Table 1). Differences in genotype did not affect FFA composition.

## Discussion

The differences in lactation period of the genotype groups could be attributed to the genotypic differences between groups and the heterosis effect on the crossbreeding. This situation was described by Voutsinas et al. (14), and Prasad and Sengar (15). Average lactation length of breeds in this study was similar to that reported by Al-Khouri (16) and Mourad (17) for Alpine goats, but milk yields were lower. The effect of lactation period ($P \leq 0.001$) on milk yield was probably due to physiological changes in the number and activity of secretory cells within the mammary gland. The highest milk yield in the crossbred and Damascus goats was attained in the fourth and fifth months of lactation, respectively. The milk yield in both groups gradually decreased from August towards drying-off. The reason for the decrease in milk yield in August, which was the last month of mid-lactation, may have been the diarrhea problems in some goats and climatic conditions, since the Hatay region is very hot and dry in August. With respect to lactation duration and milk yield, differences from other breeds, such as Saanen and Toggenburg, may have been due to diet, environmental conditions, breed, litter size, lactation number, and kidding season (18,19).

The total solid and fat contents in the milk of both breeds decreased to minimum levels in August (weeks 20-24), and then increased during the remainder of lactation. There were no differences between June and July for the crossbred. A similar observation was noted by other researchers in Alpine goat's milk (14). Since mid-lactation came in the summer (June-August), climatic conditions may have favored low fat and solid production from May to August. Another factor may have been that a dilution effect caused the increase in milk volume until the lactation peak. Reasons for demonstrating less variation of the total solid and fat contents in Damascus goat milk, compared to the crossbred, could be attributed to high adaptability to the environmental conditions of Hatay.

The highest total solid and fat values were obtained during the last month of lactation. This may have been due largely to the decrease in milk volume ($P \leq 0.05$). The average total solid and fat contents in the milk of both breeds were similar to those noted by Keskin et al. (7) and Hadjipanayiotou (20).

Individually, the percentages of major FFAs were within the range reported by other researchers (21,22). The $C_{12}$:$C_{10}$ ratio, proposed by Ramos and Juarez (23) to detect the authenticity of goat's milk, obtained in the present study (0.54 for Crossbred and 0.53 for Damascus) was similar to the value reported by Alonso et al. (21) for goat's milk ($0.50 \pm 0.04$ ).

The changes in short-chain FFAs in milk were not as great as those of long-chain fatty acids, throughout lactation. With the progression of lactation, changes in grassland and milk volume did not affect short-chain FFAs. Wijesundera et al. (24) reported that the content of SCFAs in cow's milk was unaffected by lactation period. Similar results were obtained by Kondyli and Katsiari (25) for native Greek goat's milk.

The high percentage of $C_{18} + C_{18:1}$ and low percentage of $C_{10}$, $C_{12}$, $C_{14}$, and $C_{16}$ in the first 2 months of lactation,

Table 2. Evaluation of mean percentage of individual FFAs (% of total FFA) in crossbred and Damascus goat's milks over the lactation period.

| FFA | Months of lactation | | | | | | | | | | P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | March | April | May | June | July | August | September | October | November | Mean | |
| | | | | | | Crossbred goats | | | | | |
| $C_4$ | 1.55 ± 0.09 | 1.45 ± 0.10 | 1.58 ± 0.03 | 1.68 ± 0.03 | 1.48 ± 0.01 | 1.14 ± 0.25 | 1.36 ± 0.65 | 1.56 ± 0.19 | 1.64 ± 0.12 | 1.49 ± 0.05 | NS |
| $C_6$ | 2.54 ± 0.80 | 1.70 ± 0.16 | 1.71 ± 0.35 | 1.64 ± 0.16 | 1.24 ± 0.02 | 0.97 ± 0.25 | 2.02 ± 1.03 | 1.09 ± 0.13 | 1.31 ± 0.58 | 2.47 ± 0.77 | NS |
| $C_8$ | 2.89 ± 0.09 | 2.53 ± 0.10 | 2.49 ± 0.31 | 2.63 ± 0.35 | 2.87 ± 0.18 | 2.11 ± 0.57 | 1.97 ± 0.05 | 1.76 ± 0.23 | 1.99 ± 0.26 | 2.36 ± 0.12 | NS |
| $C_{10}$ | 4.56 ± 0.72$^{abc}$ | 3.98 ± 0.16$^{ab}$ | 4.65 ± 0.77$^{abc}$ | 5.38 ± 0.23$^{abcd}$ | 5.19 ± 0.06$^{abcd}$ | 3.76 ± 1.09$^{a}$ | 5.76 ± 0.13$^{bcd}$ | 6.49 ± 0.74$^{cd}$ | 6.63 ± 0.61$^{d}$ | 5.15 ± 0.27 | * |
| $C_{12}$ | 2.23 ± 0.16$^{ab}$ | 2.03 ± 0.03$^{ab}$ | 2.21 ± 0.27$^{ab}$ | 1.53 ± 1.22$^{a}$ | 2.47 ± 0.15$^{ab}$ | 1.86 ± 0.19$^{a}$ | 3.56 ± 0.19$^{bc}$ | 4.07 ± 0.40$^{cd}$ | 5.29 ± 0.31$^{d}$ | 2.80 ± 0.30 | * |
| $C_{14}$ | 5.91 ± 0.12$^{a}$ | 5.39 ± 0.44$^{a}$ | 6.72 ± 0.77$^{ab}$ | 8.27 ± 0.05$^{b}$ | 7.92 ± 0.33$^{b}$ | 7.03 ± 0.67$^{ab}$ | 9.93 ± 0.59$^{c}$ | 10.78 ± 0.64$^{cd}$ | 12.15 ± 0.19$^{d}$ | 8.23 ± 0.54 | ** |
| $C_{16}$ | 28.21 ± 0.48$^{ab}$ | 27.01 ± 1.78$^{a}$ | 29.18 ± 2.10$^{ab}$ | 33.54 ± 1.09$^{cd}$ | 32.03 ± 0.94$^{ab}$ | 28.94 ± 0.44$^{ab}$ | 33.48 ± 1.36$^{cd}$ | 33.14 ± 0.41$^{cd}$ | 36.08 ± 0.26$^{d}$ | 31.29 ± 0.75 | ** |
| $C_{18}$ | 19.97 ± 0.55$^{de}$ | 18.98 ± 0.14$^{cde}$ | 17.40 ± 0.91$^{cd}$ | 22.68 ± 0.02$^{c}$ | 20.83 ± 1.07$^{de}$ | 18.03 ± 1.77$^{cd}$ | 15.77 ± 1.03$^{bc}$ | 12.90 ± 1.45$^{ab}$ | 9.73 ± 1.37$^{a}$ | 17.36 ± 0.96 | ** |
| $C_{18:1}$ | 24.22 ± 1.19$^{bc}$ | 25.81 ± 1.44$^{c}$ | 21.34 ± 2.15$^{ab}$ | 17.35 ± 1.24$^{a}$ | 19.73 ± 1.33$^{a}$ | 26.41 ± 0.38$^{c}$ | 20.26 ± 0.45$^{a}$ | 20.83 ± 0.15$^{ab}$ | 18.15 ± 0.44$^{a}$ | 21.57 ± 0.79 | ** |
| $C_{18:2}$ | 3.00 ± 0.01$^{cd}$ | 3.41 ± 0.17$^{d}$ | 2.50 ± 0.27$^{bc}$ | 1.81 ± 0.04$^{ab}$ | 2.41 ± 0.11$^{abc}$ | 1.68 ± 0.38$^{a}$ | 2.49 ± 0.05$^{bc}$ | 1.68 ± 0.24$^{a}$ | 2.10 ± 0.31$^{ab}$ | 2.34 ± 0.15 | ** |
| | | | | | | Damascus goats | | | | | |
| $C_4$ | 2.78 ± 0.15 | 2.66 ± 0.35 | 2.50 ± 0.09 | 2.46 ± 0.06 | 2.88 ± 0.04 | 2.97 ± 0.21 | 2.26 ± 0.04 | 2.24 ± 0.34 | 2.99 ± 0.06 | 2.64 ± 0.08 | NS |
| $C_6$ | 1.66 ± 0.04 | 2.46 ± 0.95 | 2.11 ± 0.76 | 1.94 ± 0.28 | 1.44 ± 0.14 | 1.33 ± 0.01 | 1.20 ± 0.17 | 1.54 ± 0.08 | 1.49 ± 0.12 | 1.68 ± 0.14 | NS |
| $C_8$ | 1.67 ± 0.29 | 1.94 ± 0.46 | 2.08 ± 0.43 | 1.92 ± 0.61 | 2.73 ± 1.20 | 1.34 ± 0.05 | 2.19 ± 0.83 | 2.05 ± 0.33 | 2.00 ± 0.48 | 1.99 ± 0.17 | NS |
| $C_{10}$ | 4.62 ± 0.37$^{abc}$ | 4.15 ± 0.11$^{ab}$ | 4.62 ± 0.33$^{abc}$ | 5.18 ± 0.12$^{bc}$ | 5.13 ± 0.13$^{bc}$ | 3.62 ± 0.86$^{a}$ | 4.89 ± 0.09$^{abc}$ | 6.94 ± 0.07$^{d}$ | 5.82 ± 0.35$^{cd}$ | 5.00 ± 0.24 | ** |
| $C_{12}$ | 2.37 ± 0.07$^{ab}$ | 1.69 ± 0.31$^{a}$ | 2.16 ± 0.09$^{ab}$ | 2.37 ± 0.36$^{ab}$ | 2.41 ± 0.21$^{ab}$ | 1.92 ± 0.07$^{a}$ | 2.90 ± 0.13$^{b}$ | 4.08 ± 0.12$^{c}$ | 3.98 ± 0.38$^{c}$ | 2.66 ± 0.20 | *** |
| $C_{14}$ | 6.14 ± 0.12$^{ab}$ | 5.65 ± 0.37$^{a}$ | 6.94 ± 0.05$^{b}$ | 8.07 ± 0.09$^{c}$ | 8.19 ± 0.27$^{c}$ | 6.58 ± 0.15$^{b}$ | 9.46 ± 0.43$^{d}$ | 11.21 ± 0.29$^{e}$ | 10.81 ± 0.03$^{e}$ | 8.12 ± 0.46 | *** |
| $C_{16}$ | 30.19 ± 0.07$^{abc}$ | 28.93 ± 0.34$^{ab}$ | 29.01 ± 0.38$^{ab}$ | 32.95 ± 2.37$^{cd}$ | 32.56 ± 0.62$^{bcd}$ | 28.41 ± 1.01$^{a}$ | 34.85 ± 1.05$^{d}$ | 35.83 ± 0.65$^{d}$ | 39.34 ± 1.29$^{e}$ | 32.45 ± 0.89 | ** |
| $C_{18}$ | 21.80 ± 0.16$^{abcd}$ | 21.60 ± 2.59$^{de}$ | 18.75 ± 0.28$^{cd}$ | 23.80 ± 0.14$^{e}$ | 18.66 ± 0.16$^{cd}$ | 17.21 ± 0.03$^{bc}$ | 14.09 ± 1.29$^{b}$ | 10.55 ± 0.10$^{a}$ | 8.10 ± 0.94$^{a}$ | 17.39 ± 1.30 | *** |
| $C_{18:1}$ | 23.78 ± 0.86$^{e}$ | 23.75 ± 1.06$^{bcd}$ | 23.54 ± 0.38$^{bcd}$ | 17.12 ± 1.07$^{a}$ | 19.89 ± 1.20$^{abc}$ | 26.79 ± 0.51$^{d}$ | 24.60 ± 4.58$^{cd}$ | 18.06 ± 0.02$^{ab}$ | 17.31 ± 0.17$^{a}$ | 21.43 ± 0.90 | * |
| $C_{18:2}$ | 2.84 ± 0.09$^{b}$ | 2.88 ± 0.17$^{b}$ | 2.51 ± 0.04$^{ab}$ | 2.38 ± 0.04$^{ab}$ | 2.42 ± 0.18$^{ab}$ | 2.09 ± 0.02$^{a}$ | 2.07 ± 0.33$^{a}$ | 2.24 ± 0.15$^{a}$ | 2.43 ± 0.05$^{ab}$ | 2.43 ± 0.06 | * |

$C_4$: butanoic acid; $C_6$: hexanoic acid; $C_8$: octanoic acid; $C_{10}$: decanoic acid; $C_{12}$: dodecanoic acid; $C_{14}$: tetradecanoic acid; $C_{16}$: Hexadecanoic acid; $C_{16:1}$: 9-hexadecenoic acid; $C_{18}$: octadecanoic acid; $C_{18:1}$: 9-octadecenoic acid; $C_{18:2}$: 9,12,- octadecadienoic acid. Means in the same row followed by different letters are significantly different (*P < 0.05, **P < 0.01, ***P < 0.001).

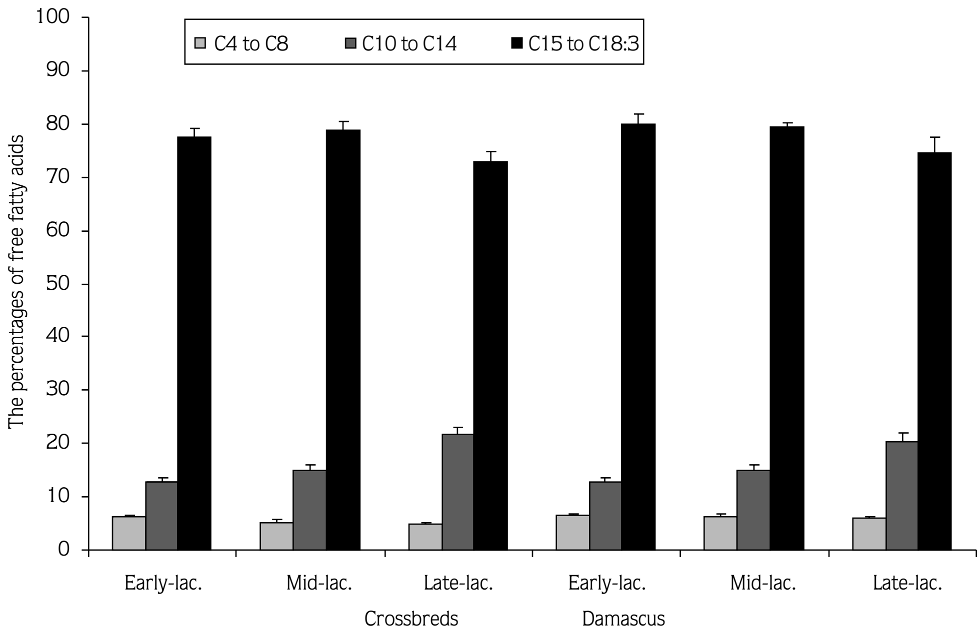


Figure. Changes in short- (SCFFA < C10), medium- (MCFFA, ≥ C10, ≤ C14), and long- (LCFFA, > C14) chain FFAs in crossbred and Damascus goat's milk over stages of lactation. Vertical lines show error bar.

when compared to the last 2 months of lactation, presumably reflected changes in the energy balance of the goats. Since energy balance is negative in these months, animals mobilize lipids stored in adipose tissues, mainly in the form of NEFAs (non-esterified fatty acids), which are very rich in $C_{18}$ + $C_{18:1}$ fatty acids (17,26).

In contrast to other months of lactation, the percentage of octadecanoic acid ($C_{18}$) in the milk analyzed in June (fourth month of lactation) for both breeds was higher than that of 9-octadecenoic acid ($C_{18:1}$), and this was also very close to value in the milk in July. This could be attributed to a decrease in desaturase enzyme activity in these months. Similar findings were obtained by Chavarri et al. (27).

Interestingly, when 9-octadecenoic acid showed a maximum value in the milk of both breeds in August, fat content, and decanoic, dodecanoic, and hexadecanoic acids were at their minimum (Tables 1 and 2). With the progression of lactation (September-November), the decrease of these fatty acids ($C_{18}$ - $C_{18:1}$) in milk was compensated for by a sharp increase in $C_{16}$, and especially $C_{14}$, $C_{12}$, and $C_{10}$ fatty acids. According to some researchers (28), the $C_{10}$-$C_{16}$-FFAs were negatively correlated to the $C_{18}$-FFAs family.

The decrease in $C_{18}$ and $C_{18:1}$, and the increase in SCFFAs, MCFFAs, and, partially, $C_{16}$ with advanced lactation may have been the result of increased fat content in milk, being dependent upon decreasing milk volume (Table 1), and a decrease in average fat globule size. Since the substrate surface for spontaneous lipolysis in the progressed period may be larger due to smaller fat globules, FFAs released from triglycerides may have increased. Similar observations were reported by Walstra and Jenness (4), and Cartier and Chilliard (29). Another reason may have been the state of the milk fat globule membrane, since the ceramide membrane material required to cover the increased surface area of the fat globules was not determined in the milk of this period, according to mass-spectrophotometer (MS) data (in another study, unpublished). In this stage (September-November), spontaneous lipolysis may also be increased.

Milk from both breeds, in terms of the $C_{18:1}$:$C_{18}$ ratio, demonstrated a considerable increase in late lactation, which was autumn. This may have been due to the effect of unprotected cottonseed in the concentrate feed on the FFAs mentioned, since there was no young ryegrass in this season (26), and/or the increased action of desaturase enzymes that convert octadecanoic acid to cis-octadecenoic acid (5).

Overall, stages of lactation that corresponded to different times of the year did not affect short-chain FFAS, whereas they caused changes in medium- and long-chain FFAs (Figure).

In the present study breed did not affect FFAs composition. According to Chilliard et al. (26), cow breed does not generally appear to affect the propensity to produce spontaneous lipolysis. Attaie et al. (30) reported that FFAs were not different in the colostrum of different goat breeds.

Although $C_4$, $C_6$, and $C_8$ FFAs remained quite constant during the lactation period, the other FFAs $\geq C_{10}$ (decanoic acid) significantly varied. Months of lactation were one of the most important factors responsible for changes in FFAs; however, it appears that season, daily variations, milk yield, and quality and quantity of feed, per se, are not the determining factors, that is, as they are dependent on stage of lactation they cannot be considered independent variables.

Briefly, although the period of lactation had an effect on FFAs, except for $C_4$, $C_8$, and $C_{10}$, daily variations and breed did not affect them. This observation provides new evidence that variation in FFAs is due mainly to the period of lactation rather than daily variations and breed.

**Acknowledgments**

Financial support for this research was provided by the Research Foundation of Mustafa Kemal University (Project no. 02 B 0901). The FFAs analyses were carried out with the GC-MS provided by the Rebuplic of Turkey Prime Ministry State Planning Organization (SPO) project (Project no: 02 K 120860).

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