Animal Science 2005, **80:** 53-60 1357-7298/04/34880053$20.00

Accuracy of predicting milk yield from alternative milk recording schemes

D. P. Berry[1, 2]†, V. E. Olori[3], A. R. Cromie[3], R. F. Veerkamp[4], M. Rath[2] and P. Dillon[1]

[1]*Dairy Production Department, Teagasc, Moorepark Production Research Centre, Fermoy, Co. Cork, Ireland*
[2]*Department of Animal Science, Faculty of Agriculture, University College Dublin, Belfield, Dublin 4, Ireland*
[3]*Irish Cattle Breeding Federation, Shinagh House, Bandon, Co. Cork. Ireland*
[4]*Animal Resources Development, Animal Sciences Group, Wageningen UR, PO Box 65, 8200 AB Lelystad, The Netherlands*

†E-mail : dberry@moorepark.teagasc.ie

Abstract

The effect of reducing the frequency of official milk recording and the number of recorded samples per test-day on the accuracy of predicting daily yield and cumulative 305-day yield was investigated. A control data set consisting of 58 210 primiparous cows with milk test-day records every 4 weeks was used to investigate the influence of reduced milk recording frequencies. The accuracy of prediction of daily yield with one milk sample per test-day was investigated using 41 874 test-day records from 683 cows. Results show that five or more test-day records taken at 8-weekly intervals (A8) predicted 305-day yield with a high level of accuracy. Correlations between 305-day yield predicted from 4-weekly recording intervals (A4) and from 8-weekly intervals were 0·99, 0·98 and 0·98 for milk, fat and protein, respectively. The mean error in estimating 305-day yield from the A8 scheme was 6·8 kg (s.d. 191 kg) for milk yield, 0·3 kg (s.d. 10 kg) for fat yield, and -0·3 kg (s.d. 7 kg) for protein yield, compared with the A4 scheme. Milk yield and composition taken during either morning (AM) or evening (PM) milking predicted 24-h yield with a high degree of accuracy. Alternating between AM and PM sampling every 4 weeks predicted 305-day yield with a higher degree of accuracy than either all AM or all PM sampling. Alternate AM-PM recording every 4 weeks and AM + PM recording every 8 weeks produced very similar accuracies in predicting 305-day yield compared with the official AM + PM recording every 4 weeks.

Keywords: *milk recording, milk yield.*

Introduction

Dairy cattle breeding programmes are predominantly based on progeny testing schemes. The compilation of ample daughter records on all traits included in the selection objective is a pre-requisite for a successful progeny testing scheme. Larger progeny group sizes are desired for lower heritability traits (e.g. fertility) in order to achieve optimal genetic gain (Philipsson, 1981). Currently in Ireland, fertility information is only available from herds participating in milk recording. Therefore, the level of milk recording greatly influences the accuracy of breeding value estimation and thus the rate of genetic gain within the Irish dairy population. However, the level of milk recording in Ireland is low relative to most other major milk producing countries (International Committee for Animal Recording (ICAR), 2002), thereby hindering genetic progress within the Irish dairy herd. During 2000, 31·7% of the Irish dairy cow population were milk recorded (ICAR, 2002). Possible reasons for this low participation in milk recording in Ireland include the cost and inconvenience of the current official milk recording service.

The current milk recording service in Ireland involves the physical visit to each herd of a milk recording official every 4 weeks (A4), 6 weeks (A6) or 8 weeks (A8). Each visit consists of a consecutive evening and morning visit with individual milk weights and samples collected. The proportion of milk-recorded herds in Ireland which participated in the A4, A6 and A8 schemes during 2000 were 58%, 32%, and 9%, respectively (ICAR, 2002). Increased participation in milk recording may therefore be achieved if the current milk recording schemes are modified to reduce cost and minimize disruption to the daily routine of the herd managers. Both of these factors can be achieved by reducing the frequency of official milk recording, reducing the number of samples recorded per test-day or a combination of both.

Before the introduction of any alternative recording scheme, it is paramount to first assess the impact of such alternative milk recording schemes on the accuracy of predicting 305-day yield and hence genetic evaluations.

Many researchers have looked at reducing the frequency of milk recording to ameliorate some of the problems associated with milk recording. In a review of 11 studies McDaniel (1969) reported that 78% of the proportional differences between actual milk yield and milk yield predicted from bimonthly samples were less than 0·05 and 98% of the proportional differences between the two schemes were less than 0·10. This compared with 93% and 100%, respectively for predicting actual yield from monthly testing. McDaniel (1969) concluded that accurate cow ranking and progeny testing could be based on samples taken as much as two months apart. Similarly, Pander *et al*. (1993) advocated the use of less frequent than A4 recording to reduce costs without a proportional loss in accuracy when estimating 305-day yield.

Alternate morning and evening milk recording schemes (Porzio, 1953) are officially approved by the International Committee for Animal Recording (ICAR) and are implemented in a number of countries including Germany, Austria, France, The Czech Republic, Croatia and Italy (ICAR, 2002). For a twice-a-day milking regime, the differences between the morning (AM) milk yield and the evening (PM) milk yield is primarily a function of milking interval, stage of lactation and also perhaps a significant interaction between milking interval and stage of lactation (Everett and Wadell, 1970). Therefore, any prediction equation used to estimate 24-h yield from either AM samples or PM samples should incorporate milking interval, lactation stage and possibly season of calving within the analysis.

Schaeffer *et al*. (2000) observed that 24-h fat yield may be predicted with an accuracy of 0·89 from an AM-milking and 0·88 from a PM-milking. Their model adjusted for the herd average time interval between AM and PM milkings and estimated the prediction equations within subclasses of days in milk, parity and season of calving. This result supported earlier findings that AM yield predicted true daily yield more accurately than PM yield (Schaeffer and Rennie, 1976). However, an alternating AM-PM recording scheme has consistently been shown to be more accurate in predicting 305-day yield than either an all AM or an all PM recording scheme (Dickinson and McDaniel, 1970; Schaeffer and Rennie, 1976).

In Ireland there is a requirement to increase both the number of young sires tested simultaneous with increased progeny group sizes per sire. Traditionally, milk records of cows have only been used for genetic evaluation once the lactation was complete or lactations in progress were projected forward using pre-defined lactation curves within contemporary groups. However, recent technological advances mean that more sophisticated computing techniques can now be applied in modelling daily milk yield. Test-day models provide an opportunity for using all test-day records, irrespective of the number of records per daughter, to calculate breeding values of sires based on the genetic relationships between animals. In such situations the entry of new participants into milk recording schemes will be beneficial, irrespective of the frequency of the milk recording adopted.

The objectives of this study were (1) to investigate the effect of reduced milking frequencies on the accuracy of computing 305-day yield; and (2) to determine the accuracy of predicting 24-h yield from a single AM or PM sample and to subsequently investigate the accuracy of predicting 305-day yield from alternative AM/PM recording schemes.

Material and methods

Data

Reduced frequency of milk recording. Data were supplied by the Irish Cattle Breeding Federation on behalf of all the Irish milk recording societies. It consisted of test-day records for 1 375 000 lactations from the years 1991 to 2001. The data were edited to retain only first parity records with at least 10 monthly test-day records, with a valid calving date and from herds that practised monthly milk recording. The final data set consisted of 58 210 primiparous cows. This data set (A4) was used to evaluate alternative milk recording schemes. Four subsets of data were derived from this data set as follows. (1) Every second test-day record was deleted to evaluate an 8-week milk recording scheme (A8). (2) Every second and third test-day record was deleted to evaluate a 12-week milk recording scheme (A12). (3) Starting the 1st month post calving and finishing the 5th month post calving three bimonthly test-day records were retained (A8-135). (4) Starting the 2nd month post calving and finishing the 6th month post calving, three bimonthly test-day records were retained (A8-246).

The investigation of the two alternative A8 schemes (i.e. A8-135 and A8-246) are important in a seasonal calving dairy system such as that in Ireland. The two alternative A8 schemes simulate a cow calving late in the calving season thereby acquiring fewer test-day records. The effect of a reduction in test-day records on the accuracy of prediction of 305-day yield must therefore be investigated.

Cumulative 305-day yields were computed for the A4 data set and the four subsets of data by the method of interpolation using previously derived lactation curves for Irish Holstein cows (Olori and Galesloot, 1999). This method computes 305-day yields separately for milk, fat and protein in each parity based on the last test date, utilizing also information from the previous lactation where present. In the present analysis all animals were primiparous cows thus no animal had a previous lactation yield. Standard lactation curves were available for 2160 contemporary groups based on season of calving, age and herd production level.

AM/PM milk recording schemes. Morning (AM) and evening (PM) milk weights and their corresponding fat and protein content were obtained from three Teagasc research herds in southern Ireland. The data set comprised 49 624 test-day records from 792 Holstein-Friesian primiparous and multiparous cows from 1993 through 2001. Test-day records that had either an AM/PM milk yield or milk composition missing were deleted from the data set. Twenty-four hour actual test-day yields were obtained by summing the AM and PM yields on each test-day. The data set was further edited to retain lactations with 30 or more test-day records. The final data set consisted of 41 874 test-day records from 683 animals.

The milking intervals, on a herd basis, ranged from 9 h : 15 h to 6 h : 18 h depending on herd and time of year. In the research herds total milking time was not greater than 1·5 h per milking and within herds each experimental group entered the milking parlour in the same sequence over the whole lactation. Milking interval times were grouped into classes of 30 min since intervals shorter or longer than 30 min were considered to be impractical for recording the information on a national basis.

Prediction of 24-h yield
The linear multiple regression model used to predict actual 24-h yield from AM or PM samples was as follows (equation 1):

$$Y_{ijk} = [b_0 + b_1(MI) + b_2(Milk)_i + b_3\ (Fat)_i + b_4\ (Protein)_i\ ]_k + e_{ijk} \quad (1)$$

where : Y_{ijk} = 24-h yield (milk, fat or protein yield); MI = herd milking interval from PM to AM (milking interval from AM to PM is directly related so was not included in the model); $(Milk)_i$ = milk yield on the ith milking of the day; $(Fat)_i$ = fat yield on the ith milking of the day; $(Protein)_i$ = protein yield on the ith milking of the day; e_{ijk} = random residual effect.

The independent variables included in the model are representative of the data available if such schemes were implemented on a national scale. As the model becomes more complex, more information is utilized in the analysis subsequently improving the accuracy of prediction; Schaeffer *et al.* (2000) reported lower accuracy of prediction when variables in the model were excluded.

Regression analyses were carried out within subclasses k to account for the heterogeneous means and variances of the different subclasses. Preliminary analyses revealed heterogeneous means and variances for 24-h yield over different parities, season of calving and days in milk. Parity was grouped into three groups (1, 2, and 3) and season of calving was also grouped into three groups (December + January, February, and March + April + May). Days in milk were grouped into 50-day intervals up to day 250 and the final class was for greater than 250 days. This resulted in separate regression coefficients being estimated for each of the 54 subclasses (3 parities × 3 seasons × 6 days in milk groups). The number of test-day records per subclass varied from 74 to 1482; the average number of test-day records per subclass was 775. All regression coefficients were estimated using the general linear model procedure PROC GLM of SAS® (Statistical Analysis Systems Institute, 2002).

Tests were carried out to determine the suitability of AM/PM schemes in predicting both 24-h yield and 305-day yield. No previous lactation yield was included for second and third parity cows when estimating 305-day yield.

Tests for comparing alternative milk recording schemes
The comparison between predicted and actual 305-day yield and 24-h yield involved estimating the bias between the different measures (i.e. the average difference between the actual milk yield and predicted milk yield) and the variance of the difference between the measures (mean square error). The average bias was computed as the mean of the difference following subtraction of the yield estimated with the scheme under investigation from the yield computed from the control data sets.

The effect of the alternative recording schemes on predicted 305-day yield was investigated by analysis of variance using the generalized linear model procedure of SAS®. Duncan's multiple range tests were used to test the significance of the difference between the alternative milk recording schemes. The null hypothesis was that no significant different existed between 305-day yield predicted from the alternative recording schemes. The similarity or otherwise between 305-day yield predicted from the alternative schemes was determined from a correlation analysis. Correlation analyses were also used to evaluate the independence of the residuals whereby a correlation of zero indicates total randomness of the error.

The accuracy of predicting 305-day yield and 24-h yield was also investigated using equation 2:

$$\text{accuracy} = (\sigma^2\text{actual}/(\sigma^2\text{actual} + \sigma^2\text{difference})) \quad (2)$$

where : σ^2actual = variance of the actual yield; σ^2difference = variance of the difference between the actual yield (this was A4-predicted 305-day yield when determining the accuracy of predicting 305-day yield) and the predicted yield.

A data subset of nine herds with over 150 lactation records per herd were assembled and Spearman rank correlations were calculated within herds between 305-day yield from alternative milk recording schemes.

Results

Table 1 provides a summary of 305-day milk, fat and protein yield estimated with the A4, A8 and A12 schemes. The Duncan's multiple comparison tests indicated that A8-predicted 305-day milk, fat and protein yield were not significantly different (P>0·05) from the A4-predicted 305-day milk, fat and protein yield. The A12 recording scheme predicted significantly (P<0·001) lower 305-day milk and fat yield but not significantly different (P>0·05) 305-day protein yield to the A4 recording scheme.

Table 1 *Summary of 305-day yields predicted from alternative milk recording schemes*

	Milk yield (kg)			Fat yield (kg)			Protein yield (kg)		
Scheme†	A4	A8	A12	A4	A8	A12	A4	A8	A12
Mean	5963	5957	5949	225	224	223	196	197	196
s.d.	1178	1177	1175	47	47	48	38	37	38
Q1‡	5140	5137	5129	192	192	190	170	171	170
Q3§	6665	6658	6649	252	253	252	219	219	219

† A4 = recording every 4 weeks; A8 = recording every 8 weeks; A12 = recording every 12 weeks.
‡ Yield at first quartile.
§ Yield at third quartile.

Table 2 *Summary statistics for the difference between 305-day yields estimated by three different milk recording schemes*

	Milk yield (kg)		Fat yield (kg)		Protein yield (kg)	
Scheme†	A4-A8	A4-A12	A4-A8	A4-A12	A4-A8	A4-A12
Mean	6·8	14·8	0·3	1·2	-0·3	0·0
s.e.	0·79	1·12	0·04	0·06	0·03	0·04
s.d.	191·3	271·3	10·1	13·9	7·1	10·2
Q1‡	-109	-152	-6	-7	-5	-6
Q3§	121	177	6	9	4	6

† A4 = recording every 4 weeks; A8 = recording every 8 weeks; A12 = recording every 12 weeks.
‡ Difference in yield at first quartile of the difference.
§ Difference in yield at third quartile of the difference.

Table 2 shows the average bias in predicting 305-day milk, fat and protein yield for each cow. Seventy-five percent of 305-day milk yields predicted using the A8 scheme were within ±200 kg of 305-day yields predicted using the A4 scheme, the corresponding figure for the A12 recording scheme was 59% for 305-day milk yield. The accuracy of the A8 and A12 schemes in estimating A4-predicted 305-day milk yield was 0·97 and 0·95, respectively. The correlation between the residuals of the A8 estimates against A4-predicted 305-day milk yield was 0·09 indicating no significant bias (P>0·05) against higher 305-day milk yield.

Mean 305-day milk yield estimated using the two alternative A8 recording schemes (A8-135 and A8-246) were significantly lower (P<0·001) than those estimated with the A4 recording scheme (Table 3). This may be due to fewer records and/or only records from the early part of the lactation being used in computing the 305-day yield. The standard deviation of the difference in estimating A4-predicted 305-day milk yield from either of the alternative A8 recording schemes was almost twice the standard deviation of the difference in estimating A4-predicted 305-day milk yield from the A8 recording scheme with five or more test-day records. The 305-day milk yield predicted from the A8-246 recording scheme was closer to A4-predicted 305-day yield (difference of 110·6 kg) than A8-135, while the standard deviation of the difference was also smaller (349·2 kg).

The correlations between A4-predicted 305-day milk, fat and protein yield with A8, A12, A8-135 and A8-246 milk recording schemes are summarized in Table 4. The correlations between A4 and A8 were always greater than the correlations between A4 and A12. The correlations between 305-day milk, fat and protein yield predicted from the A8-246 scheme were more strongly correlated with A4-predicted 305-day milk, fat and protein yield than A8-135.

The average rank correlations within herd for A4-predicted 305-day yield and 305-day yield predicted from the A8, A12, A8-135 and A8-246 recording schemes are shown in Table 5. The rank correlations between A4-predicted 305-day milk, fat and protein yield and A8-predicted 305-day milk, fat and protein yield were all greater than 0·95. The range in rank correlations within herds varied from 0·95 to 0·98 between A4- and A8-predicted 305-day milk yield. Figure 1 illustrates how the rank of 305-day yield may change when the correlation is 0·97 (the average rank correlation of the herds for 305-day milk yield). Only three lactations changed ranks of over 30 positions from a total of 179 first lactation records.

Prediction of daily yield from part-day samples

Table 6 shows the correlations between actual 24-h yield and composition, with the corresponding part-day recorded (AM or PM) yield and composition. The results indicate that AM milk yield is more highly correlated with actual 24-h milk yield than PM milk yield; the same is true for AM protein yield. However, PM fat yield was more strongly correlated with 24-h fat yield than AM fat yield. A low correlation existed between AM fat yield and PM fat yield (0·54) and between AM fat percent and PM fat percent (0·36).

Table 7 illustrates the accuracy of predicting 24-h yield from AM samples or PM samples. As expected the average

Table 3 *Summary statistics for the difference between 305-day yields estimated by three different milk recording schemes*

	Milk yield (kg)		Fat yield (kg)		Protein yield (kg)	
Scheme†	A4-A8-135	A4-A8-246	A4-A8-135	A4-A8-246	A4-A8-135	A4-A8-246
Mean	133·7	110·6	4·9	3·7	4·5	4·7
s.e.	1·61	1·45	0·07	0·07	0·06	0·05
s.d.	389·0	349·2	17·6	16·6	14·4	13·0
Q1‡	-123	-118	-7	-7	-5	-4
Q3§	366	320	15	14	13	13

† A4 = recording every 4 weeks; A8-135 = recording 1st, 3rd and 5th month post calving; A8-246 = recording 2nd, 4th and 6th month post calving.
‡ Yield at first quartile.
§ Yield at third quartile.

Table 4 *Pearson correlation coefficients, for 305-day milk, fat and protein yields, between those estimated from 4-weekly records and those estimated from alternative milk recording schemes*

	Scheme†			
	A8	A12	A8-135	A8-246
Milk	0·99	0·97	0·95	0·96
Fat	0·98	0·96	0·93	0·94
Protein	0·98	0·96	0·93	0·94

† A8 = recording every 8 weeks; A12 = recording every 12 weeks; A8-135 = recording 1st, 3rd and 5th month post calving; A8-246 = recording 2nd, 4th and 6th month post calving.

Table 5 *Average rank correlation coefficients, for 305-day milk, fat and protein yields, between those estimated from 4-weekly records and those estimated from alternative milk recording schemes*

	Scheme†			
	A8	A12	A8-135	A8-246
Milk	0·97	0·94	0·90	0·91
Fat	0·95	0·91	0·86	0·87
Protein	0·96	0·93	0·87	0·88

† A8 = recording every 8 weeks; A12 = recording every 12 weeks; A8-135 = recording 1st, 3rd and 5th month post calving; A8-246 = recording 2nd, 4th and 6th month post calving.

Table 6 *Correlation coefficients, for yield and composition, between 24-h daily record with morning record* (*AM*) *and evening record* (*PM*)

	AM-DAY†	PM-DAY‡	AM-PM§
Milk yield	0·97	0·95	0·85
Fat yield	0·84	0·90	0·54
Protein yield	0·96	0·93	0·80
Fat percent	0·80	0·84	0·36
Protein percent	0·96	0·97	0·87

† AM-DAY = correlation between AM sample and actual 24-h sample.
‡ PM-DAY = correlation between PM sample and actual 24-h sample.
§ AM-PM = correlation between AM sample and PM sample.

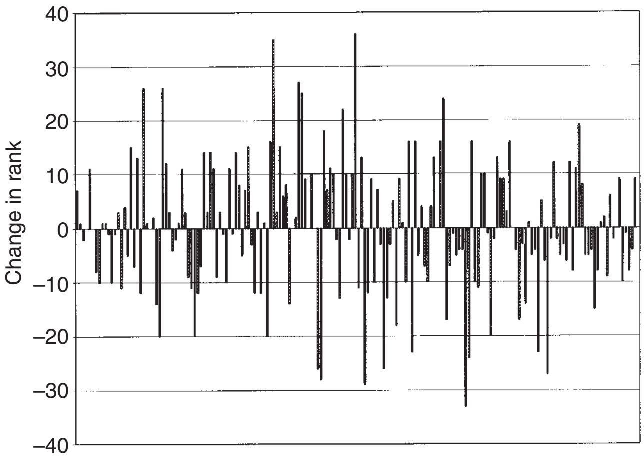

Figure 1 Change in rank of lactation yields for a herd with 179 first lactation records and a rank correlation between A4-predicted 305-day yields and A8-predicted 305-day yields of 0·97.

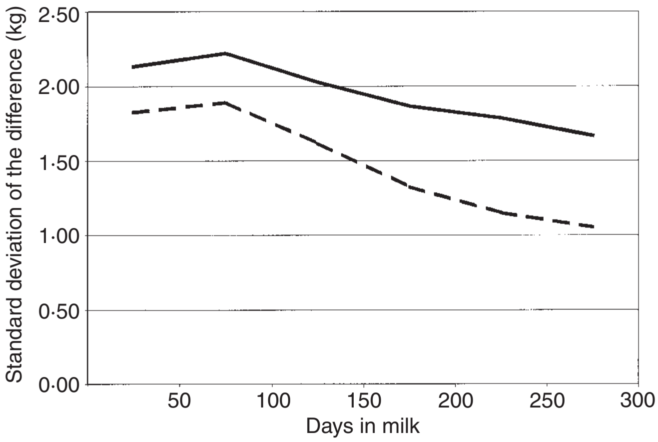

Figure 2 The average standard deviation of the difference between actual 24-h milk yield and both morning (AM, solid line) or evening (PM, dashed line) predicted 24-h milk yield by stage of lactation.

difference between actual 24-h yield and predicted 24-h yield was zero (Schaeffer and Rennie, 1976). However, the mean square error (MSE) suggests some variation; the difference between actual 24-h yield and predicted 24-h yield from AM samples varied by up to 22-kg above and below the actual yield. Figure 2 shows the standard deviation of the difference between actual 24-h milk yield and 24-h milk yield predicted from AM samples or PM samples; the average bias is zero since separate regressions were estimated within lactation stage subclasses. The trend suggests a reduction in the error of predicting 24-h milk yield from both AM samples or PM samples as the lactation progressed beyond day 100. The standard deviations of predicted 24-h milk, fat and protein yield were always lower than the standard deviations of actual 24-h yield; the standard deviation of actual milk, fat and protein yield were 7·41 kg, 0·30 kg and 0·23 kg, respectively. All correlations between actual 24-h yield and predicted 24-h yield from AM/PM samples were greater than 0·91. The accuracy of predicting 24-h yield from AM samples or PM samples were greater than 0·86. Correlations between the residuals and actual 24-h yield were significantly ($P<0{\cdot}001$) greater than zero signifying an underestimation of relatively higher milk yields.

The regressions on milking interval varied from -0·64 to 0·69 for 24-h fat yield predicted from the AM sample and varied from -0·78 to 0·01 for 24-h fat yield predicted from the PM sample. These solutions are larger than those reported by Schaeffer *et al.* (2000) and may suggest a larger variation in milking interval in the present study.

Table 8 summarizes the accuracy of predicting 305-day yield from all AM, all PM or the alternate AM/PM recording schemes. The multiple comparison tests revealed no significant bias in estimating 305-day yield across any of the schemes when compared with the 305-day yield predicted using actual 24-h yield. The standard deviation of the difference was lowest when an alternate sampling scheme was adopted rather than using either all AM or all PM samples. The accuracy of predicting 305-day milk yield from all AM, all PM, AM-PM or PM-AM samples was 0·96, 0·93, 0·97, and 0·97, respectively. Correlations between 305-day milk and protein yield from either actual 24-h yields or from AM/PM schemes were all greater than 0·95;

Table 7 *Summary statistics for the prediction of 24-h milk, fat and protein yields from either morning (AM) or evening (PM) yields*

Scheme†		s.d. of predicted yield (kg)	Correlation coefficient	MSE (kg^2)‡	Min. difference (kg)	Max. difference (kg)	Accuracy
AM	Milk	7·25	0·98	2·27	-19·2	21·6	0·96
	Fat	0·28	0·93	0·01	-1·2	1·1	0·88
	Protein	0·22	0·97	0·00	-1·1	0·7	0·95
PM	Milk	7·15	0·96	3·83	-25·9	20·6	0·93
	Fat	0·27	0·92	0·01	-2·4	1·1	0·87
	Protein	0·21	0·95	0·00	-0·9	1·0	0·91

† 24-h milk, fat and protein yields predicted from AM or PM samples, respectively.
‡ MSE = mean square error.

Table 8 *The mean difference, the standard error of the mean difference (s.e.), the standard deviation of the difference (s.d.) and the first and third quartile of the difference between 305-day yields predicted from actual 24-h yields and 305-day yields predicted from all morning (AM) samples, all evening (PM) samples and alternate AM-PM and PM-AM recording schemes*

	Scheme											
	All AM			All PM			AM-PM			PM-AM		
Yield (kg)	Milk	Fat	Protein	Milk	Fat	Protein	Milk	Fat	Protein	Milk	Fat	Protein
Mean	12·1	1·0	0·4	-2·0	-0·4	-0·1	13·0	0·5	0·4	-2·9	0·2	-0·1
s.e.	8·32	0·57	0·30	10·92	0·62	0·38	7·25	0·49	0·25	6·86	0·46	0·24
s.d.	260·6	17·8	9·3	342·1	19·4	12·0	227·2	15·3	7·8	215·0	14·5	7·6
Q1†	-145	-11	-5	-207	-11	-7	-125	-9	-4	-137	-9	-5
Q3‡	178	12	6	202	11	7	149	10	5	130	10	5

† Difference in yield at first quartile of the difference.
‡ Difference in yield at third quartile of the difference.

correlations between the respective fat yield were all greater than 0·91. The correlations between the residuals of predicting 305-day milk yield from the different schemes against 305-day yield predicted from actual 24-h yield were all significantly (P<0·001) greater than zero. This indicates that the alternative milk recording schemes generally over-estimated 305-day milk yield for relatively lower yielding cows and under-estimated yield for relatively higher yielding cows; the average bias was near zero.

Discussion

The objective of this study was to investigate the effect of alternative milk recording schemes on the accuracy of predicting both 24-h yield and 305-day yield. The results show that A8 milk recording schemes, with samples taken from all stages of lactation, predicted a 305-day yield similar to that from A4 milk recording schemes. Twenty-four hour yield can be estimated with reasonable accuracy from either AM or PM samples. Alternate AM-PM or PM-AM recording schemes taken at 4-weekly intervals predict 305-day yield more accurately than schemes involving either all AM or all PM samples and exhibit similar accuracies at predicting 305-day yield as the A8 scheme.

Reduced milk recording frequencies

The accuracy of any test-day record is a function of both the errors of the methods involved (e.g. sampling technique) but also the biological variation over the lactation period. The relative day-to-day variation in milk yield has been reported as around proportionately 0·06 to 0·08 (for review see Sjaunja (1986) and McDaniel (1969)), which should give an indication of the most appropriate milk recording frequency. Nevertheless the day-to-day variation within cow should be compared with the population variation and how it changes over the lactation. A small variation within cow when coupled with a large variation between cows suggests that the recording frequency can be extended (Svennersten-Sjaunja *et al.*, 1997).

The A4-predicted 305-day yield has been taken to be the most accurate reflection of actual 305-day yield since previous studies show an error of prediction of actual yield of about proportionately 0·02 to 0·03 of the mean (Anderson *et al.*, 1989). The lack of a substantial bias in estimating A4-predicted 305-day milk yield from either A8 or A12 recording schemes agrees with other previous reports (for review see McDaniel (1969)).

The higher error variance of the A12 recording scheme reported here makes it less suitable for predicting 305-day yield. This is similar to previous studies with simulated data which showed that A4 recording schemes were twice as accurate as A12 recording schemes for predicting actual milk yield (Erb *et al.*, 1952). In the present study the lower percentage of A12-predicted yields that were within ±200 kg of A4-predicted yields when compared with the A8 scheme agrees with reports from Bayley *et al.* (1952). They stated that 12·5% of the differences between A12 and A4 were greater than proportionately 0·10 of the mean compared with 2·2% between A8 and A4-predicted lactation yields.

The strong correlation between 305-day milk yield estimated with the different schemes agrees with Hamed (1995) who reported correlations of 0·95 to 0·98 between total lactation yield predicted from A4 and A8 recording schemes. Corresponding values for the A12 scheme in that study were 0·79 to 0·93.

Actual phenotypic milk yield may not be as important in culling decisions as within-herd ranking of cows for 305-day yield. Results clearly show that across nine herds the ranking of cows were on average very similar irrespective of whether yields were estimated using either A4 or A8 recording schemes (Figure 1). Therefore, culling of cows for low production based on A8-predicted 305-day yield is expected to remove almost exactly the same cows as would be removed by culling on A4-predicted 305-day yield. This is similar to that reported by Castle and Searle (1961) on over 5000 lactations from 30 different herds. The rank correlations tended to get weaker for A12 and the alternative A8 schemes (Table 5).

Hence, the favourable attributes of A8 milk recording reported in the present study agree with the review of McDaniel (1969) whose general consensus was that A8 milk recording may be sufficient for predicting herd average, group averages, sire evaluations and ranking cows within herds. Similarly, Pander *et al.* (1993) concluded that less frequent than monthly recording would be adequate for genetic evaluations.

The accuracy of A8 milk recording reported in this study is likely to be at the upper limit since most animals would have acquired their first test-day record within their 1st month post calving due to the editing nature of the data and all animals had five test-day records. It is for this reason that two modifications to the A8 recording scheme were implemented (A8-135 and A8-246). The A8-135 scheme simulates a cow calving late in the calving season with the result of only acquiring three 8-weekly records. The A8-246 is a further modification whereby the cow receives her first test-day sample during her 2nd month post calving. The large mean and standard deviation of the difference between A4-predicted 305-day yield and 305-day yield predicted from either the A8-135 or the A8-246 schemes shows the importance of the number of test-day records available per lactation. Tests at all stages of lactation will give a more accurate estimate of 305-day yield than tests from only the early stages of lactation. Bayley *et al.* (1952) reported that the frequency of large errors in A8 milk recording was twice as prevalent in cows first tested in the second month of lactation compared with cows first tested in the first month of lactation. Contrary to these conclusions, the recording scheme with the first test in the 2nd month (A8-246) was slightly more accurate than the A8-135 scheme in the present study. This may be due to the better attributes of the standard lactation curve method, which is better able to predict missing daily yield before the first and after the last test because of the standard curves and the use of different forward and backward projection factors (Olori and Wickham, 2001).

AM/PM milk recording

The correlations between 24-h yield and composition with AM and PM yield and composition are very similar to those previously reported on German Holstein cows (Liu *et al.*, 2000) for milk and protein yield; correlations involving fat yield and fat percentage were weaker in the present study. Nevertheless, correlations involving fat yield or fat percentage were always the weakest in both studies. The low correlations evident in the present study between AM fat yield/percent and PM fat yield/percent may be due to the effect of unequal milking intervals on fat yield and concentration (O'Brien *et al.*, 1998) and is consistent with previous results (Aumann and Duda, 1997; Trappmann *et al.*, 1997).

The strong correlation and the low MSE between actual 24-h yield and predicted 24-h yield indicate a good fit to the data. The MSE measures both unbiasness and variance of estimates, and thus should be the most appropriate statistic for ranking models (Liu *et al.*, 2000). The MSE reported in the present study (Table 7) are slightly lower than those reported by Schaeffer *et al.* (2000) while the correlations in the present study are stronger. The relative superiority of the prediction equations in the present study may be due to (a) application to the same data from which the equations were derived, (b) the larger number of records per subclass (775 *v.* 63), and (c) the data being collected from research herds with the milk samples being independently analysed.

The standard deviation of predicted 24-h yield should be close to, but never larger than the standard deviation for actual 24-h yield (Liu *et al.*, 2000); the results of the present study support this. The greater accuracy in predicting 24-h milk and protein yield compared with 24-h fat yield agrees with previous studies (Schaeffer *et al.*, 2000; Wiggans, 1986; Liu *et al.*, 2000; Poly and Poutous, 1968) and suggests that factors other than those included in the models to date may influence the fat content in milk.

Stronger correlations and lower MSE with actual 24-h yield were more evident for 24-h yield predicted from AM samples than from PM samples which agrees with the report from Liu *et al.* (2000). Similarly, the standard deviation of 24-h yield predicted from AM samples was closer to the standard deviation of actual 24-h yield than the 24-h yield predicted with the PM samples; this is similar to that shown by Schaeffer and Rennie (1976).

In agreement with previous studies (Dickenson and McDaniel, 1970; Schaeffer and Rennie, 1976) alternate AM-PM or PM-AM schemes were superior to either all AM or all PM recording schemes in estimating 305-day yield. This was due to their lower standard deviation of the bias, their stronger correlations with 305-day yield predicted from actual 24-h yield and also their higher accuracies. The PM-AM scheme was more accurate than the AM-PM scheme due to its lower mean bias, its lower standard deviation of the bias and its slightly higher accuracy of predicting 305-day yield. This is in contrast to reports from Schaeffer and Rennie (1976) who documented that the AM-PM scheme was more accurate than the PM-AM scheme. However, differences between the two alternate schemes in the present study were small. Nevertheless, under practical situations approximately half of the cows in a herd will have their first test-day sample in the morning and the other half of the herd will have their first sample in the evening.

The moderate correlations between the residuals of estimating 305-day milk yield from the AM/PM recording schemes against actual 305-day milk yield may cause some concern. This may be due to a 'double error' of firstly predicting 24-h yield from either the AM or PM samples and subsequently from predicting 305-day with the standard lactation curve method. It suggests the possible need for separate lactation curves derived specifically for AM/PM schemes. Similarly, it illustrates the importance of applying different weights for milk yield derived from AM/PM schemes when included in genetic evaluations to reflect the variance of predicted 24-h yield as well as the correlation between actual and predicted 24-h yield and perhaps also 305-day yield.

Conclusions

It can be concluded from the present study that with primiparous cows the A8 scheme, with samples taken from all stages of lactation, on average predicts a 305-day yield similar to A4-predicted 305-day yield. The A8 scheme has been shown to be adequate for within-herd ranking of 305-day yield agreeing with previous literature. Use of either AM or PM samples can accurately predict 24-h milk and protein yield; the accuracy of predicting 24-h fat yield tends to be lower.

Alternate AM-PM or PM-AM schemes at 4-weekly intervals provide a feasible alternative to conventional twice-a-day sampling A4 milk recording schemes in predicting 305-day yield without a considerable loss in accuracy. Comparing the two data sets it appears that alternate AM-PM or alternate PM-AM schemes predict actual 305-day yield with similar accuracy to the A8 recording scheme. The decision as to which scheme is most appropriate will depend on their respective costs and convenience. It is however recommended that a mixture of schemes should be adopted to increase overall accuracy of sire genetic evaluations.

Acknowledgements

The authors would like to acknowledge the farmers, the milk recording societies and the Irish Cattle Breeding Federation for providing access to their milk recording data set. Gratitude is also extended to the personnel responsible for the collection and analysis of the milk samples on the three research farms. This project was funded as part of the Teagasc Walsh Fellowship Programme.

References

Anderson, S. M., Mao, I. L. and Gill, J. L. 1989. Effect of frequency and spacing of sampling on accuracy and precision of estimating total lactation milk yield and characteristics of the lactation curve. *Journal of Dairy Science* **72:** 2387-2394.

Aumann, J. and Duda, J. 1997. Reliability of new methods in milk recording. *Proceedings of the 48th annual meeting of the European Association for Animal Production, Wien,* paper C5·7.

Bayley, N. D., Liss, R. M. and Stallard, J. E. 1952. A comparison of bimonthly and quarterly testing with monthly testing for estimating dairy cattle production. *Journal of Dairy Science* **35:** 350-355.

Castle, O. M. and Searle, S. H. 1961. Use of bimonthly records in herd testing. *Journal of Dairy Science* **44:** 1335-1343.

Dickinson, F. N. and McDaniel, B. T. 1970. Single-milking yields versus 24-hour yields for estimating lactation milk production by the test interval method. *Journal of Dairy Science* **53:** 200-207.

Erb, R. E., Goodwin, M. M., Morrison, R. A. and Shaw, A. O. 1952. Lactation studies. IV. Accuracy of different methods of estimating lactation yields. *Journal of Dairy Science* **35:** 977-987

Everett, R. W. and Wadell, L. H. 1970. Sources of variation affecting ratio factors for estimating total daily milk yield from individual milkings. *Journal of Dairy Science* **53:** 1430-1435.

Hamed, M. K. 1995. Accuracy of bimonthly and trimonthly milk recording systems for dairy cattle in Egypt. *Annals of Agricultural Science, Moshtohor* **33:** 669-679.

International Committee for Animal Recording. 2002. *Position of milk recording; methods and organisation: 2000.* www. icar. org/ yearly. html

Liu, Z., Reents, R., Reinhardt, F. and Kuwan, K. 2000. Approaches to estimating daily yield from single milk testing schemes and use of a. m. -p. m. records in test-day model genetic evaluation in dairy cattle. *Journal of Dairy Science* **83:** 2672-2682.

McDaniel, B. T. 1969. Accuracy of sampling procedures for estimating lactation yields: a review. *Journal of Dairy Science* **52:** 1742-1761.

O'Brien, B., O'Connell, J. and Meaney, W. J. 1998. Short-term effect of milking interval on milk production, composition and quality. *Milchwissenschaft* **53:** 123-126.

Olori, V. E. and Galesloot, P. J. B. 1999. Projection of partial lactation records and calculation of 305-day yields in the Republic of Ireland. *Interbull Bulletin* **22:** 149-154.

Olori, V. E. and Wickham, B. 2001. Coping with unusual lactation records in the light of the 2001 foot and mouth disease scare in Ireland. *Interbull Bulletin* **27:** 123-127.

Pander, B. L., Thompson, R. and Hill, W. G. 1993. The effect of increasing the interval between recordings on genetic parameters of test day yields of British Holstein-Friesian heifers. *Animal Production* **56:** 159-164.

Philipsson, J. 1981. Genetic aspects of female fertility in dairy cattle. *Livestock Production Science* **8:** 307-319.

Poly, J. and Poutous, M. 1968. Alternate monthly milk recording. I. Accuracy of recording monthly and every second month, for a 305-day milk period. *Dairy Science Abstracts* **30:** 454.

Porzio, G. 1953. A new method of milk recording. *Animal Breeding Abstracts* **21:** 1659.

Statistical Analysis Systems Institute. 2002. *User's guide, version 8·0·0 edition*. SAS Institute, Inc., Cary, NC.

Schaeffer, L. R., Jamrozik, J., Dorp, R. van, Kelton, D. F. and Lazenby, D. W. 2000. Estimating daily yields of cows from different milking schemes. *Livestock Production Science* **65:** 219-227.

Schaeffer, L. R. and Rennie, J. C. 1976. AM-PM testing for estimating lactation yields. *Canadian Journal of Animal Science* **56:** 9-15.

Sjaunja, L. O. 1986. Day-to-day variation in milk yield, milk composition and somatic cell count. *International Committee for Recording the Productivity of Milk Animals (ICRPMA), 25th session.*

Svennersten-Sjaunja, K., Sjaunja, L. O., Bertilsson, J. and Wiktorsson, H. 1997. Use of regular milking records versus daily records for nutrition and other kinds of management. *Livestock Production Science* **48:** 167-174.

Trappmann, W., Schwaer, P., Pauw, R. and Tholen, E. 1998. Alternating milk recording as an alternative to the A4 milk recording method. *Züchtungskunde* **70:** 85-95.

Wigans, G. R. 1986. Estimating daily yields of cows milked three-times-a-day. *Journal of Dairy Science* **69:** 2935-2940.

(*Received* 12 *July* 2003 – *Accepted* 15 *February* 2004)