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Review article

Effects of nutrition on yield and milk composition in sheep and goats

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ABSTRACT

The majority of sheep and goat milk produced in the world is transformed into cheese, therefore, feeding is a major factor affecting the quality of sheep and goat milk and, hence sheep and goat cheese quality. This discussion is an attempt to explore the influence of nutrition on milk yield and major milk components in sheep and goats. Nutrition is a vital component in an attempt to maximise milk synthesis in small ruminants, as a result correct feeding management is desirable through appropriate estimation of roughage to concentrate intake in order to optimize the utilization of feed supplements. It is suffice to suggest that feeding high producing dairy animals may be a major constraint in milk production, which implies greater attention to diet composition, feed quality, and the physical form of feedstuffs is required. The rate and extent to which a dairy sheep and goat is capable of drawing upon body reserves to meet the energy requirement at different stages of lactation is critical in determining her ability to produce and sustain a high level of milk production. In order to increase sheep and goat milk production, and to ensure high feed efficiency, dairy farmers need to pay close attention to nutritional requirement of dairy animals which may differ during different stages of lactation.

1. Introduction

Nutrition affects both the yield and composition of the milk produced (Bencini and Pulina, 1997). Therefore, besides numerous factors that alter milk yield and composition, knowledge on the effects of nutrition is useful for it concerns both yield and milk content (Bocquier and Caja, 1993). Furthermore, modification of nutrition is a powerful and short-term means of altering yield and milk composition in sheep and goats.. The aspects of the nature of dietary requirements of sheep and goat that have an influence on the yield and milk composition have been studied extensively (Goetsch, et al., 2001; Malau-Aduli et al., 2001; Cannas, et al., 2002; Carnicella, et al., 2008; Dønnem, et al., 2011). The various studies have been, fundamentally, aimed at optimising the yield and improving the quality of milk, as it comprises the raw material for the manufacture of different dairy products, especially of cheese. Cheese yield potential of milk is largely dependent on milk composition, particularly fat and protein (Banks et al. 1981; Barbano and Sherbon 1984; Gilles and Lawrence 1985; Lawrence 1993; Lou and Ng-Kwai-Hang 1992; Lucey and Kelly 1994; Van den Berg 1994; Brito et al. 2002; Guo et al. 2004). This is on the background that the composition of milk is also a function of several factors including breed, stage of lactation, climatic conditions and season (Merin et al., 1988). The chemical composition of milk, in terms of fat content and its fatty acid composition, depends on dietary (composition and availability), animal (breed, lactation stage, body condition) and environmental (especially cold and heat stress) factors. Therefore, it is important to note that the effects of nutrition are often hidden in the complexity of numerous factors that are also known to alter milk yield and composition. Such factors include for example breed (Soryal et al., 2005; Damian et al., 2008), udder morphology (Marnet and McKusick, 2001), genetics (Moatsou et al., 2004), parity (Peris et al., 1997; Salama et al., 2004; Carnicella et al., 2008; Ahuya et al., 2009; Crepaldi et al., 1999) feed and pasture (Dønnem et al, 2011), light (Flores et al., 2010), number of kids (Carnicella et al., 2008; Ahuya et al., 2009; Crepaldi et al., 1999), kidding time (Crepaldi et al.,1999) kid holding systems (Marnet et al., 2002) and milking interval (Salama et al., 2003; Salama et al., 2004). It is paramount to pay attention to nutritional provision which promote fat and protein contents because these parameters, which are routinely measured, can precisely predict cheese yield (Pellegrini et al., 1997). However, protein contents vary widely within species, and apart from nutrition it is influenced by breed, stage of lactation, climate, parity, season, and udder health status (Potočnik, et al., 2011). In addition it must be remembered that milk yield and milk composition (fat, protein, casein and serum proteins, but not lactose) are negatively correlated (Barillet and Boichard, 1987; Molina and Gallego, 1994; Fuertes et al., 1998). Milk quality can easily be controlled by the farmer with quick and obvious results, although it requires an understanding of the interactions between the composition of the diet and the quality criteria (Voutzourakis et al., 2014). Most studies point to the fact that different factors may influence the composition of milk (Lindmark-Mansson et al., 2000), therefore, information about variation of milk composition in relation nutrition is essential for implementing appropriate management practices in order to improve milk production. The present discussion is an attempt to explore the significance of nutrition on yield and major milk constituents in sheep and goat .

2. Sheep

Gilbert (1992) have written practical recommendations on the nutritional requirements of dairy sheep and recommended that the energy and protein content of the ration must be adequate to support maintenance as well as milk production. The milk production parameters varied according to the nutrient composition of feeds during lactation. Milk yield, lactose and urea in milk followed mid-lactation depressions in dairy animals due to the decreases in the protein to energy ratio and increases in the neutral detergent fibre content of the grazing forage. Milk yield was decreased by feeding oil with alfalfa haylage, but not by feeding oil with corn silage . Milk fat content tended to be increased by feeding oil with alfalfa haylage, but tended to be decreased by feeding oil with corn silage (Reynolds et al., 2006). Underfeeding ewes in early lactation impaired milk secretion (Maxwell et al. 1979), but the study did not report on the effects on the quality of the milk. Kennelly and Glimm (1998) observed that in late lactation, declining part of a lactation curve is due to hormonally directed decreases in mammary capacity so nutrition, unless it is inadequate, has little impact. If inadequate, though, milk production and lactational persistency will suffer. Nutrition should be used in late lactation to manage replenishment of body fat reserves. Robinson et al. (1979) found a slight increase in milk protein in ewes fed fishmeal, when compared with those fed soybean or peanuts protein supplements. Effects of fishmeal was attributed to an increase in the amount and profile of amino acids absorbed in the small intestine and that are available for milk synthesis. Since most sheep milk is used for cheese production, cheese yield is an important quality characteristic, affected mostly by milk protein content, but also by the fat content. Of these two macro-nutrients, the milk protein content is harder to manipulate by nutrition than the fat content. Feedstuffs high in undegradable protein include fish meal, blood meal, corn gluten meal and roasted soybeans. Treacher (1989) documented 600 to 940 ml/d improvements in milk yield with fish and blood meal supplementation of forage-fed ewes. Cannas (1995) observed that in sheep fed hay and concentrates, for a given concentration of Neutral Detergent Fiber, a reduction in the particle size of hay resulted in a reduction in chewing time and an increase in feed intake. As a result the digestibility of dry matter and Neutral detergent Fiber decreased, but the amount digested per day was not affected. The composition of volatile fatty acids in the rumen showed increased concentrations of propionate and butyrate and a stable concentration of acetate. As a consequence there was an increase in milk and milk protein yield. The supply of sufficient protein during late pregnancy and lactation influences the quantity as well as quality of milk produced. It is reported that the supply of a high level of bypass or rumen undegradable protein is essential to increase the colostrum and milk production of ewes (**Hoon, 2010).** Excessively high doses of concentrates can reduce the intake of fibre and therefore reduce chewing times and rumen pH. This can depress milk production and reduce the concentration of fat in milk (Oddy 1978; Chiofalo et al. 1993) probably because they cause rumen acidosis (Rossi et al. 1988). The protein content of the diet affects the quantity and the partition of nitrogenous substances in the milk (Bencini and Pulina, 1997). Calderon-Cortes et al. (1977) reported that milk protein was significantly reduced if ewes were fed a protein deficient diet. Robinson et al. (1979) and Pulina et al. (1995) have all shown that milk yield and concentration of milk fat can be increased by increasing the protein content of the diet.

Ruminant diets are commonly supplemented with oils or fats to meet the high energy requirements of early lactation and/or to address the composition of milk fat towards the enrichment in beneficial fatty acids (Mele et al., 2006). Due to the dietary fat, intake tended to decrease, milk fat percentage and yield were increased, and casein content was reduced. A significant effect was detected on milk casein as percentage of total protein that decreased as response to lipid supplementation (Bocquier and Caja, 1993). The interest of fat supplements in the diets of dairy sheep has increased in the past years as a result of the availability of new preparation of fat as food for ruminants. dietary calcium soaps of long chain fatty acids significantly increased the milk contents of fat and solids, in most cases, and decreased slightly milk protein content in overall lactation. Responses varied according to calcium soaps of long chain fatty acids dose and lactation stage. Milk fat content is in general negatively correlated to energy balance, whereas with protein content the correlation is positive. In consequence, in most cases, a high level of nutrition in dairy animals will depress fat content and slightly increase milk protein content. On the other hand, an increase in dietary protein supply will increase milk protein yield, if the dam has not reached its potential yield, but this response is not associated to changes in milk protein content. Concentration is reduced by feeding diets that contain large proportions of readily-fermentable carbohydrates (starch) and unsaturated fat (Palmquist, 2006). Conversely, the percentage of fat in milk can be increased by feeding rumen-inert fats, however, in ruminants, in contrast with nonruminants, dietary fats have little effect on milk fat composition. Effects of concentrate level and addition of fat were quantified from a data base recording milk fat content and yield, and fatty acid composition of milk in dairy sheep and goats. Increasing concentrate level decreases milk fat content, more intensively in total mixed rations than in rations where concentrate and forage were fed separately (Schmidely and Sauvant, 2001). Milk yield increases in ewes, and does in a curvilinear manner with increasing amounts of dietary fat. As a rule, the relationship between milk production and amount of extra fat included into the diet is curvilinear in the three species, production rises with increasing amount of fat to a maximum and decreases from a certain level of inclusion (Brown-Crowder et al., 2001; Gargouri et al., 2006). Milk production and milk fat content are not negatively affected in goats and ewes by the consumption of diets with added fat, but milk protein content decreases in ewes.When fat supply is low, the increase in milk yield is probably caused by a higher energy intake. However, milk yield decreases when fat supply is high, which may be related to diminished energy availability for milk production due to negative effects on rumen digestion and/or dry matter intake. There is a general indication in the literature that the inclusion of unprotected oils and fats rich in polyunsaturated fatty acids in the diet of dairy cows causes a decrease of milk fat yield, known as the milk fat depression syndrome, even though some reports do not agree on this (Palmquist and Jenkins, 1980). Just the opposite appears to occur with dairy ewes and goats; feed supplementation with plant oils or full fat grains increases their milk fat yield (Chilliard et al., 2003). Such an increase may exceed 2% with full fat oil seeds (Schmidely and Sauvant, 2001). The effects of lipid supplementation on milk yield were in agreement with the literature (Zervas et al., 1998). Concerning the level of dietary concentrate on milk production, the results confirmed that duringmid- and latelactation, high levels of non-fibre carbohydrates in the diet do not have positive effects on milk yield and quality (Cannas, 2002). Diets with added fat generally increase milk production compared with a control diet without added fat in ewes and goats (Martinez et al., 2013). Unprotected lipids negatively impact milk fat content in dairy cows, but not in dairy ewes and goats; negative effects of supplemental lipids on milk protein content observed in dairy cows and ewes has not been observed in dairy goats. Rotunno et al., (1998) reported that the addition of rumen-protected fat in diets for lactating ewes may improve the composition of milk fat, but it should be associated with supplemental dietary protein or, better still, rumen-protected amino acids to alleviate the decrease in milk protein due to fat supplementation. Increase in milk production when the dietary inclusion of extra fat is low could be explained by a higher energy concentration of the feed consumed. Wu and Huber (1994) pointed out that the decrease in protein content could be partially due to a dilution effect of the increased amount of milk produced because of the extra fat, as well as a shortage of available amino acids for the synthesis of protein to maintain pace with the increased milk production. Fat is present in milk as globules of different sizes where the core of triglycerides is enclosed in a triple-layer membrane (Nudda et 2014). Fat concentration in milk can be changed by diet, especially by factors affecting rumen fermentation. In another study feeding oilseeds rich in poly-unsaturated fatty acids to lactating ewes resulted in substantial changes in milk and cheese fatty acid profiles with minimal effects on milk and cheese yields. Therefore, it implies that cheeses with specific human health-promoting fatty acids can be produced from milk of ewes by selective feeding of oilseeds (Zhang et al., 2006). Indeed, the acetate,propionate concentration ratio in the rumen fluid plays a fundamental role in the synthesis of milk lipids in ruminant species. The content and source of neutral detergent fiber and non-fibrous carbohydrates (i.e., sugars, starch, soluble fiber) in the diet influence markedly the volatile fatty acid profile in the rumen. In lactating Sarda dairy ewes, leaves of different aromatic plants (*Melissa officinalis* L., *Ocimum basilicum* L. and *Thymus vulgaris* L.) were used as source of essential oils and were tested at three dosages (50, 125 and 200 g/d, DM basis) by Manca, et al., (2012). Milk yield was not affected, whereas milk fat concentration was the highest for *Melissa officinalis* L. in comparison with the other two plants. Poulton and Ashton (1972) examined the effect of the quality of diet on milk yield and composition and demonstrated that diets rich in carbohydrates and poor in fibre disturbed the function of the rumen and resulted in lower milk yields and lower concentrations of fat in the milk. However, this relationship is difficult to interpret because a higher concentration of Neutral detertegent Fiber provokes a reduction in the digestibility of the diet and a reduction in feed intake which in turn results in a reduction in milk production and a consequent increase in milk fat concentration.

3. Goat

Milk productivity depends mainly on the quantity and quality of feedstuffs (Aplocina and Spruzs, 2012). Milk composition is affected by several factors including the animals' feed, since it reflects not only their diet but also the local geographical, economical and climatic conditions (Voutzourakis et al., 2014). Egbowon (2004) highlighted that under-feeding reduces total milk production and milk components generally. There was variation in milk potential of Saanen, British Alpine and Toggenburg dairy goats does under extensive nutritional management. The Toggenburg and the British Alpine least expressed their genetic potential for milk production under extensive nutritional and management scheme. However, the milk yield from these temperate breeds under extensive management system was still much higher than the reported milk production of indigenous goats (Norris et al., 2011). This may be explained by the fact that milk production is largely affected by a combination of factors, namely, the use of improved breeds selected for milk production, a favorable nutritional environment and improved managerial practices (Devendra and Burns, 1970). The significant correlations between measurable goat milk content could be useful for selection of does for milk yield improvement strategies. The higher milk yields were observed in goats where Galega seeds and peas where added as complementary feedstuffs. Galega and peas are important protein-containing plants, in particular, are suitable for animal nutrition in organic farming, which is not allowed to use conventional feed resources (Aplocina and Spruzs, 2012).   One of the most important nutritional factors which determine milk production is energy intake especially in the intensive management systems, particularly in the early stages of lactation in goats (Flamant, et al., 1982; Morand-Fehr, et al., 1978) but also under extensive systems. Under semi-arid conditions in Mexico (Martinez-Parra, et al., 1981) and India (Shiarma, 1982) the milk yield of goats was positively related to energy intake. However, pre-partum energy levels did not influence the performance of Damascus goats in early lactation (Economides and Louca, 1981) when offered a high level of energy during lactation. However, the milk yield of high yielding dairy goats (Skjevdal, 1982) was improved by higher levels of energy intake in late pregnancy becuase of the building up of body reserves and their mobilization in early lactation to produce milk. Under such conditions a protein supplement is also necessary. Suspect that pregnancy nutrition in goats might only have a marginal effect on subsequent milk production when grazing on high quality pasture or high level of feeding in early lactation. It has been demonstrated that even in diets with concentrate levels above 60 – 70%, goats do not greatly alter their productive capacity or their metabolic well-being (Bailoni and Andrighetto, 1995; Economides, 1998; Goetsch et al., 2001; Fedele et al., 2002). However, for correct feed management in milking goats, it is desirable to estimate roughage to concentrate intake in order to optimize the utilization of feed supplements. Roughage to concentrate ratio of 30 to 70% favoured milk secretion rate the most, which was attributed to high level of concentrate which led to an increased feed and energy intake thereby increasing milk secretion (Shittu et al., 2011). Morand-Fehr et al. (1982) affirmed that the synthesis of goat milk largely depends on nutritional milk precursors present in the blood plasma and taken up by the udder. In addition an increased feeding level of 5% body weights of dry matter of fresh-cut P. purpureum was sufficient in meeting the nutrient requirements of the does hence, an increased milk secretion rate. Lactose content was found to be significantly lower in the dry season than wet season which might be due to poor nutrition during the season (Addass et al., 2013). This was in agreement with a report by Egbowon (2004), who highlighted that under feeding reduces total milk production and milk components generally. Lactose is the main determinant of milk volume and close relationship between lactose synthesis and the amount of water drawn into milk makes lactose a stable milk component (Pollot, 2004). Seasonal variation in feed resources influenced lactose content which was lower in the dry than wet season. This low value in the dry season may be linked to lower nutrition during the season. Milk components such as protein, lactose and solids nonfat content determine the value of the milk and milk composition depends largely on the volume of milk produced (Zygoyiannis, 1988). Non significant effect of season and parity on protein content of milk was due to steady nutrition and management practices under which the animals were subjected to throughout the period of study which might have suppressed the effect of season on protein content of the goats milk. It agrees with the discoveries of Hardwick, et al., (1961) who reported higher and lower proportion of milk components in well-fed and under-fed goats. Feed was an important source of variation in milk protein in Nguni and Boar goats (Mmbengwa et al., 2008). Type of feed influenced milk protein content in the Nguni goat does, with the intensive group having a higher milk protein content than the extensive group. The Boer goat does on the extensive feeding regime yielded higher milk protein content than the intensive group. The production of protein varied throughout the trial, with either one of the breeds exceeding the other at various stages. Goat milk production depends on level of intake and quality of feed, but milk fat content on the indirect effect of dilution, while protein content varies generally like milk production (Aplocina and Spruzs, 2012).

It was inferred by Mmbengwa et al., (2008) that the type of feed and breed had an influence on milk fat, with intensively managed Nguni goat does yielding more milk fat than the Boer goat does in an intensive nutritional system. In the extensive system, the Boer goat does produce more milk fat than the Nguni goat does, and an overall correlation coefficient (r) of 0.073 was observed between milk yield and milk fat. Working with Indigenous goats in Germany, Gall (1981) found that the overall values of the measured milk constituents, especially fat, were related to the milk yield of the goats. Flamant and Morand-Fehr (1982) observed that a high level of milk production is associated with a lower fat content of the milk. This was in agreement with report by Zygoyiannis and Katsaounis (1986) who found that the trend towards a lower milk fat content in goats with a higher total milk yield. This can be partly explained by a negative correlation between higher milk yield and fat content (Simos et al (1996). It was further indicated that the amount of milk fat could be related to both the genetic potential of the goats, and to the comparatively low milk yield associated with the nutritional environment (Gall 1981). Because fat is the main compound of cheese, several studies have focused on the effects of feeding and nutrition on milk fat content and deeply discusses feeding strategies aimed at increasing the levels of healthy fatty acids, such as conjugated linoleic acid and omega-3 FA, in milk and cheese in the human diet. Aplocina and Spruzs, (2012) observed that goat milk production and its fat content can rise when grass forage is at an early growth stage. When supply of concentrates in diets increases to 60% of total dry matter intake, fat content may decrease slowly and linearly, but if concentrate intake reaches 60–80%, fat content may decrease rapidly due to an increasing shortage of fibrosity in the ration. Palina and Rassu (1991) demostrated that the concetration of fat in the milk is correlated positively with the concetration of fiber in the diet. However, this relationship is difficult to interpret because a higher concentration of Neutral Detergent Fiber provokes a reduction in the digestibility of the diet and a reduction in feed intake which in turn results in reduction in milk production and consequent increase in milk fat concetration. Milk yield increases in dairy goats in a curvilinear manner with increasing amounts of dietary fat. When fat supply is low, the increase in milk yield is probably caused by a higher energy intake (Martínez et al., 2013). However, milk yield decreases when fat supply is high, which may be related to diminished energy availability for milk production due to negative effects on rumen digestion and/or dry matter intake. Teh et al., (1994) observed that fat supplementation at 3% of the total diet can increase fat percentage in milk from high producing dairy goats in early lactation. There was also a tendency of the rumen-inert fat increasing long-chain fatty acids and to reducing short-chain fatty acids of milk

The major carbohydrate in goat milk is lactose (Chandan et al 1992). Singh and Sengar (1990), observed that milk lactose content declined with a decrease in milk yield, as the lactation period progressed. This concurs with the findings by Mmbengwa, et al., (2008) studying Nguni and Boer goat breeds, which also showed a decline in milk lactose content as the lactation period progressed.

4. Conclusion

Dietary factors that affect milk fat and protein content and cheese yield have been reviewed previously, hence it is suffice to conclude that focusing on appropriate nutritional needs of dairy animals is the critical element in improving milk yield and quality of sheep and goats. This discussion points out the noticeable ability of the diet composition to modify the milk constituents in sheep and goat dairy production enterprisess. Plane of nutrition using different ingredients from cheap sources can improve the milk components as long as the diet is well-formulated to reach the desired milk nutritional goals. Interestingly, the fiber source and level can be important factors influencing the effect of different fat supplements on fatty acid profiles with positive effects on human health. It is suffice to note that when planning dairy goat improvement programs attention should be paid to such selection features that with improving of goat nutrition allow achieving of higher milk yield, milk fat and protein content of milk. Dairy goat and sheep genetic improvement can be done through within population selection programmes although this approach takes a long time to realise the results. Crossbreeding of indigenous animal genetic resources with high-performance foreign dairy goat and sheep breeds is also a possible dairy animal improvement strategy. This may be applicable for smallholder dairy farmers who have compromised management characterised by low inputs. However, the success of any dairy breeding program will depend on improvement in feeding regime to maximize milk genetic potential. Farmers need low-cost diets using locally available feeds that can provide sufficient milk of good quality. Locally available nonconventional feedstuffs can be integrated into balanced dairy animal nutritional requirement, decreasing feed costs especially of resource-poor dairy farmers, while enhancing total yields of milk and milk constituents without compromising milk quality components. This will greatly improve the profitability of dairy enterprise.

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