Sjournals
Scientific Journals
Scientific Journal of Biological Sciences (2015) 4(1) 1-9
ISSN 2322-1968
doi: 10.14196/sjbs.v4i1.1791

Contents lists available at Sjournals
Scientific Journal of
Biological Sciences
Journal homepage: www.Sjournals.com

Review article

Genotype influencing yield and milk composition in different dairy production systems

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ARTICLE INFO

Article history,
Received 06 January 2015
Accepted 26 January 2015
Available online 29 January 2015

Keywords,
Genotype
Yield
Composition
Dairy production

ABSTRACT

The milk yield and milk composition of dairy animals are influenced by a large number of factors. Generally, these factors are based on genetic and non-genetic differences between dairy animals. While the genetic potential of an animal is fixed at conception, non genetic factors such as nutrition, management, milking frequency, rearing methods, stage of lactation, etc. determine whether genetic potential is attained. Therefore, the maximum marketable milk yield with different fat and protein content is desirable to producers to increase farm profitability and can be affected by choice of appropriate genotype. The present discussion explores the consequences of choice of genotype in dairy production enterprises for the milk yield and composition. The discussion points to the fact that genotype affect either yield or milk composition during the entire lactation. However, across genotypes fat and protein yields are affected by both the quantity of milk produced and fat or protein percentages in the milk.

1. Introduction

Dairying provides one of the most cost effective methods of converting crude animal feed resources into high quality protein rich food for human consumption (Abaye et al., 1991; O' Conner, 1993; Gebre et al., 2000). However, yield and composition of milk is a function of several factors including genotype (Merin et al., 1988; Guney et al.,(1990; 1992). Variations in the contents of ewes' milk are due to the differences among races and breeds. These genetic variations affect the composition of milk and thus theccharacteristics of the dairy products. Additionally, some factors such as lactation, season, feeding, psychological state and health of the animal cause variations in theccomposition of milk either at macro or micro level (Haenlein, 1996). The composition of ewe and goat milks varies over a wide range because of genetic differences between species, between breeds within species and within breeds (Haenlein, 2002). Average genetic composition differences between species, ewe versus goat versus cow, and compared to human milk are considerable (Posati and Orr, 1976) in absolute and relative terms. Keskun, et al., (2004) cited one of the reason for the low goat's milk production was that the majority of the goat population (93.4%) in Turkey was composed of indigenous hair goats with low milk yields (70-150 kg/lactation) and short lactation periods (154 days). In Egypt, several authors have reported that genotype had significant effect on milk yield (Aboul-Naga et al., 1981; Mousa, 1991; Morsy, 2002; Hamdon, 1996, 2005). There was a negative correlation between milk yield and milk components, mainly total solids, protein and fat, and that the magnitude of this relation varies depending on the breed and the number of lactations (Anifantakis and Kandarakis, 1980; Calderon et al., 1984; Joubert, 1997). In some developing countries dairy goat improvement strategies have mainly been crossbreeding of indigenous goats with exotic dairy types, resulting in crossbred populations with varying levels of exotic genes (Bradford, 1981; Ruvuna et al., 1988; Das et al., 1996).

2. Cattle

Milk composition varies considerably among breeds of dairy cattle (Zinash et al., 1988; Chamberlain, 1990). Jersey and Guernsey breeds give milk with about 5% fat while the milk of shorthorns and Friesians contains about 3.5% fat , while Horro cows can give milk containing up to 7% fat O' Connor, (1994). The acceptable range of fat content of the milk in cattle is 2.5 to 7% (Rehrahie and Yohannes, 1999). The milk from Holstein cows (the source of the majority of milk for human consumption in Western societies) has about 3.2% protein, 3.4% fat and 4.6% of lactose (Akers, 2002). It must be emphasized that cow's milks have a wide composition range due to breeds, e.g. average Holstein milk fat at 3.4 percent versus average Jersey milk fat at 5.1 percent, and milk protein from 3.3 percent to 3.9 percent (Anifantakis, 1986), besides other breeds. However, there are variations in the milk composition due to breed and stage of lactation (Mepham, 1987). Boran (Ethiopian zebu breed) performance evaluation at Holetta Research Center showed high variability in milk yield and lactation length that ranged from 1 to 1800 kg and 3 to 300 days, respectively under hand milking condition (Gojjam et al 2002). The study suggested that the low milk yields and short lactation length observed under this condition might not reflect the true genetic potential of the animal. This is evident because the low yield reported under hand milking in their study was not sufficient to successfully foster growth of a calf to weaning age, whereas cows normally support their calves to this age under suckling condition.

3. Goat

Goats are important milk producers (Devendra & McLeroy, 1982), however, except for the Boer goat that has been subject to genetic selection, the genetic potential of tropical livestock for milk is generally low. Sacker and Trail (1966) reported higher milk yields in goats during the rainy season while Mittal et al (1977) reported significant seasonal effects in Barbari goats, but not in Jamnapari goats. It would be reasonable to suggest that there was genotype by environment interaction in milk performance in Barbari and Jamnapari goat breeds. There should be a continuation of the evaluation and description of the milk performance potential to cover the two genotypes in different zones of the country. It is also critical to select animals in the environment in which they will perform. In a study, assessing the milk potential of Saanen, British Alpine and Toggenburg dairy goats does under extensive nutritional management, it was observed that Saanen produced more milk (1.45 kg day-1) than the British Alpine and Toggenburg dairy goats breeds. Toggenburg produced the least amount of milk (0.56 kg). All breeds produced less than their reported production under improved management regimes. The Toggenburg and the British Alpine least expressed their genetic potential for milk production under extensive nutritional and management scheme (Norris et al., 2011). Banda et al., (1992) observed that the overall contents of total solids, fat, solid non fat, ash, protein, lactose and energy observed in local goats, Boer and their crosses in Malawi were much higher than those of other goat breeds, except those of the West African Dwarf and the pygmy goats, as summarised by Parkash and Jenness (1968) and Devendra and Burns (1983). Differences in dam genotypes in total and daily milk production were evident in their study. Levels attained by the local does were much higher than those reported for other tropical/subtropical breeds (Devendra and Bums, 1983). Examples of crosses for dairy production are the Alpine breeds a result from the German Alpine and Kenyan Alpine goat breeds (Kipserem et al., 2011). Generally, proper feeding would enhance production of the dairy goats and, consequently, better milk yields which can enable farmers to cater for their household needs as well as for the dairy enterprise. To produce adequate milk, a dairy goat requires a well-balanced diet for both self-maintenance and production of milk (Kamau et al., 2008). Smallholder dairy farming can complement the intensive dairy production enterprise and can operate a successful with proper breeding and feeding especially by use of supplements and concentrates, that can yield sufficient milk for household consumption as well as for enterprise. The breed was, however, surpassed by far by the Beetal and Jamnapari of India and the Damascus of Cyprus. The estimates of Boer goats are very much lower than those observed on the same breed elsewhere in Africa (Ueckermann et al, 1974). It was concluded that the breeding of both the Damascus and the crossbred should be encouraged in the Mediterranean region of Turkey in order to increase goat milk production since both breeds had higher milk yields than that of the Hair goat (Keskin et al., 2004). The highest mean milk carbohydrate content was produced by Saanen goats and the least carbohydrate content was observed in the British Alpine. No particular trend is observed in the carbohydrate content in relation to the amount of milk. This is contrary to the observed tendency of carbohydrate content to decline with a decrease in milk production (Singh and Sengar, 1990). Goats in Greece and Sardinia produce milk with higher level of total solids, fat and protein. Breeds like Alpine and Saanen produce milk with lower fat, protein and casein contents (Pal et al., 2010). Donkin and Boyazoglu (2000), indigenous goats produce about 23 kg per lactation lasting on average 94 days. In Nigeria, Akinsoyinu et al., (1977) observed that the mature goat's milk contained higher mean percentages of fat (6-9) and lactose (6-3) than any temperate breeds of goats and indigenous dairy cattle, but their protein (3-9%) and total ash (0-8%) contents were comparable with any temperate breeds of goats. The percentage protein, lactose, fat and total solids declined slightly with advance in lactation and there was a steady fall in milk yield. The crude composition of the protein fraction of milk from different species of mammals has been characterized, and among them, goat milk stands out due to the presence of compounds with important metabolic properties for human nutrition. Describing the three important aspect about the goat milk protein of two Brazilian goat breeders: absence of α-s1 casein in the protein profile, differences between the milk protein composition produced by goats of Alpine and Saanen breeders (Costa et al., 2014). Generally, the increase of milk production is associated with a decrease of the milk constituents (Henderson and Peaker, 1987; Barnes et al., 1990), however, total milk fat yield was higher b with inreased daily milkings. The goats, however, had to rely on natural resources while also rearing one or more kids during the lactation. The same author reported that Saanen goats produced more than 700 kg of milk over a lactation period of 288 days. Mba et al., (1977) working with West African dwarf (Fouta djallon), Red Sokoto (Maradi) and Saanen lactating goats, hand-milked in a period of 12 weeks observed that the milk of West African dwarf goats contained more of milk components than the milk of the Red Sokoto or Saanen goats. 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. However, in South Africa it was at that time already noted that while some dairy goats may actually produce a considerable amount of milk over a 24 hour period, the true proof of the value of a dairy goat is only shown over a lactation period of 300 days. The studies on dairy goats a relatively small number of records established that the average milk yield of registered dairy goats of all breeds was on average 954 kg over an average lactation period of 276 days. The fat concentration of the milk of these dairy goats was 3.45% (Hofmeyr, 1959;1962). Mburu et al., (2014) in a study on rearing Alphine dairy goats for smallholder production systems in Kenya, dairy goat average milk production was 1.90 litres per day, with the appendix grade in Kieni East giving the highest production of 2.69 liters per day while foundation grade in Mukurweini gave the lowest, 0.98 litres per day. The higher milk production in Kieni East, which is a semi arid area, was noted to be due to good feeding practices where 43% of the farmers used concentrates during milking and also 48% supplemented the feed with minerals. It was concluded that the low-input farming conditions affected the Alphine goats milk production.

This is a good example where the use of exotic dairy goats in breeding programmes for smallholder production systems has become popular, however information on the milk production traits is scarce. In characterization of milk yield of the Tswana goat of Botswana, Adogla-Bessa and Aganga (2000) concluded that Tswana goats have the potential to respond to increasing levels of energy intake by increasing milk yield to relatively high levels. Energy intake is an important consideration when characterizing milk yield, as it has been shown that energy intake accounts for 71% of the variation in milk yield observed in Matabele goats (Sibanda, 1992). The mean daily milk yields observed by Adogla-Bessa and Aganga (2000) were comparable with the results of Sibanda (1992) who reported yields of 0.66 kg/day for Matabele goats, but are higher than the figure of 0.3 kg/day reported for the Malawi goat (Banda et al., 1992). They are, however, lower than that reported for the Boer goat (1.5–2.5 kg/day; Casey & Van Niekerk, 1988). In a review, Paggot (1992) reported that 0.56 kg/day was typical of tropical goats. Responses measured in this trial indicate that given adequate feed, the milk yield of Tswana goat can surpass this average. The differences in milk yields were influenced by milking method, hand milking versus machine milking. The yield capacity of the Tswana goat could be higher, as Banda et al. (1992) and Ueckermann et al. (1974) found that estimates produced by hand milking were 36.5% less than those obtained by suckling and weighing or following injection of oxytocin.

4. Sheep

In Egypt, several authors have reported that genotype had significant effect on milk yield (Aboul-Naga et al., 1981; Mousa, 1991; Morsy, 2002; Hamdon, 1996, 2005). In United Staes in European and Middle Eastern breeds produced 200 to 550 kg, for instance Assaf (Gootwine and Goot, 1996), Lacaune (Barillet, 1995), and East Friesian (Sonn, 1979; Kervina et al., 1984), while an early limitation to the industry was the low milk production of domestic breeds (50 to 80 kg) (Sakul and Boylan, 1992). One of the local breeds in Turkey is the Awassi breed produce about 181-202 kg milk between their 170th and 200th days of lactation. If appropriate conditions are provided, this amount may increase to 380 kg. When 60 days of lamb feeding is eliminated from this period, it can be said that ewe milk can be collected during 99 days of lactation. Daily milk yield and total milk yield in Kermani fat tailed ewes during the suckling and post-weaning periods averaged 610 g and 62 kg, respectively (Kahtuei et al., 2008). Guirgis et al., (1980) and Reuiz et al., (2000) reported 167-287 kg milk yield/head within a lactation period of 84-183 days/year in Awassi sheep. Total milk yield was reported by Pollolt and Gootwine (2001) to be 506±161 kg within 214±49 days in an improved Awassi flock in Palestine under an intensive production system. The averages pertinent to the Awassi in Jordan, Turkey and Lebanon are respectively, 800-2000 g/day (Hailat, 2005), 94.7-218.8 kg (Gursoy, 2005) and 222 kg (Choueiri et al., 1966). Such differences in yield of Awassi ewes could be attributed to different feeding practices, condition of ewes and the degree of inbreeding likely to be present in the different flocks. Similar effects of breeding group on milk yield have been stated earlier by other workers (Mavrogenis, 1995; Izadifard and Zamiri, 1997). Mason (1967) reported that the Awassi sheep possess a high potential for milk production although the annual yield of ewes in unimproved flocks has been estimated at only 40 kg, to which about 20 kg taken by the lamb must be added. Afolayan et al., (2001) observed low milk yield in Yankasa ewes which was attributed to shorter lactation lengths (84 days). In general, the values of pre-weaning milk yield obtained from Yankasa ewes were quite low compared to other tropical breeds like Hamdani (Maroof et al., 1986); Karadi (Mohammed, 1982; Kuitaibani, 1981) and Awassi (Eliya and Juma, 1970; Karam et al., 1971). This might partly be due to differences in method of milk extraction by these authors. In some cases some studies used oxytocin injections prior to milking, others estimated milk yield using lamb weight differences before and after suckling. The use of hand milking herein without any prior stimulation might be inefficient for total evacuation of milk from the udder. Moreover, there was difficulty in extracting milk from Yankasa breed of sheep because of the small sized teat. The shapes of the lactation curves were similar but the mean milk intake of the Texel x Blackface lambs was substantially greater than that of the pure-bred lambs at all points on the lactation curve (Peart et al., 1975). Genotype of ewe had an effect on total and average daily milk yield and length of lactation. Chios ewes had the highest lactation (87.99 kg in 101.3 day) than Rahmani ewes (53.15 kg in 92.62 day) (Abd Allah et al., 2001). Genetic differences in milk composition within species have a wide range for ewe milk fat from 4.6 percent to 12.6 percent (Casoli et al., 1989) and an average of 7.1 percent (Anifantakis, 1986); for ewe milk protein from 4.8 to 7.2 percent and an average of 5.7 percent, depending on breed. Other components follow these rangesProtein content for Chios and Farafra milk differed significant and averaged 5.62 and 5.31%, respectively. Chios ewes had higher milk energy (4.59MJ/kg) than Farafra once milk energy (4.34 MJ/kg) (Hamdon et al., 2000). The performance differences in milk yield and composition in the two goat genotypes were attributed to inbreeding in Chios flock and nutritional regime used were not suitable. Moreover, the better performance of Farafra ewes could be due to more adaptation for Egyptian subtropical conditions than exotic breed. The higher milk energy of Chios ewes was due to their higher fat percent than Farafra ewes. Banda reported that milk constituents in sheep were lower than those reported for Middle Atlas of Morocco (Gatenby, 1986). The changes in the composition of sheep milk in their study were different from the results reported for dairy goats in the temperate areas (Parkash and Jenness, 1968). Juarez, (1986) observed that goat milk composition have great differences, depending on breed, e.g. for milk fat from 2.3 percent to 6.9 percent and an average of 3.3 percent; for goat milk protein from 2.2 percent to 5.1 percent and an average of 3.4 percent. A major portion of this variation includes negative correlations between milk yield and composition, i.e. low yields have higher contents and vice versa. There were few or no breed differences in milk yield and composition among Rambouillet, Columbia, Suffolk, and Polypay ewes. However, Suffolk ewes, which lost significantly more body weight during lactation than other ewes, were less adapted to the range production system investigated, especially when litter size was greater than one and nutrient availability was limited. The number of lambs nursing was a major factor influencing milk production (Snowder and Glimp, 1991).

5. Implications

From the discussion it is logical to assume that differences in milk yield and compositional values exist among species and breeds within the same species (cattle, sheep and goats). However, through charcterization an effort should be made to identify the milk potentiality of the local breeds of sheep and goats, inorder to improve all over milk production in different developing countries. Milk production is largely affected by a combination of factors, and use of improved breeds selected for milk production, a favorable nutritional environment and improved managerial practices are significant sources of variation on yield and composition of milk produced. It is important to note that improved breeds have been bred to suit intensive condition accompanied by high plane of nutrition. Therefore, anything short of a balanced diet will inhibited the breeds from expressing their genetic potential for milk production. It should be emphasized that although the milk production of improve dairy breeds (cattle, goat, sheep) may be lower than the expected production in extensive production systems, the yield definitely will still be much higher than the milk production of local breeds. Indigenous cattle, goats and sheep are known to be poor milkers, in this case crossbred may be beneficial for use by smallholder farmers. Crossbreeding of improved dairy animal genetic resources and local animal dairy species improves adaptability of the crossbreds hence providing reasonably adequate milk to the smallholder farmers thus improving livelihoods through reduction in malnutrition and increased income that may be accrued through sales of excess milk. Milk production from local genotypes in developing countries is very low and most of the time difficult to measure. In goats and sheep, lactations are short, and barely sufficient for their young ones' needs, in spite of the generous grazing during the rain season. In such a case crossbreeding of improved dairy with local genotypes might assist in producing much higher amounts of milk, and sustained milk production for longer lactation. However, local goats have shown very high levels of milk fat and protein, whereas pure bred dairy animals showed much lower levels. The milk composition of crossbred might be higher than some improved dairy breeds, but considerably lower than that of the local dairy animals. In summary, can suggest that crossbreeding is a viable strategy to improve milk production in developing countries. The yield of crossbred goats is nevertheless sufficient for subsistence or household purposes. The breed and genotype of animals can affect the quality and quantity of milk produced. Selection for dairy production has led to the creation of specialist dairy breeds that produce more milk than meat breeds. However there is a negative correlation between milk yield and milk composition hence animals that produce more milk usually have a lower concentration of milk fat and protein.

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