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Genetics of Dairy Goats: A Review

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RESEARCH PAPERS

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ABSTRACT

The literature on genetics of dairy goats was reviewed to point out not only world wide research but also the need for research in the United States to achieve the goal of uniform national genetic evaluations similar to those now available for dairy cattle. The number of breeds studied and the variety of research are remarkable. The numbers of animals and records involved in most studies, however, suggest large sampling variances of estimates.

INTRODUCTION

The objective of the USDA-DHIA genetic evaluation program is identification of genetically superior animals so that the germ plasm from these animals can be utilized to improve the genetic value of future generations. The use of USDA-DHIA data for dairy cattle has been remarkably successful in helping to increase yield, efficiency, and profitability of individual animals and entire herds (6). Similar genetic improvement is feasible for dairy goats. This review is an attempt to identify published work on the breeding of dairy goats since interest in dairy goats is increasing. For example, the American Dairy Goat Association, which has members in the United States, Canada, and Mexico, registered 18,431 dairy goats between January and September, 1975. Although there has not been a recent census, there are believed to be over 300,000 goats in the United States (17). Cumulative genetic improvement by thorough selection and grading-up programs surely will lead to increases in output of these dairy animals. As an example, grading-up of native Korean goats with the Saanen breed produced remarkable results. Lactation records for 6 yr were analyzed for 235 Saanen, 55 native Korean goats, 33 Saanen × Korean (F_1), 50 Saanen × F_1 (B_1), and 20 Saanen × B_1 (B_2) female goats. For the Koreans, F_1's, B_1's, and B_2's, milk yields averaged 91, 288, 355, and 373 kg (20). The average length of lactation increased whereas fat content decreased significantly as the proportion of Saanen blood increased. These results offer an indication of the kind of results that can be obtained from dairy goats. The first step towards achieving such progress is identification, compilation, and interpretation of data on dairy goats.

ADJUSTMENT FOR FACTORS AFFECTING PRODUCTION

For milk production, as for many other quantitative traits, the compilation of universally uniform data often has proven difficult. Adjustments for such factors as age, frequency of milking, time and length of milking, age at first kidding, breed, kidding interval, and other known environmental factors are needed but are usually unavailable, making uniform adjustment of data difficult at best.

Age and Season Effects

Data in 1966 on 230 Czechoslovakian White Polled goats showed that goats which kidded in February, March, April, or May averaged 1047, 985, 928, and 859 kg of milk (16). Persistency of lactation indexes (LPI) of 86, 95, 86, and 83 were calculated. The LPI from first to tenth lactations were 91, 87, 88, 86, 84, 84, 89, 87, 91, and 84.

Other workers have shown that milk yield increases linearly with age until about the third to fifth lactations when it then tends to decrease. Milk records of Local White, Short-Wooled goats in Bohemia and Moravia from 1950 to 1964 included 5639 completed lactations. Production was lowest (766 kg) in the first lactation and then increased to a maximum (1045 kg) in the fifth lactation, after which it gradually decreased (15). Butterfat percentage (BF%) was lowest (3.5%) in the first lactation and greatest (3.7%) in the sixth lactation.

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To determine effects of age and lactation number on milk production, data were collected for over 3 yr on 142 Saanen goats (28). Milk yield increased from 751 kg to 1201 kg from 1 to 3 yr of age. In the 4th yr, there was a slight but nonsignificant decline, and at 5 yr or older, there was a sharp decrease to 965 kg. The BF% decreased with increasing milk yield, and at 1, 3, and 5 yr of age, butterfat production was 31, 40, and 38 kg.

A study (35) of the effects of genetic and nongenetic factors on such economic traits of Beetal goats as milk yield in first lactation, kidding interval, and age at first kidding showed that year, season of kidding, and lactation length had highly significant effects on milk yield. These factors jointly explained 63% of the total variability in milk yield in first lactation. Lactation length alone accounted for 58% of the total variability.

Body Weight and Body Measurements

In addition to age, lactation number, and lactation length, body weight also affects milk production. Gall (7) showed that about 60% of the variation in milk yield was attributable to body weight, rumen volume, skeletal size, muscle volume, and body fat. Milk production in Don goats in 1974 was correlated significantly with body weight (24). For 136 dam-daughter pairs of Don goats, milk production in the first lactation had a .39 correlation with body weight. In the second lactation, this correlation was .43. Production of 200-day fat-corrected milk (FCM) (18) during the first five lactations of 46 female German Improved Fawn does showed that correlations of milk yield with body weight at kidding ranged from .23 to .33 and with body weight 5 wk after kidding from .19 to .29.

From 1960 to 1970, body weight and body measurements were recorded on German Improved Fawn does during the 10th wk of first and third lactations and on does slaughtered in the 10th wk of their first lactation. Multiple regression analysis showed that 80% of the total variation in milk yield was related to variation in body measurements (8). In another study (33), body measurements on 79 Fawn goats taken during the 5th and 10th wk of their first lactation had repeatabilities for body weight (.97), loin length (.97), depth of abdomen (.91), breadth of abdomen (.95), and forehead to nose length (.98). The multiple correlation coefficient for the regression of milk yield on loin length, depth of abdomen, breadth of abdomen, and length from forehead to nose was .133. The correlation between milk yield and body weight was .132. The multiple correlation for the regression of milk yield on body weight plus loin length, depth of abdomen, breadth of abdomen, and length from forehead to nose was .20. The correlation between FCM at time of measurement and depth of abdomen was .07. Although abdominal depth showed the highest correlation of any linear body measurement with milk yield, its predictive value was low.

The shape of goat udders and teats showed significant correlation with milk yield (13). Data on 588 Czechoslovakian White Polled does showed that rounded, egg-shaped, and pendulous udders occurred in 73%, 25%, and 2% of the does. Funnel-shaped and cylinder-shaped teats occurred in 50% and 38% of the goats. Circumference of udder before milking averaged 50.6 cm. Distance between teats was 15.8 cm, length of left teat averaged 6.7 cm, and the average left teat circumference was 9.5 cm. Teat ground clearance was 23.6 cm on the average. Milk yield was correlated with left teat length .21, left teat circumference .22, and teat ground clearance .97.

Milking Procedures

Comparisons between machine milking and hand milking have not shown conclusively whether differences in milking procedures influence milk output. In one such comparison, goats were assigned randomly to be hand or machine milked (19). The milking machine was that designed by Alfa Laval for milking goats in the Netherlands to operate at 30 cm vacuum with 80 pulsations per min. In 1 h, 39 goats were machine milked to yield a total of 35 kg (including 8 kg strippings). In the same amount of time, 30 hand milked goats yielded 30 kg of milk. Reports from other researchers (2) suggest that to adapt goats quickly to machine milking, selection should be on rate of flow rather than on milk yield. In an experiment with 33 Saanens and 10 Chamois coloreds, no genetic correlation was significant between milk yield and rate of flow (machine milking) in 1- to 2-yr-old does in their first lactation.

Effects of time of milking on milk output were examined by Caruolo (4). Two goats, under a continuous lighting regime, were milked hourly for 51 h. Four other goats were milked at 13-h intervals for 32 consecutive milkings. Milk production was not dependent on time of milking.

Heritabilities, Repeatabilities, and Correlations

From an analysis of 3567 samples of milk from 457 does in 45 herds of Norwegian goats (31) heritabilities of average yield per operational year for milk yield, BF%, and milk flavor were .55, .22, and .25 (Table 1). However, heritabilities of milk yield (morning yield only) and BF% (daily yield) were .40 and .10. Repeatabilities were .40, .35, and .28 for milk yield, fat percent, and milk flavor (Table 2). These repeatabilities refer to repeatability within lactation year, as opposed to repeatability from one lactation to the other, and were computed as the correlation between test days on the same goat (intralactation correlation). The strongest milk flavor was in milk in the 2nd to 6th mo of lactation and was stronger in goats aged less than 5 yr than in older ones. Flavor also was correlated with milk yield and with BF% but not with feeding intensity or season. The phenotypic correlations between flavor and milk yield, flavor and BF% were .19 and −.33 while the genotypic correlations were .77 and −.28.

Heritabilities for milk yield in the first to

TABLE 1. Heritabilities for traits of goats.

Traits	Breeds	Heritabilities	Reference
Milk yield per operational year	Norwegian	.55	31
Butterfat % per operational year		.22	
Milk flavor		.25	
Milk yield (morning yield)		.40	
Butterfat % (daily yield)		.10	
1st lactation milk yield	Indian Beetal	.32	26
2nd lactation milk yield		.29	
3rd lactation milk yield		.32	
4th lactation milk yield		.28	
5th lactation milk yield		.16	
Lactation milk yield	Saanen Toggenburg French Alpine Nubian	.17 ± .20	9
Total butterfat yield	Saanen Toggenburg French Alpine Nubian	.22 ± .20	9
Lactation milk yield	Norwegian	.32	37
Lactation butterfat yield		.33	
Total fat %		.29	
Age at 1st kidding	Indian Beetal	.54 ± .12	35
1st lactation milk yield		.25 ± .08	
1st kidding interval		.15 ± .09	
Lactation milk yield	Saanen	.68	29
Total fat yield		.56	
Age at 1st kidding		.51	

TABLE 2. Repeatabilities of traits of goats.

Traits	Breeds	Repeat-ability	Refer-ence
Body weight	German Improved Fawn	.97	33
Loin length		.97	
Depth of abdomen		.91	
Breath of abdomen		.95	
Milk yield	Norwegian	.40	31
Butterfat %		.35	
Milk flavor		.28	

fifth lactations were .32, .29, .32, .28, and .16 from an analysis of data on Indian Beetal goats (26). The records collected for 37 yr included 4912 lactations of 1432 does, the progeny of 114 sires. The average milk yield was 137 kg in an average 147-day lactation. Analysis of data (9) on 41 Saanen, 57 Toggenburg, 79 Alpine, and 58 Nubian goats gave heritabilities of .17 ± .20 for milk production and .22 ± .20 for fat production.

Heritabilities of age at first kidding, milk yield in first lactation, and first kidding interval were .54 ± .12, .25 ± .08, and .15 ± .09 from a study on Indian Beetal goats (35). The genetic correlations of age of first kidding with milk yield in first lactation and with first kidding interval were moderately high and negative (Table 3). The genetic correlation between milk yield in first lactation and first kidding interval was, however, positive and low. The phenotypic correlation between age at first kidding and yield in first lactation was positive and low, the correlation of first kidding interval with age at first kidding and with yield in first lactation was negative and low, and the environmental correlation between age at first kidding and milk yield in first lactation was positive and high. The environmental correlation of age at first kidding with kidding interval was negative and low. These correlations indicate that selection for younger age at first kidding probably would increase yield in first lactation and also increase kidding interval. A selection index for dairy goats which combined age at first kidding and yield in first lactation was formulated in 1970 by Singh et al. (36): $I = 3.1X_2 - X_1$, where X_1 and X_2 were age at first kidding and yield in first lactation. These variables are deviations from overall means. Use of this index was expected to decrease age at first kidding by 80.6 days, increase the kidding interval of 14.2 days, and increase yield in first lactation 21.5 kg per generation.

Heritability of udder measurements such as udder circumference, udder length, udder width, distance between teats, left teat length, left teat circumference, and teat ground clearance were estimated (14) from data on 249 does sired by 88 bucks to be .17, .91, .97, .86, .85, .79, and .98.

In an experiment (1) on the genetic variability of machine milking time in lactating goats for first lactation records of 780 does sired by 77 Saanen or Chamois-colored bucks heritability for machine milking was .69 and genetic correlation of milking time with 100-day milk yield was .37.

In young Saanen goats, heritabilities of weight at 1, 2, 3, 5, and 7 mo were .63, .51, .48, .49, and .49 for 1080 female progeny of 64 males which were weighed regularly *until 8 mo* of age (30). Weight at 3 mo was closely correlated with weight at 5 and 7 mo (.91 and .89).

REPRODUCTIVE TRAITS

Other important considerations in the genetics of dairy goat performance are relationships between breeding season and kidding interval, kidding percentage, twinning percentage, triplet percentage, birth weight, and gestation length.

Usually both kidding interval and age at first kidding vary with breed. Age at first kidding was 21 mo and 25 mo while kidding interval was 350 days and 355 days for 25 French Alpine and 14 Anglo Nubian does (10). Average birth weights were 3.5 kg and 2.9 kg. In a

TABLE 3. Correlations between traits of goats.

Traits	Breeds	Correlation	Reference
Lactation milk yield and body weight	Don	.39 (in 1st[b] lactation) .43 (in 2nd[b] lactation)	24
Lactation milk yield and depth of abdomen Lactation milk yield and body weight	German Improved Fawn	.07[b] .132[b]	33
Lactation milk yield and left teat length Lactation milk yield and left teat circumference Lactation milk yield and teat ground clearance	Czechoslovakian White Polled	.21[b] .22[b] .97[b]	13
Lactation milk yield and milking time	Saanen and Chamois Colored	.37[a]	1
Lactation milk yield and milk flavor	Norwegian	.77[a] .19[b]	31
Milk flavor and BF %	Norwegian	-.28[a] -.33[b]	31

[a]Genetic correlation.
[b]Phenotypic correlation.

population of White Angora × Don goats (23) birth weights averaged 3.5 kg and 3.0 kg for males and females. Mature adult weights were 48.3 kg for males and 33.3 kg for females. However, average birth weights (25) were 2.2 kg, 2.3 kg, 2.2 kg, 2.1 kg, 2.3 kg, and 2.3 kg for Angora purebreds, Angora × Gaddi, Angora males × F_1 females, Angora males × first backcross females, inter se breeding of the second backcross, and inter se breeding of the previous groups.

The West African dwarf goats of Ghana and Nigeria (32) had an average kidding rate of 184%. Age at first kidding averaged 362 days while the first kidding interval was 258 days. Birth weight averaged 1.4 kg with a range of .5 kg to 2.5 kg. Body weight at 1 yr of age averaged 12.9 kg with a range of 9.9 to 18.9 kg while mature body weight of the females (36 mo of age) averaged 24.8 kg. For the Red Sokoto goat, which is one of the tropical breeds of dairy goats in Northern Nigeria, Chad, and Niger Republics of West Africa, the average age at first kidding was 427 days for 227 observations (12). Kidding interval averaged 332 days for 655 observations. Following parturition during September to April, May to June, and July to August, kidding intervals averaged 343, 302, and 266 days. In Jamnapari-Malabari crossbred goats of India (27), the following averages were from 101 kiddings of 40 Malabari does and 144 kiddings of 52 Jamnapari × Malabari does: ages at first kidding 495 days and 534 days and kidding intervals 285 days and 299 days. Season had a significant effect on the percent of crossbred does kidding per month (17.3 in November to January vs. 9.3 in February to May) but not in the Malabaris.

Multiple Births

The Malabari goats also provide interesting data on multiple births (22). Of the 85 kiddings of Malabari does recorded at the Kerala College Farm, Trichur, India, 47%, 42%, and 11% yielded singles, twins, and triplets. For does aged 2 yr, 2 yr to 3 yr, 3 yr to 4 yr, 4 yr to 5 yr, and 5 yr, the numbers of kiddings were 40, 18, 8, 4, and 15, of which 32, 4, 4, 0, and 0 involved singles; 8, 12, 3, 3, and 10 involved twins; and the remainder were triplets. Does aged less than 2 yr produced significantly more singles than does of other ages. The sex ratio of males to females was 50:50 for singles, 54:46 for twins, and 41:59 for triplets. The Damascus goat (5) had for 483 normal births, a sex ratio of males to females of 59:41, a twinning percentage of 53%, and a triplet percentage of 9%. Average birth weights for males were 4.4 kg and 4.0 kg for females. Average birth weights for twins (both sexes) were 3.6 kg and 3.1 kg for triplets (both sexes). Data (21) analyzed on 254 kids born 1950 to 1965 of 1) local Malaya, 2) .5-Anglo Nubian × (local by .5-Anglo Nubian), and 3) .75-Anglo Nubian × (local by .75-Anglo Nubian) crossbred goats showed that the mean birth weights of single male kids from first, second, and subsequent kidding dams were 1.9, 3.0, and 3.3 kg. Kidding intervals were 259 ± 22.4 days, 374 ± 34.6 days, and 360 ± 45.8 days. The local goats had the highest twinning percentage (58%), followed by the .75-Anglo Nubian crosses (53%), and the .5-Anglo Nubian crosses (49%). Repeatabilities for birth weight ranged from .01 to .24, .16 to .46, and .16 to .35 for these breed groups. The estimates for litter size were .08, .14, and .20. Another study (3) with Anglo Nubians showed that the birth weight of kids of 50 Anglo Nubian × Granada goats at a farm near Monterey in Mexico averaged 2.4 kg for males and 2.1 kg for females. At 30 days of age, the weights averaged 4.3 kg and 4.2 kg. The difference between males and females was significant at birth but not at 30 days of age.

Ten Nubian, 26 Saanen × Nubian, 9 Saanen, and 20 Zaraibi goats (bucks) averaged 1.8, 1.9, 2.6, and 2.5 kg in weight at birth and 12.0, 21.8, 25.9, and 19.6 kg at 48 wk (34). Corresponding weights for the does were 1.6, 1.8, 2.2, and 1.9 kg at birth and 10.5, 17.6, 20.8, and 18.5 kg at 48 wk of age. The number of kids per year averaged 1.9, 1.0, and 1.8 for 14 Nubian, 14 Saanen, and 16 Zaraibi does. The percentages of single births were 43%, 59%, and 39% while the percentages for triplet births were 2%, 0%, and 4%. It has been believed that the breeding season has some effect on both birth weight and kidding intervals in goats. However, no results have been published to support this assumption. Rather, the year-season interaction was significant especially in gestation length of goats (11). In an experiment in India on the Black Bengal goats, of 261 kiddings from 1955 to 1959, 49%, 30%, and 21% occurred in the summer, winter, and monsoon seasons. Gestation lengths averaged 144 ± .2 days but varied significantly with year and season. Season also affected proliferation and fecundity of the West African Red Sokoto goats (12). Over 3 yr, fertility (number of parturitions/number of breedings), fecundity (number of young/female), proliferation (young born/females giving birth), and the productivity (number of young at 6 mo/females) were 114%, 167%, 147%, and 140%.

CONCLUSIONS

Breeding programs for dairy goats have not been applied as extensively as with dairy cattle. Nevertheless, research has been substantial and encouraging and is being carried on with dairy goats in many countries. There is, however, still a great need for more work on the genetics of dairy goats. There are still no uniform national genetic evaluations for dairy goats in the United States, partly because of the lack of sufficient research. Accurate identification of individual animals also does not compare favorably with that for dairy cattle. If sufficient data of a suitable accuracy and with proper identification are available, then acceptable genetic evaluation procedures similar to the ones being used by the USDA-DHIA for dairy cattle can be applied after necessary research is accomplished. Genetic evaluation of bucks and does would form the basis for implementing a national program for genetic improvement of dairy goats.

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