Yield, composition, fatty acid profile and CLA content of milk from goats fed with different levels of OPF

Pitunart Noosen1* Ulia Renfelia Baysi1

Abstract

The objective of this study was to evaluate the effect of different inclusion levels of OPF in total mixed ration (TMR)-based diet on yield, composition, FA profile and CLA content of milk in dairy goats. Six nulliparous female dairy goats (Saanen x Thai native, 19-21 months old, first lactation) were randomly set according to a 3x3 Latin square design with 2 replications for receiving diets consisted of 0% OPF (OPF0), 20% OPF (OPF20) and 40% OPF (OPF40). The average weight of the goats was 32.48±1.30 kg (mean±s.d.). The findings of this study showed that dry matter intake (DMI) and all nutrient intake of the goats increased significantly as OPF inclusion was increased (p<0.05), excluding crude protein intake (CPI) (p>0.05). Goats from OPF40 group had the highest CPI, however, there was no significant difference (p>0.05) in CPI of OPF20 and OPF0 groups. Feeding OPF altered the composition of protein and lactose, density and freezing point (p<0.05). However, it did not influence (p>0.05) the composition of fat, solid non-fat and minerals in the milk. There were no significant differences in oleic acid, dihomo-γ-linoleic acid, and eicosapentaenoic acid in milk fat of goats (p>0.05). 40% OPF inclusion increased the production of LnA, DHA, CLA and the ratio of PUFA:SFA; and lowered AA production and n-6:n-3 ratio of goat milk (p>0.05). It can be concluded that 40% OPF inclusion in TMR-based diet can be used as an alternative to producing goat’s milk with enriched potential health benefits.

Keywords: oil palm fronds, TMR-based diet, dairy goats, milk fatty acids profile, CLA

1Animal Production Innovation and Management Division, Faculty of Natural Resources, Prince of Songkla University, Songkhla 90110, Thailand

*Correspondence: pitunart.n@psu.ac.th (P. Noosen)
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Introduction

In several countries, goat’s milk has become one of the economic interests and an alternative for those who have allergies to dairy cow products (Schettino et al., 2017). Goat’s milk can be categorized as a functional food due to the large number of bioactive components and the easiness of digestion (Savoini et al., 2019). Nutritional quality in food products has become important because there is an increase in consumer awareness of the link between health and diet (Hilali et al., 2018). In the human diet, milk and dairy products are the major sources of saturated fatty acids (SFAs) (Babay et al., 2018). It is well documented that humans with high SFA consumption tend to have a higher risk of cardiovascular disease (CVD). Conversely, dietary polyunsaturated fatty acids (PUFAs) from dairy products has been associated with many health benefits (Yurchenko et al., 2018; Markey et al., 2017; Hilali et al., 2018). PUFAs, in particular conjugated linoleic acid (CLA), has physiological effects as an anti-mutagenic, anti-tumor, anti-diabetic (type II), an agent of body fat reduction (anti-obesity), anti-carcinogenic (fight against cancer), an agent of atherosclerosis prevention, an immune function enhancer, an anti-hypertensive, a hyperglycemia reduction agent and bone mineralization improvement agent in human body (Koba and Yanagita, 2013; Bouattour et al., 2008; Gomez-Cortes et al., 2018; Tudisco et al., 2015; Castro et al., 2009; Jacobs et al., 2011).

Although the composition of fatty acid (FA) in milk is affected by biohydrogenation of rumen and conversion of Δ9-desaturase enzyme, modifying animals diet can make large changes to the milk FA profile (Liu et al., 2016; Yurchenko et al., 2018; Bayat et al., 2018; Hilali et al., 2018). Basal diet composition together with source and type of lipid supplementation can affect milk FA composition (Bayat et al., 2018). Animals fed with fresh pasture tend to have a better CLA and vaccenic acid (VA) contents in milk compared to animals fed with dried forages. The possible reason is either fresh pasture may improve the growth of rumen’s specific bacteria that is liable to CLA production or inhibit the VA to stearic acid final reduction (Nudda et al., 2005). Moreover, dietary PUFA sources decreased medium-chain SFA and n-6:n-3 ratio and increased milk CLA concentration, which are favorable as milk with a better nutritional quality for human consumption (Morsy et al., 2015; Marin et al., 2011; Castro et al., 2009).

Oil palm frond (OPF) is a fibrous crop residue that is abundantly available (Dalton et al., 2017). OPF has been utilized as a long-term ruminant feed with no toxic effect (Hassan et al., 1991). OPF contains PUFAs, especially linolenic acid (LnA; C18:3n-3) and linoleic acid (LA; C18:2n-6) (Hassim et al., 2010). The inclusion of OPF in a ruminant diet can increase the proportion of unsaturated fatty acid (UFA) in sheep plasma and rumen contents via regulation of rumen biohydrogenation or restriction of microbial access to facilitate the continuous availability of dietary UFA (Ghani et al., 2017). Nevertheless, information regarding dietary different levels of OPF to improve yield, composition, FA profile and CLA content of milk in dairy goats is limited. Therefore, the objective of this study was to provide a report on different OPF inclusion levels in TMR-based diet to produce goat’s milk with an improved FA profile and CLA content.

Materials and Methods

Animals, Housing and Experimental Diets: Six lactating dairy goats (Saanen x Thai native, 19-21 months old, first lactation) were blocked by parity and balanced for milking days and body weight. The animals were then randomly arranged in a 3x3 Latin square design with 2 replications. The average weight of the goats was 32.48±1.30 kg (mean±sd.). All animal handling procedures and experimental protocols were based on the Institutional Animal Care and Use Committee, Prince of Songkla University (U1-01633-2558), based on the Ethical Principles and Guidelines for the Use of Animals, National Research Council of Thailand. Each goat was kept in a stainless steel individual pen in the goat section of the Animal Innovation Production and Management Division, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus. Ivermectin injection (Ivomec) was administered to provide efficacy against parasitic infestations.

The goats were provided free access to water and mineral blocks. Three treatment diets consisting of a basal diet (OPF0; 40% rice straw + 60% concentrate), the basal diet with 50% rice straw replacement with OPF (OPF20; 20% rice straw + 20% OPF + 60% concentrate) and the basal diet with 100% rice straw replacement with OPF (OPF40; 40% OPF + 60% rice straw). All treatment diets were set up as iso-nitrogenous and iso-caloric total mixed rations (TMR). The diets were provided ad libitum. A Tenera hybrid breed (Dura x Písifera) more than 5 years old from the Faculty of Natural Resources, Prince of Songkla University was used and was harvested daily. Rice straw and OPF were chopped into 0.5-2 cm length and then mixed with grains on a daily basis to comply with the treatment diets.

The experiment was carried out in three periods. Each period was divided into 14 days for adaptation time and 30 days for data collection. Body weights (BW) of the goats were recorded weekly before morning feeding. Feed intake and milk production were recorded daily throughout the data collection.

Data Collection and Laboratory Analysis Procedures: Feed Sampling Procedures: The samples of diets were collected once every 5 days to analyze feed composition. Additional feed samples were taken to determine the FA composition. The standard methods of AOAC (1998) were used to analyse the dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and ash of the feed and residual feed. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the method described by Van Soest et al. (1991) with adaptation for Fiber Analyzer. The amount of EE was obtained by extracting the samples with dichloromethane using a Soxtec System based on AOAC (1998). All nutrient compositions were expressed based on the final DM. A calorimeter (LECO AC500) was used to determine the gross energy (GE) of the diets.
Milk Yield, Milk Composition and Milk FA Profile: Milk samples were collected twice a day (120 ml each), in the morning and afternoon milking during the data collection time. An additional milk sample from each goat (120 ml) was collected for milk FA profile analysis. Milk samples were stored at -20°C until milk composition and milk FA analysis. The samples of milk were sent to a laboratory for fat, protein, total solid, solid non-fat and lactose analysis (AOAC, 1990) by mid-infrared spectrophotometry (Lactostar).

Lipid in milk samples was extracted following the method of Zhang et al. (2015). The samples of milk from each goat were pooled and then extracted in 4 mL of isopropanol and hexane (ratio 2/3, v/v), then followed by the solution of 2 mL sodium sulfate and centrifuged at 2,500 x g at 20°C for 20 mins. The supernatant was moved into a hydrolysis tube and dried with a nitrogen flow. A 2 mL of NaOCl-methanol was then pipetted to the dry sample. The mixture was entirely blended using a vortex mixer and heated for 15 mins at 50°C. After the period of cooling, 2 mL of methanol was added to the mixture and provide a time of 15 mins at 80°C for the mixture to react. After cooling down, 3 mL of deionized water and 6 mL of hexane were added to the mixture. The mixture was completely homogenized utilizing a vortex mixture and was centrifuged at 2,500 x g at 20°C for 20 mins. The supernatant was poured into a graduated tube with hexane and fitted to 10 mL. Approximately 1 g of anhydrous sodium sulfate was added.

Fatty acid methyl esters (FAMEs) of feed and milk samples were analyzed using gas chromatography (GC) fitted with an HP-88 fused-silica capillary column (100 m x 0.25 mm with a film thickness of 0.2 µm). The temperature of the column was initially held for 35 mins. The injector temperature was kept at 250°C and the detector temperature was maintained at 300°C. The volume of injection was 1 µL. Each peak was identified by utilizing the pure methyl ester standards.

Statistical Analysis: Analysis of variance (ANOVA) for 3x3 Latin Square using SPSS Statistics version 16 was performed on the DM, nutrient intake, milk yield, milk composition and milk FA profile to study the influence of the treatment diets. The parametric model was denoted as \(X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijk}\), where \(X_{ijk}\) is the examination from animal \(j\) with diet \(i\), in period \(k\). Whereas, \(\mu\) stands for the overall mean, \(\alpha_i\) is the OPF levels effect (\(i = 0\%, 20\%, 40\%\)), \(\beta_j\) is the animal effect (\(j = 1, 2, 3, 4, 5, 6\)), \(\gamma_k\) is the period effect (\(k = 1, 2, 3\)) and \(\epsilon_{ijk}\) is the residual effect. Duncan’s new multiple range tests were further performed to determine differences between treatment means (Steel and Torrie, 1980).

Results

Chemical Compositions and Fatty Acids Profile of Treatment Diets: The chemical compositions and fatty acids (FA) profile of the treatment diets are presented in Table 1 and Table 2. The inclusion of OPF increased the moisture content and lowered the ash content of TMR-based diets. All treatment diets had similar CP and gross energy (GE) contents. The treatment diet with the highest percentages of EE and fiber was OPF40, followed by OPF20 and OPF0. OPF40 and OPF20 had a similar amount of LnA, whereas OPF0 was the lowest. Compared to the diet without OPF inclusion, OPF20 and OPF40 contained a higher FA from the n-3 family. A similar PUFA:SFA ratio was indicated in all treatment diets. OPF inclusion in TMR-based diet lowered n-6:n-3 ratio. The ratio of n-6:n-3 in OPF0, OPF20, and OPF40 were 8.7:1, 5.1:1, and 4.8:1, respectively.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Chemical compositions of experimental diets</th>
<th>Treatmenta</th>
<th>OPF0</th>
<th>OPF20</th>
<th>OPF40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM (%)</td>
<td></td>
<td>87.82</td>
<td>67.04</td>
<td>55.62</td>
<td></td>
</tr>
<tr>
<td>CP %-DM</td>
<td></td>
<td>17.86</td>
<td>17.43</td>
<td>17.07</td>
<td></td>
</tr>
<tr>
<td>EE %-DM</td>
<td></td>
<td>1.80</td>
<td>2.42</td>
<td>2.84</td>
<td></td>
</tr>
<tr>
<td>Ash %-DM</td>
<td></td>
<td>10.44</td>
<td>8.65</td>
<td>7.57</td>
<td></td>
</tr>
<tr>
<td>NDF %-DM</td>
<td></td>
<td>31.61</td>
<td>38.07</td>
<td>48.80</td>
<td></td>
</tr>
<tr>
<td>ADF %-DM</td>
<td></td>
<td>19.31</td>
<td>20.26</td>
<td>22.04</td>
<td></td>
</tr>
<tr>
<td>Gross energy</td>
<td>Cal/kg DM</td>
<td>3984.93</td>
<td>4021.32</td>
<td>4087.62</td>
<td></td>
</tr>
</tbody>
</table>

DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral digestible fiber; ADF: acid detergent fiber.
a) OPF0: 60% concentrate + 40% rice straw; OPF20: 60% concentrate + 20% rice straw + 20% oil palm fronds; OPF40: 60% concentrate + 40% oil palm fronds.
Dry Matter and Nutrient Intake: The dry matter and nutrient intake of dairy goats fed with different inclusion levels of OPF are shown in Table 3. The findings of this study showed that dry matter intake (DMI) and all nutrients intake of the goats increased significantly as OPF inclusion increased (p<0.05), except for crude protein intake (CPI). Goats from the OPF40 group showed the highest CPI, however, there was no significant difference (p>0.05) in CPI of OPF20 and OPF0 groups. Based on percent body weight (%BW), the DMI of goats fed with OPF40 was 1.14 and 1.06 fold higher than those fed with OPF0 and OPF20, respectively. Fat, fiber and OM intake of the goats increased as the inclusion of OPF was increased. The intakes of EE, OM, NDF, and ADF of the OPF40 group were the highest.

Milk Yield and Milk Composition: Milk yield and milk composition of dairy goats fed with OPF in TMR based diet are shown in Table 4. The highest milk yield was reported in the OPF40 group. However, there was no significant difference in the milk yield of OPF0 and OPF20 groups. Although OPF0 and OPF20 had similar milk yield, goats from OPF20 group produced higher nutrient due to its higher milk density. Goats with higher inclusion of OPF produced higher fat, solid non-fat (SNF), protein, lactose and minerals per day. The highest production of those nutrients was on the OPF40 group, while the lowest was on the OPF0 group. The inclusion of OPF in TMR-based diet of dairy goats altered the composition of milk protein, lactose, density and freezing point but did not alter the composition of milk fat, solid non-fat, and minerals.

Table 3  Dry matter and nutrients intake of lactating dairy goats fed with different levels of oil palm fronds

<table>
<thead>
<tr>
<th>Item</th>
<th>OPF0</th>
<th>OPF20</th>
<th>OPF40</th>
<th>SEM</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM Intake</td>
<td>1113.3</td>
<td>1170.1</td>
<td>1292.6</td>
<td>13.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>%BW</td>
<td>3.40</td>
<td>3.63b</td>
<td>3.86</td>
<td>0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>g/kg BW</td>
<td>80.9</td>
<td>86.5b</td>
<td>92.3</td>
<td>1.46</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nutrient intake (g/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OMI</td>
<td>996.8</td>
<td>1068.9</td>
<td>1194.7</td>
<td>12.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CPI</td>
<td>198.8</td>
<td>203.9</td>
<td>220.6</td>
<td>2.32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EEI</td>
<td>20.0</td>
<td>28.3</td>
<td>36.7</td>
<td>0.36</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NDFI</td>
<td>351.8</td>
<td>445.4</td>
<td>630.8</td>
<td>6.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ADFI</td>
<td>214.9</td>
<td>237.1b</td>
<td>284.9</td>
<td>2.89</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SEM = standard error of the means; n = 3; DMI: dry matter intake; BW: body weight; CPI: crude protein intake; EEI: ether extract intake; NDFI: neutral digestible fiber intake; ADFI: acid detergent fiber intake; OMI: organic matter intake.

1) OPF0: 60% concentrate + 40% rice straw; OPF20: 60% concentrate + 20% rice straw + 20% oil palm fronds; OPF40: 60% concentrate + 40% oil palm fronds.

abc Means in the same row with different superscript are statistically different (p<0.05).
Table 4  Milk yield and milk composition of dairy goats fed with oil palm frond in TMR based diet.

<table>
<thead>
<tr>
<th>Items</th>
<th>OPF0</th>
<th>OPF20</th>
<th>OPF40</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>Milk (kg/d)</td>
<td>1.08±</td>
<td>1.09±</td>
<td>1.40±</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>Fat (g/d)</td>
<td>30.90±</td>
<td>34.20±</td>
<td>41.80±</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Solid non-fat (g/d)</td>
<td>88.15±</td>
<td>93.71±</td>
<td>116.89±</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>Protein (g/d)</td>
<td>31.81±</td>
<td>33.86±</td>
<td>42.03±</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Lactose (g/d)</td>
<td>46.82±</td>
<td>48.99±</td>
<td>62.10±</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Minerals (g/d)</td>
<td>10.41±</td>
<td>10.93±</td>
<td>13.57±</td>
<td>0.18</td>
</tr>
<tr>
<td>Composition</td>
<td>Fat (%)</td>
<td>2.87</td>
<td>3.03</td>
<td>3.00</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Solid non-fat (%)</td>
<td>8.18</td>
<td>8.65</td>
<td>8.33</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Protein (%)</td>
<td>2.95±</td>
<td>3.14±</td>
<td>3.00±</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Lactose (%)</td>
<td>4.35±</td>
<td>4.62±</td>
<td>4.43±</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Minerals (%)</td>
<td>0.97</td>
<td>0.98</td>
<td>0.97</td>
<td>0.01</td>
</tr>
<tr>
<td>Density</td>
<td>1.024±</td>
<td>1.0259±</td>
<td>1.0248±</td>
<td>0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Freezing point (°C)</td>
<td>-0.5541±</td>
<td>-0.5761±</td>
<td>-0.5537±</td>
<td>0.003</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

SEM: standard error of the means; n =6; OPF0: 60% concentrate +40% rice straw; OPF20: 60% concentrate +20% rice straw +20% oil palm fronds; OPF40: 60% concentrate +40% oil palm fronds.

a,b,c: Means in the same row with different superscript are statistically different (p<0.05).

**Milk Fatty Acid Profile:** Table 5 presents the milk fatty acid profile of dairy goats fed with different inclusion levels of OPF. OPF inclusion up to 40% in the treatment diets significantly increased (p<0.05) the concentrations of elaidic acid (C18:1n9t), linoleaidic acid (C18:2n6t) and a-linolenic acid (ALA; C18:3n3). Similar concentrations of stearic acid (C18:0), eicosatetraenoic acid (C20:4n3), and docosahexaenoic acid (DHA; C22:6n3) concentrations were indicated in OPF20 and OPF40 groups (p>0.05). Meanwhile, OPF0 had lower concentrations of those FAs (p<0.05). There was no significant difference in linoleic acid (LA; C18:2n6c) of OPF20 and OPF40 groups. However, the values were lower than the OPF0 group. The lowest concentration of arachidonic acid (AA; C20:4n6) was in the diet with 40% OPF inclusion. Dietary OPF did not alter oleic acid (C18:1n9c), dihomo-y-linoleic acid (DGLA; C20:3n6), and eicosapentaenoic acid (EPA; C20:5n3) in milk fat of goats (p>0.05). OPF40 contained the highest PUFA and CLA contents and the highest UFA:SFA ratio compared to OPF20 and OPF0 (p<0.05). There was no significant difference in SFA concentration and n-6:n-3 ratio of OPF40 and OPF20, however, the values were significantly lowered than OPF 0. The ratio between n-6 and n-3 in OPF40 and OPF20 was 3.66 and 4.11, respectively.

Therefore, the higher the inclusion of OPF in the diet of the present study, the lower the ratio of n-6:n-3 FA.

**Dry Matter and Nutrient Intake:** The DMI of OPF0, OPF20, and OPF40 were 3.40%, 3.63%, and 3.86% BW, respectively. Exotic breeds raised in tropical areas have typical DMI values of about 3.6% BW (Stares et al., 1992). It means that OPF0 had DMI lower than the suggested DMI for Saanen in tropical areas. The findings of this study also indicate that higher moisture content, low palatability of rice straw and lower n-6:n-3 ratio due to OPF inclusion significantly increased DMI and nutrient intake of lactating dairy goats, although diets with higher OPF inclusion contained higher levels of NDF. The treatment diets with OPF inclusion had 60-70% DM, while the diet without OPF contained 90% DM. Adequate moisture content in complete feed can increase palatability and DMI by improving texture and diluting undesirable flavors (Lahr et al., 1983). Similar to the findings of this study, Meiske and Goodrich (1971) also reported that feeding feedlot steers with a diet containing roughly 66% DM resulted in the maximum DMI. Moreover, high silica content in rice straw also contributes to its lower palatability and thus feed intake (Nguyen et al., 2020; Oladosu et al., 2016).

We did not observe the effect of n-6:n-3 ratios on fermentation patterns, however, lowered n-6:n-3 ratios in the diet with OPF inclusion may have changed rumen microbial population, thus it could overcome the effect of NDF on DMI. Decreased level of n-6:n-3 PUFA ratios in the diet increases the proportion of cellulolytic bacteria namely *R. albus* and *R. flavofaciens* (Ebrahimii et al., 2017). Additionally, Greco et al. (2015), showed a consistent result with this study that feeding a 3:9:1 ratio of n-6 and n-3 FA resulted in lactating Holstein cows with better DMI. PUFA's potentially affect hepatic oxidation and have the ability to stimulate the release of gut peptides to alter DMI. Opposite results have been reported where dietary different n-6:n-3 ratio did not influence the DMI of lactating goats and growing lambs (Bouattour et al., 2008; Kim et al., 2007).

**Discussion**

**Chemical Compositions and Fatty Acid Profile of Treatment Diets:** All treatment diets were formulated as iso-nitrogen and iso-caloric diets, so they were similar in CP and GE contents. Similar values for CP and EE of diets with OPF inclusion were previously reported by Ebrahimii et al. (2015), and Hamchara et al. (2018), respectively. The higher moisture content of OPF20 and OPF40 could be attributed to the form of OPF used in this study that was fresh and was chopped daily. NDF and ADF contents of OPF20 and OPF40 were also close to the value reported by Ebrahimii et al. (2015). Previous studies also reported that linolenic acid (C18:3 n-3) in OPF (24.97%) is higher than in rice straw (1.72%) (Ebrahimii et al., 2015; Taiera, 1983).
Milk Yield and Milk Composition: Higher milk production of OPF40 compared to OPF0 and OPF20 was the result of greater nutrient intake, especially CPI. Protein is an essential limiting nutrient for producing milk and achieving high yields in ruminants (Salo, 2018). Based on Looper (1994), feed provides the nutrients that are the precursors, either directly or indirectly, of the principal milk solids. Thus, an increase in feed intake usually results in the production of a greater volume of milk.

There was no significant difference in milk fat percentage amongst the treatment diets. However, the maintains the rumen pH (Banakar et al., 2018).

Table 5  Milk fatty acids profile of lactating dairy goats fed with oil palm frond in TMR based diet.

<table>
<thead>
<tr>
<th>Items</th>
<th>Treatment</th>
<th>OPF0</th>
<th>OPF20</th>
<th>OPF40</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acids profile (g/100 g FA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4:0, Butyric acid</td>
<td>1.52±</td>
<td>1.97±</td>
<td>2.42±</td>
<td>0.135</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>C6:0, Caproic acid</td>
<td>1.47±</td>
<td>1.60±</td>
<td>1.62±</td>
<td>0.089</td>
<td>0.445</td>
<td></td>
</tr>
<tr>
<td>C8:0, Caprylic acid</td>
<td>0.71±</td>
<td>0.98±</td>
<td>1.15±</td>
<td>0.034</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C10:0, Capric acid</td>
<td>1.49±</td>
<td>1.49±</td>
<td>1.39±</td>
<td>0.052</td>
<td>0.296</td>
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<tr>
<td>C12:0, Lauric acid</td>
<td>1.83±</td>
<td>1.64±</td>
<td>1.37±</td>
<td>0.035</td>
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<tr>
<td>C14:0, Myristic acid</td>
<td>7.85±</td>
<td>7.43±</td>
<td>6.81±</td>
<td>0.102</td>
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<tr>
<td>C16:0, Palmitic acid</td>
<td>27.72±</td>
<td>25.79±</td>
<td>23.79±</td>
<td>0.308</td>
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<tr>
<td>C18:1, Palmitoleic acid</td>
<td>1.45±</td>
<td>1.45±</td>
<td>1.39±</td>
<td>0.03</td>
<td>0.209</td>
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<tr>
<td>C17:0, Heptadecanoic acid</td>
<td>0.62±</td>
<td>0.60±</td>
<td>0.46±</td>
<td>0.02</td>
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<tr>
<td>C18:0, Stearic acid</td>
<td>12.08±</td>
<td>12.29±</td>
<td>12.26±</td>
<td>0.049</td>
<td>0.025</td>
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<tr>
<td>C18:1n9t, Elaidic acid</td>
<td>6.20±</td>
<td>7.49±</td>
<td>9.20±</td>
<td>0.244</td>
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<tr>
<td>C18:1n9c, Oleic acid</td>
<td>29.54±</td>
<td>29.12±</td>
<td>29.47±</td>
<td>0.203</td>
<td>0.306</td>
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</tr>
<tr>
<td>C18:2n6t, Linolelaidic acid</td>
<td>0.54±</td>
<td>0.71±</td>
<td>1.01±</td>
<td>0.031</td>
<td>0.000</td>
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<tr>
<td>C18:2n6c, Linolic acid (LA)</td>
<td>2.25±</td>
<td>2.06±</td>
<td>2.00±</td>
<td>0.051</td>
<td>0.016</td>
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<tr>
<td>C18:3n3, o-Linolic acid (LnA)</td>
<td>0.58±</td>
<td>0.91±</td>
<td>1.18±</td>
<td>0.044</td>
<td>0.000</td>
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<tr>
<td>C18:3n6, γ-Linolic acid</td>
<td>0.01±</td>
<td>0.01±</td>
<td>0.01±</td>
<td>0.003</td>
<td>0.927</td>
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<tr>
<td>C20:0, Eicosaenic acid</td>
<td>0.21±</td>
<td>0.19±</td>
<td>0.14±</td>
<td>0.009</td>
<td>0.001</td>
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<tr>
<td>C20:1, Gadoleic acid</td>
<td>0.06±</td>
<td>0.03±</td>
<td>0.02±</td>
<td>0.005</td>
<td>0.001</td>
<td></td>
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<tr>
<td>C20:2, Eicosadienoic acid</td>
<td>0.10±</td>
<td>0.09±</td>
<td>0.05±</td>
<td>0.01</td>
<td>0.025</td>
<td></td>
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<tr>
<td>C20:3n3, Eicosatrienoic acid</td>
<td>0.01±</td>
<td>0.02±</td>
<td>0.02±</td>
<td>0.002</td>
<td>0.004</td>
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<tr>
<td>C20:3n6, Dihomo-γ-linoleic acid (DGLA)</td>
<td>0.02±</td>
<td>0.02±</td>
<td>0.03±</td>
<td>0.004</td>
<td>0.513</td>
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<tr>
<td>C20:4n6t, Arachidonic acid (AA)</td>
<td>0.16±</td>
<td>0.15±</td>
<td>0.13±</td>
<td>0.007</td>
<td>0.014</td>
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<td>C20:5n3, Eicosapentaenoic acid (EPA)</td>
<td>0.04±</td>
<td>0.04±</td>
<td>0.05±</td>
<td>0.005</td>
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<tr>
<td>C22:0, Docosanoic acid</td>
<td>0.11±</td>
<td>0.45±</td>
<td>0.25±</td>
<td>0.136</td>
<td>0.260</td>
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<tr>
<td>C22:1n9t, Erucic acid</td>
<td>0.02±</td>
<td>0.02±</td>
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<td>C22:2, Cetoleic acid</td>
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<td>0.01±</td>
<td>0.01±</td>
<td>0.004</td>
<td>0.955</td>
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<td>C22:6n3, Docosahexaenoic acid (DHA)</td>
<td>0.03±</td>
<td>0.12±</td>
<td>0.13±</td>
<td>0.012</td>
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<td>C23:0, Tricosanoic acid</td>
<td>0.03±</td>
<td>0.02±</td>
<td>0.01±</td>
<td>0.006</td>
<td>0.095</td>
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<tr>
<td>C24:0, Tetracosanoic acid</td>
<td>0.03±</td>
<td>0.02±</td>
<td>0.03±</td>
<td>0.006</td>
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<tr>
<td>C9,T11</td>
<td>1.17±</td>
<td>1.27±</td>
<td>1.63±</td>
<td>0.056</td>
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<tr>
<td>C9,C11</td>
<td>0.02±</td>
<td>0.02±</td>
<td>0.02±</td>
<td>0.003</td>
<td>0.919</td>
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<tr>
<td>T9,T11</td>
<td>0.12±</td>
<td>0.15±</td>
<td>0.18±</td>
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<td>0.000</td>
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<tr>
<td>SFA</td>
<td>56.90±</td>
<td>55.65±</td>
<td>52.80±</td>
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<tr>
<td>MUFA</td>
<td>38.05±</td>
<td>38.78±</td>
<td>40.76±</td>
<td>0.323</td>
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<tr>
<td>PUFA</td>
<td>5.06±</td>
<td>5.58±</td>
<td>6.44±</td>
<td>0.108</td>
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<tr>
<td>n-6</td>
<td>4.30±</td>
<td>4.39±</td>
<td>5.01±</td>
<td>0.079</td>
<td>0.000</td>
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<tr>
<td>n-3</td>
<td>0.65±</td>
<td>1.08±</td>
<td>1.37±</td>
<td>0.044</td>
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<tr>
<td>n6:n3</td>
<td>7.16±</td>
<td>4.11±</td>
<td>3.66±</td>
<td>0.233</td>
<td>0.000</td>
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<tr>
<td>PUFA:SFA</td>
<td>0.09±</td>
<td>0.10±</td>
<td>0.12±</td>
<td>0.003</td>
<td>0.000</td>
<td></td>
</tr>
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</table>

1 OPF0 .60 %concentrate +40 %rice straw; OPF20 .60 %concentrate +20 %rice straw +20 %oil palm fronds; OPF40 .60 %concentrate +40 %oil palm fronds.
2 FA fatty acids; SFA -sum of saturated fatty acids; MUFA -sum of monounsaturated fatty acids; PUFA -sum of polyunsaturated fatty acids.
3 Sum of n-6 fatty acids.
4 Sum of n-3 fatty acids.

In the present study, there were divergences in the milk protein and lactose compositions among dairy goats fed with different levels of OPF inclusion. One explanation for these results may be related to the relative amounts of energy and protein available in the rumen. Previous studies have addressed the fact that milk protein content may respond to energy-protein interaction, although the results have been varied.
Milk Fatty Acid Profile: The milk FA profile of goats in this study was dominated by oleic acid, palmitic acid, stearic acid, elaidic acid and myristic acid. The findings were in agreement with studies by Ferrand-Calmels et al. (2014), Cossignani et al. (2014), and Lopez et al. (2019). However, the presence of caproic acid (C6:0), caprylic acid (C8:0) and capric acid (C10:0) in the present study were lower than the reported values of those previous studies. Caproic, caprylic and capric acids are medium-chain FAs that have been named after goats because of their prevalence in goat’s milk. They makeup to 15% of total FA in goat’s milk is responsible for its flavor (Kompan and Komprij, 2012). Dietary high-level pasture tends to lower the production of capric acid in goat’s milk (LeDoux et al., 2002). Goats fed with OPF40 contained the highest caprylic acid which can give beneficial effects. Caprylic acid is one of the alternatives as intra-mammary infusion against bovine mastitis (Nair et al., 2005) and is effective in inactivating infant pathogens such as respiratory syncytial virus and herpes simplex virus (Isaacs et al., 1995).

Feeding OPF40 to lactating dairy goats resulted in milk with lower AA and higher DHA contents, compared to OPF0. AA is categorized as a PUFA essential for normal health. However, it also contributes to the inflammation process and leads to the promotion of mediators responsible for wound healing and resolving inflammation (Tallima and Ridi, 2017). On the other side, DHA has been known for playing an important role in inflammation, immunity and the functional development and growth of the infant’s brain (Lee and Jenkins, 2011; Horrocks and Yeo, 1999). DHA is a bihydrogenation product of LnA. LnA turns into stearidonic acid (18:4n3) and eicosatetraenoic acid (20:4 n-3) to create eicosapentaenoic acid (EPA; 20:5n3). In its later stage, EPA is metabolized to be eicosanoids or DHA (Schmitz and Etherton and Krauss, 2020). The inclusion of OPF enhances the DMI and milk yield of lactating dairy goats. Feeding OPF to lactating dairy goats alters the composition of protein and lactose, density and the freezing point of milk. However, it did not affect the percentage of fat, solid non-fat and minerals in milk. The inclusion of 40% OPF in TMR-based diet increased the production of LnA, DHA, CLA, and PUFA:SFA ratio. It also decreased AA production and n-6:n-3 ratio of goat milk. Feeding 40% OPF in TMR-based diet can be used as an alternative to producing goat milk with enriched potential health benefits.

Acknowledgements

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References


