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ORIGINAL RESEARCH

Milk yield and composition of crossbred Sahelian × Anglo-Nubian goats in the semi-intensive system in Mali during the preweaning period

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Abstract The aim of this study was to evaluate milk yield and its composition during the preweaning period for Sahelian goats (SG) and Anglo-Nubian (AN) crossbred depending on some factors. The experiments were conducted from January to December 2008 for 44 suckled and hand-milked does, randomized, and divided into two equal groups: SG (n=22) and F_1 Anglo-Nubian × Sahelian goats (1/2AN; n=22). The does and their offsprings were kept in a pen where they stayed indoors for 45 days before they were allowed outdoors when the weather was suitable. Each category received supplemental feeds depending on the season (rainy season, dry cold season, and dry hot season). The average daily milk yield was recorded weekly from parturition to 100 days of age. Individual milk samples were taken for chemical analysis in connection with the yield measurements twice per month from the fourth week of lactation throughout the different seasons (rainy, cold dry, and hot dry). The daily milk yield differed between breed types (P=0.001) during the preweaning, while the effect of kids' sex on daily milk production was not significant. Litter size affected milk yield up to day 60 (P=0.032) where does with twins producing more milk than those with single kid. However, at day 100, both groups had similar (P=0.001) milk production. Total milk yield at weaning increased by 103 % in 1/2AN over SG. The highest concentration of total solids of milk was (12.76 %) recorded in the hot dry season. The results of this study indicate that crossbreeding native Sahelian goats with high potential Anglo-Nubian buck improved milk production and its composition.

Keywords Anglo-Nubian · Crossbreed · Milk yield · Milk composition · Sahelian goats

Abbreviations

SG	Sahelian goats
1/2AN	F_1 of AN × Sahelian goats
RS	Rainy season
DCS	Dry cool season
DHS	Dry hot season
DNPIA	Direction Nationale des Productions et Industries Animales
DNS	Direction Nationale des Statistiques
DNA	Direction Nationale de l'Agriculture

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Introduction

Livestock production constitutes the main source of income for more than 30 % of the population of Mali and represents the principal source of animal protein supply for its population. It contributes up to 10 % in gross domestic product in the country (DNPIA 2008). Goats are bred in extensive pastoral (nomadic grazing) and agropastoral system (sedentary grazing) in Mali. The stock is estimated at 13.1 million goats (DNPIA 2008). They provide mostly meat and produce milk all year round with a low yield (Sangaré and

Pandey 2000). Their milk is usually insufficient and rarely sold. In spite of this important stock, small ruminant husbandry has several constraints that are related to health, feeding, management, and genetics. Those factors call for a decreasing of milk yield which is estimated to be 627 g day^{-1} with 4 % fat during the first 12 weeks of lactation and 108 g day^{-1} at 26 weeks (Sangaré and Pandey 2000). Theoretically, milk consumption per capita was estimated to 10–30 l per year in Mali (Bonfoh 2005), and about 60 % of the dairy products consumed were imported (DNS 1999).

An improvement in the goat milk yield and composition of the local breeds can be made through improved management and crossbreeding with higher yielding local or exotic goats (Zahraddeen et al. 2007). Moreover, the milk production potential of local Sahelian goats in the semiarid zone can be improved through selective breeding or crossbreeding them with exotic Anglo-Nubian breed (Sanogo et al. 2010). A crossbreeding program is currently underway in Mali to improve milk production of native Sahelian goats by siring them with imported Anglo-Nubian bucks. The present study deals with some factors influencing milk production and chemical contents of native Sahelian does and their crossbred with Anglo-Nubian goats in the F_1 generation, which proved as a success in this improvement program.

Materials and methods

This research was carried out in the Regional Center of Agronomic Research at Samé in the region of Kayes, located between 14°29′ N and 11°34′ W. The average rainfall varies from 550 to 900 mm $year^{-1}$ (DNA 2007). The vegetation consists of thorny plants and shrubs. The average daily maximum temperature in the city is 35 °C, with temperatures usually peaking in April and May at an average of 46 °C. The seasonal characteristics of the area are rainy season (June–September), dry cold season (October–January), and dry hot season (February–May).

Animals and management system

This study was conducted on a herd of native Sahelian goats, crossbred with two Anglo-Nubian bucks, imported from England in 2004. It was in the framework of a cooperative research initiative between the Czech University of Life Sciences, Prague, Institute of Tropics and Subtropics (CULS Prague), and Institute of Rural Economy, Mali. Forty-four does were randomly located in two groups as follows: 22 Sahelian goats (SG) and 22 F_1 of AN × Sahelian goats (1/2AN) does. Calibrated beakers for milk measurement, feeders, and watering tanks were provided. Two cement shelters were built with large boxes for the does and a small one for the kids. Each box had a solid floor and an open yard of 10×6 m.

All the goats were kept in a semi-intensive system, grazing natural pasture from 9:00 to 11:00 a.m. and from 3:00 to 6:00 p.m. Besides rangeland grazing, the animals received additional feeds as supplements depending on the season, the age (animal category), and the physiological state of the animal. They received supplemental feeds as shown in Table 1 as determined by Nantoumé et al. (2011). Aliment Bétail Huicoma is a concentrate mixture of 2/3 cottonseed hulls and 1/3 cottonseed meal. The bush hay is natural that includes mainly a grameneous species *Shonefeldia gracilis* that is collected and stored for use during the dry season. This supplementation program takes into account the scarcity and the lower nutritive value of feed resources as related to the animal productions during the different seasons. Therefore, the effect of the season on milk production was no longer an issue because of the supplementation depending on the season that would have biased that effect.

Data collection

Data were collected from January to December 2008 for two types of breeds (SG and 1/2AN). The first evaluation of milk yield was done after 7 days after parturition, and then, weekly measurements were done after separating kids from the dams at night and then during the daytime along 100 days (at 30, 60, and 100 days) of lactation. The does were hand-milked twice a day (evening and following morning) for milk yield evaluation. Kids were double weighed before (P1) and after suckling (P2). The difference in weight P2−P1 gave the amount of milk consumed per kid, and then, the residual milk was milked and measured. The total of these two quantities of milk gave the production of milk in

Table 1 Quantities of feed supplements given per animal category (in grams per animal per day) depending on the age and the season

Categories	Rainy season	Cold dry season	Hot dry season
Young	0	100 g of aliment bétail Huicoma (ABH[a])	100 g of bush hay + 100 g of ABH[a]
Adulte	0	200 g of ABH[a]	200 g of bush hay + 200 g of ABH[a]
Lactating female	200 g of cottonseed meal	400 g of cottonseed meal	200 g of bush hay + 400 g cottonseed meal

[a] Mixture of 1/3 of cottonseed meal and 2/3 cottonseed hulls

the afternoon. The same method was used to evaluate milk production of the following morning. The daily milk production was monitored by adding these two partial yields (Nantoumé et al. 2005). The result of the first control was multiplied by the number of days between the birth and the first control. The results of two consecutive measurements (controls) were added and divided by two and multiplied the daily yield by the interval between two controls. At the end of lactation for each female, the last quantity was multiplied by seven. Milk sampling was carried out throughout the entire lactation period of each does twice per month. After each milking, samples of 30 ml of milk were taken, labeled by the animal number, and analyzed for fat, protein, solids-not-fat, density, and added water contents using the LactiCheck Analyzer (Model LC-01),[1] a compact, portable, and reliable machine.

Statistical analysis

The statistical analysis was done using the general linear model procedure in SAS software package (SAS 2002) for a completely randomized design, with the variable milk yield at 30, 60, and 100 days of lactation. The treatments were analyzed for their significance using one-way analysis of variance. Duncan's multiple range was used to compare the means of daily milk production and its composition of different types of does with a significance level of $P<0.05$. Two statistical models of fixed mains effects were used:

$$\text{Model I}: \quad Y_{ijk} = \mu + A_i + B_j + C_k + E_{ijk}$$

where Y_{ijk} represents the average of the daily milk production at various periods for ith genotype with jth litter size and kth sex of kids; μ=general mean; A_i=effect of the ith genotype (i=SG and 1/2AN); B_j=effect of jth litter size (j= single and twin), and C_k=effect of the kth sex (k=female and male); E_{ijk} is residual error term N. Similar model was used to evaluate the percentage of total solids, butterfat, and protein contents of milk depending on genotype, season of lactation, and litter size with interaction between season × breed type. It is expressed as follows:

$$\text{Model II}: Y_{ijk} = \mu + A_i + B_j + S_k + (A \times S)_{ik} + E_{ijk}$$

where Y_{ijk} represents the percent of total solids, butterfat, and protein of milk; μ, A_i, B_j, and E_{ijk} have the same meaning as in model I. S_k=the effect of kth season (k=rainy, dry cool, and dry hot seasons), and $(A \times S)_{ik}$=the interaction between genotype and season of lactation.

[1] Page & Pedersen International, Ltd, 158 West Main Street Hopkinton, MA, 01748, USA.

Results

Milk production

Daily milk yield at various ages of kids and total yield, depending upon particular factors, is presented in Table 2. Total milk yield at 100 days was 67.4 l in SG versus 137 l in 1/2AN, while the milk yield in 1/2AN was increased to 103 % above that of SG. Daily milk yields at birth were 0.3 and 0.7 l (P=0.001) for Sahelian goats and 1/2AN does, respectively. This tendency was maintained until 100 days with 0.6 and 0.8 l for SG and 1/2AN, respectively. Daily milk production was affected by genotype and litter size at various stages of lactation. Lactation curves of the SG and the crossbred 1/2AN are presented in Fig. 1.

Litter size affected milk yield up to day 60 (P= 0.032) where does with twins producing more milk than those with single kid. At the end of the experiment (day 100), daily milk yields were similar (P=0.001) and average daily milk yields were 0.5 and 0.6 l for does with single kid and those with twins (P=0.001), respectively. Average daily milk yields increased to 36 % for does with twins above those with single until day 60. Sex of kid had no influence either on daily milk yield or on total milk production during the experimental period (Table 2).

Milk composition

Total solids, butterfat, and protein contents depending on particular factors are presented in Table 3. Total solids and butterfat were increased (P=0.0014) by 12 and 22.6 % respectively, while the litter size was not affected (P=0.32). The season of year affected the composition of milk in total solids (P=0. 012), butterfat, and protein contents (P=0.001). The highest value of total solids was recorded in the hot dry season (Table 3). There was no significant difference for total solids content between the rainy season and the hot dry season, for butterfat contents between the cold dry season and the rainy season, while the protein content increased in favor of the rainy season. The interaction between the breed type and the rainy season affected (P=0.001) butterfat and protein contents (P=0.0014) that increased with SG in the rainy and the hot dry seasons, while no significant difference was found in butterfat percentage. Significant difference (P=0.021) was found in the overall mean of interaction between breed type and season for total solids. Cold dry season × breed type affected total solids and butterfat contents, but not the protein content. Hot dry season × breed had increased the difference between breeds in favor of the crossbred 1/2AN (Table 3).

Table 2 Daily milk yield at various ages of kids and total yield, depending upon particular factors

Factor	*N*	Daily milk production (liters)				Total yield (liter)
		Day 7	Day 30	Day 60	Day 100	
Genotype						
SG	22	0.3[b]	0.8[b]	0.7[b]	0.6[b]	67.4[b]
1/2AN	22	0.7[a]	1.9[a]	1.7[a]	0.8[a]	136.6[a]
P		0.001	0.001	0.001	0.001	0.001
SEM		0.05	0.06	0.06	0.08	0.06
Litter size						
Single	40	0.5[b]	1.4[b]	1.2[b]	0.7[a]	89.4[b]
Twins	4	0.6[a]	1.5[a]	1.3[a]	0.8[a]	114.6[a]
P		0.001	0.001	0.032	0.053	0.003
SEM		0.06	0.14	0.13	0.07	0.09
Sex						
Female	23	0.5	1.4	1.2	0.7	102.6
Male	21	0.5	1.3	1.2	0.7	101.4
P		0.057	0.061	0.052	0.086	0.062
SEM		0.04	0.09	0.03	0.02	0.05

Mean values within the same column with different superscript letters differ significantly at 0.05 level of probability

N number, *SG* Sahelian goat, *AN* Anglo-Nubian, *P* probability, *SEM* standard error mean

Discussion

Milk yield

Our results show that the crossbred animals surpassed the native Sahelian goats in term of daily milk yield from parturition to 100 days of lactation. That is probably due to the hybrid vigor of F_1 offspring, an additional improvement by the Anglo-Nubian sire. In the same region of Kayes, the local breed, the Sahelian goats, produced lower yields within shorter lactation periods. The length of the lactation fluctuated from 59 to 76 days and milk productions were 0.35 l on average after the kids have suckled and 0.60 l as total daily yield (Nantoumé et al. 2005). Most results are within the milk yield range (0.400–1.000 $lday^{-1}$) as stated by Malau-Aduli et al. (2003); Missohou et al. (2005) reported that the average daily milk production was 0.54 l for the duration of lactation from 3 to 6 months for Sahelian goats in Senegal. The total milk yield was higher than that found by Mumba et al. (2003) for indigenous Malawi goats and for Saanen crossbreeds because of hybrid vigor of crossbred and the proper employed management system to the native Sahelian goats. Our results obtained in this study are in accordance with those reported by Cissé et al. (2002) with higher level reached at week 3 for Sahelian goats in Senegal. Nianogo and Ilboudo (1992) reported an average from 0.47 to 0.735 l between 1st to 14th weeks for Sahelian goats, with a peak of production of 1.275 l/head/day^{-1}. The values of our study were higher than those reported by Montaldo et al. (1995), for local Mexican goats with high-grade and low-grade Alpine, Saanen, and Toggenburg. Contrary to this, litter size had no significant effect on total milk yield (El-Hassan El-Abid and Abu Nikhaila 2010). Average daily milk yields were greater for does with twins than those with single kid. The report was consistent with that published by Macciotta et al. (2005) and Montaldo et al. (1995), where goats with twins at parturition had higher milk yield than those with single kid. This large milk production of does was probably due to the large size of does bearing twins. In our study, doe with twins' recorded 36 % higher daily milk yield than those with single kid once at day 60. Sangaré and Pandey (2000) found that milk yield was affected by litter size. Milk production was 0.736 $lday^{-1}$ for does with twins versus 0.692 l for does with single kid during the first 12 weeks of lactation. Delgado-Pertíñez et al. (2009) in Payoya local dairy goats reported that the sex of

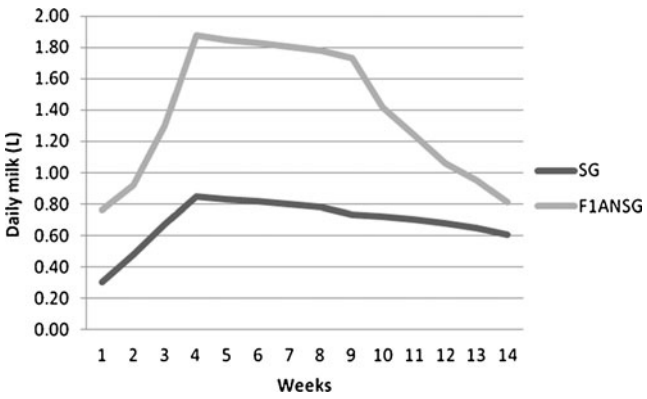

Fig. 1 Lactation curves of the SG and the crossbred F1ANSG

Table 3 Total solids, butterfat, and protein contents depending on particular factors

Factor	Total solids (%)	Butterfat (%)	Protein (%)
Genotype			
SG (n=22)	11.5[b]	4.7[b]	3.9[b]
1/2AN (n=22)	12.9[a]	5.8[a]	4.1[a]
P	0.001	0.001	0.0014
SEM	0.21	0.12	0.03
Season			
Rainy season	12.4[a]	48[b]	4.3[a]
Dry cool season	11.6[b]	5.1[b]	3.8[c]
Dry hot season	12.7[a]	5.9[a]	3.9[b]
P	0.012	0.001	0.001
SEM	0. 19	0.13	0.07
Litter size			
Single	12.2[a]	5.3[a]	3.9[a]
Twin	12.3[a]	5.2[a]	4.0[a]
P	0.61	0.68	0.32
SEM	0.14	0.06	0.04
Interaction season × genotype			
SG × RS	11.9[c]	4.8[c]	3.9[cb]
1/2AN × RS	12.9[b]	4.9[c]	4.6[a]
SG × DCS	11.1[d]	4.2[d]	3.8[cd]
1/2AN × DCS	12.1[c]	5.8[b]	3.7[d]
SG × DHS	11.7[c]	5.2[c]	3.8[cd]
1/2AN × DHS	13.7[a]	6.7[a]	4.0[b]
P	0.021	0.001	0.0014
SEM	0.12	0.07	0.04

Mean values within the same column with different superscript letters differ significantly at 0.05 level of probability

SG Sahelian goat, *n* number of animals, *AN* Anglo-Nubian, *P* probability, *SEM* standard error mean, *RS* rainy season, *DCS* dry cool season, *DHS* dry hot season

kids did not result in a significant influence on daily milk production during all period of the trial.

Milk composition

Goat milk composition studied in our experiment showed an increase of concentration of solids-not-fat, butterfat, and protein in the crossbred over the native SG. That was probably due to the hybrid vigor of F_1 offspring, gained from the high potential of Anglo-Nubian sire. Analogous levels were obtained in improved goats reported elsewhere by Morgan et al. (2003) who reported total solids of 11.6 % in goat milk in France; Berhane and Eik (2006) for Abergelle goats; and Prasad and Sengar (2002) in crossbred Barbari × Black Bengal. Salem et al. (2004) found that milk of crossbreds Damascus × Barky had better milk properties than the milk of the pure Barky breed, but lower than that of Damascus goats. Cooper (2001) found that milk composition and quality of crossbred Saanen × indigenous were higher than indigenous goat in Malawi. Total solid percentages were lower than those reported by Malau-Aduli et al. (2003) for the Red Sokoto and Sahelian, respectively, but similar to that found by Kouniba et al. (2007) for Alpine goat in Northern Morocco. Butterfat of Sahelian goats showed higher values than those found by Malau-Aduli et al. (2003) for the Red Sokoto and the Sahelian, respectively, in Nigeria and Mohamed et al. (2007) in Sudanese Nubian. Crossbred 1/2AN had lower butterfat than that reported by Stephen et al. (2004) for the Boer, but within the range of 3.34–5.26 % for Australian rangeland goats and for local goat of Morocco (Kouniba et al. 2007).

Protein content of Sahelian goats was similar to that reported by Carnicella et al. (2008) in Maltese goats in Italy. That of 1/2AN was comparable to the value of 4.16 % found by Berhane and Eik (2006) for Abergelle goats, while Mioč et al. (2008) mentioned that the content of protein was similar between breeds. The seasonal effect of total solids and protein found in our study was in agreement with the literature published by Kala and Prakash (1990) for Indian goats and Mohamed et al. (2007) for Sudanese Nubian. However, Zahraddeen et al. (2007) found no significant effect between dry and wet seasons for indigenous goats in Nigeria. The significant interaction between breed and season suggests that protein concentration may decrease during the cold dry season with a higher level in the rainy season. Litter size had no effect on the composition of milk and this finding is in accordance with the report of Carnicella et al. (2008) in Maltese goats. In contrast, Ćinkulov et al. (2006) reported that goats with more than one kid at parturition had higher milk, fat, and protein yield than goats with single kids in Italy.

Conclusion

The study has shown that the crossbred goats had better daily milk yield throughout the experiment, with 103 % over the native SG. It indicated also that 1/2AN surpassed the native Sahelian goats in term of concentration of major milk components with an increase of 1.57 and 0.24 for butterfat and protein contents, respectively. The chemical composition of milk varied significantly during seasons and with breeds. It is therefore suggested that a large improvement in the goat milk yield and composition of the local breeds can be made through improved management and crossbreeding with high potential Anglo-Nubian buck to improve the economic value of the local goats.

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