ANALYSIS OF INBREEDING IN SOME ANGLO NUBIAN DAIRY GOAT FARMS IN THE PHILIPPINES

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ABSTRACT

Average inbreeding and co-ancestry coefficients were determined for 172 Anglo Nubian does born from 21 sires and 161 dams based on pedigree information using the tabular method of computing coefficients of relationships. The milking goats born between 1996 and 2012 produced 570 lactation records gathered from 2000 to 2016. Average inbreeding coefficient among males, among females, and among all individuals was 0.000 (0.00%), 0.0011 (0.11%) and 0.0010 (0.10%), respectively. Average coefficient among 172 does with lactation records was 0.0014 (0.14%). The rate of inbreeding based on effective population size is 0.0065 (0.65%) per generation, equivalent to a buck-doe ratio of 1:11.1 by natural mating. Average coefficient of co-ancestry among males, among females, between males and females, and among all individuals was 0.000 (0.00%), 0.0185 (1.85%), 0.0109 (1.09%), and 0.0172 (1.72%), respectively. The results of the correlation and regression analysis showed no significant relationship (P>0.05) between individual inbreeding coefficient with total milk yield, lactation length, daily milk yield, number of lactations, age at first kidding and kidding interval. No inbreeding depression in these traits for the local Anglo Nubian herds was reported in this study.

Keywords: Anglo Nubian dairy goats, coefficient of inbreeding and co-ancestry, inbreeding

INTRODUCTION

Inbreeding has been shown to adversely affect livestock breeding populations (Bijma *et al*., 2001; Weigel, 2001) as a result of an increased frequency of deleterious recessive alleles. Although inbreeding does not create the undesirable recessive genes, inbreeding allows them to be expressed due to increased homozygosity (Bondoc, 2008). Inbreeding depression or the undesirable effects of inbreeding especially on lowly heritable but economically important traits such as reproductive efficiency and survival usually lead breeders to avoid mating among relatives. This is also an important consideration in research that focuses on the preservation of rare breeds or maintenance of genetic diversity within closed nucleus breeding schemes. However, inbreeding cannot be avoided or limited indefinitely, especially in small populations and at some point, all animals will be closely related and inbreeding will inevitably increase (Gipson, 2002).

Uncontrolled inbreeding even in intense selection programs and large effective population size may also lead to inbreeding depression (McDaniel, 2001). The expected result of high selection intensity is high homozygosity, resulting in decreased future

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selection response and decreased fitness. The apparently large population size of many livestock breeds can also be misleading because inbreeding is primarily a function of selection intensity. High selection intensities allow increased relatedness within some breeds by reducing the effective number of parents (Weigel, 2001). Furthermore, inbreeding will be difficult to avoid in populations that (1) routinely use modern reproductive technologies, such as artificial insemination to allow the widespread use of only a few select sires across a breed (Gipson, 2002) and (2) enhanced use of genetic evaluations computed with greater accuracy of prediction of estimated breeding values (EBVs) which in turn, would increase the likelihood of selection of related individuals (Bijma *et al*., 2001; McDaniel, 2001; Weigel, 2001). The latter is due to the use of family information so that groups of relatives often have similar EBV's and therefore tends to be selected or culled as a group, thereby increasing relatedness among the breed.

While these practices may be widely used in dairy goats of some developed countries, local dairy goat producers in the Philippines should be aware of the level of inbreeding in their herds and take action to minimize it. In this regard, the objective of this study was to evaluate the coefficient of inbreeding and co-ancestry based on pedigree information kept by a few selected dairy goat farms. The effect of inbreeding on available milk records was estimated to determine if inbreeding depression was a problem in the local Anglo Nubian breeding population.

MATERIALS AND METHODS

This study was based on 172 Anglo Nubian does from 4 selected dairy goat farms, namely, Mindanao Baptist Rural Life Center located in Bansalan, Davao Del Sur (approx. 06°47′N 125°12′E, 157 mASL), Naga City Goat Farm in San Felipe, Naga City, Camarines Sur (approx. 13°38′N 123°12′E, 12 mASL), and Small Ruminant Center (SRC) Institutional Herd and SRC Experimental Herd in Central Luzon State University (CLSU), Muñoz, Nueva Ecija (approx. 15°44′N 120°55′E, 78 mASL). Data used were part of a National Dairy Goat Science and Technology research program that analyzed 570 lactation records gathered from 2000 to 2016 (Bondoc *et al*., 2017).

The milking goats in all farms born between 1996 and 2012 were maintained in a similar intensive production system. Does and bucks were raised in separate pens and hand mated throughout the year.

Expected inbreeding in the population (ΔF) can be computed based on effective population size (N_e), as commonly used by conservationists in natural populations, i.e. $\Delta F = 1 / (2 \times N_e)$. Effective population size is derived from the formula (Falconer and MacKay, 1996): $1/N_e = 1/(4 \times N_m) + 1/(4 \times N_f)$ where N_m and N_f are number of males and females used as parents in each generation. The purpose of determining N_e is to estimate the number of animals that would produce the observed rate of inbreeding if bred under ideal conditions in one generation (Lacy, 1995). Characteristics of an ideal population, however, include equal variance in family size, large number of breeders, random mating, equal sex ratio, absence of selection, mutation, or migration, and discrete generations (Falconer and Mackay, 1996).

Average inbreeding coefficient and coefficient of ancestry within sex category (i.e. bucks or does) were computed through knowledge of the pedigree using the tabular method of computing coefficients of relationships. The INBREED procedure of SAS (2009) was used to calculate the average covariance or inbreeding coefficients for a pedigree for each sex, assuming that the parents of individuals in the current generation are defined in the previous generation.

The inbreeding coefficient of individual X (i.e. f_{XX}), which is the probability that the pair of alleles carried by the gametes that produced it is identical by descent (Falconer and McKay, 1996), is equal to the co-ancestry between its parents. The co-ancestry between individuals X and Y (i.e. f_{XY}) with parents A and B and C and D, respectively is equal to $f_{XY} = ¼ (f_{AC} + f_{AD} + f_{BC} + f_{BD})$. The inbreeding coefficient for an offspring of X and Y, called Z, is computed as the co-ancestry between X and Y, i.e. $F_Z = f_{XY}$. Assuming that X's parents are A and B, the co-ancestry between X and A is $f_{XA} = ½ (f_{AB} + f_{AA})$. The inbreeding coefficient for an offspring of X and A, denoted by Z, is $F_Z = f_{XA} = ½ (f_{AB} + f_{AA})$.

Simple descriptive statistics were determined for total milk yield, lactation length, daily milk yield, number of lactations, age at first kidding and kidding interval using the MEANS procedure of SAS (2009), see Table 1. The effect of inbreeding on lactation records (i.e. total milk yield (kg), lactation length (days), daily milk yield (kg/day), number of lactations, age at first kidding (days) and kidding interval (days) was then determined using the CORR and REG procedure of SAS (2009). The statistical model included lactation records as dependent variables and the inbreeding coefficients and year of birth as independent variables.

RESULTS AND DISCUSSION

Table 1 shows a total of 244 Anglo Nubian goats consisting of 21 males (i.e. sires of does) and 223 females (i.e. as does or dams) were used in the computation of inbreeding and co-ancestry coefficients. This is equivalent to a buck-doe ratio of 1: 11.1 by natural mating. Only 2 inbred does were identified, each with inbreeding coefficient equal to 0.125. Anglo Nubian does DG431164800 and DG623241047 were born from the same sire (DG320547880) and dam (DG662916753) on April 2, 2005. While they are full sibs, their dam was also found to be a granddaughter of their sire (see Table 2). Average inbreeding coefficient among 172 does with lactation records was 0.0014 (or 0.14%).

Table 3 shows that average inbreeding coefficient among males, among females, and among all individuals (sum of all males and females) was 0.000 (or 0.00%), 0.0011 (or 0.11%)

Table 1. Simple descriptive statistics for various milk traits from 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. Pedigree of inbred animals* found in the local Anglo Nubian data set.

Doe ID	Sire ID	Dam ID	Inbreeding coefficient
Inbred animals:			
DG431164800	DG320547880	DG662916753	0.125
DG623241047	DG320547880	DG662916753	0.125
Non-inbred dams and grand dams:			
DG662916753	DG810043773	DG382577748	0.000
DG382577748	DG320547880	DG727086209	0.000

* Only 2 inbred does were found out of 172 Anglo Nubian does with lactation records (i.e. 170 does have zero inbreeding coefficients).

and 0.0010 (or 0.10%), respectively. This is considerably lower than when inbreeding was estimated on the basis of effective population size. The effective population size (N_e) and rate of inbreeding (ΔF) is equal to 77.06 and 0.0065 (0.65%) per generation, respectively. Both estimates were, however, lower than the threshold value of 0.5% per year, which has been proposed as an acceptable upper value (Nicholas, 1989), although this may depend on inbreeding depression data reported for a particular species. In pigs, for example, an average inbreeding coefficient greater than 2% per year is usually considered to be alarming (Smith *et al*., 1976).

Table 3. Average of inbreeding and co-ancestry coefficients* in the local Anglo Nubian herds.

	N, F_Z or f_{XY}	Remarks/implications
Number of males	21	Also number of sires of does
Number of females	223	Sum of 172 does or dams with lactation records and 51 other dams with no lactation record.
Number of individuals	244	Sum of 21 males and 223 females
Average inbreeding coefficient (i.e. F_Z)		
- Male x Male	0.0000	Average inbreeding coefficient among 21 males, i.e. no inbred sire was found
- Male x Female	-	-
- Female x Female	0.0011	Average inbreeding coefficient among 223 females
- Over Sex	0.0010	Average inbreeding coefficient among all males and females (N=244)
Average co-ancestry coefficient (i.e. f_{XY})		
- Male x Male	0.0000	No relationship among sires
- Male x Female	0.0109	Average relationship between males and females
- Female x Female	0.0185	Average relationship among females
- Over Sex	0.0172	Average relationship among all individuals

* Based on initial number of Anglo Nubian does with lactation records = 172. However, 11 Anglo Nubian does have missing pedigree information (i.e. parents are not known).

The low inbreeding coefficients could be attributed to the local breeding practices and management conditions. The local Anglo Nubian farms use unselected bucks to breed purebred does through natural mating. This is unlike dairy goat selection programs that demonstrated rapid genetic progress, where accumulation of inbreeding is expected via heavy impact of a few selected sires or families (Weigel, 2001). In such case, the breeding goats are chosen to have a common ancestral (pedigree) background or relationship. Due to the use of family information, groups of relatives often have similar EBV's and therefore tend to be selected or culled as a group, thereby increasing relatedness among the breed. For example, Gipson (2002) reported that inbreeding is increasing in Alpine, Nubian, Saanen and Toggenburg breeds in the United States. American goat producers appear to be selecting more within family lines for purebred animals, leading to an increased rate of inbreeding in this registry status. Gipson (2002) also found that estimates of inbreeding depression for average standardized milk, fat, and protein yields were greater for higher producing breeds than for the lower producing breeds.

Average coefficient of co-ancestry among males, among females, between males and females, and among all individuals was 0.000 (0.00%), 0.0185 (1.85%), 0.0109 (1.09%), and 0.0172 (1.72%), respectively (see Table 3). The non-zero values for average co-ancestry coefficients suggest that inbreeding is always accumulating even when avoiding inbreeding (McDaniel, 2001) and therefore should be controlled. Knowledge of these relationships will be helpful in avoiding mating between close relatives and selecting animals on the basis of relatives' records (Bondoc *et al.*, 2000). In particular, the current levels of inbreeding (ΔF) in the next generation and in the future can be reduced by mating animals with minimum co-ancestry. The rate of inbreeding, however, needs to be limited in order to maintain diversity at an acceptable level so that genetic variation will still be present and animals can respond to changes in environment and to selection (McDaniel, 2001).

The results of the correlation and regression analysis showed no significant relationship ($P>0.05$) between individual inbreeding coefficient with total milk yield, lactation length, daily milk yield, number of lactations, age at first kidding and kidding interval. No inbreeding depression in these traits in the local Anglo Nubian herd was therefore reported in this study. This is largely because 242 goats or 99.18% of the total number of individuals considered in the analysis of inbreeding had zero inbreeding coefficients. In general, the extent to which depression is seen in measured traits may also depend on the breed of animal, the trait, the genetic load of the founding animals, and the environment (MacKinnon, 2003).

In this study, inbreeding had no significant effect on the reduction of total milk yield, lactation length, daily milk yield, lactation number, age at first kidding and kidding interval. As a result, the impact of inbreeding and its economic impact on milk traits in Anglo Nubian goats cannot be determined. The low average inbreeding coefficient also reflects the effectiveness of controlled mating to avoid mating of relatives despite the low effective population size and increasing co-ancestry coefficients among the breeding individuals.

While the computed inbreeding may not appear to be increasing rapidly enough to become a problem in the Anglo Nubian farms, inbreeding should not be ignored. Local goat raisers should continue to monitor their herds for changes of inbreeding and relationship. Emphasis should be more on the implementation of an efficient selection program based on accurate breeding value estimation and advanced reproductive technology (i.e. artificial insemination and multiple ovulation and embryo transfer) rather than simply avoiding inbreeding in the local herd. With a local selection program for dairy goats, the goal would then be to maximize selection response at an acceptable level of ΔF (Quinton *et al*., 1992; Klieve *et al*., 1994; Weigel, 2001). For example, an increase of less than 1% F per generation is usually deemed acceptable for most populations (Quinton *et al*., 1992; McDaniel, 2001).

Although inbreeding may have adverse impact on reproduction traits such as fertility, pregnancy, and kidding, resulting in fewer kids per herd, improvement of such lowly heritable traits may be enhanced substantially by improving the local management and breeding practices. Complete pedigree records gathered on-farm should also be the norm, since missing information on sire and dam identification may result in a substantial apparent increase in rate of inbreeding (e.g., Gipson, 2002).

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REFERENCES

Bijma P, Van Arendonk JAM and Wooliams JA. 2001. Predicting rates of inbreeding for livestock improvement schemes. *J Anim Sci* 79:840-853.

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

Bondoc OL, Veluz CD, Pabico JP and Argañosa VG. 2000. Analysis of inbreeding in a local herd of Duroc pigs. *Philipp Agric Scientist* 83(2): 198-200.

Bondoc OL, Del Rosario NA, Manalili LLG and Cruz EM. 2017. *Genetic and phenotypic trends in milk production traits of Anglo Nubian goats from selected farms in the Philippines.* Paper presented during the 54th Philippine Society of Animal Science Annual Meeting and Scientific Convention. Cebu City.

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

Gipson TA. 2002. *Preliminary observations: inbreeding in dairy goats and its effects on milk production.* Proc. 17th Ann. Goat Field Day, Langston University, Langston, OK.

Klieve HM, Kinghorn BP and Barwick SA. 1994. The joint regulation of genetic gain and inbreeding under mate selection. *J Anim Breed Genet* 111: 81-88.

Lacy RC. 1995. Clarification of genetic terms and their use in the management of captive populations. *Zoo Biol* 14: 565-578.

MacKinnon KM. 2003. Analysis of inbreeding in a closed population of crossbred sheep. *MSc Thesis*. Virginia Polytechnic Institute and State University Blacksburg, Virginia, USA.

McDaniel BT. 2001. Uncontrolled inbreeding. *J Dairy Sci* 84(E. Suppl.): E185-E186.

Nicholas FW. 1989. *Evolution and Animal Breeding*. Hill WG and Mackay TFC ed. Wallingford: CAB Intl. pp. 201-209.

Quinton M, Smith C and Goddard ME. 1992. Comparison of selection methods at the same level of inbreeding. *J Anim Sci* 70: 1060-1067.
SAS. 2009. *SAS/STAT ® 9.2 User's Guide.* 2nd ed.
Smith C, Jordan CHC, Steane DE and Sweeney MB. 1976. A note on inbreeding and genetic relationships on British tested pig. *Anim Prod* 27: 125-28.
Weigel KA. 2001. Controlling inbreeding in modern breeding programs. *J Dairy Sci* 84(E. Suppl.): E177-E184.