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ESTIMATION OF DAILY AND LACTATION MILK YIELD FROM ALTERNATIVE MILK RECORDING SCHEME

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Summary

Statistical methods were to developed and evaluated for the estimation of daily and 305-day lactation milk yield of dairy cattle from alternative milk recording scheme. Data included 7,815 individual test-day milk yield records collected according to the A4 milk recording method on 769 cows reared on 15 family farms. Daily milk yield was estimated using five different methods. The 305-day lactation milk yields were calculated from estimated daily milk yields using the Test Interval Method. The correlation between estimated and true milk yields, as well as the basic statistics of difference between estimated and true milk yield were used as the evaluation criteria for estimation methods. The linear regression of daily to partial milk yields with taking into account the interval between successive milkings proved to be the most accurate one in estimating daily milk yield, either from morning or evening records. The doubling of morning or evening milk yield highly overestimated and underestimated the daily milk yield, respectively. When 305-day lactation milk yields were compared no notable differences between evaluated methods were found.

Keywords: Dairy cattle, Alternative method, Daily yield, Lactation yield, Estimation.

Introduction

Milk recording enables data acquisition on animals that are under selection. These data are the basis for the evaluation of breeding value as well as for the improvement of herd management of dairy animals. The referent milk recording method by the International Committee for Animal Recording (ICAR,

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2003) is the A4 method which implies the recording of the milk yield of two consecutive milkings (in the evening of the test day and the following morning) per animal every four weeks.

With the aim of milk recording cost reduction, in the last decades several milk recording methods have been developed (Porzio, 1953; Putman and Gilmore, 1968; McDaniel, 1969; Wiggans, 1981). Increased participation in milk recording and cost reduction could be achieved by extending the interval between successive milk recordings, by measuring only one milking per test-day (alternative milk recording method – AT) or by their combination. The implementation of the AT method, beside cost reduction (Everett and Wadell, 1970; Hargrove and Gilbert, 1984; Aleandri and Tondo, 2003), also results in faster genetic gain from selection (Cassandro et al., 1995, Cassandro et al., 2003), greater flexibility in organizing the work of supervisors, increased number of herd served by one supervisor and less disruption of the milking routine. According to the AT method, milk recording is obtained alternatively, either at morning or at evening milking; therefore, milk yield measured at each milking should be corrected by adequate coefficients. In other words, daily milk yield is estimated by statistical model previously developed and tested (ICAR, 2003). Different genetic and environmental factors such as breed, season, herd management, health status, lactation stage and parity can be the cause of alternation in milk yield. According to numerous studies (Putnam and Gilmore, 1970; Everett and Wadell, 1970; Lee and Wardrop, 1984; Hargrove, 1994; Harding, 1995; Klopčič et al., 2001, 2003; Jovanovac et al., 2005; Gantner et al., 2006), the interval between successive milkings is one of the most important effects on milk yield at each milking. The accuracy of daily milk yield estimation depends on how successfully the mentioned factors would be taken into account, that is, on the method used for estimation (Hargrove, 1994; Liu et al., 2000) while if estimation accuracy of total lactation milk yield is considered, a noticeable difference has not been detected between different estimation methods for daily yields (Cassandro et al., 1995).

The objectives of this study were to develop and evaluate methods for estimation of daily (24 h) and 305-day lactation milk yield of dairy cattle from alternative milk recording scheme (single morning and evening milking records) for Croatian milk recording system.

Material and methods

Data

Data, supplied by the Croatian Livestock Centre, included 7,815 individual test-day milk yield records collected from November 2004 to November 2006 on 769 cows reared on 15 family farms in Croatia. From all cows 58.9% belonged to the Holstein breed, while 41.1% of all cows belonged to the Simmental breed. Milk recording was performed according to the A4 milk recording method by the field officer of the Croatian Livestock Centre. At every recording, milk yield was measured in the evening and in the morning. At each milking, the initial time of current milking and the initial time of previous milking for each animal was recorded. The interval between successive milkings was computed as the time from the beginning of previous milking to the beginning of current milking. Daily milk yield was computed as evening plus morning yield. The direct factors were computed as ratio of daily to partial (morning or evening) milk yield (DMY/AM and DMY/PM), and the indirect factors as ratio of partial to daily milk yield (AM/DMY and PM/DMY). For estimation of direct and indirect factors milking interval (daily or nightly) was divided into 60-min classes. Additionally, a linear regression of daily to evening or morning records was fitted in order to detect outliers. Residuals over three standard deviations were taken as outliers and deleted from dataset. Also, logical control of data was performed according to ICAR standards (2003). Test-day records with missing evening or morning milk yield and milking interval, as well as with unreasonable calving date, lactation stage and lactation number, and ordinal number of milk recording were deleted from the database. The final dataset consisted of 7,059 test-day records from 668 cows. This dataset (dataset 1) was used for estimation of daily milk yields. For calculation of 305-day lactation milk yields, subset of records of cows with 10 consecutive test-day records per lactation was created (dataset 2).

Estimation of daily (24 h) milk yield

Preliminary analysis of variance showed that the interval between successive milkings, had statistically highly significant effect ($P < 0,001$) on the variation of partial (morning and evening) milk yield (Jovanovac et al., 2005; Gantner et al., 2006). Therefore, when daily milk yield was estimated from morning or evening record, the interval between successive

milkings was taken into account as covariate (method I.) or as classed fixed effect (method II. and method III.). Daily milk yield was estimated according to the following methods:

1. regression of daily to partial milk yields:

$$y_i = \mu + b_1 m_i + b_2 t_i + e_i$$

where:
y_i – daily milk yield;
μ – intercept;
m_i – evening or morning milk yield;
t_i – interval between successive milkings;
e_i – residual.

2. multiplying partial milk yields (AM and PM) by estimated direct factors – DF (table 3),
3. dividing partial milk yields (AM and PM) by estimated indirect factors – IF (table 3),
4. method by DeLorenzo and Wiggans (1986),
5. doubling partial milk yield (AM and PM).

Estimation of 305-day lactation milk yield

The estimated daily milk yields were used for the calculation of 305-day lactation milk yield for each cow that had 10 consecutive test-day records per lactation simulating an alternate recording scheme. The lactation milk yields were calculated using the Test Interval Method that is the reference method by ICAR (ICAR, 2003).

$$LMY = I_0 M_1 + I_1 \frac{M_1 + M_2}{2} + I_2 \frac{M_2 + M_3}{2} + ... + I_{n-1} \frac{M_{n-1} + M_n}{2} + I_n M_n$$

where:

$M_1, M_2, \ldots, M_n$ – milk yielded in 24 hours of the recording day, kg (actual or estimated);
$I_1, I_2, ,,,, I_{n-1}$ – the intervals between recording dates, days;

I_0 – the interval between the lactation period start date and the first recording date, days;
I_n – the interval between the last recording date and the 305th lactation day, days.

The evaluation criteria for estimation methods were: correlation between estimated and true milk yields, as well as the basic statistics of difference between estimated and true milk yield. Data were analyzed using SAS/STAT (SAS Institute Inc., 2000).

Results and discussion

Descriptive statistics

Descriptive statistics of the analysed data are reported in table 1. Relationship between daily, morning and evening milk yield, direct and indirect factors and milking intervals determined through correlation analysis is shown in table 2. Correlations between daily and partial (morning and evening) milk yields were statistically highly significant ($P < 0.0001$) and high (+0.966 and +0.956). Between direct and indirect factors (DMY/AM; DMY/PM; AM/DMY; PM/DMY) and daily milk yield correlations were near null, while with morning and evening milk yield correlations were low and statistically highly significant ($P < 0.0001$). Correlations among partial milk yields and milking intervals were statistically highly significant ($P < 0.0001$) and low, while between direct and indirect factors and milking intervals higher correlations were determined.

Table 1 – DESCRIPTION OF DATA (n = 7,059)
Tablica 1. – OPISNA STATISTIKA (n = 7.059)

Trait	$\bar{x}$	SD	Trait	$\bar{x}$	SD
DMY, kg	19.98	6.65	Direct factors		
AM, kg	10.60	3.67	DMY/AM	1.90	0.19
PM, kg	9.37	3.25	DMY/PM	2.16	0.25
Intervals			Indirect factors		
NI, min	765.38	57.08	AM/DMY	0.53	0.05
DI, min	677.46	56.94	PM/DMY	0.47	0.05

DMY – daily milk yield (dnevna količina mlijeka); AM – morning milk yield (jutarnja količina mlijeka); PM – evening milk yield (večernja količina mlijeka); NI – interval from p.m. to a.m. milking (noćni interval); DI – interval from a.m. to p.m. milking (dnevni interval)

Table 2 – CORRELATION BETWEEN MILK YIELDS, DIRECT AND INDIRECT FACTORS AND MILKING INTERVALS
Tablica 2. – KORELACIJA IZMEĐU KOLIČINA MLIJEKA, DIREKTNIH I INDIREKTNIH FAKTORA, TE INTERVALA IZMEĐU UZASTOPNIH MUŽNJI

Trait	AM, kg	PM, kg	DMY/AM	DMY/PM	AM/DMY	PM/DMY	NI, min	DI, min
DMY, kg	0.966 <.0001	0.956 <.0001	– 0.023 0.0543	– 0.018 0.1275	0.004 0.7598	– 0.004 0.7598	0.022 0.0621	– 0.032 0.0080
AM, kg		0.847 <.0001	– 0.259 <.0001	0.219 <.0001	0.249 <.0001	– 0.249 <.0001	0.174 <.0001	– 0.179 <.0001
PM, kg			0.245 <.0001	– 0.283 <.0001	– 0.273 <.0001	0.273 <.0001	– 0.150 <.0001	0.137 <.0001
DMY/AM				– 0.887 <.0001	– 0.970 <.0001	0.970 <.0001	– 0.547 <.0001	0.534 <.0001
DMY/PM					0.963 <.0001	– 0.963 <.0001	0.561 <.0001	– 0.543 <.0001
AM/DMY						– 1.000 <.0001	0.593 <.0001	– 0.577 <.0001
PM/DMY							– 0.593 <.0001	0.577 <.0001

DMY – daily milk yield (dnevna količina mlijeka); AM – morning milk yield (jutarnja količina mlijeka); PM – evening milk yield (večernja količina mlijeka); NI – interval from p.m. to a.m. milking (noćni interval); DI – interval from a.m. to p.m. milking (dnevni interval)

Table 3 – ESTIMATED DIRECT AND INDIRECT FACTORS
Tablica 3. – PROCIJENJENI DIREKTNI I INDIREKTNI FAKTORI

Interval, min	Direct factors*				Indirect factors*			
	Morning milking		Evening milking		Morning milking		Evening milking	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
< 600	2.2521	0.0773	2.4224	0.0106	0.4451	0.0149	0.4177	0.0018
≥ 600, < 660	2.1381	0.0109	2.2522	0.0049	0.4699	0.0025	0.4475	0.0009
≥ 660, < 720	2.0187	0.0039	2.1203	0.0031	0.4978	0.0010	0.4742	0.0006
≥ 720, < 780	1.9252	0.0024	2.0119	0.0042	0.5216	0.0006	0.4998	0.0009
≥ 780, < 840	1.8268	0.0032	1.9437	0.0134	0.5502	0.0009	0.5190	0.0029
≥ 840, < 900	1.7307	0.0055	1.9260	0.0679	0.5814	0.0016	0.5244	0.0163
≥ 900	1.6783	0.0215	–	–	0.6011	0.0070	–	–

*estimated from linear regression of direct factors (DMY/AM or DMY/PM) and indirect factors (AM/DMY or PM /DMY) on the milking interval (nightly or daily)

*procijenjeni temeljem linearne regresije direktnih i indirektnih faktora na interval između uzastopnih mužnji (noćni ili dnevni)

Estimation of daily (24 h) milk yield

Table 4 shows results from the comparison of different methods for daily (24 h) milk yield estimation from morning or evening milkings. The method with the highest correlation between estimated and true daily milk yields and the lowest difference between estimated and true daily milk yield is the most accurate one. When daily milk yields were estimated based on morning milking, correlation ranged from 97.124% to 98.211%, and when evening milk yield was used for estimation, correlations were slightly lower ($r_{T,E}$ = 96.343% – 97.650%). Similar relationships between estimated and true daily milk yield were determined by Liu et al. (2000) in whose study correlations ranged from 97.6% to 97.7% when estimated from morning milkings, as well as from 95.8% to 97.4% when estimated from evening milkings. The highest mean value of differences between estimated and true daily milk yield i.e. bias was determined in application of method V. that is doubling the partial milk yields. Doubling morning milking on an average overestimated the true daily milk yield in average amount of 1.233 kg per day, while doubling evening milking resulted in the underestimation in average amount of 1.207 kg per day. The lowest bias was observed when daily milk yield was estimated by method I. Although method I. exhibits the highest estimation accuracy, differences between estimation methods were small, with the exception of method V. which gives the lowest accuracy for both the estimation based on morning and evening records. Research results of Schaeffer and Rennie (1976), Cassandro et al. (1995), Lee and Wardrop (1984), Wangler et al. (1996), Liu et al. (2000), Jovanovac et al. (2005), Gantner et al. (2006), as well as of Jovanovac and Gantner (2007) confirm that the doubling method is the less accurate one and that different estimation methods based on regression technique, which take into account various factors that influence milk production, give higher estimation accuracy. These studies also confirm that estimates based on morning records are more accurate than those based on evening ones. Interval between successive milkings is the factor that has the highest influence on the quantity of milk yield milked in the morning or in the evening (Ormiston et al., 1967; Putnam and Gilmore, 1969; Everett and Wadel, 1970; Shook et al., 1973; DeLorenzo and Wiggans, 1986; Trappmann et al., 1998; Kawahara et al., 2000). Therefore, correct data on milking interval are necessary when daily milk yield is estimated from morning or evening records. Cassandro et al. (1995) reported that if milking interval data are questionable, doubling of partial milking yields could guarantee better estimates of daily milk yield.

Table 4 – ACCURACY OF DIFFERENT METHODS TO ESTIMATE DAILY MILK YIELD FROM MORNING OR EVENING MILKING
Tablica 4. – TOČNOST RAZLIČITIH METODA PROCJENE DNEVNE KOLIČINE MLIJEKA TEMELJEM JUTARNJE ILI VEČERNJE MUŽNJE

Method	$r^{1}_{\hat{y},y}$	$(\hat{y}-y)^2$			
		$\bar{x}$	σ	min	max
Morning milking					
I.	98.211	$1.397*10^{-15}$	1.248	– 6.490	6.452
II.	98.197	0.096	1.277	– 5.543	7.562
III.	98.196	– 0.001	1.271	– 5.609	7.394
IV.	98.095	0.079	1.337	– 6.853	8.907
V.	97.124	1.233	1.790	– 5.300	8.800
Evening milking					
I.	97.650	$-2.515*10^{-15}$	1.414	– 7.564	7.221
II.	97.533	0.152	1.516	– 7.057	9.288
III.	97.540	0.016	1.501	– 7.098	8.803
IV.	97.314	– 0.060	1.551	– 7.399	9.891
V.	96.343	– 1.207	1.762	– 7.100	4.780

[1]Correlation between estimated and true daily milk yields – korelacija između procijenjene i stvarne dnevne količine mlijeka; [2]Difference between estimated and true daily milk yields (kg) – razlika između procijenjene i stvarne dnevne količine mlijeka (kg)

Estimation of 305-day lactation milk yield

Previous studies (McDaniel, 1969; Anderson et al., 1989; Aleandri et al., 2003; Berry et al., 2005) show that estimation error of A4 milk recording method was negligible which means that the A4-estimated 305-day lactation yield could be taken as the most accurate reflection of the actual 305-day lactation yield.

Overestimation and underestimation of daily milk yields observed when estimation was based on morning and on evening records, respectively, could be partially avoided by the alternate use of AM and PM for calculation of lactation milk yields (Schaeffer and Rennie, 1976; Webb, 1980; Smith and Pearson, 1981; Liu et al., 2000). Results from the comparison of different estimation methods for 305-day lactation milk yields are presented in table 5. According to correlations between estimated and true (A4) 305-day lactation milk yields negligible differences were observed between estimation methods that is all correlation coefficients were higher than 99%. Doubling partial milk yield (method V.) resulted in the highest mean value of differences between

estimated and true 305-day lactation milk yield that is underestimation in average amount of 49 kg per lactation or 0.75% of true yield. The highest estimation accuracy was gain with application of estimated indirect factors (method III.). Similar mean values of bias of method II. and method III. were obtained by Cassandro et al. (1995). In conformity with comparison results it could be said that there are no notable differences between the tested estimation methods which could be explained by the balance of estimation error of daily milk yield from morning milking with those from evening milking.

Table 5 – ACCURACY OF DIFFERENT METHODS TO ESTIMATE 305-DAY LACTATION MILK YIELD
Tablica 5. – TOČNOST RAZLIČITIH METODA PRI PROCJENI KOLIČINE MLIJEKA U STANDARDNOJ LAKTACIJI

Method	$r^{1}_{\hat{y},y}$	$(\hat{y}-y)^2$			
		$\bar{x}$	σ	min	max
I.	99.422	– 21.869	144.021	– 403.677	361.487
II.	99.378	42.873	144.729	– 413.057	431.258
III.	99.379	4.431	143.255	– 445.521	364.978
IV.	99.444	– 12.185	138.999	– 479.322	390.995
V.	99.312	– 48.994	153.405	– 437.900	322.450

[1]Correlation between estimated and true 305-day lactation milk yields – korelacija između procijenjene i stvarne količine mlijeka u standardnoj laktaciji; [2]Difference between estimated and true 305-day lactation milk yields (kg) – razlika između procijenjene i stvarne količine mlijeka u standardnoj laktaciji

Conclusions

Based on conducted research several conclusions can be made. In estimating daily milk yield, either from morning or evening records, method I. that is linear regression of daily to partial milk yields with taking into account the interval between successive milkings proved to be the most accurate one. The use of estimated direct and indirect factors, as well as the use of method by DeLorenzo and Wiggans (1986) resulted in slightly lower estimation accuracy. The doubling method gives high estimation error that is high overestimation and underestimation of daily milk yield when estimating based on morning or evening records, respectively. The estimates based on morning records were more accurate than those based on evening ones regardless of estimation method. Eventually, when daily milk yield is estimating from AT recording scheme, method I. is recommended for routine use.

Results from the comparison of calculated 305-day lactation milk yields indicate that there are no notable differences between evaluated methods.

Furthermore, the estimation of daily and lactation milk contents from alternative milk recording scheme, as well as the impact of estimated daily milk yields use on accuracy of cow's breeding value estimation should be examined.

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