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# Changes in the fatty acid composition of goat milk fat after a 48-hour fast

Anne-Marie MASSART-LEËN, G. PEETERS

*Department of Physiology,*
*Veterinary Faculty of the University of Ghent,*
*Casinoplein 24, B-9000 Ghent, Belgium.*

**Summary.** Five lactating goats were milked twice daily. After a control period of 3 days, they were fasted for 48 hr. The milk was collected at each milking. At the end of the fasting period, milk yield fell to 28 % and milk fat to 55 % of the original yield. The percentage of milk fat increased.

Generally, the relative concentrations of fatty acids with $\leqslant$ 16 carbons, containing even and odd-numbered straight-chain as well as monomethyl-substituted fatty acids of the milk fat, decreased significantly 24 hr after food was withheld. The decrease was most pronounced for the fatty acids with the shortest chain lengths. Longer-chain acids increased or did not change. Iso and anteiso-acids seemed to follow the same, although less pronounced trend, the effect being obvious after 48 hr of fasting.

It is suggested that the decline in the proportions of fatty acids with $\leqslant$ 16 carbons was due to the inhibition of mammary gland synthesis. The increase in the proportions of longer-chain fatty acids was ascribed to adipose tissue lipolysis.

## Introduction.

The effect of fasting goats for a period of 24 hr on milk components has been studied ; fasting was found to result in a decrease of milk, lactose and fat secretions (Annison, Linzell and West, 1968 ; Linzell, 1967) : total nitrogen and fat concentration rose while the lactose concentration in the milk dropped during that period. The changes in the fatty acid composition of milk fat during fasting depended on the origin of the fatty acids (Annison, Linzell and West, 1968) : there was a decrease in the relative concentration of milk fat fatty acids derived either completely or partly from synthesis within the mammary gland and containing 16 or less carbon atoms, while the $C_{18}$ acids derived entirely from plasma lipid precursors showed a compensatory increase. The same results were obtained on fasting lactating sheep (Emmanuel and Kennely, 1983). All these studies were limited to only the major fatty acids present in the milk fat.

The biosynthesis of the odd-numbered and branched-chain fatty acids present in milk fat was investigated in a previous study (Massart-Leën *et al.*, 1983)

on perfused goat mammary glands ; it was shown that propionate acts as a precursor in the synthesis of odd-numbered and monomethyl-substituted branched-chain fatty acids ([1]). The role of propionate as a precursor in the synthesis of either iso ([2]) or anteiso- ([3]) branched-chain fatty acids could not be demonstrated by our technique. It could be expected that the propionate supply to the mammary gland would decline if lactating goats were fasted. This might result in a change in the proportions of odd-numbered and branched fatty acids in the milk.

This paper examines changes in the composition of the major even ($C_{10:0}$-$C_{20:0}$), odd-numbered and branched-chain fatty acids in goat milk fat during a 48-hr fast.

## Material and methods.

*Experimental animals.* — Five lactating, non-pregnant goats of a « fawn-coloured » breed, yielding an average of 1 041 ml of milk/day, were routinely milked daily at 8 hr and 15.30 hr. They received 1.3 kg/day of concentrates ; hay and water were available *ad libitum.* After a control period of 3 days, the food (but not water) was removed after the afternoon milking and the animals were fasted for 48 hr. A milk sample collected at each milking was analysed. A total of 10 samples was taken from each goat and cooled. Milk samples 1-6 were the controls ; samples 7-10 were obtained 16.30 hr, 24 hr, 40.30 hr and 48 hr, respectively, after fasting.

*Analytical methods.* — Quantitative analyses of milk triacylglycerols were carried out as described by Massart-Leën *et al.* (1970). The fat was extracted from the milk with ethanol-ether (3:1), and the solvent evaporated after hot filtration. Sodium methoxide (0.025 N, 0.8 ml/100 mg fat) was added (Storry *et al.,* 1967) and a part of the methylesters was analysed by capillary gas chromatography (CGC) on a duran (50 m long, 0.5 mm diameter) BDS high-loaded column (Massart-Leën *et al.,* 1981). As our gas chromatograph had limited possibilities, methylesters of $< C_{10:0}$ were not quantified. This led to an overestimation ($\pm$ 7 %) of the values included in table 1. CGC analyses of the branched-chain fatty acids were carried out on the remaining methylesters after hydrogenation. These methylesters were extracted with 1 ml of petroleum ether, 2 ml of $H_2O$ and a drop of $H_2SO_4$. Extraction was repeated three times, and the petroleum ether layers collected were evaporated at 0 °C under dry $N_2$. The residue was dissolved in methanol. Palladium on charcoal (5 %) was added and the esters were

([1]) Methyl-branches appear only on even-numbered C atoms, the C atom of the carboxyl group being counted as 1.

([2]) Containing a terminal isopropyl group ($CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-(CH_2)_n-COOH$).

([3]) Containing a methyl group on the antepenultimate carbon atom ($CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-(CH_2)_n-COOH$).

hydrogenated with $H_2$ under pressure (Christie, 1973). Saturated esters were extracted from the methanol with petroleum ether, the solvent evaporated and the esters analysed by CGC (Massart-Leën *et al.,* 1981).

The peak areas were integrated in both analyses and concentrations of the eluting components (weight percentage of total fatty acids) determined. The carbon number values of the eluting branched-chain fatty acids were compared with those obtained previously by reference standard or GC/mass spectrometry under similar chromatographic conditions (Massart-Leën *et al.,* 1981).

## Results.

After a 24-hr fast, the milk yield fell to 54.9 ± 7.5 (SEM) % of the mean yield on control days and decreased to 28 ± 5.7 (SEM) % after 48 hr. Total fat secretion (mg/min) fell to 88 ± 11.5 (SEM) % after 24 hr of fasting and to 55.0 ± 13.5 (SEM) % after 48 hr. After 48 hr, the triacylglycerol concentration of the milk rose, the amount being about twofold (10.7 g %) that of the control value (5.9 ± 0.5 g %, SEM).

The fatty acid composition of milk fat before and at different intervals during fasting is shown in table 1. The fatty acids are presented as follows : group 1, straight-chain fatty acids with an even number of C atoms ; group 2, straight-chain fatty acids with an odd number of C atoms ; group 3, monomethyl-substituted branched-chain fatty acids ; group 4, branched-chain fatty acids with iso or anteiso-configuration ; group 5, unsaturated fatty acids.

It is clear from table 1 that the composition of most of the fatty acids in groups 1, 2, 3 and 5 differed significantly from the controls, even after only 24 hr of fasting. The differences increased after a 40-48 hr fast. The effect of fasting on the proportions of group 4 fatty acids was much less pronounced. The concentrations of most of these fatty acids did not differ significantly from the control after 24 hr. Even after 40 hr, fewer acids showed significant differences in concentration than in groups 1, 2, 3 and 5.

Another striking fact during fasting was the decrease in the concentration of fatty acids with chain lengths of $\leqslant$ 16 C atoms, the effect being most marked for fatty acids with the shortest chain length. $C_{17:0}$, $C_{17:1}$, $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ increased during fasting, while $C_{18:3}$ and $C_{20:0}$ did not change significantly. Acids belonging to group 4 showed an analogous, but less evident, tendency : fatty acids with chain lengths of $\leqslant$ 16 C tended to decrease during fasting, while those with longer chain lengths seemed to increase.

## Discussion.

The focal point of this study is the effect of fasting on the composition of odd-numbered and branched-chain fatty acids present in milk fat. The diet of our goats was rich in concentrates which would suppose a higher supply of propionate to the mammary gland. Therefore, the relative proportions of odd-

TABLE 1

*Effect of starvation on fatty acid composition (g/100g fatty acids) of goat milk fat. Values are means ± SEM of mean.*

| Milk sample no. | 1-6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|
| | Control period | | Time (hr) after removal of food | | |
| | | 16 h 30 | 24 h | 40 h 30 | 48 h |
| *Group 1* : saturated straight-chain fatty acids with even number of C-atoms in the chain | | | | | |
| Carbon number of fatty acid | | | | | |
| 10 : 0 | 10.28 ± 0.20 | 9.10 ± 0.63 NS• | 7.45 ± 0.76*• | 4.78 ± 0.38***• | 3.65 ± 0.34*** |
| 12 : 0 | 5.61 ± 0.45 | 5.27 ± 0.69 NS | 4.21 ± 0.53* | 2.29 ± 0.24** | 1.71 ± 0.17*** |
| 14 : 0 | 11.94 ± 0.61 | 10.45 ± 0.80* | 8.16 ± 0.76** | 4.76 ± 0.46*** | 3.84 ± 0.34*** |
| 16 : 0 | 33.66 ± 1.40 | 29.77 ± 0.93 ** | 27.18 ± 0.92** | 23.93 ± 0.45** | 23.14 ± 0.33** |
| 18 : 0 | 5.88 ± 0.64 | 6.91 ± 0.99 NS | 8.15 ± 0.91** | 10.30 ± 0.70** | 10.46 ± 0.46*** |
| 20 : 0 | 0.15 ± 0.01 | 0.12 ± 0.02 NS | 0.12 ± 0.01 NS | 0.14 ± 0.01 NS | 0.09 ± 0.01 NS |
| *Group 2* : saturated straight-chain fatty acids with odd-number of C-atoms in the chain | | | | | |
| 11 : 0 | 0.19 ± 0.03 | 0.16 ± 0.03 NS | 0.10 ± 0.02* | 0.04 ± 0.01** | 0.03 ± 0.01** |
| 13 : 0 | 0.14 ± 0.02 | 0.12 ± 0.01 NS | 0.08 ± 0.01** | 0.04 ± 0.01** | 0.03 ± 0.004** |
| 15 : 0 | 1.07 ± 0.09 | 0.92 ± 0.08 * | 0.74 ± 0.08* | 0.53 ± 0.06** | 0.47 ± 0.04** |
| 17 : 0 | 10.54 ± 0.05 | 0.59 ± 0.06 NS | 0.80 ± 0.11** | 0.99 ± 0.05*** | 1.16 ± 0.12** |
| *Group 3*: monomethyl-substituted fatty acids with methyl-substitution in the chain | | | | | |
| Identity•••• | | | | | |
| 10.40 4-methyldecanoate + 6-methyldecanoate | 0.10 ± 0.01 | 0.08 ± 0.02 NS | 0.06 ± 0.01** | 0.02 ± 0.01** | 0.01 ± 0.004** |
| 12.40 4-methyldodecanoate | 0.04 ± 0.02 | 0.03 ± 0.01 NS | 0.02 ± 0.01** | 0.01 ± 0.001** | 0.01 ± 0.001** |
| 14.31 6-methyltetradecanoate | 0.08 ± 0.003 | 0.05 ± 0.01 NS | 0.03 ± 0.01* | 0.02 ± 0.003** | 0.02 ± 0.003** |
| 14.40 4-methyltetradecanoate | 0.07 ± 0.003 | 0.05 ± 0.01 NS | 0.03 ± 0.01* | 0.03 ± 0.003* | 0.02 ± 0.01* |
| 16.39 4-methylhexadecanoate + 12-methylhexadecanoate | 0.07 ± 0.004 | 0.07 ± 0.01 NS | 0.05 ± 0.01NS | 0.07 ± 0.01NS | 0.06 ± 0.003 NS |

*Group 4* : branched-chain fatty acids with iso or anteiso configuration

| | Identity•••• | | | | | |
|---|---|---|---|---|---|---|
| 12.55 | 11-methyldodecanoate (i)•• | 0.02 ± 0.001 | 0.01 ± 0.002 NS | 0.01 ± 0.002 NS | 0.01 ± 0.002 NS | 0.01 ± 0.002* |
| 13.55 | 12-methyltridecanoate (i) | 0.08 ± 0.01 | 0.07 ± 0.02 NS | 0.06 ± 0.03 NS | 0.05 ± 0.02 NS | 0.05 ± 0.02 NS |
| 14.55 | 13-methyltetradecanoate (i) | 0.19 ± 0.02 | 0.18 ± 0.03 NS | 0.16 ± 0.01 NS | 0.12 ± 0.01* | 0.11 ± 0.005* |
| 14.71 | 12-methyltetradecanoate (a)••• | 0.36 ± 0.02 | 0.33 ± 0.03 NS | 0.28 ± 0.03 NS | 0.19 ± 0.02** | 0.17 ± 0.01** |
| 15.55 | 14-methylpentadecanoate (i) | 0.21 ± 0.01 | 0.22 ± 0.01 NS | 0.18 ± 0.01 NS | 0.20 ± 0.02 NS | 0.19 ± 0.001 NS |
| 16.55 | 15-methylhexadecanoate (i) | 0.39 ± 0.04 | 0.35 ± 0.04 NS | 0.33 ± 0.06 NS | 0.34 ± 0.06 NS | 0.34 ± 0.05 NS |
| 16.70 | 14-methylhexadecanoate (a) | 0.52 ± 0.05 | 0.60 ± 0.05 NS | 0.57 ± 0.02 NS | 0.65 ± 0.02* | 0.64 ± 0.08 NS |
| 17.52 | 16-methylheptadecanoate (i) | 0.05 ± 0.03 | 0.06 ± 0.01 NS | 0.11 ± 0.01** | 0.13 ± 0.01*** | 0.14 ± 0.01*** |
| | *Group 5* : unsaturated fatty acids | | | | | |
| 12.44 | 12 : 1 | 0.09 ± 0.01 | 0.10 ± 0.02 NS | 0.07 ± 0.02* | 0.03 ± 0.01** | 0.02 ± 0.01*** |
| 14.46 | 14 : 1 | 0.38 ± 0.04 | 0.35 ± 0.04 NS | 0.28 ± 0.04** | 0.16 ± 0.02** | 0.13 ± 0.01** |
| 16.27<br>16.38 | 16 : 1 | 0.60 ± 0.05 | 0.68 ± 0.05 * | 0.73 ± 0.03* | 0.76 ± 0.04** | 0.74 ± 0.01** |
| 17.28 | 17 : 1 | 0.32 ± 0.01 | 0.49 ± 0.05 NS | 0.55 ± 0.03** | 0.74 ± 0.04** | 0.88 ± 0.07** |
| 18.30 | 18 : 1 + isomers | 22.84 ± 0.83 | 28.95 ± 1.86* | 34.92 ± 2.26** | 44.06 ± 1.24*** | 47.25 ± 1.06*** |
| 18.75 | 18 : 2 | 1.96 ± 0.12 | 2.28 ± 0.07** | 2.66 ± 0.12** | 3.07 ± 0.19*** | 3.25 ± 0.15*** |
| 19.48 | 18 : 3 | 0.23 ± 0.02 | 0.19 ± 0.02 NS | 0.24 ± 0.02 NS | 0.27 ± 0.02 NS | 0.27 ± 0.04 NS |
| | others | 1.95 ± 0.05 | 1.93 ± 0.13 | 1.65 ± 0.09 | 1.31 ± 0.08 | 1.12 ± 0.04 |

• : Statistical significance of differences at different fasting periods as related to the control period : NS : P > .05 ; *P < .05 ; **P < .01 ; ***P < .001.
•• : (i) = iso configuration.
••• : (a) anteiso configuration.
•••• : as identified by carbon number value.

numbered and monomethyl-substituted fatty acids in control milk samples should be higher than those obtained with a more balanced diet. This could be advantageous in studies on the influence of fasting on these fatty acids since specific decreases might be more obvious.

Linzell (1967) and Annison, Linzell and West (1968) reported a drop in the proportions of even straight-chain fatty acids ($C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{12:0}$ and $C_{14:0}$) in goats after 24 hr fasting. In fed animals, these acids are synthesized *de novo* in the gland from acetate and $\beta$-hydroxybutyrate (Popjak *et al.*, 1951). The latter reported that arterial acetate concentrations and mammary arterio-venous acetate differences decreased sharply in fasting goats. In contrast, the proportions of $C_{18:0}$ and $C_{18:1}$, which are transferred to milk fat from blood, almost doubled. Palmitic acid, which is both transferred from blood and synthesized in the mammary gland, occupied an intermediate position. Annison, Linzell and West (1968), determining changes in free fatty acid (FFA) levels and in the rates of FFA entry into the plasma, noted them as indicators of changes in the rate of lipolysis in fasting goats. Arterial FFA levels were elevated and there were large mammary arterio-venous differences. During infusion of $^{14}C$ palmitic, oleic and stearic acids, the rates of plasma palmitate, oleate and stearate entry into the circulation were much higher than those in fed animals. There was a major transfer of radioactivity into the corresponding milk fatty acids. It was concluded that long-chain FFA derived from adipose tissue were used more extensively for milk fat synthesis. In our experiments, the concentrations of even straight-chain fatty acids $C_{10:0}$, $C_{12:0}$, $C_{12:1}$, $C_{14:0}$, $C_{14:1}$ and $C_{16:0}$ in milk decreased, whereas even straight-chain fatty acids $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ increased during fasting. These results are in good agreement with the studies of Annison, Linzell and West (1968).

We found a significant decline in the proportions of odd-numbered fatty acids $C_{11:0}$, $C_{13:0}$ and $C_{15:0}$, while $C_{17:0}$ and $C_{17:1}$ rose significantly. Also, the proportions of monomethyl-substituted branched-chain fatty acids with carbon numbers 10.40 (4-methyldecanoate + 6-methyldecanoate), 12.40 (4-methyldodecanoate), 14.31 (6-methyltetradecanoate) and 14.40 (4-methyltetradecanoate) decreased significantly after 24 hr of fasting. The decline in these odd-numbered fatty acids and monomethyl-substituted fatty acids may be explained partly by their restricted synthesis from propionate in the mammary gland due to a decrease in the propionate supply. In perfusion experiments on isolated goat mammary glands, we have shown that the concentration of odd-numbered fatty acids $C_{11:0}$, $C_{13:0}$ and $C_{15:0}$ and monomethyl-substituted acids in milk increase if propionate is added to the perfusion blood (Massart-Leën *et al.*, 1981). In these perfusion experiments, the proportion of odd-numbered fatty acids increased as chain length became shorter ($C_{11:0}$, $C_{13:0}$, $C_{15:0}$). In the present experiments, these acids, classified according to the decrease in their concentrations after fasting, follow a similar order (table 1). If $C_{11:0}$, $C_{13:0}$ and $C_{15:0}$ were completely derived from propionate, their percentages should decrease in the same proportion during fasting. As this was not the case, it may be postulated that a part of them was derived from other sources such as lipolysis in the adipose tissue. Bovine perinephric fat contains all the normal odd-numbered fatty acids from $C_3$ to $C_{25}$

(Hansen, Shorland and Cooke, 1958). Blood propionate levels were not followed in our study. Hartmann and Lascelles (1965) have shown that the arterial concentration of propionate decreases by at least 50 % in cows during starvation. The rates of short-chain fatty acid entry into the venous blood draining the rumen is considerably reduced in sheep starved for 24 hr, and no propionate entry was detected in sheep starved for 48 hr (Annison and Lindsay, 1962). In our perfusion experiments on isolated goat mammary gland, we observed no synthesis of $C_{17:0}$ or $C_{17:1}$ from propionate ; these fatty acids are found in sheep adipose tissue (Christie and Moore, 1971) and originate in the rumen where they are synthesized *de novo* by micro-organisms (Emmanuel, 1974). It may be that during fasting, milk fat $C_{17:0}$ and $C_{17:1}$ were derived from adipose tissue by lipolysis. Their proportions increased as in the case of $C_{18:0}$ and $C_{18:1}$.

Monomethyl-substituted branched-chain fatty acids are present in extremely small proportions in the adipose tissue of normally-fed sheep and goats (Duncan and Garton, 1978). Barley-fed lambs and goats lay down subcutaneous fat depots with high proportions of monomethyl-substituted branched-chain fatty acids (Duncan, Orskov and Garton, 1972).

In the present study, the composition of iso- and anteiso-branched-chain fatty acids (group 4) changed less than the fatty acids of groups 1, 2, 3 and 5, even after 48 hr of fasting. However, they followed the same trend, as the proportion of long-chain acids (anteiso-$C_{17}$ and iso-$C_{18}$) increased whereas shorter-chain acids, including iso-$C_{17}$, decreased. Neither iso nor anteiso-fatty acids increased in the milk fat of perfused goat mammary gland receiving propionate (Massart-Leën *et al.,* 1983). Several metabolic pathways may be involved in the supply of iso and anteiso-branched-chain fatty acids to the mammary gland. Isobutyric, isovaleric and 2-methylbutyric acids are produced when microbes in the rumen attack valine, leucine and isoleucine, respectively ; these acids serve as primer molecules for branched-chain fatty acid synthesis ($C_{13}$, $C_{14}$, $C_{15}$, $C_{16}$, $C_{17}$ and $C_{18}$) (Allisson *et al.,* 1961 ; Emmanuel, 1974). Keeney, Katz and Allison (1962) also detected these acids in blood serum lipids and calculated that the amount of $C_{15}$ branched-chain acid passing into the lower digestive tract from the rumen could easily account for more than half of the $C_{15}$ branched-chain acid in butterfat. Iso-$C_{15}$, $C_{16}$ and $C_{17}$ and anteiso-$C_{13}$, $C_{15}$ and $C_{17}$ were found in the adipose tissue of cows, sheep and goats (Hansen, Shorland and Cooke, 1956, 1958 ; Duncan and Garton, 1978). It is suggested that, by analogy with the long-chain fatty acids of groups 1 and 2, the long-chain fatty acids of milk (anteiso-$C_{17}$ and iso-$C_{18}$) are derived by adipose tissue lipolysis during fasting. The reduction in iso-$C_{13}$, $C_{14}$, $C_{15}$, $C_{16}$, $C_{17}$ and anteiso-$C_{15}$ in the milk fat can be interpreted as a decrease in their synthesis from branched-chain amino acids and their metabolites in the goat mammary gland. Linzell (1967) reported that plasma arterial levels of $\alpha$-amino-N decreased and mammary arterio-venous $\alpha$-amino-N differences declined sharply in fasting goats. Horning *et al.* (1961) demonstrated the *in vitro* synthesis of iso- and anteiso-fatty acids from isovaleryl-CoA, isobutyryl-CoA and 2-methylbutyryl-CoA by the addition of malonyl-CoA units catalysed by a rat adipose tissue enzyme system. However, Verbeke *et al.* (1959), adding iso-valeric acid-1-$^{14}C$ to the perfusion blood of an isolated cow udder, con-

cluded that iso-valeric acid was not a direct precursor of the $C_{15}$ and $C_{17}$ iso-acids of milk fat.

As goats have very little subcutaneous tissue, the fatty acids of this tissue have a limited metabolic role during fasting. Milk production in cows, sheep and goats reaches a peak during early lactation, and there is usually a period of negative energy balance when milk production reaches a peak (see Vernon, 1981). Several facts indicate there is considerable lipolytic activity in the omental adipose tissue of goats during early lactation : the anabolic activity of omental adipose tissue is extremely low and its cells are small during early lactation (Chilliard *et al.,* 1978), plasma FFA levels increase considerably and the pattern of milk straight-chain fatty acid composition is very similar to changes in fasting animals (Chilliard *et al.,* 1977) ; the lipoprotein lipase activity of omental adipose tissue is extremely low after a 48-hr fast and high after 7-day refeeding (Chilliard *et al.,* 1979). It is suggested from all these observations that omental adipose tissue is involved in lipolysis in fasting goats as well.

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**Résumé.** *Influence du jeûne (48 heures) sur la composition des acides gras du lait de chèvre.*

Cinq chèvres sont traites biquotidiennement matin et soir, à heure fixe. A chaque traite, un échantillon de lait est prélevé. Après une période de trois jours de contrôle, les animaux sont soumis à un jeûne de 48 h. On constate une réduction de la production laitière, ainsi que de la sécrétion de matières grasses qui retombent respectivement à 28 et 55 % des valeurs initiales. Par contre, on note une augmentation de la teneur en triglycérides. Après 24 h de jeûne, on observe une diminution relative des acides gras à courte chaîne ($\leq$ 16 C) et à nombre pair d'atomes de carbone, ainsi que des acides gras ramifiés monométhyl-substitués. La réduction la plus importante s'observe au niveau des acides gras aux chaînes les plus courtes. L'importance relative des acides gras à longue chaîne ($\leq$ 16 C) s'accroit ou reste inchangé.

Dans le cas des acides gras à configuration iso et antéiso, les variations évoluent de façon analogue, mais nettement plus lente et moins prononcée. En effet, un jeûne de 48 heures semble nécessaire pour accuser des différences statistiquement valables.

Ces observations nous conduisent à supposer que la diminution proportionnelle des acides gras à courte chaîne serait dûe à l'inhibition de la synthèse endogène de ceux-ci au niveau de la glande mammaire, tandis que l'augmentation relative des acides gras à longue chaîne pourrait être attribué à la lipolyse du tissu adipeux.

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