Philipp J Vet Anim Sci 2018 44 (2): 139-150

GENETIC AND PHENOTYPIC TRENDS IN MILK PRODUCTION TRAITS OF ANGLO NUBIAN GOATS FROM SELECTED FARMS IN THE PHILIPPINES

Orville L. Bondoc[1], Neal A. Del Rosario[2], Leny Lyn G. Manalili[2] and Emilio M. Cruz[2]

ABSTRACT

Using 570 lactation records from 172 Anglo Nubian goats produced from 21 sires and 161 dams and kidding from 2000 to 2016, heritability estimates based on dam-daughter regression were 0.52 ±0.22, 0.71 ±0.22, and 0.29 ±0.22 for total milk yield (TMY), daily milk yield (DMY), and number of lactations or parity (NLact), respectively. Heritability estimates for lactation length (LL), age at first kidding (AFK) and kidding interval (KI) were close to zero or had large standard errors. Repeatability estimates were 0.46 ±0.04 and 0.47 ±0.04 for TMY and DMY, respectively. Significant genetic correlations (P<0.01) were found between TMY and LL (r=0.72), TMY and DMY (r=0.95), TMY and NLact (r=0.97), and DMY and NLact (r=0.90). Significant phenotypic correlations (P<0.01) were found between TMY and LL (r=0.59), TMY and DMY (r=0.80), TMY and NLact (r=0.51), TMY and AFK (r=-0.36), DMY and NLact (r=0.61), DMY and AFK (r=-0.39), and NLact and AFK (r=-0.33). Comparison of genetic (doe's estimated transmitting ability) and phenotypic trends from 1996 to 2012 showed environmental effects (doe's year and month of birth and/or parity) comprising 52.56%, 75.83%, 13.77% and 52.13% of the average phenotypic values for TMY, LL, DMY and NLact, respectively.

Keywords: Anglo Nubian goats, heritability, correlations, genetic and phenotypic trends, milk production traits, repeatability

INTRODUCTION

The national goat inventory in the Philippines in 2016 is about 3.71 million head worth 8.93 billion pesos. Local goat meat production increased from 54,258 mt in 2012 to 56,705 mt in 2015. However, the annual per capita consumption of chevon from 2012 to 2015 remained unchanged at 0.42 kg (Philippine Statistics Authority, 2017). In particular, the dairy-type goat inventory in 2016 is only 2,118 head, compared to 24,512 dairy cattle and 17,802 dairy buffaloes. In the same year, local goat milk production was 335,840 liters (equivalent to 1.44% of the total milk produced in the Philippines) from 1,697 does in the milking line (Philippine Statistics Authority, 2016).

[1]Animal Breeding Division, Institute of Animal Science, College of Agriculture and Food Science, University of the Philippines Los Baños, College, Laguna 4031 Philippines , [2]Small Ruminant Center, Central Luzon State University, Muñoz, Nueva Ecija 3119 Philippines (e-mail: orville_bondoc@yahoo.com).

With there is a growing interest on local goat milk production, efficient dairy goat selection programs need to be developed and this will require estimation of genetic parameters. However, studies on genetic parameter estimation of economically important traits in dairy goats in the Philippines are lacking if at all available, and mostly focused, as in the case of developing countries in the tropics, on milk yield, usually with low sample sizes and data from very few herds (e.g., Ribeiro *et al*., 1998; Gonçalves *et al*., 2002; Valencia *et al*., 2007). In the Philippines, there is no organized performance or progeny testing in central stations or commercial herds (Bondoc, 2008), with small breeding populations possibly affected detrimentally by inbreeding.

This is the first study in the Philippines with the aim to estimate heritability, as well as genetic and phenotypic correlations and measure phenotypic and genetic trends for total milk yield, lactation length, daily milk yield, number of lactations, age at first kidding and kidding interval in a local purebred Anglo Nubian population. Data used were part of a National Dairy Goat Science and Technology (NDGST) research program with the aim of determining genetic parameters using local animal performance data sets and their subsequent use in the accurate and unbiased prediction of genetic values, direct and correlated selection responses, and development of economic multi-trait selection indices for dairy goats.

MATERIALS AND METHODS

This study used 570 lactation records of Anglo Nubian goats mainly provided by the Mindanao Baptist Rural Life Center located in Bansalan, Davao Del Sur (approx. 06°47′N 125°12′E, 157 mASL) and three other goat farms (i.e. Naga City Goat Farm in San Felipe, Naga City, Camarines Sur (approx. 13°38′N 123°12′E, 12 mASL), SRC Institutional Herd and SRC Experimental Herd in Muñoz, Nueva Ecija (approx. 15°44′N 120°55′E, 78 mASL).

Using the Köppen-Geiger climate classification system based on the empirical relationship between climate and vegetation (Peel *et al*., 2007), all goat farms in the study belong to tropical (megathermal) climate group A, i.e. average temperature of 18°C or higher, with significant precipitation in every month of the year. In particular, the average annual temperature and annual rainfall in Bansalan, Davao del Sur; Naga City, Camarines Sur; and Muñoz, Nueva Ecija were 26.7°C, 27.0°C, 26.9°C and 1842 mm, 2516 mm, and 1866 mm, respectively (Climate-Data.org, 2017).

Goats in all farms were maintained in a similar intensive production system. Other breeds raised in goat farms included Alpine, La Mancha, Saanen, Toggenberg and their crosses, albeit in small numbers. Does and bucks were raised in separate pens and hand mated throughout the year. Milk production was recorded starting at 5 days after birth when kids are separated from their dam until does have dried off. Daily milk collection was done twice a day at 6-8 a.m. and 4-6 p.m. Total milk yield (kg) is the sum of the yields throughout the entire lactation period. Daily milk yield (kg/day) was computed as total milk yield divided by the lactation length (days). Goats were fed with roughage, commercial concentrate and supplemented with vitamins and minerals all year round. Cultivated forages comprised primarily of Napier (*Pennisetum purpureum*) and para grass (*Brachiaria mutica*) and leguminous species such as sickle bush or kalahari Christmas tree" (*Dichrostachys cinerea*), "ipil-ipil" (*Leucaena leucocephala*), "kakawate" or "madre de cacao" (*Gliricidia sepium*) and "balabalatong" (*Indigofera zollingeriana*) and utilized under cut and carry system.

Pooled data from the four farms consisted of 570 total milk yield (TMY), 562 lactation length (LL), 562 daily milk yield (DMY), 110 age at first kidding (AFK) and 83 kidding interval (KI) from 172 Anglo Nubian does born between 1996 and 2012. Individual dairy goat performance was recorded from 2000 to 2016, although no lactation record was found for 2010. The average number of lactations (parity) per doe was 3.28 ± 2.23.

Simple descriptive statistics were determined for TMY, LL, DMY, NLact, AFK, and KI of the Anglo Nubian breed using the MEANS procedure of SAS (2009), see Table 1. The general least squares procedures for unbalanced data were used to examine the principal sources of variation affecting each trait (single trait analysis). The following linear "fixed effects" model was used to determine, using an F-test, the appropriate model that would best describe TMY, LL, DMY, AFK and KI as the dependent variables:

$$\mathbf{y_{ijkl} = \mu + BYear_i + BMonth_j + \beta_k NLact_k + e_{ijkl}}$$

where
- $\mathbf{y_{ijkl}}$ is the dependent variable,
- $\boldsymbol{\mu}$ is the overall mean,
- $\mathbf{BYear_i}$ is the i^{th} year when the doe was born (i.e. 1996 to 2012),
- $\mathbf{BMonth_j}$ is the j^{th} month when the doe was born (i.e. January to December),
- $\boldsymbol{\beta_k}$ is the regression coefficient for $NLact_k$ which is the random covariate effect of k^{th} number of lactations (or parity), and
- $\mathbf{e_{ijkl}}$ is the error term assumed to be normally distributed with variance of errors as constant across observations.

Only those significant (P<0.05) fixed effects of the doe's year and month of birth and/or covariate effect of the number of lactations (or parity) were included in the final linear models. The list of linear models, regression coefficient (no intercept model), and their coefficients of variation (CV) are presented in Table 2.

Heritability was computed using dam-daughter regression (Becker, 1984) using the statistical model:

$$\mathbf{Z_i = ßX_i + e_i}$$

where
- $\mathbf{Z_i}$ is the observation on the daughter of the i^{th} dam,
- $\mathbf{X_i}$ is the observation on the i^{th} dam,
- **ß** is the regression of Z on X, and
- $\mathbf{e_i}$ is i^{th} error term associated with the Z's.

Table 1. Simple descriptive statistics for various milk traits in Anglo Nubian goats from the Philippines.

Trait	N	Mean	SD	Minimum	Maximum
Total milk yield (TMY), kg	172	259.88	129.11	28.80	790.85
Lactation length (LL), days	167	191.54	64.58	87.00	539.00
Daily milk yield (DMY), kg/day	167	1.38	0.49	0.24	2.96
No. of lactations (NLact)	172	3.28	2.23	1.00	10.00
Age at first kidding (AFK), days	110	624.55	188.78	395.00	1648.00
Kidding interval (KI), days	83	343.04	108.30	165.00	883.00

Table 2. Mean square F tests for the fixed effects of year and month of birth and number of lactations (parity) on various milk traits of Anglo Nubian goats from the Philippines.

Trait	Year of birth	Month of birth	No. of lactations (NLact)	Regression coefficient for NLact	CV (%)
Total milk yield (TMY)	**	*	ns	0.20 ± 5.02	32.77
Lactation length (LL)	ns	ns	**	-10.76 ± 3.66	32.24
Daily milk yield (DMY)	**	ns	*	0.044 ± 0.02	24.66
Age at first kidding (AFK)	**	ns	**	-21.76 ± 7.14	16.95
Kidding interval (KI)	ns	ns	ns	-14.26 ± 10.36	20.65

ns - no significant differences (P>0.05)
* - significant differences (P<0.05)
**- highly significant differences (P<0.01)

Heritability is: $h^2 = 2\ cov_{XZ} = 2b_{ZX}$ The standard error of the heritability estimate is approximately equal to: S.E. $(h^2) \approx 2$ / sqrt (N), where N is the number of paired observations. Repeatability (rpt) was calculated for TMY, LL, DMY and KI among Anglo Nubian does using the statistical model with unequal numbers of measurements (Becker, 1984):

$$\mathbf{y_{km} = \mu + \alpha_k + e_{km}}$$

where μ is the common mean;
α_k is the effect of k^{th} doe and
e_{km} is the environmental deviation of m^{th} measurement within a doe.

All effects are random, normal, and independent with expectations equal to zero. Repeatability was computed as: $rpt = \sigma^2_W / (\sigma^2_W + \sigma^2_E)$, where $\sigma^2_W = (MS_W - MS_E) / k_1$ and $\sigma^2_E = MS_E$. The MS_W is mean squares between does, while MS_E is mean squares between measurements, within does representing differences among measurements within the does. Also, $k_1 = (1/ (N-1))\ (m. - (\Sigma m^2_k/m.)$, where m. is total number of measurements. The standard error of rpt is:

$$\mathbf{S.E.(rpt) \approx sqrt\ \{(2(m.-1)(1-rpt)^2\ [1+(k_1-1)rpt]^2)/(k^2_1\ (m.-N)(N-1)\}.}$$

Pearson product-moment correlation coefficients were computed to estimate phenotypic correlations among milk records of Anglo Nubian does using the CORR procedure of SAS (2009). Genetic correlations (r_G) were estimated based on parent (X) - offspring (Z) correlations using the arithmetic method (Becker, 1984), i.e.

$$\mathbf{r_G = (cov_{X1\cdot Z1} + cov_{X2\cdot Z1}) / (2\ (sqrt\ ((cov_{X1\cdot Z1})(cov_{X2\cdot Z2})))}$$

where $cov_{X1\cdot Z2}$ covariance of trait 1 in dam and trait 2 in daughter,
$cov_{X2\cdot Z1}$ covariance of trait 2 in dam and trait 1 in daughter,
$cov_{X1\cdot Z1}$ covariance of trait 1 in dam and trait 1 in daughter, and
$cov_{X2\cdot Z2}$ covariance of trait 2 in dam and trait 2 in daughter.

Individual estimated transmitting abilities (ETAs) and their corresponding accuracy values (r_{TI}) were computed using the formulas below (modified from Van Vleck, 1988):

Doe ETA = $b_1p_1 + b_2p_2 + b_3p_3$

where **b_1** $nh^2 / [1 + (n-1) r]$,
b_2 $n / [n + (4-h^2) / h^2] p_2$, and
b_3 $n / [n + (4-h^2) / h^2] p_3$

Accuracy (r_{TI}) = sqrt {$(nh^2 / [1 + (n-1) r]) + a_{1\alpha} n / [n + (4-h^2) / h^2] + a_{2\alpha} n / [n + (4-h^2) / h^2]$

where **p_1, p_2** and **p_3** are least square means of own record, average of daughter records of each dam and each sire adjusted for significant factors included in the final model for each trait, respectively;
h^2 and r are computed heritability and repeatability estimates of the milk record, respectively; and
n is number of daughter records.

The doe ETA is used to compare producing abilities of does for future lactation and to predict which does should produce the best replacements.

Genetic and phenotypic trends were determined by plotting the average doe ETA (genetic) and doe's own phenotypic value by year of birth. The regression of time on average doe ETA provided an estimate of the annual (linear) rate of genetic and phenotypic change (Bondoc, 2008). The difference between the phenotypic and genetic trends represented the effect of the environment on the Anglo Nubian milk records.

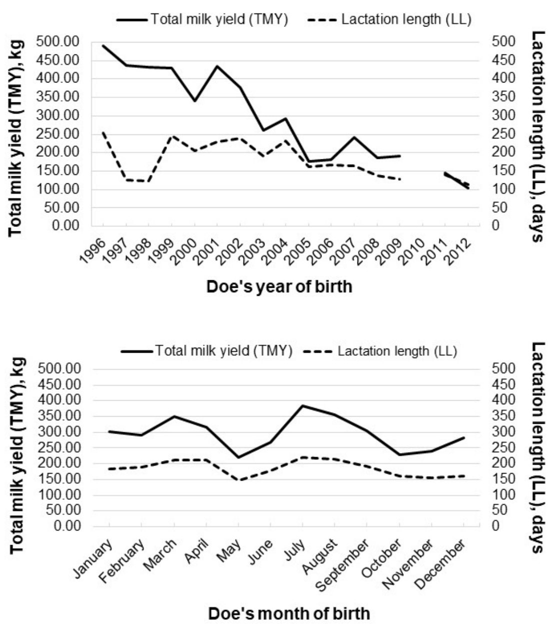

Figure 1. Effect of year and month of birth on total milk yield (TMY) and lactation length (LL) of Anglo Nubian goats.

RESULTS AND DISCUSSION

Total milk yield (259.88 ± 129.11 kg) was significantly affected by the doe's year of birth (P<0.01) and month of birth (P<0.05), but not influenced by number of lactations (parity) per doe (P>0.05). In particular, more than 300 kg milk was produced per lactation by each doe born from 1996 to 2002 but thereafter declined considerably to 103 kg for does born in 2012. More than 300 kg milk was produced per lactation by does born in January, March, April, July, August, and September, albeit no pattern associated with environmental conditions prevailing in a particular month was observed (see Figure 1). Total milk yield reported here if corrected to 305 days lactation period is about 420.90 ± 149.45 kg, and were found to be lower and less predictable than pooled average of milk yield corrected to 305 days lactation (1043.11 ± 336.36 kg) reported for Alpine, La Mancha, Nubian, Saanen and Toggenburg goat breeds in the United States by Castañeda-Bustos *et al*. (2014).

Lactation length (191.54 ± 64.58 days) was significantly affected by number of lactations per doe (P<0.01), but not significantly affected by the doe's year of birth and month of birth (P>0.05). An extra 10.76 days of lactation was observed for every increase in parity (i.e. additional kidding or lactation report). Missing lactation length (and daily milk yield) records were noted in 2005, 2006, and 2008.

Daily milk yield (1.38 ± 0.49 kg/day) was significantly affected by year of birth (P<0.01) and by parity (P<0.05), but not significantly affected by the doe's month of birth (P>0.05). Higher average daily milk yield (> 2 kg/day) was reported for does born in 1996, 1997, and 2001, while lowest daily milk yield (< 1 kg/day) was recorded for does born in 2011 and 2012. Additional 44 g milk produced per day was observed for every increase in parity.

Age at first kidding (624.55 ± 188.78 days or 20.53 ± 6.21 months) was significantly affected by year of birth and parity (P<0.01), but not significantly affected by the doe's month of birth (P>0.05). The youngest average age for does having their first kidding was 510.83 days or 16.79 months for does born in 2009. This is equivalent to an age at first successful breeding of about 360.83 days or 11.86 months. On the other hand, does born in 1998, 2000, 2001, 2002, 2004, 2007, 2011, and 2012 had their first kidding at a much older age (i.e. > 608 days or 20 months old). More kidding and lactations were associated with younger does at first kidding, i.e. additional lactation record may be expected for every 21.76 days reduction in age at first kidding. Age at first kidding reported here were older by about 3.83 months than the pooled age at first kidding (507.97 ± 153.50 days or 16.70 ± 5.05 months) reported for various goat breeds in the US (Castañeda-Bustos *et al*., 2014) and 16.59 ± 4.04 months for the Saanen breed in Mexico (Torres-Vazquez, 2009).

Kidding interval (343.04 ± 108.30 days or 11.28 ± 3.56 months) was likewise not significantly affected by the doe's year and month of birth and parity (P>0.05). This is equivalent to rebreeding the doe about 193.04 days or 6.35 months after kidding. However, substantial number of records on AFK and KI were notably missing, suggesting an ineffective method of recording the actual date of kidding all year round. Kidding interval reported here was slightly shorter by about 1.56 months than the pooled kidding interval (387.36 ± 101.52 days or 12.74 ± 3.34 months) reported for various goat breeds in the US reported by Castañeda-Bustos *et al*. (2014).

Estimates of heritabilities and repeatabilities are shown in Table 3. Heritabilities based on dam-daughter regression were 0.52 ±0.22, 0.71 ±0.22, and 0.29 ±0.22 for TMY, DMY

Table 3. Estimates of heritability and repeatability for various milk traits in Anglo Nubian goats from the Philippines.

Trait	Heritability (h^2) *		Repeatability (rpt) **	
	N dam-daughter pairs	$h^2 \pm SE$	N records per doe	rpt ± SE
Total milk yield (TMY)	84	0.52 ± 0.22	3.30	0.46 ± 0.04
Lactation length (LL)	80	0.18 ± 0.22	3.26	0.27 ± 0.05
Daily milk yield (DMY)	80	0.71 ± 0.22	3.26	0.47 ± 0.04
No. of lactations (NLact)	84	0.29 ± 0.22	-	-
Age at first kidding (AFK)	37	-	-	-
Kidding interval (KI)	28	-	1.53	0.28 ± 0.10

* Heritability estimates for AFK and KI were close to zero (with very large standard errors).
** Repeatability values were not computed for number of lactations (parity) and age at first kidding.

and NLact, respectively. These traits can thus be considered as potential selection criteria in local dairy goats. On the other hand, heritability estimates for LL, AFK and KI were close to zero or had large standard errors, implying no genetic basis to improve them. Repeatability estimates were higher for TMY (0.46 ±0.04) and DMY (0.47 ±0.04) than for LL (0.27 ±0.05) and KI (0.28 ± 0.10).

Heritability estimate for TMY in the present study (0.52) was higher than 0.22 (Valencia *et al.*, 2007) and 0.17 reported in Sannen goats in Mexico (Torres-Vasquez *et al.*, 2009) and 0.37 reported in various goat breeds in the United States (Castañeda-Bustos *et al.*, 2014). These were however, closer to the high heritability values for milk yield equal to 0.49, 0.61, 0.63, 0.53, and 0.59 for Alpine, LaMancha, Nubian, Saanen, and Toggenburg goat breeds in the United States, respectively, as reported by Iloeje *et al.* (1981). Repeatability estimate for TMY in this study (0.46) was within the range reported by different authors (0.39 to 0.55) for diverse goat populations worldwide. Constantinou *et al.* (1985) obtained a repeatability value of 0.39 for TMY in Damascus goats. Iloeje *et al.* (1981) reported repeatabilities for TMY ranging from 0.40 to 0.50 for various goat breeds in the US. Bagnika and Lukaszewics (1999) estimated repeatability for TMY of 0.42 in Poland, while a value of 0.55 was obtained by Van der Linde (2002) for the same trait in the Netherlands. In Mexico, Valencia *et al.* (2007) and Torres-Vasquez *et al.* (2009) reported repeatability values for TMY of 0.40 and 0.43, respectively.

Heritability value for LL reported here (0.18) is higher than 0.04 and 0.16 reported by Valencia *et al.* (2007) and Constantinou *et al.* (1985), respectively. Repeatability estimate for LL in this study (0.27) was higher than 0.08 and 0.11 reported by Constantinou *et al.* (1985) and Valencia *et al.* (2007), respectively.

Heritability values for AFK and KI were close to zero (negative) and may be unreliable because of difficulties related to sample size and biases from confounding. The Anglo Nubian data set in the present study suggests that AFK and KI were not heritable and can largely be influenced by management and other environmental factors. Estimates of transmitting abilities for AFK and KI were thus equal to zero.

In contrast, heritability value of 0.31 (based on 773 records) and 0.16 (based on 31,451 records) for AFK was reported by Torres-Vasquez *et al.*, (2009) and Castañeda-Bustos *et al.* (2014), respectively. In addition, Castañeda-Bustos *et al.* (2014) reported a heritability value of 0.09 for KI based on 19,528 records.

Table 4 shows that significant phenotypic correlations (P<0.01) were found between TMY and LL (0.59), TMY and DMY (0.80), TMY and NLact (0.51), and TMY and AFK (-0.36), between DMY and NLact (0.61) and DMY and AFK (-0.39), and between NLact and AFK (-0.33). This means that higher TMY and also DMY is expected with longer LL and in later lactations (higher parity). On the other hand, older does at first farrowing are associated with lower TMY and DMY, and with fewer kiddings/lactations. By comparison, phenotypic correlations between TMY and LL equal to 0.45 and 0.64 were reported by

Table 4. Phenotypic (above diagonal) and genetic (below diagonal) correlations among milk traits in Anglo Nubian goats from the Philippines.

	TMY	**LL**	**DMY**	**NLact**	**AFK**	**KI**
Total milk yield (TMY)		0.59** (N=167)	0.80** (N=167)	0.51** (N=172)	-0.36** (N=110)	0.06^{ns} (N=83)
Lactation length (LL)	0.72± 0.21 (N=80)		0.05^{ns} (N=167)	0.01^{ns} (N=167)	-0.13^{ns} (N=106)	0.20^{ns} (N=83)
Daily milk yield (DMY)	0.95± 0.11 (N=80)	0.46± 0.52 (N=80)		0.61** (N=167)	-0.39** (N=106)	-0.08^{ns} (N=83)
No. of lactations (NLact)	0.97± 0.02 (N=84)	0.51± 0.69 (N=80)	0.90± 0.18 (N=80)		-0.33** (N=110)	0.15^{ns} (N=83)
Age at first kidding (AFK)	0.0 ± 0.0 (N=37)	0.0 ± 0.0 (N=37)	0.0 ± 0.0 (N=37)	0.0 ± 0.0 (N=37)		0.13^{ns} (N=75)
Kidding interval (KI)	0.0± 0.0 (N=28)	0.0 ± 0.0 (N=28)	0.0 ± 0.0 (N=28)	0.0 ± 0.0 (N=28)	0.0 ± 0.0 (N=28)	

N is number of paired observations. For phenotypic correlations, ns means r value is not significantly different from zero, P>0.05, * means r value significantly different from zero, P<0.05, ** means r value is highly significant different from zero, P<0.01

Table 5. Average genetic values (doe ETAs) and corresponding accuracy (r_{TI}) for TMY, LL, MY, and NLact in Anglo Nubian does.

	Total milk yield (kg)	**Lactation length (days)**	**Daily milk yield (kg/day)**	**No. of lactations**
Total no. of records	565	562	541	570
No. of does with own record	172	167	167	172
No. of does with sire record	157	152	152	153
No. of does with dam record	84	83	83	84
Ave. no. of daughters per doe	3.3	3.4	3.2	3.3
Ave. no. of daughters per sire	18.2	24.3	17.4	25.0
Ave. no. of daughters per dam	5.5	5.6	5.0	5.5
Ave. doe ETA	123.3	46.3	1.19	1.57
Accuracy (doe r_{TI})	0.78	0.55	0.88	0.60

ETA is estimated transmitting ability or half the estimated breeding value (EBV)

Valencia *et al*. (2007) and Constantinou *et al*. (1985), respectively. In contrast to the negative phenotypic correlation between TMY and AFK reported here (-0.36), Torres-Vasquez *et al*. (2009) reported a phenotypic correlation of 0.04 only.

Significant genetic correlations (P<0.01) among TMY, LL, DMY, and NLact were all positive, which ranged from 0.46 (DMY and LL) to 0.97 (TMY and NLact), see Table 5. These may be used in the future when doing multiple trait selection indices. However, genetic correlations involving AFK and KI were not estimable, due to limited number of paired dam-daughter observations. The estimates of genetic correlations in this study, however, as advised by Falconer and MacKay (1996) are usually subject to large sampling errors and thus should be regarded as approximate values and not necessarily valid for other populations.

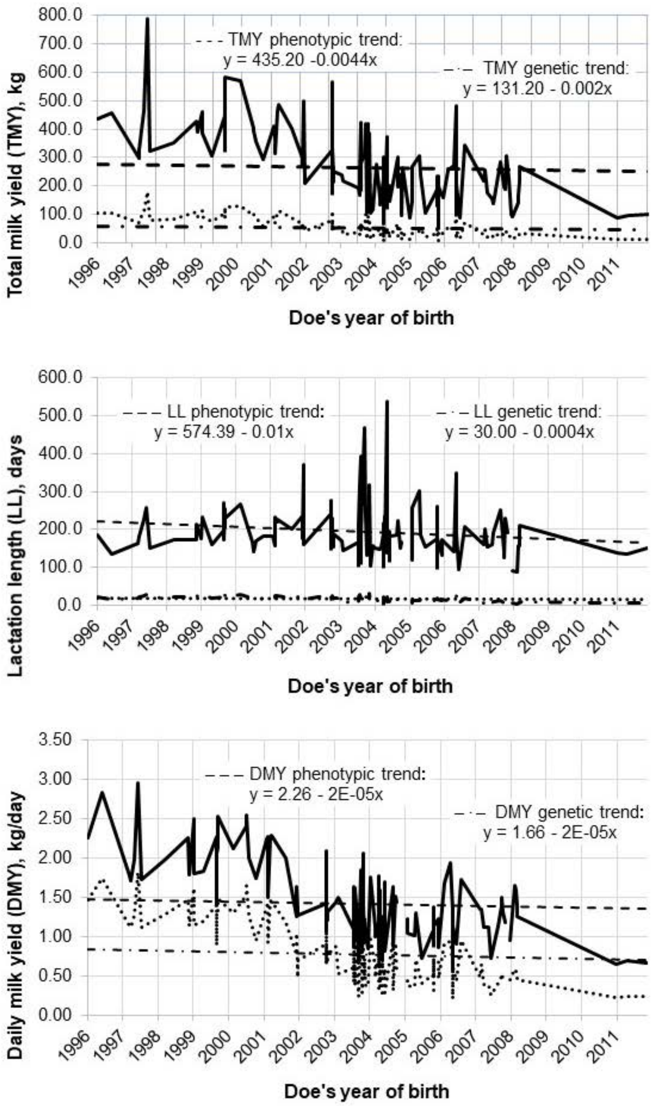

Figure 2. Genetic (doe ETAs) and phenotypic trends in total milk yield (n=172), lactation length (LL, n=167) and daily milk yield (DMY, n=167) of Anglo Nubian goats.

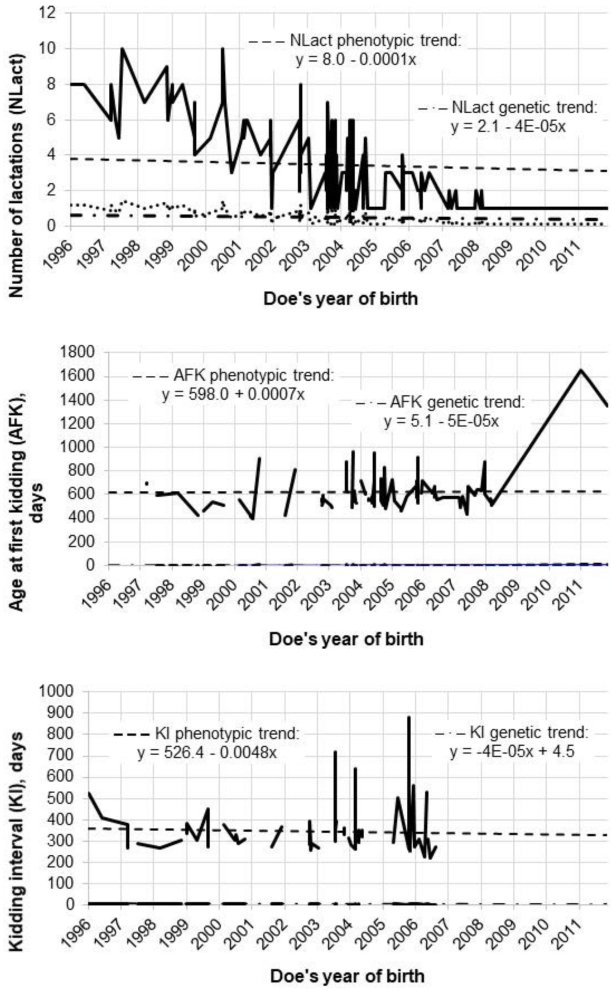

Figure 3. Genetic (doe ETAs) and phenotypic trends in number of lactation (NLact, n=172), age at first kidding (AFK, n=110) and kidding interval (KI, n=83) of Anglo Nubian goats.

Genetic correlations between TMY and LL reported in this study (0.72) was similar to 0.53 and 0.71 reported by Valencia *et al*. (2007) and Constantinou *et al*. (1985), respectively. While no genetic correlation between TMY and AFK was found in this study, Torres-Vasquez *et al*. (2009) reported a moderate and negative genetic correlation of -0.18.

Table 5 shows the number of records used in the computation of doe ETAs and r_{TI} values for TMY, DMY and NLact. Genetic (doe ETA) and phenotypic trends for TMY, LL and DMY of Anglo Nubian goats are shown in Figure 2. The genetic trend from 1996 to 2012 was flat, suggesting no effective selection program practiced on-farm for more than 16 years. The difference in average phenotypic and genetic trends represents the environmental effects comprising 52.56%, 75.83% and 13.77% of the average phenotypic values for TMY, LL and NLact, respectively. The large environmental effects (especially LL) underscore the scope for further improving the trivial non-genetic factors (e.g., general herd management, housing, nutrition and health programs) especially suited for dairy goat production in the Philippines. On the other hand, the genetic and phenotypic trends for NLact, AFK and KI of Anglo Nubian goats are shown in Figure 3, suggesting that these traits have no genetic basis and may be enhanced substantially by improving the local management and breeding practices.

Based on the computed heritabilities and genetic correlations, response to selection response for TMY, DMY and NLact in the local Anglo Nubian herds may be achieved after the derivation and use of appropriate economic indices that shall maximize the economic responses for the local market.

Genetic potential for milk production in Anglo Nubian goats may be measured primarily based on TMY adjusted for the average LL of 190 days (180 to 200 days) or simply based on DMY. Estimates of transmitting ability (ETA) and accuracy of selection (r_{TI}) may be improved by adding available information from sire and dam. A similar genetic evaluation for other dairy goat breeds using larger data sets obtained from more farms and consistently recorded under Philippine conditions is recommended.

ACKNOWLEDGMENTS

This study was supported by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) - Department of Science and Technology (DOST) of the Philippines in its implementation of the National Dairy Goat Science and Technology Program (NDGSTP). The help provided by Ms. Ana Marie P. Alo in leading the NDGSTP is gratefully acknowledged.

REFERENCES

Bagnika E and Lukaszewics M. 1999. Genetic and environmental variation of dairy traits in a Polish population of goats. *Anim Sci Pap Rep* 17: 59-65.

Becker WA. 1984. *Manual of Quantitative Genetics.* 4th ed. Pullman, Washington: Academic Enterprises. 190 pp.

Bondoc OL. 2008. *Animal Breeding: Principles and Practice in the Philippine Context*. Diliman, Quezon City: University of the Philippines Press. 386 pp.

Castañeda-Bustos VJ, Montaldo HH, Torres-Hernandez G, Perez-Elizalde S, Valencia-Posadas M, Hernandez-Mendo O and Shepard L. 2014. *J Dairy Sci* 97: 2462-2473.

Climate-Data Org 2017. Retrieved May 22, 2017 from https://en.climate-data.org/location/.

Constantinou A, Beuing R and Mavrogenis AP. 1985. Genetic and phenotypic parameters for some reproduction and milk production characters of the Damascus goat. *Z Tierzuchtg Zuchtgsbiol* 102: 301-307.

Falconer DS and Mackay TFC. 1996. *Introduction to Quantitative Genetics*. 4th ed. Harlow, Essex: Longman Group, LTD.

Gonçalves HC, Silva MA, Wechsler FS, Ramos AA, Pulz LM and Losi TC. 2002. Genetic parameters and trend for goat milk production in Brazil. *R Bras Zootec* 31: 2204-2208.

Iloeje M, Van Vleck LD and Wiggans GR. 1981. Components of variance for milk and fat yields in dairy goats. *J Dairy Sci* 64: 2290-2293.

Peel MC, Finlayson BL and McMahon TA. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrol Earth Syst Sci* 11: 1633-1644.

Philippine Statistics Authority (PSA). 2016. Dairy Industry Performance Report. Quezon City, Philippines. 5 pp.

Philippine Statistics Authority (PSA). 2017. Retrieved May 22, 2017 from http://countrystat.psa. gov.ph.

Ribeiro AC, Queiroz SA, Lui JF, Ribeiro SDA and Resende KT 1998. *Genetic and phenotypic parameter estimates and genetic trend of milk yield of Saanen goats in Southeast of Brazil.* Proceedings of the 6th World Congress on Genetics Applied to Livestock Production. Armidale, Australia, 24: 234-237.

SAS 2009. *SAS/STAT ® 9.2 User's Guide*. 2nd ed.

Torres-Vazquez JA, Valencia-Posadas M, Castillo-Juarez H and Montaldo HH. 2009. Genetic and phenotypic parameters of milk yield, milk composition and age at first kidding in Saanen goats from Mexico. *Livest Sci* 126: 147-153.

Valencia M, Dobler J and Montaldo HH. 2007. Genetic and phenotypic parameters for lactation traits in a flock of Saanen goats in Mexico. *Small Rumin Res* 68, 318–322.

Van der Linde JG. 2002. *Genetic evaluation of yield for dairy goats in the Netherlands*. In: Proceedings of the 7th World Congress on Genetics Applied to Livestock Production. Montpellier, France, pp. 1-4.

Van Vleck LD. 1988. *Notes on the Theory and Application of Selection Principles for the Genetic Improvement of Farm Animals*. Ithaca, New York: Cornell University.