An Empirical Model to Predict Part Lactation Milk Production from a Single Test-Day Record in Chios Sheep

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Summary

Individual test-day and 90-day (part) lactation records from Chios sheep, collected from 1966 to 1995 at the Experimental Station of the Agricultural Research Institute at Athalassa were used to predict total lactation milk production from a single test-day record. Data refer to twice-a-day individual milk records obtained following weaning (35 " 3 days *post-partum).* The first test was performed 7 to 14 days following weaning and the second test three weeks later. Part lactation milk production was based on at least 3 monthly tests and was calculated using the A4 method. Data were adjusted for year and season of lambing and lactation number (parity), before being used for the estimation of the parameters of the incomplete gamma function (Wood=s modified equation). The mean individual test-day yield at first and second recordings was 2.01 and 1.55 kg, respectively, while 90-day milk production was 126.6 kg/ewe. Simple product moment correlations among measures of performance were high and positive. Prediction equations using either a single test-day record (first or second) or the sum of both test-day records were effective in predicting 90-day yield. A smaller error mean square was obtained when the sum was used, but it also overestimated 90-day production by 7.58%. The use of the first test-day record underestimated 90-day production by 2.18% and that of the second test-day record overestimated it by 4.7%.

Introduction

Lactation curves provide valuable information about the pattern of milk production which are necessary for the nutritional and reproductive management of lactating animals (Wood, 1980), estimation of total lactation yield, expected time of peak, peak milk yield and persistence of yield (Wood, 1976).

Several mathematical functions have been used to estimate parameters of lactation curves, mainly in daily cattle (Wood, 1967), but also in sheep (Sakul & Boyland, 1992; Carta, Sanna & Casu, 1995; Groenewald *et al*., 1995) and goats (Williams, 1993; Ruvuna *et al*., 1995). Most of the research work deals with fitting the incomplete gamma function or Wood=s model. Other proposals include a four parameter and a six parameter function (Morant & Granasakthy, 1989) and a six parameter diphasic function (Grossman & Koops, 1988).

Recording of total lactation, based on periodic sampling at regular intervals throughout lactation, is still time-consuming and costly. Efficient dairy flock management and particularly the selection of individuals for a breeding program can only be achieved through the knowledge of individual performance for milk.

The purpose of the present work was to evaluate individual animals on the basis of one of two sequential test-day records, the first record obtained shortly after weaning and the second 20 days later or their sum using the incomplete gamma function (a modification of Wood=s equation). Also, to examine the usefulness of such estimation from a single test-day record of some accuracy, in practice.

Materials and Methods

Description of data

Data consisted of 1030 lactation records of Chios sheep, collected between 1966 and 1995 at the experimental station of the Agricultural Research Institute at Athalassa. All lactation records refer to twice-a-day milk records obtained after weaning. Ewes were weaned in batches once weekly at 35"3 days *post-partum* and the first individual test-day record was obtained 7 to 14 days following weaning. The second test-day record followed circa 20 days later and all subsequent records at monthly intervals thereafter. Part and total lactation milk yield were estimated from test-day (daily) individual records using the A4 method (ICAR, 1992).

The flock was managed in a way that allowed the lambs to enter the production cycle at an early physiological age. Hence, all lambs born in the previous lambing season either in Fall or in early Spring, were put to ram in the immediately following breeding season (August-September) and were allowed to mate. Since most older ewes were mated in May-June and those that did not conceive were remated in the Fall together with the lamb crop, two breeding seasons were artificially created (Fall and Spring). All other practices were similar, since feeding was indoor and minimum grazing was practiced on artificial barley forage. Other roughage supplements, such as alfalfa and barley hay, were fed indoors to both groups.

Statistical analyses

The first statistical analysis was performed to determine the magnitude of environmental effects on test-day records and estimate partial (90-day) and total lactation milk production. The mathematical model used was:

$$Y_{ijkl} = \mu + YRL_i + SEAS_j + LAC_k + e_{ijkl}$$

where

Y_{ijkl} represents test-day milk production at first or second recording and 90-day milk yield, in the ith year (YRL) and jth season of lambing (SEAS=10, 12, 2 and 4 for September - October, November - December, January - February and March - April, respectively)

LAC represents the kth lactation of the ewe and

e_{ijkl} is a random error term assumed to be normally and independently distributed with zero mean and variance ó^2.

Since the two test-day records were taken at a variable period following weaning, some variation in yield was expected that can be attributed to the phase of the lactation curve at that particular test. Constant estimates for year, season and lactation number effects were subsequently used to adjust the data before Wood=s equation was fitted.

Wood=s equation (1967) has been used to characterize the shape of lactation curves in sheep (Torres-Hernandez & Hohenboken, 1980; Sakul & Boylan, 1992), to estimate total lactation yield (Ruvuna *et al.,* 1995), or evaluate its appropriateness for dairy sheep by comparing actual and fitted curves, using several test-day records in time. Estimation of total lactation yield from a single test-day record has also been attempted. The principle has been described by Wood (1974) and it is based on the direct relationship that exists between the two variables and some assumptions about the error in measuring at a particular point in time.

Following the same principles, a modified Wood=s equation was used to estimate part-lactation milk production from a single test-day record or the sum of the first two records, as follows:

$$Y_n = an^b e^{-cn}$$

which was modified, such that week of lactation was substituted by the test-day milk yield and daily production on the 4th day of lactation by the total production of milk 90 days *post-partum*.

Hence,

$$Y_i = ax^b e^{-cx}$$

where

a, b and c are parameters to be estimated.

Model parameters were estimated by nonlinear least squares using PROC NLIN of SAS (SAS, 1985), using computational algorithms (Marquardt, 1970; Ralston & Jerich, 1978).

Results and Discussion

Mean squares and tests of significance for test-day milk yield (first and subsequent tests) and 90-day yield are given in Table 1. All traits were significantly affected by year and season of lambing and lactation number (parity) except 90-day yield, which was not affected by year of lambing. That was expected since a part record should not show much variation from one year to another when management and feeding practices were almost identical in the present study (Table 2). Test-day (daily) production at the first recording following weaning, although variable, shows a remarkable consistency around 2.0 kg per day (Table 2). The interval from weaning to first test is also consistent, considering that the practice from 1986 to 1989 (7-day interval) was maintained, until it was changed from 1993 onwards when first test-day record was obtained 14"3 days after weaning. The second interval (from first to second recording) was also stable (circa three weeks), with the exception of 1993 (four weeks). Total production estimated from test-day records and the actual period from weaning to the second test-day record (equivalent to about 40 to 50 days) is also shown in Table 2. With the exception of 1989, 90-day milk yield was consistent through years. Consistency and high association was also evidenced from the simple correlations (Table 3), where the milk production on first or second test was highly correlated with milk production for the total period (r=0.92 and r=0.89 for first and second test-day records, respectively) and with 90-day yield (r=0.84 and r=0.80 for the same tests as above). Total lactation yield and 90-day yield were also highly correlated (r=0.88). Because of the high and positive associations between single test-day records and estimated 90-day milk yield, we may assume that the objectives of the present study were met.

Estimated parameters, the mean square of error and predicted 90-day milk yield for each of three methods of estimation are given in Table 4. The lowest mean square of error was when the sum of the two test-day records was used. All predictions were close to actual 90-day production (126.6 kg) computed from the data using the conventional method (A4 method). The closest predicted value obtained was when the first test-day milk production was used (123.8). This is consistent with the expectation that choosing a period when an animal yields more consistently or by using the average of consecutive records the error is reduced (Wood, 1974). It should be reminded that the first test-day record was obtained following weaning, which is a period clearly after the peak in sheep. Van Vleck and Henderson (1961) also suggested (in cattle) that day to day variation after the third month is small enough to allow a single test-day record to provide a reasonable selection criterion. This is more substantiated by the high correlations found in the present study compared to those reported by the previous authors.

Using the second test-day record or the sum of the two tests resulted in the overestimation of 90-day yield (4.68% and 7.58% for the second test-day and the sum, respectively).

It may be concluded that the modified Wood=s equation can be used to estimate, with a reasonable accuracy, 90-day milk production. Perhaps more important than the prediction of individual performance is the fact that it permits the classification of individuals (rank) and thus evaluation following the application of an animal model for purposes of selection and culling.

The present findings are in agreement with the results of Van Vlechand Henderson (1961), Wood (1974) and Groenwald *et al.* (1995) who concluded that nonlinear equations can be used to predict total lactation from a single record. They both stated that parity may influence the prediction. In the present study parity and season of lambing were accounted for, before the model was fitted.

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Table 1. Mean squares and tests of significance for test-day and 90-day milk yield.

Source[1]	df	DYLD1	DYLD2	TDYLD	TMILK	MLK90
YRL	6	1.39**	1.53**	5.54**	34347.7**	3328.5
SEASL	3	2.82**	1.16*	5.85**	23356.4**	11518.4**
LAC	5	3.96**	2.07**	11.53**	30325.3**	14699.5**
Error	1015	0.46	0.33	1.27	5207.7	1868.3
Total	1029					

[1]YRL = year of lambing; SEASL = season of lambing; LAC = lactation number; DYLD1 = individual daily production of milk at the first test; DYLD2 = individual daily production of milk at the second test; TDYLD = total of first and second test; TMILK = total milk production for the period from weaning to the second test; MLK90 = 90-day milk production.

Table 2. Overall means for all traits studied.

	Year						
Trait[1]	86	87	88	89	93	94	95
N	187	177	152	154	83	137	140
DYLD1	2.05	2.00	2.08	2.02	1.85	1.96	2.01
DYLD2	1.68	1.61	1.64	1.58	1.34	1.55	1.48
TDYLD	3.73	3.61	3.72	3.61	3.18	3.51	3.49
DAYS1	7.2	7.0	7.1	7.3	14.3	13.9	13.6
DAYS2	19.8	17.6	22.9	21.2	27.5	21.0	21.8
TPER	42.0	39.6	45.0	43.5	56.8	49.9	50.4
TMILK	75.06	68.86	81.38	75.09	90.76	86.10	88.24
MLK90	125.70	126.82	130.02	118.23	120.43	133.13	130.35

[1] N = number of observations; DYLD1 = daily milk yield at first test; DYLD2 = daily milk yield at second test; TDYLD = total of first and second test; DAYS1 and DAYS2 are the days from weaning to first or second test; TPER = total days from weaning to second test; TMILK = total milk yield corresponding to total period; MLK90 = 90-day milk production.

Table 3. Simple product moment correlations among test-day milk production and estimated part lactation yields.

Trait[1]	DYLD2	TDYLD	TMILK	MLK90
DYLD1	0.65	0.92	0.74	0.81
DYLD2		0.89	0.57	0.80
TDYLD			0.73	0.88
TMILK				0.79

[1] For explanation of abbreviations see Table 2.

Table 4. Estimated parameters, mean square of error and predicted 90-day milk yield from Wood=s modified model using one or the sum of two individual test-day records.

	Parameters				
Test-day	A	B	C	MS Error	Predicted 90-day milk yield
First	71.69(1.67)	0.74(0.08)	0.03(0.03)	694	123.8
Second	91.98(3.11)	0.77(0.07)	0.01(0.04)	698	132.1
Sum (1+2)	37.08(1.33)	1.01(0.07)	0.01(0.02)	428	136.2

Figures in parentheses represent the standard error of the estimates.