Nutritional quality indices of milk fat from goats on diets supplemented with different roughages

E.K. Osmari a,*, U. Cecato b, F.A.F. Macedo b, N.E. Souza c

a Secretary of Agriculture, Livestock, Fishery and Agribusiness-SEAPPA/RS, Av. Getúlio Vargas, 1384, 90150-900 Porto Alegre, Rio Grande do Sul State, Brazil
b Department of Animal Science, State University of Maringá-UEM, Av. Colombo, 5790, 87020-900 Maringá, Paraná State, Brazil
c Department of Chemistry, State University of Maringá-UEM, Av. Colombo, 5790, 87020-900 Maringá, Paraná State, Brazil

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ABSTRACT

The experiment was conducted to evaluate the nutritional indices of milk fat of 1/2 Boer × Saanen goats on diets supplemented with three roughages. Eighteen goats under a semi-intensive system were divided into groups, and fed an ad libitum supplement of sorghum silage, maize silage or mulberry hay. Nutritional indices were determined from three milk samples taken during winter (August) and spring–summer (average of November and December). Using mixed statistical models, the animal error was computed as a random effect. The season and supplement were fixed. The winter season was markedly better for all variables (P < 0.01), while short-chain fatty acids did not change (P > 0.05). Interactions only occurred between the thrombogenic index and the C12:0/C10:0 ratio, where the higher values that are potentially more harmful to human health were obtained in the spring–summer season in animals fed maize silage, followed by the averages of other treatments during the same season. The values for unsaturated fatty acids, atherogenic index and thrombogenic index indicated differences between supplements, with better values for goats fed with sorghum silage and mulberry hay. Grazing Boer × Saanen goats supplemented with mulberry hay or sorghum silage provided milk with better lipid indices for the prevention of human coronary diseases.

1. Introduction

Fatty acids can promote or prevent atherosclerosis and coronary thrombosis because of their effects on serum cholesterol and low density lipoprotein-cholesterol concentrations. So fats not only provide energy in the diet, but also have an important role in promoting good health in humans (Silva-Hernandez et al., 2007; Ulbright and Southgate, 1991). As lipid research has intensified over recent decades, the health benefits of long-chain fatty acids (LCFA) have been recognized. According to Cutrignelli et al. (2008), in 1984 the Committee on Medical Aspects of Food Policy (COMA) recognized seven dietary factors implicated as important in the development of coronary heart disease (CHD); two are recognized as promoting and the others as protective. The implication of fatty acids in CHD development may be summarized as follows: stearic acid (C18:0) does not raise serum cholesterol, the short-chain (C7:0–C11:0) saturated fatty acids (SCFA) do not influence cholesterol concentration in the blood, while lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0) are recognized as atherogenic factors. Based on these considerations, Ulbright and Southgate (1991) suggest equations for the atherogenic (AI) and thrombogenic indices (TI),
indicating that C12:0, C14:0, and C16:0 are atherogenic and that C14:0, C16:0, and C18:0 are thrombogenic. However, Chilliard and Ferlay (2004) point out that stearic acid (C18:0) is not related to increased cholesterol because it is metabolized to oleic acid (C18:1), with levels of 6–11% of C18:0 and 18–23% of C18:1 being nutritionally desirable. Therefore, the intake of certain dietary saturated fatty acids, particularly some medium-chain fatty acids (MCFA), myristic (14:0) and palmitic (16:0) acids, as well as trans-monounsaturated fatty acids, have been associate with an increase in arteriosclerosis, coronary-heart disease and cancer (Silva-Hernandez et al., 2007). The sensorial qualities of milk are influenced by the short-chain fatty acids (SCFA), C4:0–C10:0, responsible by the rancid flavor in milk (Ferlay et al., 2006).

As the characteristics of milk fat are influenced by dietary supplements given to animals (Bouattour et al., 2008; Ferlay et al., 2006; Silanikove et al., 2010), a higher level of unsaturated fatty acids in the animals’ diet can increase the desirable fatty acids (DFA) in the milk. It has been shown that breed also has an effect on fatty acids (FA) in the milk of dairy goats (Ferlay et al., 2006), but there is no known interaction between the Boer cross-breed and nutritional factors. As milk yield may be affected by the seasonality of pasture, the forage type could also modify milk fatty acids. Even Tifton 85, a tropical grass recommended for goats, because of its small size, good quality and productivity, often does not provide enough nutrients for the requirements of lactation during the dry season, because of its low energy content. The environmental conditions in South Brazil in the winter favor the use of C3 grasses such as oat grass, with high crude protein, resistance to cold, high acceptability, and low fiber levels (Moreira et al., 2001). Even so, depending on the seasonality of pasture, roughage supplementation may be necessary for the viability economic of dairy goats breeding. Comparisons between studies show that milk fat from diets including maize silage is richer in SCFA and linoleic acid, but poorer in α-linolenic acid compared with grass silage or pasture diets (Chilliard and Ferlay, 2004). According to (Ferlay et al., 2006), compared with fresh grass, grass silages have disadvantages in mono- and polysaturated fatty acids levels of milk, including conjugated linoleic acid (CLA). The aim of this study was to determine the effects of season and supplementation of different roughages on fatty acid composition in goats’ milk, to improve the nutritional quality of milk fat and so benefit human health.

2. Material and methods

2.1. Animals, management and sampling

The study was conducted at the Iguatemi Experimental Farm (FEI) of the State University of Maringá (UEM), Paraná State, Brazil. The local climate is classified under the Köppen Climate Classification System as Cfa, humid subtropical, a mild mid-latitude climate with no dry season, hot summers and few frosts (Correa, 1996). Eighteen 1/2 Boer × Saanen does grazing under a semi-intensive system, in their first lactation with an average body weight of 46.87 kg (P > 0.05) at the beginning of lactation, were divided into three balanced groups with ad libitum supplementation of sorghum silage (SS), maize silage (MS) or mulberry hay (MH). After a post-parturition adaptation period of 19 days, daily milk yield and milk composition of individual goats together with feed intake, was recorded and analyzed. Details are provided elsewhere (Osmari et al., 2009). All the goats grazed two paddocks during the day, one with oat grass (Avena strigosa Screeb var. lapar 61) or PAV (6995 m²), and other with Tifton 85 grass (Cynodon spp.) or PTI (6995 m²). Fertilizer was applied to the oat grass at the rate of 220 kg/ha of NPK 8-20-20 and 80.7 kg N/ha. PTI received 48 kg N/ha of urea. The animals grazed on PAV during the mornings and on PTI during the afternoons. Goats were limited to no more than 0.42 kg dry matter of concentrate per day in the morning, containing 13% crude protein (CP) and 73% total digestible nutrients (TDN) during the first 60 days after birth, increasing to 17% CP and 79% TDN for the rest of the lactation due to drought, when the animals grazed only on the Tifton pasture. After the second milking, the goats were fed their allocated roughage in their stalls. For calculation of the nutritional indices of milk fat, three milk samples were grouped in two seasons: PERI, in August (winter) and PERIL, containing an average of November and December (spring–summer). Samples were collected twice a day from the goats, with 2/3 from the morning milking and 1/3 from the second milking. Samples were frozen for subsequent analysis of the fatty acids (FA) profile.

2.2. Fatty acid methyl esters analyses

Total lipids were extracted from the milk samples after defrosting and centrifugation at 18,000 × g for 5–10 min (Murphy et al., 1995). Triacylglycerols were then transesterified to methyl esters using the ISO 5509 method (ISO, 1978), and effected modifications in dilution due to higher fat concentration of samples, with a solution of 4 mL n-heptane and 4 mL KOH/MeOH 2 mol/L in a test tube, and shaken for 4 min. Samples of 1 μL were taken from the upper layer for analysis. Fatty acid methyl esters (FAME) were determined using a Shimadzu 14A (Tokyo, Japan) gas chromatograph equipped with a flame ionization detector and fused-silica capillary column (100 m × 0.25 mm × 0.20 μm of bicineanopropyl polysiloxane, CP-Sil 88). Identification of fatty acids was carried out by comparing FAME peak retention times with standards obtained from Sigma (St. Louis, MO, USA). Peak areas were determined by a CG-300 computing integrator (CG Instruments, Brazil). Data were calculated as normalized area percentages of fatty acids. The nutritional quality indices of lipids were determined using the fatty acids, estimating the unsaturated fatty acids (UFA) by summing the polyunsaturated (PUFA) and monounsaturated (MUFA), and desirable fatty acids (DFA) by summing the unsaturated fatty acids and stearic acid:

\[
DFA = (UFA + C18:0)\]

The ratio of hypocholesterolemic and hypercholesterolemic fatty acids (HH) was HH = (C18:1n−9 + C18:2n−6 + C20:4n−6 + C18:3n−3 + C20:5n−3 + C22:5n−3 + C22:6n−3) / (C14:0 + C16:0)

The atherogenic (AI) and thrombogenic indices (TI) were calculated using the equations of Ulbright and Southgate (1991). In the equations, C14:0 is considered to be 4 times more atherogenic than other FA, so it is assigned the coefficient ‘4’. The C18:1, n−6 and remaining monounsaturated FA are assigned coefficients of 0.5 because they are less anti-atherogenic than the n−3 FA, which are assigned a coefficient of 3, as follows:

\[
AI = \sum_{n-3}^{n-6} \sum_{n-6}^{n-3} MUF A + \sum_{n-6}^{n-3} C14:0 + C16:0 + C18:0
\]

\[
TI = \sum_{n-3}^{n-6} \sum_{n-6}^{n-3} MUF A + 0.5 \sum_{n-6}^{n-3} + \sum_{n-6}^{n-3} \sum_{n-6}^{n-3}
\]

2.3. Statistical analyses

All the statistical analyses were performed using mixed models, according to a 3 × 2 balanced factorial arrangement; animal was the replicate (total of 18 goats). UFA, DFA, AI, TI, HH, (C18:0 + C18:1)/C16:0,
SCFA, MCFA, LCFA, and the C12:0/C10:0 ratio were statistically analyzed by ANOVA, using the SAEG program (SAEG, 2001). The nutritional quality indices of lipids were studied and described by the following model:

$$Y_{ik} = \mu + S_i + P_j + SP_{ij} + e_{ik}.$$

where $Y_{ik}$ is the individual observed variable, $\mu$ the mean value, $S_i$ the fixed effect of the supplement ($i=1$, sorghum silage; $i=2$, maize silage; $i=3$, mulberry hay), $P_j$ the fixed effect of the season ($j=1-2$), $SP_{ij}$ the interaction between the supplement of the order $i$ and the season of the order $j$, and $e_{ik}$ the residual error. The statistical mixed model included the fixed effects of supplement (SST, MST and MHT), and the season (PERI and PERII), interactions between supplements and seasons, residual error as fixed effects and animal as random effects within the supplement. Trends for significance were declared at $P=0.05$–0.10. The significance level was declared at $P<0.05$.

3. Results

Estimates of the lipid indices are shown in Tables 1 and 2. The winter season, during early lactation, was markedly better for all variables (Table 1), except for the short-chain fatty acids, which were not affected ($P>0.05$) by the feed supplement or by the season studied. An increase in TI, AI, MCFA, and C12:0/C10:0 and a decrease in UFA, DFA, HH, (C18:1 + 18:0)/16:0, and LCFA, were seen as lactation progressed. The values for UFA, AI and TI showed differences between supplements, with the better values observed for goats in the SST and MHT groups. Trends for differences between supplements were observed for DFA, HH and LCFA. Interactions occurred only between TI and the C12:0/C10:0 ratio, where higher values were obtained in PERII in the MST group, followed by the averages for the other treatments during the same season.

4. Discussion

Unlike MCFA, SCFA (C4:0 – C10:0) are classically either unchanged or only slightly reduced by increased lipid supplementation in the diet or body lipid mobilization, therefore these experimental data are consistent with those of Chilliard and Ferlay (2004). The main fatty acids stored as triglycerides in ruminant adipose tissue are 16:0, 18:0 and 18:1n–9. Thus, lipid mobilization which occurs in early lactation and when the energy balance is negative induces a sharp increase in stearic, oleic and polyunsaturated acids, inhibiting de novo synthesis of fatty acids with less than 16 carbons in milk (Chilliard and Ferlay, 2004). This is reflected in the results, with higher values for TI, AI, MCFA, and C12:0/C10:0 and lower ones for UFA, DFA, HH, (C18:1 + 18:0)/16:0, and LCFA for PERI. Certain fatty acids exert a specific effect on the hardness and spreadability of butter. An increased palmitic acid concentration combined with a decrease in short-chain FA lead to lower spreadability. The 16:0/18:1n–9 ratio is the most accurate indicator of butter firmness (Chilliard and Ferlay, 2004), therefore it can be expected that the lower (C18:1 + C18:0)/16:0 ratio during the second season will provide a firmer butter, because of the increase of palmitic acid as lactation progresses. In addition to higher values for undesirable indices as lactation progresses, Silanikove et al. (2010) cite in their review that a problem unique to goats is that marked elevation in somatic cell count (SCC) in milk coming from bacteria-free glands towards the end of lactation (Raynal-Ljutovac et al., 2007) and a possibility that is being considered in Israel is to separate the milk collected from late lactating goats and allocate this milk for marketing only for drinking, as this late-lactation milk is also less suitable for cheese making. For Okine et al. (1999), the (C18:1 + C18:0)/16:0 ratio may be a better indicator of the cholesterolemic tendency of a fat source, with a higher ratio deemed to be nutritionally superior. The levels found by Okine et al. (1999) for this ratio, in a study of canola oil supplementation in goats, ranged from 0.97 to 1.46, agreeing with our results of 0.96–1.69.

The higher values of TI and C12:0/C10:0, potentially more harmful to human health, seen during PERII in the MST group corroborate the findings of Chilliard and Ferlay (2004) and Ferlay et al. (2006), concerning the disadvantages of maize silage against fresh temperate grass (oat grass in PERI in this trial) or hay based-diets with regard to UFA, DFA and AI. The only exception was found for C12:0/C10:0 in the MHT group, where no significant difference was found between the two seasons, which suggests that the quality of mulberry hay during the latter period may have partially offset the effect of PAV during early lactation on the production of both fatty acids, a fact that deserves to be clarified by further study. Magalhães (2007) emphasizes the use of a C12:0/C10:0 (lauric:capric) ratio of about 0.50 to indicate the authenticity of goat dairy products. In this author’s study, this relationship was maintained, irrespective of the concentration of protein in the diet, confirming the validity of this tool in the identification of goats’ milk. Higher values for the ratio of hypocholesterolemic and hypercholesterolemic fatty acids (HH) are desirable, considering the specific effects of fatty acids on cholesterol metabolism. The utilization of diets characterized by low AI and TI values could reduce the potential risk of CHD (Cutrignelli et al., 2008; Menezes et al., 2009; Ulbright and Southgate, 1991).

The range of values obtained for AI (2.20–3.29) were in agreement with results reported in the literature for goats’ milk (Bouattour et al., 2008; Magalhães, 2007; Salama et al., 2005). In their review, Silanikove et al. (2010) reported that several studies showed that milk and cheese from grazing goats had better quality parameters for human nutrition than that produced from the milk of goats fed indoors, with concentrations of CLA and polyunsaturated fatty acids being higher in the milk fat of pasture-fed goats, together with a significant reduction in the atherogenic index of the fatty acids. The quality of sorghum silage was lower than the others because of a higher neutral detergent fiber content (79.25%) and a lower crude protein content (6.81%), resulting in a lower intake of the silage, as explained in a previously published paper focusing on milk yield and feed intake during this trial (Osmari et al., 2009). Thus, as the type of supplement was not significant for milk yield, a higher substitutive effect of pasture in the SST group was observed during PERI (oats + Tifton) and PERII (Tifton), resulting in a higher rumen pH and LCFA level in milk, making it comparable to the MHT group during PERII for most variables.
Table 1
Percentage composition of nutritional quality indices (g/100 g of milk fat) for Boer × Saanen goats supplemented with three roughages.

<table>
<thead>
<tr>
<th>Indices of fatty acids</th>
<th>Means, %</th>
<th>SE</th>
<th>Means by season of year</th>
<th>P-value(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>VC, %</td>
<td>PERI</td>
</tr>
<tr>
<td>UFA(^d)</td>
<td>30.81</td>
<td>0.85</td>
<td>9.83</td>
<td>34.58</td>
</tr>
<tr>
<td>DFA(^e)</td>
<td>40.96</td>
<td>1.16</td>
<td>8.95</td>
<td>46.16</td>
</tr>
<tr>
<td>AI(^f)</td>
<td>2.43</td>
<td>0.13</td>
<td>19.47</td>
<td>1.86</td>
</tr>
<tr>
<td>TF(^g)</td>
<td>2.97</td>
<td>0.13</td>
<td>15.56</td>
<td>2.35</td>
</tr>
<tr>
<td>HH(^h)</td>
<td>0.75</td>
<td>0.04</td>
<td>19.08</td>
<td>0.96</td>
</tr>
<tr>
<td>[(C18:0 + C18:1)/C16:0]</td>
<td>1.32</td>
<td>0.07</td>
<td>25.62</td>
<td>1.69</td>
</tr>
<tr>
<td>C12:0/C10:0</td>
<td>0.53</td>
<td>0.02</td>
<td>12.43</td>
<td>0.48</td>
</tr>
<tr>
<td>SCFA (C4:0 – C10:0)</td>
<td>13.50</td>
<td>0.40</td>
<td>22.23</td>
<td>13.74</td>
</tr>
<tr>
<td>MCFA (C12:0 – C16:0)</td>
<td>43.88</td>
<td>1.13</td>
<td>8.43</td>
<td>38.43</td>
</tr>
<tr>
<td>LCFA (&gt;16:0)</td>
<td>41.16</td>
<td>1.20</td>
<td>9.01</td>
<td>46.62</td>
</tr>
</tbody>
</table>

\(^a\) Value = *P < 0.05; **P < 0.01.
\(^b\) SE = standard error.
\(^c\) VC = coefficient of variation.
\(^d\) PER = season.
\(^e\) SUP = supplement.
\(^f\) UFA = unsaturated fatty acids.
\(^g\) DFA = desirable fatty acids.
\(^h\) AI = atherogenic index.
\(^i\) TI = thrombogenic index.
\(^j\) HH = hypo:hypercholesterolemic acids.

Table 2
Effects of treatment and interactions of nutritional quality indices (g/100 g of milk fat) by season for Boer × Saanen goats supplemented with three roughages.

<table>
<thead>
<tr>
<th>Season of year</th>
<th>Supplements</th>
<th>SST(^a)</th>
<th>N</th>
<th>MST(^b)</th>
<th>N</th>
<th>MHT(^c)</th>
<th>N</th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFA(^d)</td>
<td>32.12A</td>
<td>12</td>
<td>28.76B</td>
<td>12</td>
<td>31.55AB</td>
<td>12</td>
<td>30.81</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>AI(^e)</td>
<td>2.25B</td>
<td>12</td>
<td>2.81A</td>
<td>12</td>
<td>2.23B</td>
<td>12</td>
<td>2.43</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>MCFA (C12:0 – C16:0)</td>
<td>43.20AB</td>
<td>12</td>
<td>46.34A</td>
<td>12</td>
<td>42.11B</td>
<td>12</td>
<td>43.88</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Interactions supplements × seasons</td>
<td>TIF(^f)</td>
<td>PERI</td>
<td>2.39CD</td>
<td>6</td>
<td>2.45CD</td>
<td>6</td>
<td>2.22D</td>
<td>6</td>
<td>2.35B</td>
</tr>
<tr>
<td></td>
<td>PERII</td>
<td>3.10BC</td>
<td>6</td>
<td>4.18A</td>
<td>6</td>
<td>3.48AB</td>
<td>6</td>
<td>3.59A</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.74B</td>
<td>12</td>
<td>3.32A</td>
<td>12</td>
<td>2.85B</td>
<td>12</td>
<td>2.97</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>PERI</td>
<td>0.48C</td>
<td>6</td>
<td>0.50BC</td>
<td>6</td>
<td>0.47C</td>
<td>6</td>
<td>0.48B</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>PERII</td>
<td>0.61AB</td>
<td>6</td>
<td>0.70A</td>
<td>6</td>
<td>0.45C</td>
<td>6</td>
<td>0.59A</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.54AB</td>
<td>12</td>
<td>0.60A</td>
<td>12</td>
<td>0.46B</td>
<td>12</td>
<td>0.53</td>
<td>36</td>
</tr>
</tbody>
</table>

Different letters indicate statistically significant difference between the means (P<0.05) by Tukey’s test.

\(^a\) SST = sorghum silage
\(^b\) MST = maize silage
\(^c\) MHT = mulberry hay
\(^d\) UFA = unsaturated fatty acids
\(^e\) AI = atherogenic index
\(^f\) TI = thrombogenic index.

5. Conclusion

Grazing Boer × Saanen goats with supplementation of mulberry hay or sorghum silage provided milk with better lipids indices for the prevention of human coronary diseases.

Conflict of interest
None declared

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References


