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ABSTRACT

Multiplicative age-season adjustment factors for milk and fat yields of five breeds of dairy goats were estimated by fitting a three-way, mixed classification model containing random effects for does with fixed effects for herd-year-season and age-season for 7544, 1994, 7456, 3307, and 4599 lactation records collected from 1965 to 1976 from Alpine, LaMancha, Nubian, Saanen, and Toggenburg dairy goats in the United States. These factors reflect changes in milk and fat yields associated with age and season of freshening. As with dairy cattle, these factors indicated that milk records of goats are affected differently in different seasons for a particular age. Season of freshening affected younger does more than their older herdmates. Does freshening in January through March produced larger milk yields than their herdmates that freshened at later months of the year. In general, does reached peak production at 34 to 38 mo of age and declined after 50 mo of age.

Repeatabilities for milk yield were .33, .29, .35, .27, and .35 for Alpine, LaMancha, Nubian, Saanen, and Toggenburg breeds. The adjustment factors indicate that age factors for dairy cows currently being used for adjusting goat records should be replaced by separate factors developed for specific breeds of dairy goats. No such set of age-season adjustment factors has been adopted universally for dairy goats in the United States. Factors in this study, however, could serve as a guide for such a set of adjustment factors.

INTRODUCTION

Milk production is influenced by several factors which make comparison of lactation records for genetic evaluation and management purposes difficult. Some of these factors, such as age-season effects, are fixed so that adjustment factors can be developed to make records comparable. Such adjustments have been 1) to reduce sampling variances due to unequal ages, 2) to remove biases from comparisons of animals or groups of animals or different ages, and 3) to estimate what a specific record would have been if made at a standard age. The primary use of age adjustment is to eliminate biases in comparison of young animals with older herdmates.

Several studies (2, 11, 12, 16, 19) also have shown that cows calving in certain seasons have higher milk and fat yields than those calving in other seasons. Season of calving affects younger cows differently from older ones (6). According to Cameons (3), seasonal variation exerts its influence on production in two main ways. Changes in temperature and humidity, as reported by McDowell et al. (7), act directly on the homeostatic mechanisms of the animals and bring about adjustments in behavior which tax efficiency of energy utilization with an eventual decline in milk energy output. They (7) also reported that seasonal variations directly influence forage quality and quantity. McDowell et al. (8) showed that with no variation in feed quality and quantity, the component of variance for seasons is negligible, whereas the feed component alone could account for about 30% of all variation in lactation performance.

There is general agreement (3, 19) that cows

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calving in late fall and early spring in the United States have higher milk yields than cows calving in summer months. Seasonal effects affect high-production herds more than low-production herds (19). The season of calving also affects younger animals differently from older ones (16). This phenomenon generally has been referred to as age-by-season interaction. Miller (9) reported that sire proofs were biased when all daughters of a sire calved in the same season and that age-by-season interaction was responsible for this bias, since at that time the same age factors were used for all seasons of freshening. However, Van Vleck (18), using data from New York dairy herds, observed an age-by-season interaction and suggested that "factors should not be constructed to correct first for age, and then for season effects; instead factors should be developed taking into account age and season simultaneously." Adjustment factors which take age, season, and age-by-season effects into account simultaneously, therefore, may be necessary for goat records as well as for cattle records.

For several years, adjustment factors developed for dairy cattle have been used to adjust dairy goat records, because correction factors have not been developed specifically for dairy goats. Since such factors have not been developed fully for different breeds of dairy goats, this study was initiated to estimate the appropriate correction factors to adjust dairy goat records to a standardized age and season of freshening.

MATERIALS AND METHODS

Initial data consisted of 72,352 305-day lactation records of various dairy goat breeds on DHI (Dairy Herd Improvement) test from 1965 to 1976 made available by the Animal Improvement Programs Laboratory (AIPL) of

TABLE 1. Number of records in each age-season subclass for various breeds.

	Alpine		LaMancha		Nubian		Saanen		Toggenburg	
	Season		Season		Season		Season		Season	
Age (mo)	1[a]	2[b]	1	2	1	2	1	2	1	2
10	25	25	11	11	12	9	25	8	19	11
11	146	88	42	38	61	68	61	42	72	34
12	197	261	62	90	101	179	103	130	92	132
13	79	336	43	114	127	276	37	173	63	172
14	13	210	9	100	50	269	11	114	14	115
15	1	127	1	50	20	178	2	48	12	73
16	9	57	2	23	8	100	9	25	4	58
17	5	19	1	12	8	44	1	11	7	28
18	9	20	4	11	21	31	8	7	13	16
19	42	17	9	7	53	35	22	7	23	17
20	50	14	25	8	94	30	22	6	31	12
21	114	19	44	5	132	33	51	7	75	25
22	199	42	49	11	180	53	73	11	105	21
23	223	88	78	25	238	102	98	46	150	57
24	220	167	61	36	185	132	70	74	119	75
25–27	111	312	38	103	160	342	22	154	75	212
28–30	9	34	5	21	30	86	12	22	13	26
31–33	124	41	41	15	203	78	59	24	92	25
34–36	472	211	123	40	446	196	179	74	293	125
37–42	81	275	37	52	143	283	22	109	56	148
43–48	398	172	80	24	457	178	163	58	254	115
49–54	46	189	20	35	80	183	17	85	28	112
55–60	262	113	38	11	268	112	105	42	169	69
> 60	402	378	41	24	425	398	152	141	270	280

[a]Season 1 (January to March).

[b]Season 2 (April to July).

the USDA. These included 16,203, 4592, 15,084, 7104, and 9359 lactation records from Alpine, LaMancha, Nubian, Saanen, and Toggenburg breeds. The remaining 20,010 records were from goats identified as an "experimental" breed. Data were edited and screened for correctness. Only records initiated at a minimum of 10 mo of age and which terminated normally were in this study. Records which contained incomplete information on herd codes, kidding dates, age at freshening, breed of bucks, or dams of does were eliminated. Duplicate records were eliminated also. Projection factors were not used. The minimum days in milk recorded for any of the does was 230 days, so the only restriction placed on the length of actual records was a ceiling of 305 days. After these edits, the remaining data comprised 7544 Alpine records, 1994 LaMancha records, 7456 Nubian records, 3307 Saanen records, and 4599 records from the Toggenburg breed. Twenty-four age groups and two seasons of freshening groups (January through March and April through July) were obtained for each breed. Three seasons (January through February, March through April, and May through July) for year-season groupings were delineated for each herd. Such a choice of different number of seasonal groupings for the age-season effects and the herd-year-season effects should result in nonsingularity of the final equations to be solved. Lactation records started in August through December comprised less than 4% of the total records and were included in the July group. The number of records in the 48 age-season subclasses for the various breeds are in Table 1.

To obtain the age-season adjustment factors, a procedure similar to the method reported by Miller (10) was followed. The model for the mth production record of the lth doe freshening in the kth year-season in the jth herd and falling

TABLE 2. Average lactation yields and multiplicative age-season adjustment factors for Alpine goats.

	Season 1 (Jan–Mar)				Season 2 (Apr–Jul)			
	Average lactation yields		Adjustment factors		Average lactation yields		Adjustment factors	
Age	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
(mo)	(kg)	(kg)			(kg)	(kg)		
10	26.3	630	1.38	1.38	19.1	551	1.69	1.86
11	22.7	669	1.42	1.38	20.0	577	1.61	1.59
12	23.1	677	1.44	1.43	20.4	595	1.64	1.62
13	21.3	621	1.39	1.40	20.0	574	1.67	1.68
14	19.1	615	1.75	1.68	19.1	544	1.74	1.76
15	15.0	422	1.48	1.40	16.8	473	1.78	1.69
16	21.3	600	1.27	1.32	16.3	445	1.81	1.86
17	25.4	687	1.04	1.32	18.6	512	1.72	1.74
18	25.4	690	1.32	1.32	15.9	438	1.81	1.75
19	25.4	727	1.21	1.21	18.1	510	1.41	1.50
20	28.1	720	1.21	1.18	23.6	660	1.41	1.44
21	26.3	765	1.19	1.18	22.7	644	1.37	1.36
22	26.3	733	1.19	1.21	25.9	746	1.19	1.24
23	26.8	766	1.16	1.15	28.1	811	1.15	1.15
24	27.2	813	1.10	1.08	26.3	770	1.13	1.13
25–27	24.9	732	1.12	1.06	26.3	727	1.23	1.22
28–30	27.2	784	.93	.98	25.4	721	1.38	1.23
31–33	30.4	895	1.05	1.04	24.5	692	1.19	1.23
34–36	30.8	868	1.00	1.00	27.7	801	1.12	1.10
37–42	31.3	863	1.01	1.00	25.9	747	1.14	1.22
43–48	29.5	855	1.04	1.01	26.3	769	1.15	1.19
49–54	27.7	888	1.01	1.02	24.9	769	1.20	1.29
55–60	27.2	813	1.06	1.03	24.9	628	1.21	1.22
> 60	26.8	769	1.15	1.03	22.7	714	1.30	1.31

in the ith age-season of freshening group was

$$y_{ijklm} = \mu + a_i + h_{jk} + d_{jl} + e_{ijklm}$$

where μ is an unknown constant common to all records, a_i is a fixed effect due to the ith age-season of freshening, h_{jk} is a fixed effect common to the kth year-season of freshening in herd j, d_{jl} is a random effect associated with doe l in herd j, with mean zero and variance σ_d^2, and e_{ijklm} is the random error term associated with the mth record of the lth doe started in the kth year-season in the jth herd and in the ith age-season subclass, with mean zero and variance σ_e^2. The covariances between any two e's, any two d's, and any d and e are zero.

Repeatability of milk yield for the various breeds was calculated by Henderson's Method 1 and was used to calculate the ratio $\sigma_e^2/\sigma_d^2 = (1-r)/r$, where r is repeatability. The r's for milk yield of Alpine, LaMancha, Nubian, Saanen, and Toggenburg breeds were .33, .29, .35, .27, and .35. The same estimates were used for fat yield.

The number of equations to be solved was reduced by absorbing the doe and herd-year-season equations. By sorting the data in order of age-season of freshening within does within herds, it was possible to collect each doe equation completely before reading in information for the next doe. Similarly, all records within a herd were processed in sequence, and the herd-year-season equations were completed and absorbed before a record from the next herd was processed. Doe equations were absorbed into herd-year-season equations, and the resultant equations were absorbed into age-season equations.

To obtain a full rank coefficient matrix, the μ equation and the equation for the first age-season subclass were constrained to zero. From solutions obtained from these absorbed

TABLE 3. Average lactation yields and multiplicative age-season adjustment factors for LaMancha goats.

	Season 1 (Jan–Mar)				Season 2 (Apr–Jul)			
	Average lactation yields		Adjustment factors		Average lactation yields		Adjustment factors	
Age	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
(mo)	(kg)	(kg)			(kg)	(kg)		
10	20.0	477	1.68	1.70	19.1	450	1.81	1.90
11	20.9	563	1.52	1.51	18.6	501	1.58	1.58
12	22.2	611	1.43	1.42	20.9	520	1.64	1.64
13	20.4	538	1.70	1.62	19.1	499	1.66	1.68
14	21.3	566	1.54	1.45	18.6	477	1.70	1.71
15	17.7	390	1.28	1.39	16.8	440	1.66	1.65
16	23.6	583	1.39	1.34	17.2	396	1.67	1.66
17	24.5	590	1.01	1.08	18.1	485	1.34	1.57
18	27.7	708	1.00	1.02	20.9	511	1.39	1.57
19	26.3	698	1.21	1.17	21.3	506	1.72	1.85
20	24.9	642	1.12	1.15	25.4	529	1.36	1.44
21	24.9	649	1.07	1.10	34.0	841	1.11	1.28
22	23.6	636	1.19	1.15	22.2	537	1.27	1.29
23	28.1	739	1.08	1.08	27.2	736	1.16	1.28
24	28.1	720	1.09	1.08	24.5	556	1.28	1.28
25–27	29.9	781	.99	1.05	24.5	623	1.23	1.26
28–30	30.4	661	.98	1.02	22.7	577	1.36	1.38
31–33	29.0	743	1.00	1.02	26.3	633	1.02	1.07
34–36	29.5	781	1.00	1.00	26.3	707	1.07	1.09
37–42	27.7	732	1.01	1.03	25.4	654	1.15	1.18
43–48	27.7	719	1.05	1.03	22.7	580	1.18	1.18
49–54	25.4	666	1.19	1.03	26.3	640	1.15	1.15
55–60	25.4	636	1.13	1.07	26.8	631	1.08	1.15
> 60	25.4	635	1.22	1.08	26.3	601	1.21	1.17

equations and average milk and fat yields as reported in Tables 2, 3, 4, 5, and 6, multiplicative age-season adjustment factors for milk and fat production were computed. These factors were derived with base records made from freshenings at 34 mo of age in the first season as indicated by the equation

$$f_{ij} = M_b/[M_b - (S_b - S_{ij})]$$

where f_{ij} is the multiplicative age-season adjustment factor for age i in season j, M_b is the average yield for records started by freshening at 34 to 36 mo in season 1, S_b is the solution for the base age of 34 to 36 mo in season 1, and S_{ij} is the solution obtained for age i in season j.

RESULTS AND DISCUSSION

Age-season adjustment factors for milk and fat yields of various breeds are included in Tables 2, 3, 4, 5, and 6. The factors as presented here were not smoothed. Copies of smoothed factors developed from this study are available from the AIPL, USDA, Beltsville, MD.

Average yields of milk at various ages and seasons of freshening differed. Differences also were similar for average yields of fat. Does freshening in the first season (January through March) produced larger milk yields than does freshening in April through July. These differences, however, are proportionately a little less than those reported by McDowell et al. (8) for first-lactation Holstein cows. Season of kidding affected younger does more than their older herdmates.

Average peak yields occurred when does freshened between the ages of 33 and 38 mo. There was, however, an initial but general decline in lactation yields for ages between 10 and 15 mo, followed by a sharp increase up to 25 mo of age, and then by a gradual rise to peak production. Lactation yields declined for

TABLE 4. Average lactation yields and multiplicative age-season adjustment factors for Nubian goats.

	Season 1 (Jan–Mar)				Season 2 (Apr–Jul)			
	Average lactation yields		Adjustment factors		Average lactation yields		Adjustment factors	
Age	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
(mo)	(kg)	(kg)			(kg)	(kg)		
10	18.6	391	1.44	1.53	16.3	350	1.65	1.87
11	21.8	508	1.46	1.47	20.0	449	1.85	1.79
12	23.6	552	1.37	1.35	20.4	457	1.69	1.68
13	24.0	550	1.28	1.30	20.4	455	1.67	1.66
14	21.8	549	1.33	1.31	20.0	441	1.59	1.59
15	26.8	590	1.38	1.28	19.5	432	1.56	1.57
16	32.2	696	1.20	1.25	19.1	412	1.57	1.57
17	30.4	659	1.00	1.25	19.1	411	1.58	1.57
18	22.2	557	1.21	1.25	18.1	386	1.53	1.56
19	25.9	572	1.21	1.25	20.0	435	1.27	1.27
20	26.8	596	1.19	1.17	23.6	507	1.23	1.25
21	25.9	617	1.19	1.22	21.8	482	1.22	1.24
22	24.5	591	1.24	1.23	24.9	547	1.27	1.29
23	28.1	633	1.07	1.09	24.5	547	1.24	1.23
24	28.6	641	1.09	1.07	26.3	599	1.19	1.18
25–27	28.6	654	1.05	1.04	25.4	564	1.20	1.19
28–30	29.5	635	1.09	1.02	24.5	573	1.15	1.15
31–33	33.1	727	.94	1.00	25.9	553	1.13	1.13
34–36	31.8	694	1.00	1.00	29.5	683	1.02	1.11
37–42	31.8	707	.99	.99	26.2	603	1.11	1.11
43–48	32.7	733	.98	.98	29.9	646	1.04	1.06
49–54	32.2	716	.95	.99	28.6	527	1.07	1.07
55–60	31.3	704	1.00	1.01	27.2	592	1.11	1.12
> 60	28.6	639	1.09	1.02	24.0	532	1.22	1.25

does kidding after 50 mo of age. The initial decline in fat and milk yields between 10 and 15 mo was more pronounced for does kidding from January through March than for does kidding in later months. Since this initial decline was for four breeds (Alpine, LaMancha, Saanen, and Toggenburg), an attempt was made to establish a biological basis to explain such an observation. Goats have a gestation length of 5 mo and an off-season of freshening from September through December due to seasonality in estrus. Cool months of fall induce estrus in goats whereas hot summer months depress estrus. In a study on the periodicity of ovarian changes and their effects on the seasonality of estrus in dairy goats, Turner (17) reported that goats generally exhibit intense ovarian activity and strong estrus in September through December, with a depressed ovarian activity and anaestrus between April and August. Other workers including Kupfer (5) and Shelton (15) confirm that these seasonal ovarian activities produce a peak season for mating (September through December) and a low season (April through August). They also showed that the peak season for kidding is between January and March, with an off-season of September through December. Consequently, does freshening at 15 mo of age in February must have been bred 5 mo earlier in September and were born the previous November, which coincides with the off-season for kidding. Being born within the off-season may be associated with depressing the production of these does as compared to those kidding at 10 mo of age.

Relationship was inverse between average yields of milk and their corresponding adjustment factors. Relationships were similar for fat yields. For any age at freshening, factors for season 2 were consistently higher than those for season 1. Differences between these factors also varied according to age of does at freshening.

TABLE 5. Average lactation yields and multiplicative age-season adjustment factors for Saanen goats.

	Season 1 (Jan–Mar)				Season 2 (Apr–Jul)			
	Average lactation yields		Adjustment factors		Average lactation yields		Adjustment factors	
Age	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
(mo)	(kg)	(kg)			(kg)	(kg)		
10	23.6	691	1.40	1.36	20.9	605	1.47	1.61
11	26.3	735	1.29	1.26	21.3	603	1.62	1.61
12	23.1	672	1.46	1.42	23.1	654	1.50	1.51
13	24.9	698	1.41	1.44	20.9	573	1.61	1.60
14	16.2	522	1.62	1.61	20.4	586	1.72	1.72
15	10.4	345	1.67	1.26	19.1	562	1.58	1.55
16	20.4	602	1.28	1.21	16.8	476	1.53	1.61
17	44.9	1043	1.28	1.26	18.1	513	1.47	1.51
18	24.9	729	1.21	1.26	18.6	532	1.46	1.48
19	25.9	739	1.10	1.11	25.4	684	1.18	1.26
20	25.9	772	1.20	1.15	23.6	684	1.19	1.20
21	26.8	752	1.25	1.23	24.9	729	1.15	1.15
22	27.7	793	1.16	1.12	19.5	570	1.30	1.28
23	28.1	793	1.00	1.06	26.8	730	1.15	1.18
24	29.5	829	1.09	1.06	25.9	754	1.18	1.14
25–27	28.1	791	1.12	1.05	24.5	698	1.26	1.13
28–30	29.5	841	1.03	1.05	21.3	667	1.30	1.18
31–33	31.8	875	1.01	1.02	23.6	703	1.12	1.10
34–36	31.3	876	1.00	1.00	28.1	773	1.11	1.14
37–42	29.9	865	1.00	.99	26.3	748	1.17	1.16
43–48	29.9	839	1.04	1.04	25.9	727	1.16	1.17
49–54	29.0	796	.97	1.00	24.0	688	1.24	1.23
55–60	30.8	794	1.04	1.02	21.8	622	1.38	1.37
> 60	24.5	679	1.24	1.06	21.3	606	1.42	1.43

TABLE 6. Average lactation yields and multiplicative age-season adjustment factors for Toggenburg goats.

	Season 1 (Jan–Mar)				Season 2 (Apr–Jul)			
	Average lactation yields		Adjustment factors		Average lactation yields		Adjustment factors	
Age	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
(mo)	(kg)	(kg)			(kg)	(kg)		
10	22.7	704	1.38	1.39	19.1	590	1.55	1.55
11	22.7	673	1.27	1.31	19.5	604	1.71	1.72
12	22.7	672	1.33	1.35	20.0	599	1.46	1.52
13	23.1	695	1.26	1.29	19.5	599	1.48	1.53
14	25.9	697	1.13	1.17	20.4	631	1.42	1.43
15	20.9	635	1.11	1.12	17.7	545	1.40	1.46
16	25.4	751	1.01	1.03	19.1	579	1.43	1.50
17	23.6	693	1.13	1.18	18.1	565	1.41	1.50
18	23.6	693	1.16	1.17	23.1	659	1.33	1.42
19	23.6	697	1.18	1.19	22.7	636	1.14	1.19
20	24.5	730	1.08	1.08	21.8	629	1.17	1.20
21	25.9	771	1.13	1.13	21.3	630	1.17	1.19
22	25.9	774	1.05	1.06	22.7	661	1.25	1.27
23	25.9	783	1.05	1.06	22.7	686	1.20	1.18
24	26.3	811	1.07	1.07	23.1	710	1.17	1.16
25–27	26.3	810	1.05	1.05	23.1	702	1.19	1.18
28–30	32.2	924	1.00	1.00	20.9	661	1.15	1.15
31–33	30.8	873	1.00	1.00	22.2	690	1.10	1.18
34–36	29.5	835	1.00	1.00	26.3	796	1.02	1.15
37–42	29.0	816	1.02	1.02	25.9	773	1.10	1.14
43–48	28.6	879	1.00	1.03	25.9	804	1.10	1.14
49–54	26.8	833	1.01	1.03	23.6	748	1.14	1.15
55–60	25.9	812	1.02	1.03	23.1	733	1.23	1.16
> 60	24.0	743	1.10	1.14	20.4	752	1.29	1.18

These differences suggest that season of kidding affects older does more than younger does. Although the magnitude of the adjustment factors for the various ages differed from breed to breed, these differences were relatively small and may be of little practical importance. The results are similar to (1, 4, 13, 14).

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