



Crossbreeding effects on milk yield and components of Saudi Aradi, Damascus goats and their crosses

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ABSTRACT

The objective of the study was to improve productivity of Aradi goat breed (A), for milk production traits through crossbreeding with the imported Damascus goats (D). Milk yield and composition were measured biweekly from kidding up to the 24th weeks of lactation. Direct additive genetic effects, direct heterosis, maternal heterosis, and direct recombination effects were determined. Crossbred goats showed improved milk yield and components compared to the local Aradi purebred. The estimates of direct heterosis expressed as percentages relative to parental purebreds showed a range of 3.1 to 6.9% for milk traits. Estimates of direct additive effects for milk traits were significantly higher in favour of Damascus goats by 31.7%. The estimates for milk components were mostly insignificantly in favour of Damascus goats for fat, SNF, protein, lactose and ash. Crossbred goats were associated with significant heterotic improvements for daily milk yield, fat, SNF, protein and ash.

Key words: Crossbreeding, Direct heterosis, Goats, Maternal heterosis, Milk traits

In the last two decades, new technologies in goats breeding were applied successfully to rapidly multiply the populations of elite breeds (Pawshé *et al.* 1994, Thibier 1996). Information on breeds of goats and, in particular, tropical dairy goats are poorly documented (Knights and Garcia 1997). Boer goats were used successfully to improve growth performance of indigenous breeds through crossbreeding (Waldron *et al.* 1997, Cameron *et al.* 2001). According to Dickerson (1992), direct effects of crossing reflect the difference between the crossed breed groups. In most cases, crossbred litters obtained from mating bucks of local breeds with does of exotic breeds were better than those obtained from the reverse mating (Yonghong 1999, Jiabi *et al.* 2003), i.e. mothering and milking abilities of exotic breeds are better than those of local breeds. Crossing between exotic breeds with each other generally exhibited heterotic effects on litter and lactational performance (Mugambi *et al.* 2007). This means that exotic breeds are higher in their non-additive genetic effects compared to local breeds. Therefore, the objective of this study is to examine the effect of improving milk productivity of the Saudi Aradi local goats through crossbreeding with Damascus goats.

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MATERIALS AND METHODS

Aradi goats (240) were randomly divided into 2 groups (A_1 and A_2) of 120 does each. The first group of Aradi does (A_1) was inseminated artificially from semen of elite bucks of the same breed (A_1) to develop local dairy line through selection for milk production, while the second was inseminated with semen of Damascus breed (D_1) to produce first crossbred goats. In the same time, does of Damascus breed (120) were inseminated from bucks of the same breed to produce purebred litters and progenies. Crossbred does of $\frac{1}{2}D\frac{1}{2}A$ were backcrossed with Damascus bucks to get the genetic group of $\frac{3}{4}D\frac{1}{4}A$. Accordingly, the breeding plan permitted produce of 4 genetic groups of AA, DD, $\frac{1}{2}D\frac{1}{2}A$, and $\frac{3}{4}D\frac{1}{4}A$.

Management and feeding: All does were housed in a semi-shaded/open front barn and ear-tagged. Goats were fed on a commercial concentrate and alfalfa hay. The amount of concentrate and hay were calculated according to the nutritional requirements for goats dependent on animal ages and production status. Water, straw, salt and minerals supplemented in blocks were given *ad lib.* to all animals.

Milk yield and composition: After kidding, the milk yield of an individual doe was recorded every 2 weeks. At the same time, 50–100 ml milk samples from each doe were taken and preserved with sodium azide (0.1 mg/100 ml) and kept at 4°C until analysis for fat, solids not fat, protein, lactose

and ash, ultrasonic milk analyzer, calibrated for goat milk.

Models of statistical and genetic analysis: All pooled data (collected from 2006 through 2011) were statistically analyzed using the general linear model procedures of the analysis Systems with a subsequent Duncan test to compare mean values, Comparison between two mean values was done by independent sample T test. Variances calculated by SAS program applying REML procedure (SAS 1999) were used as starting values in the analyses of single-trait animal model.

Data of milk yield and milk composition were analysed applying MTDFREML of single-trait animal model (Boldman *et al.* 1995). The single-trait animal model in the matrix notation is:

$$y = Xb + Z_a u_a + e$$

Where y, vector of observed trait for does; b, vector of fixed effects (genetic group; year-season, litter size, stage of lactation); u_a , vector of random effect of the doe; X and Z_a are the incidence matrices relating records to the fixed effects and additive genetic effects, respectively; e, vector of random error.

Genetic model and estimation of crossbreeding effects: The procedure of generalized least squares (GLS), using CBE program of Wolf (1996), is used to estimate crossbreeding effects. Dickerson's model (1973) was used in the program as summarized by Dickerson (1992) and Wolf *et al.* (1995). The linear model used was:

$$y = Xb + e, \text{Var}(y) = V$$

where y, vector of genetic groups means; X, incidence matrix of the coefficients for crossbreeding effects; b, vector of crossbreeding genetic parameters; e, vector of residual effects; V, full covariance matrix of y.

The coefficients relating genetic crossbreeding parameters to the means of the genetic groups are shown in Table 2 (Wolf *et al.* 1995). The maternal additive effects showed a high collinearity with the direct additive effects because the reciprocal cross was not carried out, and the corresponding errors were expected to be highly correlated. For this reason the maternal additive effects were excluded from the model and the estimates of the direct additive effects must be interpreted as a balance between direct and maternal additive effects. The crossbreeding parameters of direct additive effects and

direct and maternal heterosis were estimated using the CBE program of Wolf (1996). The parameters estimated are representing differences between the lines in terms of direct additive genetic effects ($G^I = G_A^I - G_D^I$), direct heterosis (H^I), and maternal heterosis (H^M). Thus, we have three parameters to be estimated (a vector called b-vector):

$$b = \begin{bmatrix} (G_A^I - G_D^I) & H^I & H^M \end{bmatrix}$$

The estimates of b were calculated by the method of generalized least squares (GLS) using the following equation:

$$\hat{b} = (X' V^{-1} X)^{-1} X' V^{-1} y$$

RESULTS AND DISCUSSION

Comparisons between crossbreeding and genetic groups: The results of ANOVA showed that stage of lactation had a highly significant effect on milk yield and its fat content (Table 2). Crossbred litters of $\frac{1}{2}D\frac{1}{2}A$ and $\frac{3}{4}D\frac{1}{4}A$ had increased milk yield traits compared to Aradi purebred litters (Table 2). Increases of crossbred milk litters components were also significantly high compared to Aradi purebred litters.

Direct additive genetic effects: Estimates of direct additive effects for milk traits are presented in Table 3. The estimates of direct additive effects for milk yield were significantly high in favour of Damascus goats by 31.7% (0.326 kg). The estimates for milk components were also significantly in favour of Damascus goats for fat (4.3%), solids not fat (1.7), and protein (3.4).

The improvements in milk production traits for $\frac{1}{2}D\frac{1}{2}A$ and $\frac{3}{4}D\frac{1}{4}A$ crossbred goats were expected and could be useful in crossbred litters intended for commercial scale of production. Outcome of Saudi Aradi goats relative to Damascus and their $\frac{1}{2}D\frac{1}{2}A$ and $\frac{3}{4}D\frac{1}{4}A$ crosses for different milk yield (kg) and their components indicates that involving Damascus genes in crossbreeding program with local goats in hot climate country resulted in an increase in milk traits. The Damascus breed is recognized as the best representative of Arabian and tropical milk goats (Devendra 1988). In Saudi Arabia, Dosari *et al.* (1996) reported that Aradi goats yielded more milk (160.3±6.37 kg/lactation) than other indigenous

Table 1. Genetic groups of kids with their sires and dams and coefficients of the matrix relating genetic group means of kids with crossbreeding parameters

Genetic group					Coefficients of the matrix				
	Kid	Sire	Dam	Grand-dam	Mean	D_A	D_D	H^I	H^M
AA	A	A			1	1	0	0	0
DD	D	D			1	0	1	0	0
$\frac{1}{2}D\frac{1}{2}A$	D	A			1	.5	.5	1	0
$\frac{3}{4}D\frac{1}{4}A$	D	$\frac{1}{2}D\frac{1}{2}A$		A	1	.5	.5	.5	1
									0.25

D_A and D_D , Direct additive genetic effects for the Aradi breed and the Damascus breed, respectively; H^I , direct heterosis; H^M , maternal heterosis; R^I , direct recombination genetic loss.

Table 2. Least-square means of genetic groups and tests of significance for milk traits in Jouf and Qassim

Location	Milk trait	Aradi (A)	Damascus (D)	$\frac{1}{2}D\frac{1}{2}A$	$\frac{3}{4}D\frac{1}{4}A$	Significance			
						Genetic group	Year-season	Litter size	Stage of lactation
Jouf	Milk yield (kg)	0.86±0.03	1.19±0.03	1.09±0.03	1.11±0.05	***	***	***	***
	Fat (%)	4.06±0.09	4.24±0.09	4.17±0.11	4.28±0.14	***	***	***	***
	SNF (%)	8.28±0.06	8.31±0.06	8.59±0.06	8.64±0.08	***	***	***	***
	Protein (%)	3.84±0.03	3.92±0.03	3.74±0.04	3.99±0.05	***	***	***	***
	Lactose (%)	4.06±0.03	4.09±0.03	4.06±0.02	4.31±0.04	***	***	NS	***
	Ash (%)	0.72±0.01	0.73±0.01	0.75±0.01	0.76±0.01	***	***	***	***
Qassim	Milk yield (kg)	0.66±0.05	0.89±0.06	0.83±0.06		***	***	***	***
	Fat (%)	3.38±0.25	3.44±0.28	3.26±0.24		*	*	NS	***
	SNF (%)	7.93±0.21	8.21±0.24	8.37±0.22		*	*	NS	NS
	Protein (%)	3.36±0.09	3.48±0.14	3.58±0.15		*	*	NS	NS
	Lactose (%)	4.18±0.13	4.25±0.14	4.49±0.17		*	*	NS	NS
	Ash (%)	0.67±0.03	0.68±0.04	0.78±0.04		*	*	NS	NS

NS, Nonsignificant; * P<0.05; ***P<0.001.

Table 3. Estimates of direct additive effects, direct heterosis and their standard errors ($H^I \pm SE$ and $D^I \pm SE$, respectively)) for milk yields (g) and components (g/100g) in Jouf and Qassim

Milk trait	Jouf herd $D^I = (D^I_D - D^I_A)$				Qassim herd $D^I = (D^I_D - D^I_A)$			
	Estimate±SE	$D^I\%^+$	Estimate±SE	$H^I\%^+$	Estimate±SE	$D^I\%^+$	Estimate±SE	$H^I\%^+$
Milk yield (kg)	0.326±0.072**	31.7	0.071±0.05*	6.9	0.237±0.065**	30.4	0.052±0.08*	6.7
Fat (%)	0.18±0.028*	4.3	0.12±0.04*	4.1	0.06±0.018	1.7	0.15±0.035*	4.3
SNF (%)	0.03±0.086	0.3	0.295±0.13*	3.5	0.28±0.082*	3.4	0.21±0.041*	3.2
Protein (%)	0.08±0.048	2.0	0.14±0.004*	3.6	0.12±0.052*	3.5	0.14±0.185*	3.1
Lactose (%)	0.03±0.062	0.7	-0.015±0.001	-0.3	0.07±0.068	1.6	0.075±0.226	1.7
Ash (%)	0.01±0.018	1.3	0.025±0.001*	3.4	0.01±0.12	1.4	0.015±0.003*	3.7

⁺ $D^I\%$, $[D^I \text{ in units} / (\text{average of purebreds})] \times 100$. ⁺ $H^I\%$, $[H^I \text{ in units} / (\text{average of purebreds})] \times 100$. NS, nonsignificant; *P<0.05; **P<0.01.

breeds. In Egypt, Abdelsalam *et al.* (2004) and Saber (2005) reported that milk yield increased in crossbreds as the blood of Damascus breed increased and the crossbred does produce more milk than the local goat breed Barki (B). Saber (2005) reported that the milk production of the crossbred does exceeded that of the local breed by about 39.07% for ($\frac{1}{2}D.\frac{1}{2}B$) genotype, 41.27% in ($\frac{3}{4}D.\frac{1}{4}B$), 43.72% in ($\frac{1}{4}D.\frac{3}{4}B$) and 22.01% in backcross ($\frac{3}{4}B.\frac{1}{4}D$).

Direct heterosis: Estimates of direct heterosis effect for milk traits are presented in Table 3. The crossbred genotypes showed significant increase in daily milk yield by 71 g. There were also significant increase in fat, SNF, protein, and ash by 0.12, 0.30, 0.14, and 0.025%, respectively. Estimates of direct heterosis expressed as percentages relative to the parental purebreds have shown moderate improvements in milk traits and ranged from 3.4 to 6.9%. The present results of direct heterosis indicate that crossbred genotypes were associated with relatively favorable heterotic effects on milk yield and milk components. In India, Sahni and Chawla (1982) reported that crosses between Beetal goats and Saanen and Alpine goats resulted in 65 to 130% increase in milk

production over the pure Beetal. Also they reported 75 to 145% increases in milk production from crosses involving the Barbari/Alpine and Barbari/Saanen. Jan and Gupta (1992) reported higher annual lactation yields in Alpine/Nubian $\times$ Beetal crossbred does than in purebred Alpine, Nubian and Beetal.

Maternal heterosis (H^M): Estimates for maternal heterosis

Table 4. Estimates of maternal heterosis and their standard errors ($H^M \pm SE$) for milk traits

Milk trait	Maternal heterosis	
	Units±SE	$H^M\%^+$
Milk yield, kg	0.082±0.046 **	7.9
Fat (%)	0.13±0.154	3.1
SNF (%)	0.35±0.102*	4.1
Protein (%)	0.11±0.332	2.8
Lactose (%)	0.23±0.104*	5.7
Ash (%)	0.03±0.016*	4.8

⁺ $H^M\%$, $[H^M \text{ in units} / (\text{average of purebreds})] \times 100$. *P<0.05; **P<0.01.

Table 5. Estimates of direct recombination losses (R^1) and their standard errors (SE) for milk yields (g) and components (g/100g) Jouf and Qassim

Milk trait	Direct recombination losses in units $\pm$ SE	
	Jouf Farm	Qassim Farm
Milk yield (kg)	$-0.68 \pm 0.24^*$	$-0.48 \pm 0.18^*$
Fat (%)	-0.04 ± 0.12^{NS}	-0.04 ± 0.13^{NS}
SNF (%)	-0.05 ± 0.64^{NS}	-0.03 ± 0.52^{NS}
Protein (%)	-0.06 ± 0.74^{NS}	-0.06 ± 0.74^{NS}
Lactose (%)	-0.04 ± 0.28^{NS}	-0.03 ± 0.21^{NS}
Ash (%)	-0.07 ± 0.21^{NS}	-0.08 ± 0.14^{NS}

NS, Nonsignificant; *, $P < 0.05$.

are shown in Table 4. There were significant increases in milk yield, SNF, lactose and ash by 82 g, 0.35%, 0.23%, and 0.03%, respectively, compared to the original Aradi flock results. The estimates expressed as percentages for mid-parents have shown a range of 2.8 to 7.9%. However, the estimates in most cases significantly indicated that crossbred dams had considerable maternal heterotic effects in terms of milk production and components.

Direct recombination effects: Comparing estimates of direct recombination losses with direct heterosis in this work showed that estimates of direct heterosis for the majority of the studied traits were generally higher than the estimates of direct recombination effects.

Estimates of direct recombination losses in heterosis obtained by crossbred does for milk yield were significant, while the estimates for all milk components were insignificant (Table 5). Moreover, these estimates of direct recombination effects were mostly inconsistent compared to those estimates of direct heterosis. Insignificant recombination effects for milk traits were found in the present study which shed light on the option of crossbreeding which is probably the most suitable method for introducing milk production potential to the local goat breeds.

It can be concluded that crossbred dams had considerable maternal heterotic improvements in milk production and components. The favourable estimates of direct and maternal heterosis would be an encouraging factor for the goat producers in tropical and sub-tropical countries to use crossbred does on commercial scale. Results of recombination effects for milk traits leads to the conclusion that crossbred does resulting from crossing Damascus with native breeds of goats in the tropics and sub-tropics could be effective to develop a maternal line characterized by high milk production associated with rich components and consequently, high productivity in does could be attained. Finally, there is a potential advantage to use crossbred dams and sires with Damascus genes to develop parental lines (maternal and paternal) having more available heterosis to be used in crossbreeding stratification systems in Saudi Arabia and other hot Arabian countries.

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