Milk composition and fatty acids profile at different stages of lactation in Jamnapari crossbred goats

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Abstract
Milk is one of the essential products in the human diet, rich in nutritive components. The inter-specific differences of goat and cow milk composition clearly show that goat milk is rich in beneficial fatty acids content. The composition and fatty acids of milk is affected by various factors including stage of lactation. Thus, the objectives of this study were to evaluate milk composition (fat, protein, lactose and total solid) and fatty acid profiles at different stages of lactation in the dairy goats. Milk yield and samples were obtained from 33 lactating Jamnapari crossbred goats, aged between 2 and 4 y, from a dairy goat farm. Does were fed with the same diet (cut fodder and soy wastes) throughout the lactation period. Milk samples were taken from each goat on 10-15, 42-63 and 98-112 d postpartum and named as early, mid, and late lactation stage, respectively. Milk samples were analysed to determine milk composition and fatty acids profile. Results revealed that milk yield was the highest ($P<0.05$) during mid-lactation (785 mL) and consequently low in fat (F) and total solid (TS) content. The milk yields were higher ($P<0.05$) in F and TS content at early (5.10% F; 14.65% TS) and late (4.56% F; 14.71% TS) lactation stages. The protein (3.57%) and lactose (5.29%) content remained unchanged ($P>0.05$) throughout this study. Low level of cholesterol-raising fatty acids in human nutrition known as myristic and palmatic acids were detected at early lactation stages ($P<0.05$) compared to mid and late lactation stages. However, the value of individual medium-chain triglycerides in particularly caproic and caprylic acids were also at low value ($P<0.05$) during early lactation stage. Oleic acid had a higher value at the beginning of lactation ($P<0.05$) until the mid-stage of lactation. The fat content which coincided with oleic acid was concentrated during early lactation stages with the expense of caproic and caprylic acids which were also beneficial in human nutrition. In conclusion, milk yield, composition and fatty acid profiles of Jamnapari goats were altered by the stage of lactation. Low levels of individual MCT, especially caprylic and capric acids, and including myristic and palmatic acids (long chain fatty acid) in goat milk during the early stage of lactation. The highest value of rumenic acid and the decrease in stearic and oleic acid levels in goat milk occurred during mid-stage of lactation.

Keywords: Goat milk, fat, medium-chain triglycerides, oleic acid.

Introduction

Milk is one of the essential products in the human diet, rich in nutritive components. Lipid composition is a crucial component of milk from nutritional point of view, milk and meat from ruminant origin contain higher amount of saturated fats than most oils of plants origin. Goat milk and its products such as yogurt, cheese and powdered milk have benefits for humans. The composition of milk is one of the most important factors that

determine its value in the market. The milk fat is a major contributor to the energy density of whole milk and is essential to many of the physical properties, manufacturing qualities and organoleptic characteristics of dairy products (Harvetine *et al*., 2008). Nowadays, the goat milk demand is growing due to affliction of consumers who are having allergy with cow milk and other gastro-intestinal ailments (Haenlein, 2004).

The interspecific differences of goat and cow milk composition clearly show that goat milk is rich in beneficial fatty acids content (Ceballos *et al*., 2009). Goat milk was predominant in terms of medium-chain triglycerides (31% more than cow milk), omega-3 (50% more than cow milk) and omega-6 polyunsaturated fatty acids (10% more than cow milk) and also the total level of conjugated linoleic acid (34% more than cow milk). Typically, the consumption of saturated fatty acids is subjected to the risk of cardiovascular disease. In spite of the saturated structure of medium chain triglycerides (MCT), the caproic (C6:0) and caprylic acids (C10:0) were act as antiviral agents. Apparently, the lauric acid (C12:0) was believed to contribute to the risk of hypercholesterolemia. The conjugated linoleic acid has been attributed with various beneficial properties for consumer health, such as anticarcinogenic and antilipogenic effects (McGuire and McGuire, 2000). Therefore, by justifying the uniqueness of goat milk in human nutrition, it is an advantage for farmers to harvest the milk that is concentrated with beneficial fatty acids content intended for human consumption.

The animals (breed and species) and environmental factors such as feeding regime, lactation stage, animal health and management have been reported to have a profound impact on milk composition (Morand-Fehr *et al*., 2007; Ceballos *et al*., 2009; Mestawet *et al*., 2012). The fatty acids profile of milk can be influenced by the energy balance in lactating animals. The changes in milk yield, dry matter intake considering the diet composition and nutrient density at different lactation stages determine if an animal is in positive and negative energy balance.

It is estimated that currently, the milk consumption per capita in Malaysia was still low at about 34 litres (DVS, 2015) which was 6 times lower than the recommended per capita consumption of 200 liter/ annum by the World Health Organisation (WHO). The demand for goat milk has increased due to awareness of problems with traditional medical treatments such as affliction, especially in developed countries (Haenlein, 2004). It is important to support our local dairy producers and provide the important facts to the consumer on the benefits of milk consumption for our health. Thus, the objectives of this study were to evaluate milk composition (fat, protein, lactose and total solid) and fatty acid profiles at different stages of lactation in Jamnapari crossed dairy goats.

Materials and Methods

Milk sampling

The study was carried out on 33 lactating Jamnapari crossbred goats aged between 2 to 4 y, from a dairy goat farm in Negeri Sembilan, Malaysia. The goats were fed diets based on cut fodder and soy bean wastes and fed according to the milk yield. The goats were divided into three different groups according to days of lactation, early (10-15 d post kidding; n=6), at the mid (around 42-63 d post kidding; n=14) and late (around 98-112 d post kidding; n=13). Milk collected from the complete milking of each individual was pooled, measured and sampled. Prior to sampling, milk was mixed thoroughly and later 50 ml of milk was

transferred into a sterilised glass container and stored in the container at 4°C during transportation to laboratory. Each sample was further divided into two portions to be analysed for milk composition and fatty acid profile analysis.

Composition of milk

Approximately 20 ml of milk sample was incubated in water bath (Techne Tempette Junior TE-8J Water Bath) at 40°C for 5 min. Each sample was analysed for milk fat, protein, lactose, solid-non-fat (SNF) and total solid (TS) content by using a milk analyser, Milko-scan 134 A/B (N Foss electric, Denmark).

Fatty acid profiles - Milk fat extraction

Milk fat was extracted by using a modified Folch *et al.* (1956) method. Approximately 2 ml of milk samples were homogenized with 40 ml chloroform-methanol (2:1, v/v) solution (Merck KGaA, Darmstadt, Germany). The mixture was filtered after standing for 12 h and 10 ml normal saline was added. The lipid phase was then collected into round bottom flask and evaporated. Then, the extracted lipid was added with 100 µL of internal standard (4mg/mL of heneicosanoic acid [C21] in chloroform-methanol) prior to fatty acid methyl ester (FAME) preparation to quantify individual fatty acid concentration within the sample.

Preparation of fatty acid methyl ester (FAME) and analysis

Preparation of FAME was based on the method developed by Van Wijngaarden (1967). The dried extracted lipid was diluted in 2 ml of potassium hydrochloride in methanol and 14% boron trifluoride-methanol was added into the mixture after reheating. About 4 ml of deionized water and 4 ml of petroleum ether (Merck kGaA, Darmstadt, Germany) was added after reheating the mixture. Finally, the petroleum phase containing FAME was separated by centrifugation and 1µL of FAME were injected into Gas Chromatography (GC) using 6890N Network GC system (Agilent Technologies Inc., USA) fitted with HP-88 (88%-cyanopropyl aryl-polysiloxane) silica capillary column (60m x 0.25m internal diameter x 0.20µm) (Agilent Technologies Inc., USA). The individual FAME peak was identified according to the similar retention time by using known external standard of FAME. The quantitative analysis was analysed based on the proportional comparison of the chromatographic peak areas between an identified fatty acid and known internal standard (heneicosanoic acid [C21]).

Statistical analysis

A one-way analysis of variance (ANOVA) was used to determine the milk yield, milk composition and fatty acid profiles among three lactation stages with General Linear Model (GLM) procedure of SAS 9.3 (Statistical analytical Institute Inc. Cary, North Carolina, USA).

Results and Discussion

Milk yield and compositions

The total milk yield and milk composition of Jamnapari goats at different stages of lactation are shown in Table 1. In the current study, the milk yield peaked ($P<0.05$) at mid-stages (42 – 63 d in milk) of lactation with volume of 785 ml. These findings were consistent with Louca *et al.* (1975), where the peak of Damascus goats were located between 5 to 6 wk post-partum. The result obtained was slightly higher

compared to Hassan *et al.* (2010) with the highest production of Jamnapari does at 616 ml at 56th day in milk. The mammary development and regression are the good evidence for the changes in milk yield throughout lactation stages. The lowest milk yields ($P<0.05$) obtained were in both early-stage (10-15 d in milk) and late-stage (98-112 d in milk) of lactation (458 ml and 438 ml, respectively). The decline in milk yield results from gradual loss of mammary secretory epithelial cells from peak lactation onwards. This was most probably due to apoptosis of epithelial cells, which could be detected throughout lactation period and it is also most prevalent during post-out lactation involution (Wilde *et al.,* 1997). On the other hand, the surviving epithelial cells are still be able to maintain their capacity to synthesize milk.

The results of milk fat and total solid content showed significant differences among lactation stages. Milk fat and total solid appeared to be significantly higher ($P<0.05$) at early (5.10 % milk fat; 14.65% TS) and late (4.56% Milk fat; 14.71% TS) lactation compared with mid (3.37 % milk fat; 12.3% TS) lactation. In accordance with most studies, the milk fat and total solid content increased towards the end of lactation period which coincided with a decrease in milk yield (Ketto *et al*., 2014; Kralickova *et al*., 2013). The milk fat and TS reached the lowest values ($P<0.05$) in mid-stage of lactation, 3.37% and 12.30%, respectively. This tendency could be explained by the highest volume of milk yield due to dilution effect (Chalupa and Sniffen, 2000). Protein and lactose content were, however, had no changes ($P>0.05$) throughout the lactation stages. In contrary, Pavic *et al*. (2005) found that all milk components of mid and late lactation were higher than at early lactation (first 60 days) in sheep. The difference in the finding probably due to the difference in number of days used by Pavic *et al.* (2005), where the first 60 days of lactation is considered as early. In contrast, 10-15 days and 42 – 63 d of lactation in this study were grouped as early and mid-lactation, respectively. The constant result of lactose content reflected its role as an osmotic regulator and a compensator for variations in all other components. The relatively balanced content of lactose in goat milk during lactation was also reported by Kuchtik *et al*. (2015). The protein content did not vary significantly ($P>0.05$) throughout the lactation stages. Mech *et al.* (2008) suggested that milk protein was not a contributing milk component to increase milk yield. Some researchers reported that protein contents were higher in early and late lactation stages (Mestawet *et al*., 2012; Ibnelbachyr *et al*., 2015). However, others found that protein contents decreased significantly from early to late lactation (Olechnowicz and Sobek, 2008; Mahmoud *et al*., 2014).

Table 1. Total milk yield (ml) and milk composition (%) of Jamnapari goats at different stages of lactation

Variables	Early stage (10 - 15 days)*	Mid stage (42-63 days)*	Late stage (98-112 days)*
	Mean±SEM	Mean±SEM	Mean±SEM
Total milk yield (ml)	458.33 ± 61.12[b]	785.71 ± 120.15[a]	438.46 ± 43.17[b]
Milk fat (%)	5.10 ± 0.44[a]	3.37 ± 0.41[b]	4.56 ± 0.22[a]
Protein (%)	3.61 ± 0.11	3.45 ± 0.09	3.64 ± 0.10
Lactose (%)	5.41 ± 0.07	5.25 ± 0.10	5.22 ± 0.10
Total Solid (%)	14.65 ± 0.46[a]	12.30 ± 0.38[b]	14.71 ± 0.34[a]

[ab] mean values within the row with different superscripts differ significantly at P<0.05;
*Post-kidding

Fatty acid profiles

Figure 1 shows the composition of saturated and unsaturated fatty acids of milk fat at early, mid and late stages of lactation of Jamnapari goats. The amount of saturated fatty acids was dominant to unsaturated fatty acids regardless of the stage of lactation. However, there was no effect of lactation stages (P>0.05) on the total saturated and unsaturated fatty acids of Jamnapari goat milk at early (66.9 g and 33.2 g/100 g FAME), mid (67.3 g and 33.3 g/100 g FAME) and late (65.2 g and 34.8 g/100 g FAME) stages of lactation. The average saturated fatty acids content and unsaturated content were 66 g and 34 g/100 g FAME, respectively. The total saturated fatty and unsaturated acids of Tunisia indigenous goats milk at late lactation was 72.25 g and 27.8 g/100 g FAME, respectively (Ayeb *et al*., 2016). The results reported for Jamnapari goats' milk was 10.1 % lower in total saturated fatty acid and 20% higher in unsaturated fatty acid compared with the Tunisia indigenous goats.

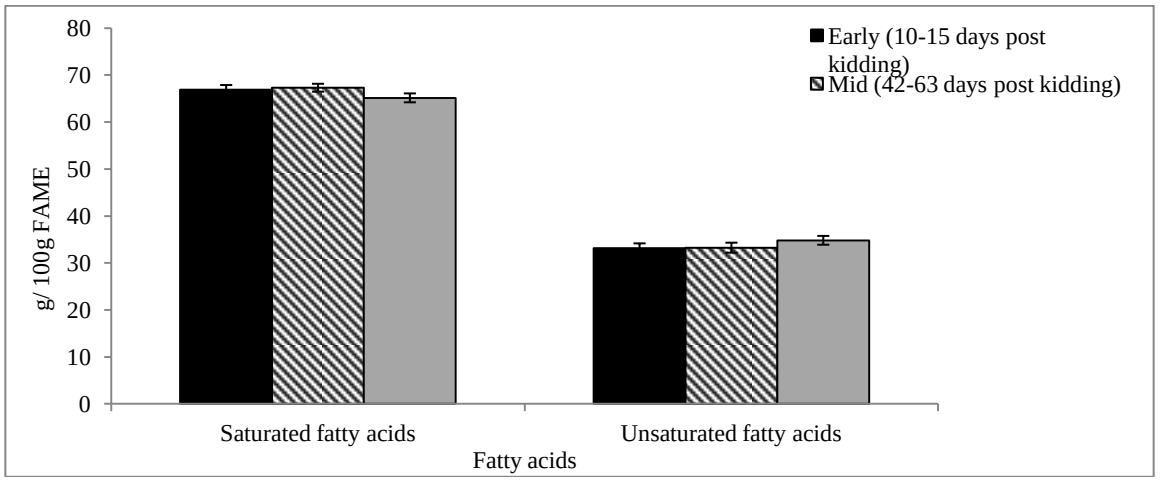

Figure 1: The composition of saturated and unsaturated fatty acids of milk fat at early, mid and late stages of lactation of Jamnapari goats

The differences in fatty acids proportions are influenced by the extensive metabolism of lipids involving lipolysis and biohydrogenation, and *de novo* synthesis from carbohydrate precursor (Jenkins, 1993; Mansbridge and Blake, 1997). The fatty acids are derived, almost equally, from either *de novo* synthesis from circulating acetate (C2) or β-hydroxybutyrate (C4) or directly from preformed fatty acids in blood lipoproteins. *De novo* synthesis in the mammary tissue produces the majority of the saturated fatty acids from C4 to C14 and half the palmitic acid (16:0) (Mansbridge and blake, 1997).

Medium chain triglycerides (MCT)

In the present study, medium chain triglycerides (MCT) refer to mixed triacylglycerols of saturated fatty acids with a chain length of 6 – 12 carbons, namely hexanoic acid (C6:0, common name caproic acid), octanoic acid (C8:0, common name caprylic acid), decanoic acid (C10:0, common name capric acid) and dodecanoic acid (C12:0, common name lauric acid (Figure 2). Sum of MCT was similar (P>0.05) during early, mid and late lactation stages (11.00 g, 13.26 g and 12.49 g/ 100g FAME, respectively). The present findings are in agreement with Güler *et al*. (2007) where the MCT composition was similar throughout the stage of lactation in milk (early, mid and late) of German Fawn crossbreds (12.2 g , 11.1 g and 13.4 g/ 100g FAME, respectively) and Damascus goats (10.32 g, 10.97 g and 12.56 g/ 100g FAME, respectively).

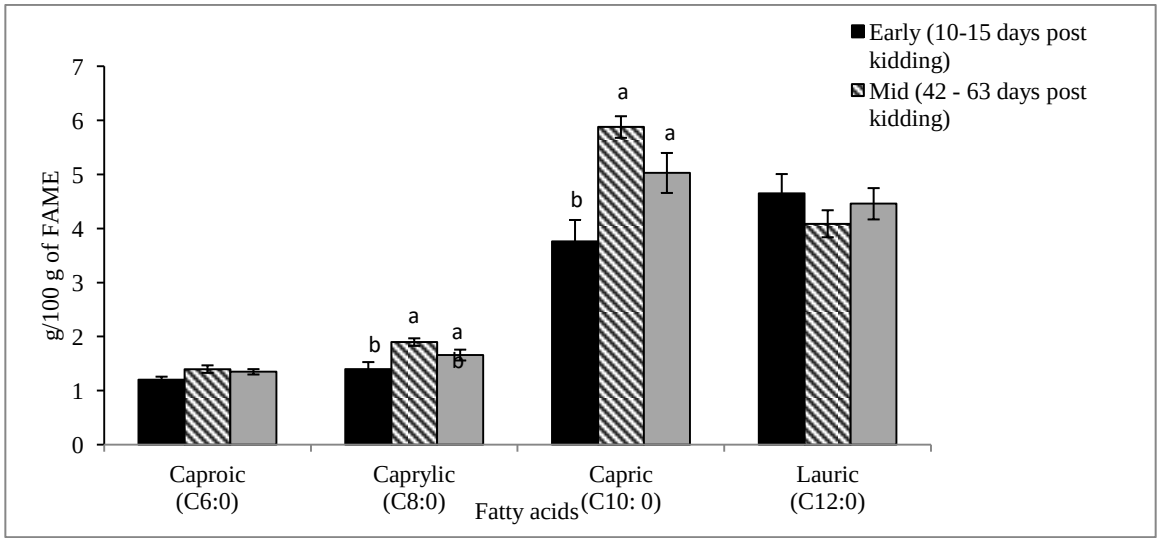

Figure 2: The Medium Chain Triglycerides composition of goat milk fat at early, mid and late stages of lactation of Jamnapari goats

It is well-documented that the MCT in goat milk are superior to cow milk. Ceballos *et al*. (2009) had proven a difference of 62% MCT between goat and cow milk (21g vs. 8g). However, the result obtained was much lower (11-13g/100g FAME of total MCT) as compared to several reports, ranging from 21 to 34g (Ceballos *et al*., 2009; Strzalkowska *et al*., 2009). As was to be expected, the milk produced from goats supplemented with soybean waste resulted in low of C4 to C16 milk fatty acids and consequently raised the

levels of long-chain fatty acids (Mansbridge and Blake, 1997). This is due to both higher secretion of long-chain FA in the blood (dilution effect), and a lower *de novo* synthesis of FA. The long-chain FAs are potent inhibitors of mammary FA synthesis, through a direct inhibitory effect on acetyl-CoA carboxylase activity.

During the early stage of lactation, caprylic and capric acids in goat milk were the lowest and increased significantly ($P<0.05$) by the mid-stage of lactation. This in an agreement with Banskalieva (2001), with the lowest value of C8:0 and C10:0 during 3-10 d post-kidding and highest value during 60-90 d in the milk of three goat breeds. This trend was also described by Marounek *et al.* (2012) in their study using White Shorthair goats. The total of MCT (caprylic, capric and lauric) in colostrum increased from 8.7% to 11.1% on the fourth day of lactation. The physiological limitation of goats to consume adequate dry matter to meet energy requirement resulted in lower values of short chain fatty acids during early stage of lactation. The dietary supply of acetate decreases, and consequently reduces the production of *de novo* short-chain fatty acids by mammary tissue and increases the mobilization of adipose tissue fatty acids (Palmquist *et al*., 1993). Another explanation was provided by Belyea and Adams (1990) who proposed that during the early stage of lactation, the animals are in negative energy balance and the mobilization of adipose tissue fatty acids consisting of long-chain fatty acids inhibits *de novo* synthesis of short-chain fatty acids by mammary tissue. When compared to cow milk, goat milk is composed of slightly higher caproic (C6:0), caprylic (C8:0) and capric (C10:0) acids and slightly lower in butyric (C4:0) and palmitic acids (C16:0). This results from different regulation of mammary cells between these species in the elongation process of fatty acids in the mammary glands involved in the fatty acid synthase complex (Ceballos *et al*., 2009; Chilliard *et al*., 2000).

The demand for goat milk is growing widely concerning its nutritional value and benefits to human health. The MCT are recognized for their medicinal values for many human disorders and diseases (Haenlein, 2004). The MCT are metabolized in a different way from those containing long chain fatty acids, being readily hydrolysed in digestive tract and can be absorbed directly without subsequent re-esterification. Not surprising, this is due to the uniqueness of chemical and physical properties of MCT. They have a lower melting point, smaller molecule size, liquid at room temperature and less energy dense. High level of saturated fatty acids intake in humans is believed to increase the risk of coronary heart disease by increasing total low density lipoprotein (LDL) cholesterol (Mensink, 2016). Despite of that condition, by considering the weight of individual MCTs, both C8:0 and C10:0 increased significantly ($P<0.05$) at mid until late stages of lactation. According to Chilliard *et al*. (2006), the short chain fatty acids (C6:0, C8:0 and C10:0) are synthesized *de novo* in the mammary gland. Therefore, this statement indicates that the changes of mammary secretory epithelial cells during mid-stage of lactation increased the amount of C8:0 and C10:0. These MCTs were reported as antiviral agents and the antiviral activity of C10:1 was also demonstrated against human immunodeficiency (HIV) virus (Thormar *et al*., 1994). No negative effects of C8:0 and C10:0 on blood cholesterol have been reported (German and Dillard, 2004). Lauric acid (C12:0) represents a major saturated fatty acid within the MCTs ranged between 4.1 to 4.7g throughout the lactation stages ($P>0.05$). Similarly, the antimicrobial properties of C12:0 were demonstrated against *Listeria monocytogens*, food-borne pathogens, and spoilage bacteria, resulting in

increased hygienic quality and shelf life of milk and milk products. However, C12:0 may potentially lead to hypercholesterolemia (German and Dillard, 2004).

Long-chain saturated fatty acids

The composition of long chain saturated fatty acids in goat milk at early, mid and late stages of lactation is shown in Figure 3. The myristic acid had a lower value in the early stage (6.26 g/ 100 g FAME), increased ($P<0.05$) at the mid-stage of lactation (7.16 g/100 g FAME) and maintained this level thereafter until the end of lactation. A similar trend was found by Soryal *et al*. (2003). The caproic, caprylic, capric and myristic acids in goat milk were at the lowest during 15 d post-kidding and significantly increased by 90 d in milk. The prevalent FA in caprine milk throughout the lactation stages are palmatic (C16:0) and stearic (C18:0). These FAs are mainly stored as triglycerides in ruminant adipose tissue. Animals will mobilize the converted energy storage in the form of non-esterified fatty acid (NEFA) during negative energy balance. Palmitic acid had a lower value ($P<0.05$) during early lactation stage (20.47 g/100 g FAME), a significantly higher value ($P<0.05$) at mid-stage of lactation (22.24 g/100g FAME) and maintained higher value until the end of lactation stage. The content of palmitic acid in goat's milk were reported to be in the range from 23.2 to 34.8 % (Park *et al.*, 2007). However, the findings obtained in the present study are slightly lower than Park *et al.* (2007). According to Cattaneo *et al.* 2006, the palmitic acid content can be reduced by the addition of fish oil to goat diets. The palmitic acid level also could be reduced by increasing the protein content in feed (Czadeurna *et al.* 2010). Soryal *et al*. (2003) suggested, approximately one half of palmitic acid is derived from *de novo* fatty acids synthesis and the remainder is derived from circulating blood lipids. During negative energy balance at early lactation stage, a low dry matter intake would result in a lower synthesis of half the amount of palmitic acid. At the same time, the stearic acid supply from adipose tissue is maintained and markedly decreases ($P<0.05$) in the mid-stage of lactation. The decrease of stearic acid was believed to be associated with the increase of palmitic acid. A similar trend was found by Bankskalieva (2001) with low values at early lactation and peak values after 60 d in Nubian and Toggenburg goats. The average of stearic acid content in goat milk is within the range of 7.85 – 16.60%. A high value of stearic acid was recorded at early stage of lactation (22.91 g/100 g FAME). Most of the fatty acids content in soybean based were rich in linoleic, oleic and palmitic acid about 50%, 30% and 10%, respectively (Kanghae *et al.*, 2017). In this case, the extent of rumen biohydrogenation forming the saturated final end product (stearic acid) depends on the amount of lipids in the dietary soybean waste. According to Jenkins and Bridges (2007), the losses of linoleic and oleic acids from unprotected fat source were about 82% and 86%, respectively. In another perspective, the increased proportion of stearic acid, and also oleic and linoleic acids was due to the starvation effect (Massart-Leen and Peeters, 1985). It was concluded that long-chain FFA derived from adipose tissue was more extensively for milk fat synthesis.

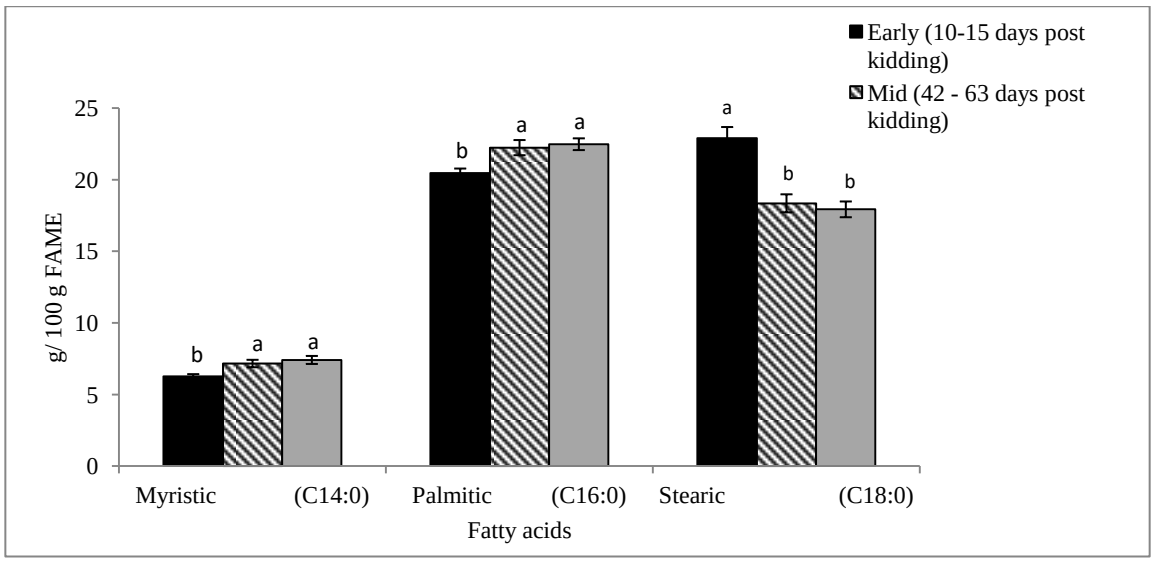

Figure 3: Long chain saturated fatty acids composition of goat milk at early, mid and late stages of lactation

Unsaturated fatty acids

Figure 4 shows the composition of unsaturated fatty acids of goat milk at different stages of lactation. Monounsaturated fatty acids, primarily oleic acid, are a major component of milk fat in ruminants. Oleic acid present in milk is derived from desaturation of stearic acid (C18:0) in mammary tissue and adipose tissue in the case of ruminants. During mid-stage of lactation, C18:0 and C18:1 were at the lowest value (18.35 and 24.84 g/ 100g FAME). Previous studies suggested that these fatty acids were used up for energy storage and deposited in adipose tissue (Chilliard *et al*., 2003). Since the animals are regaining their body weight at mid lactation and reach optimum during late-lactation stage. These findings are in agreement with the value of oleic acid which increased significantly ($P<0.05$) during late-stage of lactation, from 25 to 30 g/ 100 g FAME. However, the value of C18:0 remained unchanged. According to Hawke and Taylor (1983), oleic acid is the main component of short-chain fatty acids changes. The administration of the oleic acid at the sn-3 position of triacylglycerol molecule affected the value of short-chain fatty acids. According to Okine *et al.* (2003), the concentration of oleic acids in late lactation in Alpine does was increased significantly from 18 to 25% with the increasing levels of dietary canola oil (0-4%). The minimal changes of fatty acid profiles beyond 4% level of canola oil intake were observed. A study conducted by Van Nieuwenhove *et al*. (2008) showed that the content of oleic acids between Holando-Argentino cows and Anglo-Nubian goats fed on pasture was not different with average of 24%.

The levels of polyunsaturated fatty acids (PUFA) were similar ($P>0.05$) throughout the lactation stages, ranging from 2.15 to 2.78 g/100 g FAME. The PUFAs are not been synthesised locally by ruminant tissues. Their levels are highly influenced by feeds and dependent on the amount of PUFAs flowing out the rumen (Chilliard *et al.*, 2000). Low level of PUFA in milk was clearly explained by Mansbridge and Blake (1997). PUFAs tend to concentrate in the phospholipids and cholesterol esters of the

HDL and the uptake of fatty acids into the mammary gland from HDL is poor. Under normal conditions, the major preformed fatty acids (C16:0, C18:0 and C18:0) are delivered to mammary glands by LDL and VLDL or chylomicrons. This may explain the different levels of these fatty acids found in milk. There was no significant difference in linoleic acid among the lactation stages with the average of 0.38 g/100 g FAME. The value of linolenic acid was highest at mid-stage of lactation (0.62 g/100 g FAME) and reduced significantly ($P<0.05$) at the end of lactation stage (0.38 g/ 100 g FAME). The total amount of linoleic and linolenic acids in milk depends on the amount of by-pass dietary lipids and cannot be synthesized by ruminants (Chilliard *et al*., 2003). Therefore, previous studies suggested that decrease in dry matter intake during late stage of lactation reduced the chance of by-pass fatty acids into mammary gland. Rumenic acid is derived from ruminal biohydrogenation of conjugated linoleic acids (CLA) and desaturation of second intermediate *trans*-vaccenic acid by delta-9 desaturase which takes place in mammary tissue. Rumenic acid is the major isomers (80 to 90%) of CLA found in ruminant milk fat (Bauman *et al.*, 2001). The value of rumenic acid was highest ($P<0.05$) during mid-stage (0.79 g/100 g FAME) compared to early (0.40 g/100 g FAME) and late-stage (0.46 g/100 g FAME) of lactation. Because the animals were offered the same diet, the decrease in stearic and oleic acid levels in milk may suggest increased activity of rumen microorganisms and more output of *trans*-vaccenic in the mid-stage of lactation. Corl *et al*. (2001) estimated that 78% of the total *cis*-9 *trans*-11 CLA in milk fat was endogenously synthesized. However, lesser amount of *cis*-9 *trans*-11 CLA found in milk fat originated from rumen. Therefore, we suggest that the main source *trans*-vaccenic acid as a precursor of rumenic acid originates from dietary linolenic acid during mid-stage of lactation. In line with a study conducted on Brown Shorthair and Anglo-Nubian goats, Kala *et al.* (2016) traced a small proportion of rumenic acids accounted for 1.21 and 0.53% FA, respectively. The level of total CLA and rumenic acid can be increased by the inclusion of vegetable oils and marine oils which rich in PUFA. The supplementation of linseed oil (57% of linolenic acid) in dietary forage showed an improvement in the composition of linolenic (0.32 to 0.68%) and rumenic acids (0.59 to 2.25%) (Chilliard *et al.,* 2002).

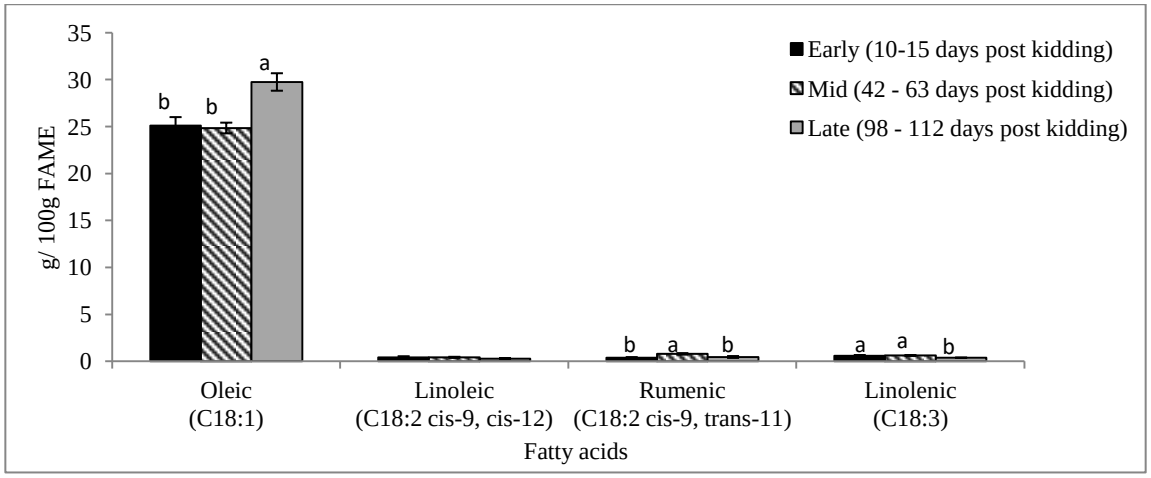

Figure 4: Unsaturated fatty acids composition of goat milk at early, milk and late stages of lactation

Conclusion

In conclusion, our results demonstrated that lactation stage has an effect on the milk fatty acid profiles. Low levels of individual MCT, especially caprylic and capric acids, and including myristic and palmatic acids (long chain fatty acid) are likely to be related to the physiological restriction resulting in low dry matter intake during the early stage of lactation. The maximum value of oleic acid at late-stage of lactation was associated to fat deposition in the form of adipose tissue. The biohydrogenation of dietary linoleic and linolenic acids was the only source for the formation of *trans*-vaccenic acids as the precursor of rumenic acids. The highest value of rumenic acid and the decrease in stearic and oleic acid levels in goat milk may suggest increased activity of rumen microorganisms and more output of *trans*-vaccenic acid during mid-stage of lactation.

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