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Review article

Influence of stage of lactation on quantitative and qualitative milk production parameters in goats

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ABSTRACT

Goat lactation is synonymous to an agricultural production function with three distinct production regions namely, early, mid and late lactation. It is characterised by an increase in milk yield in early lactation to a possible peak in the mid lactation and then a decline in milk yield as it reaches the end of lactation. However, the other milk constituencies (protein, fat, lactose, etc) do not follow the same trend as total milk yield through the 3 lactation stages. Therefore, it is suffice to suggest that the understanding of the physiological changes in these stages of lactation is crucial in maximizing milk production in goats. The present discussion explores the importance of different stages of lactation in milk production in influencing yield and milk composition. Milk yield and its composition are influenced by various factors, among these stage of lactation is very significant. The proportion of protein, lactose, fat and total solids declined slightly with advance in lactation and a steady fall in milk yield. This is on the basis that milk yield is a function of the number of mammary secretory cells and their metabolic activity change during the course of lactation. The significant stage of lactation effect in most studies may have practical implications in determining optimal feeding management to maximize total lactation yield and milk composition. Therefore, the knowledge of physiological activities during different stages of

lactation is critical to dairy animal nutrition and management decision support systems for optimization of goat dairy flock production processes.

1. Introduction

Of the total world population of goats, 94 percent are said to be found in developing countries, supplying 73 percent of the milk produced by goats (Devendra, 1987). In terms of goat breeds, some have a greater potential for milk production and are known to be kept primarily for this purpose (Gall 1975). Although the production and consumption of cow milk is the largest throughout he world, one may observe a growing demand for milk of other farm animals, such as goats, which is recognized in developed countries as a "niche" product (Kanwal et al. 2004; Haenlein and Wendorff 2006; Krzyżewski et al. 2009). There is an increasing interest in goat milk due to inherent species-specific biochemical properties that contribute to nutritional quality through developing sustainable nutritional strategies for reducing saturated and increasing specific unsaturated fatty acids in ruminant milk, based on the potential benefits to long-term human health (Haenlein, 2004). Charnobai et al. (1999) stated that total solids values decreased during the initial months and increased at the end of lactation. Milk production is a function of the stage of lactation, usually measured in the number of days in milk (Swalve, 1995). Milk yield and its composition are influenced by breed, age of the ewe, litter size, nutrition, health of the animals, environment, stage of lactation, etc. Among these factors, the stage of lactation is very significant (Pavić et al., 2002; Oravcova et al., 2006, 2007; Kuchtik et al., 2008). A number of animal (species, breed) or environmental (lactation stage, feeding regime, animal health and management) factors affect milk composition Leibetseder, 1996; Wojtowski et al., 2001; Chillard et al., 2003; Gorecki et al., 2004). The percentage protein, lactose, fat and total solids declined slightly with advance in lactation and there was a steady fall in milk yield (Akinsoyinu et al., 1977). In sheep, stage of lactation in addition to breed, lambing season, parity and litter size significantly affected milk yield, fat and protein, with the only exception of parity in fat and litter size in protein content (Komprej, et al., 2012). The concentration of fat and protein in milk tends to decrease rapidly at the start of the lactation, and after falling to the minimum point increases slowly until the lactation is completed (Wood, 1976). An attempt has been made to assess the nutritive value of goat milk taking into consideration various factors (Crepaldi et al., 1999; Andrade and Schmidely 2006, Matsushita et al. 2007, Zehra et al., 2007; Carnicella et al., 2008), little is known about its composition and physical traits in relation to the stage of lactation (Strzałkowska et al. 2008). The Red Sokoto goats gave milk of higher content than did Saanen goats, even at an early stage of lactation. Butterfat, protein, lactose and energy values were significantly affected by stages of lactation and tended to rise with advancing lactation; this was particularly so with West African dwarf goats (Mba et al., 1975). Ibeawuchi et al. (2003) observed that the mature milk constituents were significantly affected by stage of lactation. These constituents tended to increase with advancing lactation. Particularly during lactation there are significant changes in the amount and composition of goat milk (Wuschko and Seifert, 1992). The present discussion is an attempt to explore the significance of stage of lactation on yield and major milk constituents in goat milk production.

2. Milk yield and lactation stages in goats

Milk production is largely dependent on the shape of the lactation curve. Relevant elements of the lactation pattern are the peak yield, which represent the maximum milk yield during the lactation and the lactation persistency which expresses the ability of animals to maintain a reasonable constant milk yield after the lactation peak (Cannas et al., 2002). In a study to evaluate milk yield and composition of Damascus does raised under Sudan condition, it was observed that different stages of lactation affected their milk yield and composition as the chemical constituents were reduced with the progress of lactation (Mahmoud et al., 2014). The decline in the mean daily milk yield after the peak was due to advancement of lactation (Harding, 1999). This supported Strzalkowska et al., (2009). Laes-Fettback and Peters (1995) evaluated three Egyptian goat breeds, Baladi, Zaraibi and Damascus and reported that all the breeds had high persistency, with a slightly higher yield during the initial part of lactation in Zaraibi and Damascus. The milk production differences were observed between first lactation

and third lactation, as well as second lactation and third lactation (Cismas et al., 2012).The percentages of fat, protein, lactose, ash, total solids and solids non fat were higher with advancement of lactation in different breeds (Gitam, et al., 2014). Stage of lactation had conspicuous effects on milk quality of goats despite different rearing systems (Singh et al., 2014). Each component, protein, lactose and solid non fat showed the lowest values during early lactation, and then significantly increased towards the end of lactation (Darwesh, et al., 2013). Aganga et al., (2002) who studied the effect of lactation on composition of Tshwana goat reported that minerals fluctuated throughout the lactation period. The pattern of daily milk yields in goats significantly rising to maximum within two weeks and then decreasing afterwards to end of lactation was observed by Ehoche and Buvanendran (1983) in the Red Sokoto goat.

Stage of lactation significantly affected milk constituents where fat and protein contents were negatively and lactose contents positively correlated with milk yield. The observed trend of milk yield could have resulted due to proliferation of myoepithelial cells of the mammary gland especially at the early stage of lactation. Knight and Wilde (1993), reported that mammary cells multiplied during early lactation and declines as lactation progresses. According to Stojević et al., (2005) during the early stage of lactation the liver of high productivity dam undergoes extensive physiological and biochemical changes to counteract the adverse effects of negative energy balance The correlations between protein, lactose, fat, and dry matter yields with liver metabolites activity. Determination of biochemical parameters in blood serum can provide valuable information regarding dairy dam nutrition and physiological status in relation to age and stage of lactation. Due to liver functionality blood biochemical attributes are important indicators of the metabolic activity in lactating animals (Karapehlivan et al., 2007). During lactation, secretary cells of mammary gland utilize 80% of the blood circulating metabolites for milk synthesis, depending on the speed of infiltration of precursors of milk compounds (i.e. free amino acids, glucose and fatty acids).

Milk yield is a function of the number of mammary secretory cells and their metabolic activity and both are not static, but change during the course of lactation (Stelwagen, 2001).Lipogenesis is impaired and the increased fatty acid release, supported by norepinephrine and epinephrine stimulation, induce an increase in lipase activity of mammary gland, to provide the substrates for milk fat synthesis (Nazifi et al. 2002). As a result lactating goats experience an increased in total protein level of serum with the progress of lactation due to the catabolism of protein for milk synthesis (Krajnicakova et al. 2003).Composition of goat milk varies considerably during a lactation, with the major changes usually occurring soon after the start of lactation. The first secretion to be collected from the gland is called colostrum. The composition of the secretion gradually changes to that of mature milk. Evidence exists that efficient milking is of supreme importance for goats at peak lactation stage because of a higher secretion rate at this stage of lactation (Knight, 1995). Kuchtik et al., (2008) observed that the stage of lactation had a highly significant effect on the contents of all milk components. However, only the contents of total solids, solids non-fat, fat, protein and casein gradually increased with the advancement of lactation. The percentages of crude protein, fat and lactose contents were significantly different in the four stages of lactation (colostrum, early, mid and late), while the differences in the total solid, pH and ash contents were not affected by the lactation stages (Zahraddeen, et al., 2007). Early and late lactation milk had significantly higher contents of milk components (Mestawet et al., 2012). In cattle high rates of increase in milk yield and high milk yields in early lactation were predisposed to udder disease afterwards, this resulted in cows with high milk production over a long period but with low lactation persistency beign predisposed to udder disease after the peak of lactation. However there was no difference in total milk yield between incidence and non-incidence groups in all stages, suggesting that, for a comparable level of lactation, cows without udder diseases have flatter lactation curves (Yamazaki et al., 2009).

3. Crude protein and stages of lactation in goats

Stage of lactation was an important source of variation on crude protein content of goat milk (Beyene and Seifu (2005) in Borana goat milk in Ethiopia, and variations of crude protein of milk due to the stage of lactation were reported previously (Katanos et al., 2005). Protein content showed a downward trend until mid-lactation before significant increase towards the end of lactation. This is a similar trend where protein was reduced during the mid lactation stage and increased at the late stage of lactation (Keskin et al., 2004). Egbowon (2004) reported that milk protein percentage is inversely related to milk yield. Brendehaug and Abrahemsen (1986) observed that protein value decreased during the early stage of lactation and then increased until the end of lactation. This implies that protein started at a moderate level, decreased to the lowest level during peak lactation and gradually

increased towards the end of lactation in accordance with the inverse relationship with milk production. Protein percentage was highest in late lactation (Peris et al., 1997; Soryal and El Shaer, 2006; Mohammed et al., 2007; Norris et al., 2011). This appears to reflect a low degree of proteolysis in late-lactation milks. Ahamefule et al. (2003) obtained milk protein values of 4.26, 4.23 and 4.34% for West African Dwarf goat in early, mid and late lactation stages. Similarly, higher milk protein values were also reported by Jenness, (1980) and Akinsoyinu et al. 1981) for Red Sokoto goat (4.38, 4.70%) in a related study. Small decreases in mammary blood flow, amino acids transport activity, and amino acids concentrations accounted for the lower uptake of amino acids in late compared with early lactation (Mabjeesh et al., 2002). Strzalkowska et al., (2009) reported that in Polish White improved goats that the protein content of milk increased with the progress of lactation. The increase in protein and fat content could be due to the decline milk yield (Mioc et al., 2008). During earlier and mid stages of lactation, the milk yield was high, however, during late lactation when milk yield was low, protein and fat content were higher (Mahmoud et al., 2014).

4. Fat content and stages of lactation in goats

The quality of milk is better explained by the fat and protein concentration (Quinn et al., 2006). Goat milk contains higher contents of long-chain fatty acids than cow milk (Juarez and Ramos, 1987). Additionally, goat milk contains a much higher proportion of the short and medium chain fatty acids in comparison to cow milk (Haenlein, 2001). Fat and total solid percentage was at its highest at the late stage of lactation and followed by early stage and mid stage of lactation. This variation could be explained by the negative correlation between milk yield with fat and total solid content (Merkhan, 2011). A similar trend was found earlier by Baker (2007), Agnihotri and Rajkumar, (2007), Mohammed et al. (2007), Guler et al. (2007) and Rajkumar, (2007). Palmquist et al. (1993) reported that the variations in fat content were related to lactation stages in addition to other various factors, such as, temperature, quantity of milk produced, breed and feed type. Milk fat showed a decline from week 1-8 in **d**ifferent goat breeds raised in the same environment in South Africa (Pambu et al., 2011). The behaviour of fat content showed a decreased with advances in stage of lactation (Zahraddeen, et al., 2007). This was contray to reports by Beyene and Seifu (2005) who observed significant increase in the fat content of Borana goat with stage of lactation. This decline was also observed by Bouattour et al. (2008) who reported that the response of milk fat secretion is usually higher during early lactation because de novo lipogenesis is usually more active after peak lactation than before it. After peak lactation, dietary fatty acids would probably be partitioned more to the adipose tissues synthesis. However, Egbowon (2004) reported that fat content of milk decreased from the beginning of lactation to a minimum in mid-lactation and continuously increased until the end of lactaton; an inverse relationship with milk production similar to the case of protein content. Fat content was lowest in mid lactation and significantly increased in early and late lactation stages. The influence of stage of lactation on goat milk fat was reported by Bhosale et al., (2009). Earlier findings by Morand-Fehr et al. (2007) suggested that milk fat content was stable at the first stage and then decreased under the effect of dilution; this was also the opinion of Chilliard et al. (2003) indicated that milk fat content is high after parturition and decreases during the major part of lactation in goat, which was related to a decrease in fat mobilization. These explanations are all in agreement with Fernandez et al. (2008) who arguered that in general fat and protein content were greater at the beginning than at the end of lactation when milk volume decreased. Goat milk lipolysis and lipoprotein lipase activity vary considerably and in parallel across goat breeds or genotypes, and are low during early and late lactation, as well as when animals are underfed or receive a diet supplemented with protected or unprotected vegetable oils (Chilliard et al., 2003). This could contribute to decreases in the specific flavor of goat dairy products with diets rich in fat. The content of conjugated linoleic acid in goat milk increased significantly with the progress of lactation (Strzałkowska et al., 2009), but it was lower than that reported by Park et al. (2007). The level of short chain fatty acids in goat milk reached its maximum at the start of lactation and next dropped reaching a minimum during stage 3. This trend was in disagreement with observation by Soryal et al. (2005), who observed a high content of short chain fatty acids at the beginning, and then in the last stage of lactation. The short chain fatty acids concentration in the milk of goats is important, as it decides about the palatability and sensory properties of milk and dairy products obtained (Eknes et al. 2009, Talpur et al. 2009). Conjugated linoleic acid concentration of milk fat during lactation from goats managed in a semi-intensive production system, which consisted of grazing on a woody and herbaceous pasture with the supplementation of mixed concentrate and vetch hay, did not vary significantly throughout the lactation. This was in agreement with the findings of Tsiplakou et al., (2006), however contrary to

obsrvation in goats grazing on a 60 % Leguminosae and 40 % grass pasture which fluctuated significantly during lactation (D'Urso et al., 2008). It was suggested that the difference in milk conjugated linoleic acid content of goats between the two studies might be attributed to variations in botanical and chemical (especially poly unsaturated fatty acids) compositions of the pastures grazed by the goats. Atasoglu et al., (2009) reported that fatty acid composition of goat milk shows variations, depending upon stage of lactation. The physiological and biochemical facts of the unique qualities of goat milk are just barely known and little exploited, especially not the high levels in goat milk of short and medium chain fatty acids, which have recognized medical values for many disorders and diseases of people (Haenlein, 2004).

5. Lactose and stages in lactation in goats

Higher content of lactose were observed at the beginning of lactation in comparison with middle of lactation (Bhosale et al., 2009). The lactose content was initially high (in the colostrum) but decreased significantly during the remainder of lactation. Similarly, Brendehaug and Abrahamsen (1986) found that lactose content decreased throughout lactation. Boros (1986) however observed that lactose was fairly constant over the lactation period showing no substantial changes. Lactose content showed the lowest value during early lactation and then significantly increased to attain the maximum value during mid and late lactation (Soryeal and El Shaer, 2006; Hassan et al., 2010). The lactose content in the course of lactation was relatively the most constant of all components of milk which confirms its role as an osmotic regulator and a compensator for variations in all other components. Small variations were observed between lactation phases for lactose (Pina et al., 2006). Lactose is synthesized and secreted at the same rate as the milk, which makes it the most stable milk nutrient (Pulina et al., 2008). Ahamefule et al., (2012) observed that lactose composition was fairly comparable in two goat breeds, recorded lactose concentrations of 4.46, 4.62 and 4.60% in early, mid and late lactation stages in West African Dwarf goat which affirm the relative consistency of lactose in milk. Lactose is a disaccharide synthesized in the udder. It is composed of a molecule of galactose joined to a molecule of glucose.

6. Nutritional requirements and stage of lactation in goats

As it is known, nutritional value of milk is closely related with its composition, which is highly affected by factors such as stage of lactation, breed, feed, season, etc. (Meri et al., 1988; Haenlein, 1980). Provision of appropriate dairy goat nutrition involves combining various feedstuffs into an acceptable and palatable ration to meet nutrient requirements for lactation in different stages The nutrients considered in dairy goat diet formulation are energy, protein, minerals, vitamins and water and these vary depending on the stage of lactation, gestation, growth and the season of the year. The balance of nutrients will determine the performance, health and financial gain from a dairy goat enterprise. According to Tovar-Luna, et al., (2010) efficiency of use of dietary metabolizable energy for lactation differed among stages of lactation and was greater for the higher concetrate diets. However, the recovered energy in tissue gain was similar among stages of lactation and between diets and was not different from 0. Early lactation is a critical time for does because they need to be challenged, but dry matter intake lags behind the milk demand. Challenge or lead feeding is necessary to determine the genetic potential of dairy mother. However, in mid lactation should concide with peak dry matter which is approximately equal to nutrient requirements for milk production. However, in late lactation, grain feeding should be equal to milk production fed along with ad libitum good quality hay or forage. Milkers may need to gain extra weight to replenish body stores for the next lactation. It is more efficient to add extra weight to does in late lactation than in the dry period. Proper nutrition in dairy goats is critical during dry period because mistakes can adversely affect the subsequent lactation. Three diets namely, mountain natural rangelands during early lactation, agricultural pastures during mid-lactation, and indoor stall feeding during late lactation were tested to assess body weight, body condition and plasma metabolites as well as milk production (milk yield, milk fat and milk protein contents). At the end of lactation milk yield decreased in all feeding situations, proving that goats gave priority to the body reserves through replenishment over milk production in order to ensure the next cycle (Kharrat et al., 2010). Dairy goat nutrition is the main factor in performance and production efficiency, and its study is necessary for the formulation of diets, to predict animal performance and to plan and to control the production system (Pina et al., 2006) at different stages of lactation. Therefore, when alternative feeds are included in the diet, the ability of the feed to influence the animal performance should be evaluated in relation to the stage of lactation. Goetsch et al. (2001)

reported that high levels of concentrate diet (65%) depressed milk yield in does in late lactation compared with a 50% concentrate diet. High levels of concentrate diet that depress milk production during late lactation might not be true for efficiency of energy use and milk production over the entire lactation period in Alpine dairy goats (Min et al., 2005).

7. Implications

The significant stage of lactation effect in most studies may have practical implications for determining optimal feeding management to maximize total milk yield througout the lactation period. It seems by applying specific management practices, or a combination thereof, at any time during lactation, the farmer has tools to manipulate the performance of dairy goats at each lactation stage. It is suffice to suggest that appropriate management practices could be applied after peak lactation to increase milk yield, and perhaps slow down the rate of postpeak decline in milk yield, but can also be used to promote mammary involution near drying-off. Therefore, the knowledge of physiological activities during different stages of lactation is critical to goat dairy nutrition and management decision support systems for optimization of dairy herd production processes. Details of physiological udder activities related to specific lactation stage are important in milk production , and could be used to identify and promote the most productive animals in the flock. The prediction of annual milk production within different lactation stages can assist dairy farmers in determining the efficiency of their farming operation in relation to their physical inputs resulting in a wider gross profit margin.

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