

Genetic Evaluation of Yield and Type Traits of Dairy Goats in the United States

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ABSTRACT

Genetic evaluations of US dairy goats are calculated annually by USDA from records that are available through Dairy Herd Improvement programs and the American Dairy Goat Association (ADGA). The number of does in test plans used in genetic evaluations was 11,273 during 1999; participation in linear appraisal programs during 1999 was 3784 does, a decrease from the mean of 4285 does over the last 5 yr. For evaluation of yield traits, an animal model similar to that used for dairy cattle is used, but analysis is across breeds. Lactation records for the first six parities of does that were born since July 1973 and kidded since January 1976 are edited within limits appropriate for goats, projected to 305 d, and adjusted for kidding age and month. Evaluations are computed for milk, fat, and protein yields and component percentages; an economic index based on genetic merit for milk, fat, and protein yields (MFPS) is calculated, based on economic values for dairy cattle. A multitrait animal model is applied to 13 linear type traits and final score. A single-trait calculation method is accomplished by applying a canonical transformation. Annual genetic progress for does born during 1996 as a percentage of mean breed yield was lowest for Toggenburgs (-0.1%/yr, milk; 0.0%/yr, fat and protein) and highest for Saanens (0.9%/yr, milk and protein; 1.0%/yr, fat). Annual genetic trend for type traits across breeds for does born during 1996 was 0.67 for stature; 0.37 for rump angle; 0.34 for teat placement; 0.22 for suspensory ligament; 0.20 for strength; 0.16 for teat diameter; 0.12 for rump width; 0.09 for rear legs; 0.06 for dairyness; 0.05 for final score; 0.01 for fore udder attachment and udder depth; -0.1 for udder depth; and -0.12 for rear udder height. Two production-type indexes are computed by ADGA with 2:1 and 1:2 weightings for yield (represented by genetic merit for fat-corrected milk) and type (represented by genetic merit for final score).

(**Key words:** goat, genetic evaluation, milk yield, conformation)

Abbreviation key: ADGA = American Dairy Goat Association; AIPL = Animal Improvement Programs Laboratory; DE = daughter equivalent; DRPC = dairy records processing center; DYD = daughter yield deviation; MFPS = economic index based on genetic merit of milk, fat, and protein yields; PA = mean PTA of parents; PPA = predicted producing ability; PTI = production-type index; REL = reliability; YD = yield deviation.

INTRODUCTION

Dairy goat owners participate in the same DHI milk-recording programs that were developed for dairy cattle with some adaptations for species differences (Ashbrook, 1985; Lawrence and Murrill, 1985). Group testing allows members of a group to supervise the collection of data in each other's herds so that the cost of milk recording can be reduced and the program can be extended into geographic areas where supervisors are not available (Lawrence and Murrill, 1984, 1985). Characteristics of goat milk may make SCC less useful as a measure of udder health than for cows (Guss, 1984; Loewenstein and Speck, 1984). At some dairy records processing centers (DRPC), parameters that are specific to dairy goats, such as shorter gestation interval, are used (Murrill, 1985). Goat yield data are forwarded by DRPC to the Animal Improvement Programs Laboratory (AIPL), ARS, USDA (Beltsville, MD), along with the cow data. Factors specific to goat records are used by AIPL to project lactation lengths (USDA, 1988, unpublished research) and to standardize yields to mature equivalents (Finley et al., 1984) in preparation for calculation of national genetic evaluations.

GENETIC EVALUATION

Genetic evaluations of dairy goats in the United States are calculated annually by AIPL from yield data supplied through DHI and from type and pedigree data supplied by ADGA (Spindale, NC) (Wiggins and Hubbard, 1991). Evaluations for milk, fat, and protein yields have been calculated since 1983 (Wiggins et al., 1984) for bucks and since 1984 for does (Weller et al., 1987). An animal model replaced the sire model for yield traits during 1987 (Wiggins et al., 1988). Evaluations for type have been calculated since 1986 for final score (Wiggins and Hubbard, 1991) and since 1989 for linear type traits (USDA, 1989, unpublished research). During 1995, a multitrait animal model replaced the sire model for type traits (Luo et al., 1995).

Evaluations are computed for Alpines, Experimentals, LaManchas, Nubians, Oberhaslis, Saanens, and Toggenburgs and for crossbred animals from those breeds. Only animals with registered sires are evaluated (Wiggins et al., 1994).

Yield Traits

The number of does in test plans used in genetic evaluations was 11,273 during 1999 (Wiggins, 2000). Yield for only the first 305 d of each lactation is considered. Shorter records are projected to a 305-d equivalent (USDA, 1988, unpublished research); however, terminated records must have a length of ≥ 15 d, and records in progress must be ≥ 40 d. Records with shorter lactation lengths or a length of >305 d are excluded.

Lactation records are adjusted for age and season of kidding by standardizing yield to the equivalent of that for 3-yr-old does that kidded from December through March (Finley et al., 1984). Birth dates of does must be on or after July 1, 1973; kidding dates must be on or after January 1, 1976 (Wiggans et al., 1994). The interval between consecutive kiddings of a doe must be ≥ 6 mo (Wiggans, 1985).

Actual milk yield per day must be ≥ 0.9 kg but ≤ 13.5 kg at the start of lactation. As DIM increase to 305, this upper limit is reduced to 11.5 kg. Fat percentage must be ≥ 2.0 but ≤ 7.5 (Wiggans et al., 1994). After record projection and adjustment (Wiggans, 1984), milk yield for an entire lactation must be ≥ 181 kg but ≤ 2948 kg.

Only information from the first six parities of a doe are included in the evaluation for computational convenience and because parities after sixth contribute little additional information for estimation of genetic merit (Wiggans et al., 1988). Records from later parities for does with a missing first-lactation record are included as are later-lactation records from does that have changed herds (Wiggans et al., 1994). Although including such records may introduce some bias into genetic evaluations, the improvement in accuracy from the added information is considered to be more important.

Milk, fat, and protein yields are evaluated directly with an animal model across breeds; evaluations for fat and protein percentages are calculated from yield evaluations (Wiggans et al., 1988; Wiggans, 1989). The formula that represents a 305-d lactation record that has been adjusted for age and season of kidding (Wiggans, 1989) is:

$$y = m + a + p + c + e,$$

where y = adjusted lactation record, m = effect of management group, a = genetic merit (breeding value) of the doe, p = effect of permanent environment for the doe, c = effect of interaction between herd of the doe and her sire, and e = remaining unexplained residual. Management groups are defined by herd, kidding month, and parity (first or later). Number of adjacent kidding months included in a management group (kidding season) can range from 2 to 12. A kidding season is extended in 2-mo increments to include at least five lactation records in each management group. If the requirement for five lactation records is not satisfied by a 6-mo kidding season, then records from first and later parities are combined, and the required number of records is reduced to three. If a sufficient number of records for comparison still is unavailable, the kidding season continues to be extended up to a maximum of 12 mo. Because analysis is across breeds, does of other breeds can serve as management group mates (Wiggans, 1989).

Pedigrees are traced back as far as possible, but every ancestral path eventually ends with unknown parents. Animals with only one kid, no lactation records, and parents that are not being evaluated also are considered to be unknown parents. The unknown parents are grouped, and their genetic merit is included in evaluations of descendants. Separate groups of unknown parents are defined for each breed to recognize the differing genetic backgrounds of each breed and for parents of animals born before or after 1974 to recognize the genetic improvement that has occurred over time (Wiggans et al., 1988).

Nongenetic factors (such as disease or superior rearing) that influence only the yield of the individual doe and not the yield of her progeny are represented by p .

Table 1. Differences between breeds in mean EBV for does born during 1995.

Breed	Milk	Fat	Protein
Alpine	0	0.0	0.0
Experimental	-56	-0.2	-0.5
LaMancha	-161	-2.1	-2.4
Nubian	-245	2.0	-0.8
Oberhasli	-225	-7.0	-6.5
Saanen	20	0.4	0.9
Toggenburg	-38	-3.0	-1.6

The similarity in yield between daughters of the same buck that are being milked in the same herd that is not due to genetics is reflected by c . The impact of a single herd on the evaluation of a buck can be limited by accounting for c , which also has a particularly large influence on evaluations of bucks with distinctly unequal numbers of daughters per herd.

A heritability of 25% is assumed for milk, fat, and protein yields (Wiggans et al., 1994). The portion of phenotypic variation assigned to other random factors is 16% for permanent environment, 14% for herd-sire interaction, and 45% for the remaining unexplained residual (Wiggans et al., 1994).

Genetic evaluations are reported to the dairy goat industry as PTA, which is half of breeding value and is the genetic merit that an animal is expected to contribute to its progeny. To show the sources of information that contribute to an evaluation, a PTA can be represented (VanRaden and Wiggans, 1991) as:

$$PTA = w_1(PA) + w_2(YD/2) + w_3(\overline{2PTA_{kid} - PTA_{mate}})$$

where w = weights that sum to 1 and indicate how much emphasis is placed on each source of information, PA = mean PTA of sire and dam (parent average), and YD = yield deviation = $y - (m + c + p)$. The PA indicates the contribution to the evaluation of the animal from its parents. If either parent is unknown, an unknown-parent group effect is substituted for the PTA of that parent. The performance of the doe is represented by YD , which is weighted by factors dependent on lactation length. The progeny contributions to the evaluation of an animal are expressed by

$$\overline{2PTA_{kid} - PTA_{mate}},$$

which is the mean of the portion of progeny evaluations (PTA_{kid}) that can be attributed to the animal's genetic merit after adjusting for the genetic merit of mates (PTA_{mate}). If a mate is unknown, an unknown-parent group effect is substituted for PTA_{mate} , and that kid receives a weight of only two-thirds when calculating progeny mean.

Although all breeds are analyzed together, yield PTA are comparable only within breed because the mean genetic merit of does that were born during 1995 for each breed is subtracted from the animal's genetic merit (Table 1). This procedure establishes does born during 1995 as the genetic base for each breed. The base is updated every 5 yr (Wiggans et al., 1994).

For bucks, a weighted mean of daughter YD that have been adjusted for the merit of mates is provided with evaluations (VanRaden and Wiggans, 1991). This daughter yield deviation (**DYD**) provides an indication of the performance of the daughters of a buck without consideration of his parents or sons.

Table 2. Mean yields of does born during 1996 and annual genetic trend by breed.

Breed	Does (no.)	Yield			Genetic trend		
		Milk	Fat	Protein	Milk	Fat	Protein
		------(kg)-----			-----(%/yr)-----		
Alpine	1413	1066	36	33	0.9	0.6	0.8
Experimental	218	899	33	28	0.6	0.4	0.4
LaMancha	635	898	36	30	0.4	0.5	0.5
Nubian	1028	890	42	34	0.7	0.8	0.7
Oberhasli	190	882	33	26	0.8	0.6	0.7
Saanen	673	1060	37	33	0.9	1.0	0.9
Toggenburg	464	970	32	29	-0.1	0.0	0.0

¹Percentage of mean yield of does born during 1996 based on quadratic regression of breeding value on birth year.

In addition to PTA, PA, YD, and DYD, a predicted producing ability (**PPA**) is calculated and provided to the industry to indicate the future production of a doe (VanRaden and Wiggans, 1991). The PPA includes *p* and *c* as well as *a* and is useful in predicting the relative performance of a doe in the next lactation rather than the performance of future progeny (Wiggans et al., 1988).

Genetic evaluations for milk, fat, and protein yields are combined into the MFP\$ economic index (Wiggans and VanRaden, 1989). The economic values for milk components used to calculate MFP\$ for dairy cattle are used for dairy goats:

$$MFP\$ = \$0.010(PTA_{milk}) + \$1.15(PTA_{fat}) + \$2.55(PTA_{protein})$$

Although goat milk has substantially higher economic value than cow milk (Haenlein, 1984a), the relative weights for milk, fat, and protein are useful for combining those traits into a single index (Wiggans et al., 1994). The current economic weights were implemented in July 2000 (VanRaden, 2000), and they are updated every 5 yr when the genetic base is updated.

Percentile rankings of dairy goats are based on MFP\$. High-ranking does and bucks are designated as elite based on percentile ranking (Wiggans et al., 1994). For bucks to qualify, they must be in the top 15% of bucks with daughters that were born during the last 4 yr. Does must be in the top 5% of does that kidded during the last 2 yr and have a termination code in their latest record that indicates that they are still alive.

The measure of the accuracy of a genetic evaluation is called reliability (**REL**) (VanRaden and Wiggans, 1991). All sources of information are converted to daughter equivalents (**DE**) (VanRaden and Wiggans, 1991). A DE is the amount of information contributed by one daughter with one lactation. The DE from the parents of an animal, its own records, and its progeny are summed. Then REL is calculated as $DE/(DE + 14)$, where 14 is a reflection of the heritability of yield traits (Wiggans et al., 1994). For bucks, information from an additional daughter in the same herd contributes less than if that daughter had been in a different herd (VanRaden and Wiggans, 1991).

Yield evaluations are computed in July of each year and distributed to DRPC and to ADGA for release to the industry. The evaluations also are available from queries on individual bucks and does and as downloadable files and printable lists at the AIPL web site (<http://aipl.arsusda.gov>).

Evaluations in July 1999 were calculated for 198,698 does and 43,763 bucks. Of those bucks, 9075 bucks had ≥ 5

daughters, which is required for release of a buck evaluation to the industry (Wiggans, 1989). Genetic trend (Table 2) differed by breed. Annual genetic progress for does that were born during 1996 as a percentage of mean breed yield was lowest for Toggenburgs (-0.1%/yr, milk; 0.0%/yr, fat and protein) and highest for Saanens (0.9%/yr, milk and protein; 1.0%/yr, fat).

Type Traits

Participation in ADGA linear appraisal programs (American Dairy Goat Association, 1993) in 1999 was 3784 does, which is a decrease from the mean of 4285 does over the last 5 yr. Appraisals for final score and 13 primary linear traits [stature, strength, dairyness, rump angle, rump width, rear legs (side view), fore udder attachment, rear udder height, rear udder arch, medial suspensory ligament, udder depth, teat placement (rear view), and teat diameter] are provided to AIPL by ADGA. Linear traits are scored between biological extremes on a continuous scale. Final scores range from 50 to 99; scores for linear traits range from 1 to 50. Type records are adjusted for the age of the doe at appraisal (USDA, 1989, unpublished research; current adjustment factors available at <http://aipl.arsusda.gov/memos/html/goat.type.age.html>). All appraisals for a doe are included in genetic evaluations (Luo et al., 1997).

Type traits of dairy goats are evaluated with a multitrait animal model (Luo et al. 1997):

$$y = h + a + p + e$$

where *y* = adjusted type record, *h* = effect of appraisal date for the herd, *a* = genetic merit (breeding value), *p* = effect of permanent environment for the doe, and *e* = remaining unexplained residual. A multitrait evaluation permits scores from one trait to affect the evaluation of another trait through the genetic correlations among the traits (Mistzal et al., 1993). A canonical transformation is applied to the data so that a single-trait calculation method can be used (Lin and Smith, 1990). An effect for the interaction of herd and sire was not included in the model for type analysis because of the difficulty of applying a canonical transformation with multiple random effects. Heritabilities (Table 3) for linear type traits range from 0.19 for rear udder arch to 0.52 for stature; heritability for final score is 0.27 (Luo et al., 1997).

Similar to yield data, type data are analyzed across breeds (Luo et al., 1997). However, the resulting evaluations are not adjusted for breed means because of smaller breed differences than for yield traits. Therefore, type evaluations are comparable among breeds.

Table 3. Heritabilities for type traits, standard deviations of EBV, and annual genetic trends for does born during 1996

Type trait	Heritability	SD of EBV	Annual genetic trend
Final score	0.27	0.64	0.05
Stature	0.52	2.58	0.67
Strength	0.29	0.72	0.20
Dairyness	0.24	0.60	0.06
Rump angle	0.32	1.48	0.37
Rump width	0.27	0.51	0.12
Rear legs (side view)	0.21	1.15	0.09
Fore udder attachment	0.25	0.86	0.01
Rear udder height	0.25	0.75	-0.12
Rear udder arch	0.19	1.11	0.02
Medial suspensory ligament	0.33	1.06	0.22
Udder depth	0.25	0.97	-0.01
Teat placement (rear view)	0.36	1.11	0.34
Teat diameter	0.38	1.74	0.16

Type evaluations for final score and linear traits are computed annually in November. The PTA and REL for each trait are provided to ADGA for further distribution to the industry. Evaluations also are available from queries on individual bucks and does and as downloadable files at the AIPL web site (<http://aipl.arsusda.gov>). The November 1999 evaluations included appraisals from 1988 through 1999. Evaluations for final score in November 1999 were calculated for 66,441 does and 21,987 bucks. Of those bucks, 1945 bucks had ≥ 5 daughters. Annual genetic trend for type traits across breeds for does born during 1996 (Table 3) ranged from 0.67 for stature to -0.12 for rear udder height.

Production-Type Indexes

As part of a sire development program, ADGA combines genetic evaluations for yield and type into a production-type index (PTI) that represents the economic merit of the traits evaluated for the animal (Wierschem and Dickinson, 1989). Yield is represented by PTA for FCM, which reflects each breed's average fat percentage (Table 4), and type is represented by PTA for final score. Comparisons of PTI among animals should be made only within breed.

After PTA_{milk} has been converted to PTA_{FCM} , two PTI are calculated (Wierschem and Dickinson, 1989). The first PTI formula emphasizes yield twice as much as type:

$$PTI = 100[2(PTA_{FCM}/SD_{PTA_{FCM}} + (PTA_{final\ score}/SD_{PTA_{final\ score}})]/3.$$

where SD = standard deviation. The other PTI formula emphasizes type twice as much as yield:

$$PTI = 100[(PTA_{FCM}/SD_{PTA_{FCM}} + 2(PTA_{final\ score}/SD_{PTA_{final\ score}})]/3,$$

Table 4. Means for fat percentage by breed.

Breed	Fat percentage
Alpine	3.5
LaMancha	3.5
Nubian	4.5
Oberhasli	3.7
Saanen	3.4
Toggenburg	3.3

A parent mean for PTI is calculated by ADGA to identify young bucks with superior genetics for progeny testing.

SUMMARY AND DISCUSSION

National genetic evaluations for yield and type traits of dairy goats in the United States are calculated annually by AIPL. Yield evaluations are released to the dairy goat industry in July, and type evaluations are released in November. Evaluations are available to producers through ADGA or at the AIPL web site (<http://aipl.arsusda.gov>). Pedigree and yield information also is available at the AIPL web site. The yield information includes individual test-day data. After a test-day model has been implemented for dairy cattle, a similar system will be developed for dairy goats so that test-day data can be used directly for genetic evaluation of yield traits as is done in Canada (Sullivan and Wiggans, 2000).

Genetic evaluations are a useful tool only if they lead to progress toward the breeding goal. For dairy goats, seasonal breeding and the resulting fluctuations in milk supplies that are available throughout the year have made development of new markets difficult and have dampened the importance of increased milk yield as a breeding goal (Guss and Ace, 1984; Haenlein, 1984b). Greater rates of genetic improvement are likely if the economics of goat milk production improve. Because of the large number of progeny possible for an individual buck, especially because of AI and the short generation interval, genetic improvement could be rapid.

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