PRELIMINARY OBSERVATIONS: INBREEDING IN DAIRY GOATS AND ITS EFFECTS ON MILK PRODUCTION

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Introduction

When two related individuals are mated, they produce an inbred offspring. Inbreeding tends to increase homozygosity in the population. In 1922, a geneticist by the name of Sewell Wright developed a method to measure inbreeding using a parameter called the inbreeding coefficient or simply F (Wright, 1922). The inbreeding coefficient is defined as the probability that two identical genes (one from each of the parents) is found at the same locus within the offspring. The inbreeding coefficient varies between 0 (0%) and 1 (100%) - a higher value indicating that the parents of the animal concerned were more closely related. The inbreeding coefficient is a function of the number and location of the common ancestors in a pedigree. It is not a function, except indirectly, of the inbreeding of the parents.

Unfortunately in most cases, inbreeding reduces the productivity and viability of the inbred individual. This reduction in productivity and viability is called inbreeding depression. In dairy cattle, estimates of inbreeding depression were similar for Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey, and Milking Shorthorn (Wiggans et al., 1995). For Holsteins, the most populous breed, estimates were –65.2 lb for milk, -2.38 lb for fat, and -2.14 lb for protein. That is for every increase of 1% level of inbreeding in Holsteins, those animals gave 65.2 less lb of milk, 2.38 less lb of butterfat, and 2.14 less lb of protein.

Numerous studies have examined methods to minimize the effect of inbreeding, and therefore inbreeding depression, in various selection schemes for various livestock species (Bijma et al., 2001; Meszaros et al., 1999; Weigel, 2001). In reality, inbreeding is difficult to avoid in populations that routinely use modern reproductive technologies, such as artificial insemination and embryo transfer, and(or) that routinely use genetic evaluations for the selection of progenitors (Bijma et al., 2001; McDaniel, 2001; Weigel, 2001). Artificial insemination allows for the widespread use of only a few select sires across a breed. Genetic evaluations computed with greater accuracy of prediction of breeding values have increased the likelihood of selection of related individuals. Both of these practices are widely used in dairy goats. However, it is not known to what extent inbreeding depression exists for production traits in dairy goats. The objective of this study was to evaluate rate of inbreeding and inbreeding depression in dairy goats.

Material and Methods

Average standardized milk, fat, and protein yields and calculated inbreeding coefficients were acquired through USDA Animal Improvement Laboratory Program. Standardized yields are yields averaged over all a doe's lactations, are adjusted for age and season, and are projected to 305 day yields. Rate of inbreeding was analyzed using analysis of covariance. The statistical model included inbreeding coefficient as the dependent variable and breed, registry status, year of birth, and all two-way interactions as independent variables. Breed and registry status were categorical variables, year of birth was a covariate, and the two-way interaction involving year of birth were used to test for heterogeneity of slope (Littell et al., 1991). Breeds included in this study were Alpine, LaMancha, Nubian, Saanen, and Toggenburg. Registry status included American, Grade, and Purebred. An analysis of covariance was also conducted to evaluate rate of inbreeding and inbreeding depression in dairy goats. The statistical model included average standardized milk, fat, and protein yields as dependent variables and the inbreeding coefficients model. Independent variables included inbreeding coefficient, year of birth, breed, registry status, and all two-way interactions. Breed and registry status were categorical variables, inbreeding coefficient and year of birth were covariates, and the two-way interaction involving inbreeding coefficient were used to test for heterogeneity of slope. The regression coefficient for inbreeding coefficient was used as the estimate of inbreeding depression and year of birth was used to account for genetic progress. The data analysis for this study was generated using SAS/STAT software, Version 7 of the SAS System for Windows. Copyright © 1998. SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Results and Discussion

Over 132,000 lactation records (individual does) were available for this study and are presented in Table 1. Alpines account for 29% of the records, LaMancha 10%, Nubian 35%, Saanen 13%, and Toggenburg 13%. American registry status accounted for 31% of the total records, Grade 8%, and Purebred 61%.

The range and frequency of inbreeding coefficients are presented in Table 2. Over half of the records had zero inbreeding. Over 89% had an inbreeding coefficient of 10% or less, over 93% had an inbreeding coefficient of 13% or less, and nearly 99% had an inbreeding coefficient of 25% or less. The mating of half-sibs is roughly equivalent to an inbreeding coefficient of 12.5% and the mating of full-sibs is roughly equivalent to an inbreeding coefficient of 25%.

The change in inbreeding coefficient (F) expressed by birth year is presented in Figure 1. As can be seen from Figure 1, the rate of inbreeding is increasing in all breeds. The rate of inbreeding is 0.229 F/year for Alpine, 0.146 for LaMancha, 0.237 for Nubian, 0.247 for Saanen, and 0.232 for Toggenburg. Rates of inbreeding were not significantly different for Alpine, Nubian, Saanen, and Toggenburg; however, the rate of inbreeding was significantly lower for LaMancha than for the other four breeds. For registry status, the rate of inbreeding is 0.193 for American, 0.209 for Grade, and 0.253 for Purebred.

Inbreeding depressions for milk, fat, and protein yield by breed are presented in Table 3. Using Nubian as an example, for every 1% increase in inbreeding there was a corresponding decrease of 2.98 lb in milk production. In all cases, Alpine demonstrated the greatest magnitude of inbreeding depression for milk, fat, and protein yields. For milk, inbreeding depression ranged from -11.28 in Alpine to -2.84 in LaMancha. For fat, inbreeding depression ranged from -0.371 in Alpine to -0.151 in LaMancha. For protein, inbreeding depression ranged from -0.283 in Alpine to -0.103 in Nubian.

Table 4 presents the mean for the standardized yields for milk, fat, and protein yields. Dividing the inbreeding depression in Table 3 by its corresponding production mean in Table 4 gives a percentage reduction in overall production. The high-producing Swiss breeds, Alpine, Saanen, and Toggenburg, have often been compared with Holstein dairy cattle, and the lower producing LaMancha and Nubian have been compared with Jersey dairy cattle. The percentage reduction in overall milk production for each percentage increase in inbreeding was 0.42 and 0.19% for Swiss and lower producing breeds, respectively. In Holsteins, milk production decreased 65.2 lb for every 1% increase in inbreeding (Wiggans and VanRaden, 1995) and decreased 77.1 lb in another study (Thompson et al., 2000). With the current milk production levels of Holsteins, this represents, on average, a 0.28% decrease in overall milk production. This 0.28% reduction for Holstein is b of the value in the Swiss breeds. For milk production in Jerseys, one study found an inbreeding depression of -46.9 (Wiggans and VanRaden, 1995) and -39 in another study (Thompson et al., 2000). With the current milk production levels in Jerseys, this represents, on average, a 0.24% decrease in overall milk production. The percentage reduction for lower producing goat breeds (LaMancha and Nubian) and Jerseys seems to be comparable.

The percentage reduction in overall fat production for each percentage increase in inbreeding was 0.41 and 0.22% for the Swiss and lower producing breeds, respectively. In Holsteins, fat production decreased 2.38 lb for every 1% increase in inbreeding (Wiggans and VanRaden, 1995) and decreased 3.05 lb in another study (Thompson et al., 2000). With the current fat production levels in Holstein, this represents, on average, a 0.30% decrease in overall fat production. Like milk production, this 0.30% reduction for Holstein is b of the value in the Swiss breeds. For fat production in Jerseys, one study found an inbreeding depression of -2.27 (Wiggans and VanRaden, 1995) and -1.89 in another study (Thompson et al., 2000). With the current fat production levels in Jerseys, this represents, on average, a 0.26% decrease in overall fat production. The percentage reduction for lower producing goat breeds (LaMancha and Nubian) and Jersey seems to be comparable.

The percentage reduction in overall protein production for each percentage increase in inbreeding was 0.39 and 0.18% for the Swiss and lower producing breeds, respectively. In Holstein, protein production decreased 2.14 lb for every 1% increase in inbreeding (Wiggans and VanRaden, 1995) and decreased 2.38 lb in another study (Thompson et al., 2000). With the current protein production levels in Holstein, this represents, on average, a 0.30% decrease in overall protein production. Unlike milk and fat production, this 0.30% reduction for Holstein is similar to the value for the Swiss breeds. For protein production in Jerseys, one study found an inbreeding depression of -1.94 (Wiggans and VanRaden, 1995) and -1.92 in another study (Thompson et al., 2000). With the current protein production levels in Jerseys, this represents, on average, a 0.30% decrease in overall milk production. The percentage reduction for lower producing goat breeds (LaMancha and Nubian) and Jersey seems to be comparable.

Summary and Conclusions

Inbreeding is increasing in all breeds of dairy goats at about the same yearly rate, except for LaMancha, which has a significantly lower rate of increase. The rates of inbreeding for all breeds are approximately half of a threshold value of 0.5% per year, which has been proposed as an acceptable upper value (Nicholas, 1989). However, dairy goat producers should be aware of the level of inbreeding in their herds and take action to minimize it. Over all breeds, producers appear to be selecting more within family lines for Purebred animals than for American or Grade animals. This has lead to an increased rate of inbreeding in this registry status. Higher producing breeds, such as Alpine, Saanen and Toggenburg, had significantly greater inbreeding depression for average standardized milk, fat, and protein yields than did lower producing breeds, such as LaMancha and Nubian. Even when these estimates of inbreeding depression were expressed as a percentage of overall production, these values were greater for higher producing breeds than for the lower producing breeds. These values for overall production were approximately -0.40% for the higher producing breeds and -0.20% for the lower producing breeds. When compared with high producing breeds of dairy cattle, the higher producing goat breeds seemed to be more susceptible to the effects of inbreeding and had a sharper reduction in overall production levels for milk and fat but not for protein. When compared with lower producing breeds of dairy cattle, the lower producing goat breeds seemed to be less susceptible to the effects of inbreeding and had a lesser reduction in overall production levels for protein but overall reductions in milk and fat yield were comparable.

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Table 1. Distribution of standardized lactation records by breed and by registry status.

Breed	American	Grade	Purebred	**Total**
Alpine	15,988	3,161	19,745	**38,894**
LaMancha	5,199	951	7,208	**13,358**
Nubian	6,247	3,202	36,704	**46,153**
Saanen	8,785	1,570	6,475	**16,830**
Toggenburg	4,661	1,188	11,182	**17,031**
Total	**40,880**	**10,072**	**81,314**	**132,266**

Table 2. Distribution of inbreeding coefficient (F).

F	**No.**	**Percent**	**F**	**No.**	**Percent**	**F**	**No.**	**Percent**
0	68222	51.579	17	554	0.419	34	32	0.024
1	12323	9.317	18	363	0.274	35	8	0.006
2	9618	7.272	19	645	0.488	36	12	0.009
3	7363	5.567	20	279	0.211	37	12	0.009
4	4820	3.644	21	216	0.163	38	85	0.064
5	3586	2.711	22	175	0.132	39	12	0.009
6	4547	3.438	23	130	0.098	40	8	0.006
7	2558	1.934	24	73	0.055	41	9	0.007
8	2141	1.619	25	1796	1.358	42	4	0.003
9	1893	1.431	26	394	0.298	43	7	0.005
10	1204	0.910	27	294	0.222	44	9	0.007
11	946	0.715	28	237	0.179	45	2	0.002
12	575	0.435	29	148	0.112	47	1	0.001
13	3671	2.775	30	87	0.066	49	6	0.005
14	1229	0.929	31	146	0.110	50	2	0.002
15	763	0.577	32	69	0.052	52	1	0.001
16	951	0.719	33	40	0.030			

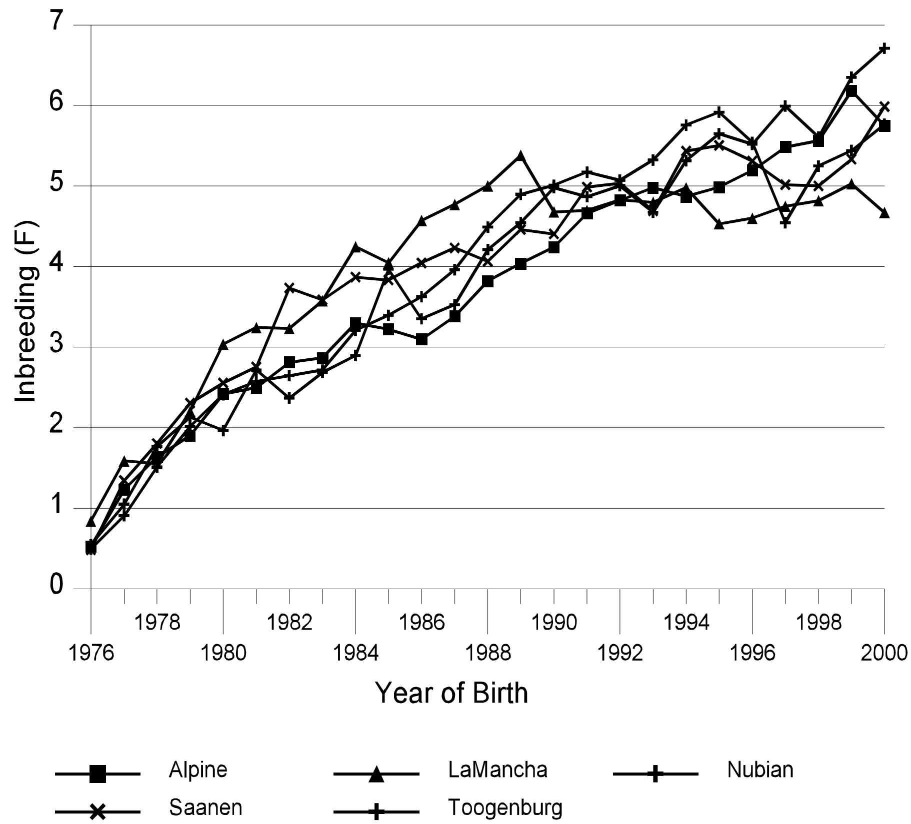

Figure 1. Change in Inbreeding coefficient (F) based upon birth year of the doe.

Table 3. Inbreeding depression for milk, fat and protein yield by breed.

Breed	Δmilk(lb)/%inbreeding	Δfat(lb)/%inbreeding	Δprotein(lb)/%inbreeding
Alpine	-11.28[a]	-0.371[a]	-0.283[a]
LaMancha	-2.84[b]	-0.152[b]	-0.135[bc]
Nubian	-4.37[b]	-0.226[b]	-0.103[b]
Saanen	-7.02[c]	-0.239[bc]	-0.216[ac]
Toggenburg	-10.24[a]	-0.345[ac]	-0.272[a]

Table 4. Means of average standardized milk, fat, and protein by breed.

Breed	Milk (lb)	Fat (lb)	Protein (lb)
Alpine	2,268[a]	79.4[a]	66.3[a]
LaMancha	2,011[b]	77.4[b]	63.8[b]
Nubian	1,891[c]	88.8[c]	69.4[c]
Saanen	2,347[d]	80.9[d]	69.2[c]
Toggenburg	2,233[e]	73.4[e]	62.0[d]

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