Detection of abnormal recordings in Irish milk recorded data

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The objective of this study was to detect abnormal recordings of milk yield, fat concentration and protein concentration in Irish milk-recorded data. The data consisted of 14,956 records from both commercial and experimental herds with 92% of the recordings recorded manually and the remainder recorded electronically. The method used in this paper was a modified version of the method employed by the Animal Improvement Programs Laboratory in Maryland, USA and conformed with the guidelines outlined by the International Committee of Animal Recording. The results illustrate the effectiveness of detecting abnormal recordings in Irish milk records. The method described in this paper, defines the upper and lower limits for each production trait and these limits along with the slope parameters were used to determine if a recording was abnormal or not. Three percent of milk yield recordings, 5% of fat concentration recordings and less than 1% of protein concentration recordings were found to be abnormal. The proportion of values declared abnormal in manually recorded and electronically recorded data were examined and found to be significantly different for fat concentration.

Keywords: dairy cows; fat; milk yield; protein

Introduction

The accuracy of milk component analysis is very important to most dairy farmers and to various facets of the dairy industry. Results are used to estimate individual cow performance as well as for genetic evaluation (Bertrand, 1996). Abnormal recordings are defined as values that deviate significantly from a cow's other recordings. Abnormally low or high

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values could be a result of injury or recording errors such as meter malfunctions or improper sampling as well as data entry error or incorrect identification (Guthrie, 1994; Slater and Webster, 2001a; Slater and Webster, 2001b). Recent estimates in Ireland indicate that just over 380,000 cows out of a total dairy population of 1.1 million cows are milk recorded (ICBF, 2006). This represents 33.4% of cows but only 20.6% of herds. Generally milk recording in Ireland is conducted manually by third party labour from seven milk-recording organisations. It is common practice for sick cows not to be recorded. Anecdotal evidence would suggest that often their test values are "predicted" by the farmer or by the "recorder", or test day values are declared "missing".

In 2004, the Irish Cattle Breeders Federation (ICBF) together with Dairygold Co-op conducted a pilot scheme, which involved the introduction of an electronic do-it-yourself (DIY) milk recorder (ICBF, 2004) in Ireland, involving 140 herds. The implications of such a scheme are that there are lower overhead costs for the participating farmer, less steps from data collection to database entry, thus the system is more cost efficient than the traditional manual milk recording schemes for the service supplier (ICBF, 2004). This makes it potentially a more attractive recording system and may encourage a greater uptake of milk recording.

Currently, there is no objective method in place to detect abnormal recordings in Irish milk-recorded data; detection depends on observations made by the dairy farmer or the milk recorder. An objective method for detecting abnormal recordings should be fundamental.

The International Committee for Animal Recording stated in their revised recording guidelines (ICAR, 2002) that true daily-test values collected from animals labelled by the farmer as sick, injured, under treatment or in heat must be used in the computation of the lactation record unless the test value is less than 50% of the previous test value or less than 60% of the predicted test value; where these conditions are met the test values may be considered as missing. Wiggans, VanRaden and Philpot (2003) proposed a method for detecting and adjusting abnormal test day yields at the Animal Improvement Programs Laboratory in Maryland, USA. The objective of this study was to examine the method of Wiggans *et al*. (2003) in detecting abnormal recordings of milk yield, milk fat concentration and milk protein concentration and to compare the incidence of abnormal recordings under two methods of milk recording – manual and electronic.

Materials and Methods

Data

The data used comprised a total of 16,086 lactations from two data sets (Quinn, Killen and Buckley, 2005). Data set 1 comprised 14,198 lactations of monthly test-day recordings from 79 commercial spring-calving dairy herds. Data set 2 comprised 1,888 lactations of weekly yields, from six experimental herds attached to Teagasc Dairy Production Research Centre, Moorepark. This data set included 1,888 lactations from 872 individual cows, of which 1,408 lactations were spring/summer calving and the remainder were autumn/winter calving (defined as calving from July to December). Lactation number ranged from 1 to 16 across the data sets. For the purposes of this study, lactation number was categorised as lactation 1, lactation 2 and lactation 3 or greater (Cunningham, 1972; Killen and Keane, 1978; Lideaur *et al*., 2000; Dechow *et al*., 2004). Animals with fewer than five recordings were deleted from data set 1 and lactations of less than 25 weeks dura-

tion were removed from data set 2. After editing, data sets 1 and 2 consisted of 13,229 and 1,727 lactations, respectively, and they were amalgamated for the analysis. In total there were 167,426 recordings; 153,528 recorded manually and 13,898 recorded electronically using the ICBF do-it-yourself milk recording system.

Definition of upper and lower limits

The cut-off points that determine whether or not a value is described as abnormal must be established before the abnormal recordings can be identified. A lower limit of 60% of the predicted test day value was used, complying with the guidelines of the International Committee for Animal Recording (ICAR, 2002). An upper limit of 150% of the expected value was chosen to capture the most extreme values (Wiggans *et al*., 2003). As cows are more likely to produce an abnormally low yield rather than an exceptionally high yield (Wiggans *et al*., 2003) the limits were designed to take this into account.

Estimation of slope parameters

Before proceeding to detect the abnormal values, the parameters for estimating the slope of the lactation curves needed to be estimated using the method outlined by Wiggans *et al*. (2003). These were calculated separately for milk yield, fat concentration and protein concentration. Second and subsequent test day slope values were estimated from the preceding test day using the following expression:

$$(p_i - p_{i-1})/(TD_i - TD_{i-1}) = b_0 + b_1 TD_{i-1} + b_2 TD^2_{i-1} + b_3 p_{i-1} + b_4 (TD_{i-1}) p_{i-1} + e$$

where p_i = milk yield, fat concentration or protein concentration on test day i (TD_i). Wiggans *et al.* (2003) estimated the parameters by lactation stage (<50 *DIM* (days in milk) and ≥50 *DIM*) and lactation number; however, in this study lactation week was used instead of lactation stage so that the estimates of the slope parameters would be more accurate, and calving month was included as it was deemed appropriate by Cunningham (1972), and also on the basis of the findings of Quinn *et al*. (2005). This was done by calculating the mean values for each calving month and within each calving month for each lactation week. The slope between the first and second test day was estimated by using the subsequent test day value instead of the preceding test day in the following way:

$$(p_1 - p_2)/(TD_1 - TD_2) = b_0 + b_1 TD_2 + b_2 TD_2^2 + b_3 p_2 + b_4 (TD_2) p_2 + e$$

where p_i = milk yield, fat concentration or protein concentration on test day i (TD_i).

Detection of abnormal values

The predicted test day value (apart from the first test day) was calculated, using the slope parameters, as follows:

$$\hat{p}_i = p_{i-1} + \hat{b}(TD_i - TD_{i-1})$$

where $\hat{p}_i$ = predicted milk yield, fat concentration or protein concentration on *TDi,* p_{i-1} = observed milk yield, fat concentration or protein concentration on the preceding test day and

$$\hat{b} = b_0 + b_1 TD_{i-1} + b_2 TD^2_{i-1} + b_3 p_{i-1} + b_4 (TD_{i-1}) p_{i-1}$$

using b_0, ... b_4 as estimated above.

If there was no preceding normal recording, p_i was tested against the herd mean value, adjusted for days in milk. The first *TD* value was tested against the second *TD* value, if the second was declared normal, as follows:

$$\hat{p}_1 = p_2 + \hat{b}(TD_2 - TD_1)$$

where $\hat{p}_1$ = predicted milk yield, fat concentration or protein concentration on the first test day, p_2 = observed milk yield, fat concentration or protein concentration on the second test day and

$$\hat{b} = b_0 + b_1 TD_2 + b_2 TD^2{}_2 + b_3 p_2 + b_4 (TD_2) p_2$$

using b_0, ... b_4 as estimated above.

If the second test day value was declared abnormal then the first recording was tested against the herd mean value adjusted for *DIM* (Wiggans *et al.*, 2003).

The simplicity of this method is demonstrated as follows; if for example there were seven recordings for a certain cow (r_1, r_2, r_3, r_4, r_5, r_6, and r_7), then each of the recordings, r_2 through to r_7, is compared to the preceding recording which has been declared normal. If there is no preceding normal recording the recording being tested is compared to the herd mean value adjusted for *DIM*. However, as the first recording, r_1 can have no preceding normal recording it is compared to the second recording r_2, if r_2 is normal. If r_2 is abnormal then r_1 is also compared to the herd mean value adjusted for *DIM*. If r_1, r_2, r_3 and r_4 were declared normal and r_5 was declared abnormal then r_6 would be compared to r_4.

The number of abnormal recordings was examined and compared for milk yield, fat and protein concentration data. Then a test of two proportions was used to determine if there were significant differences in the number of abnormal recordings between electronically and manually recorded data.

Results

Just over three percent (3.3 %) of milk yield recordings were detected as being abnormal (when lactation week one was omitted the incidence was reduced to 2.7%); for fat and protein concentration, the corresponding levels of abnormal recordings were 5.3% (5.3% when lactation week one was omitted) and 0.003% (0.002% when lactation week one was omitted), respectively. The percentage of total recordings that were declared abnormal for each lactation number category per production variable are shown in Table 1. It is evident that lactation number is not a major contributing factor to the number of abnormal recordings. The percentage of abnormal recordings per lactation week over a lactation period for milk yield, fat concentration and protein concentration are shown in Figures 1, 2 and 3, respectively.

It is clear from Figure 1 that 51% of lactation week one recordings were declared abnormal, of these 39%, 25% and 36% were from cows in their first, second and third or greater lactations, respectively. However, after the first lactation week the percentage of abnormal recordings remained relatively constant (at approximately 1.3%) until the end of lactation with 52% of those abnormal recordings being under the lower limit value. Ninety six per cent of the abnormal recordings from first lactation cows were declared abnormally low. For cows in their second and third lactation or greater 66% and 75% of the abnormal recordings were abnormally low, respectively.

Both fat and protein concentration follow a similar trend to milk yield (See Figures 2 and 3). However, milk is rela-

Table 1. Percentage of recordings deemed abnormal for milk yield, fat concentration and protein concentration in each lactation category

Variable	Lactation category		
	1	2	3+
Milk yield	3.27	2.58	3.90
Fat concentration	4.17[a]	4.44[a]	6.32[b]
Protein concentration	0.003	0.002	0.003

[ab] Within rows, means without a common subscript differ significantly ($P < 0.05$).

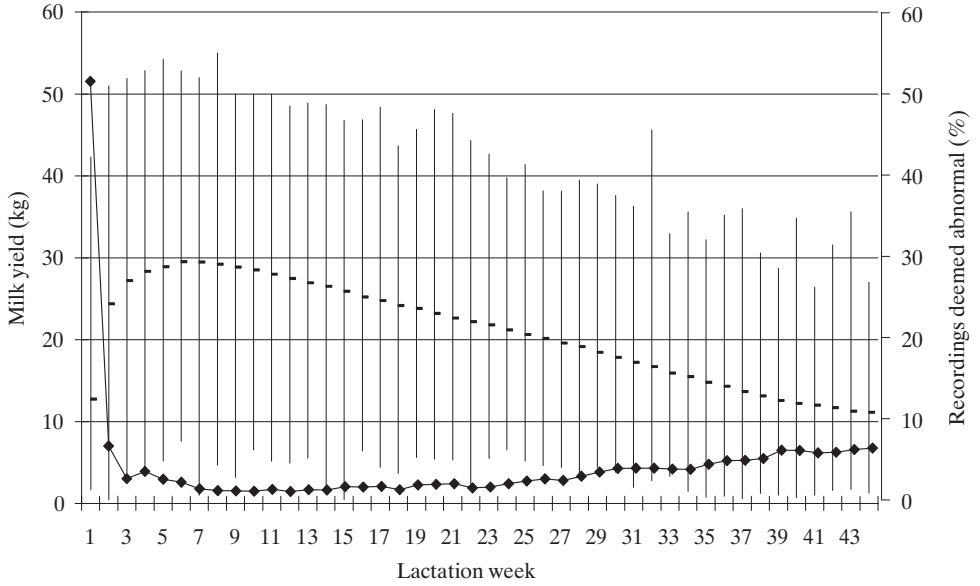

Figure 1. Percentage of milk yield recordings per lactation week declared abnormal (-◆-) and the mean (--) and range (|) of milk yield values for each week of lactation.

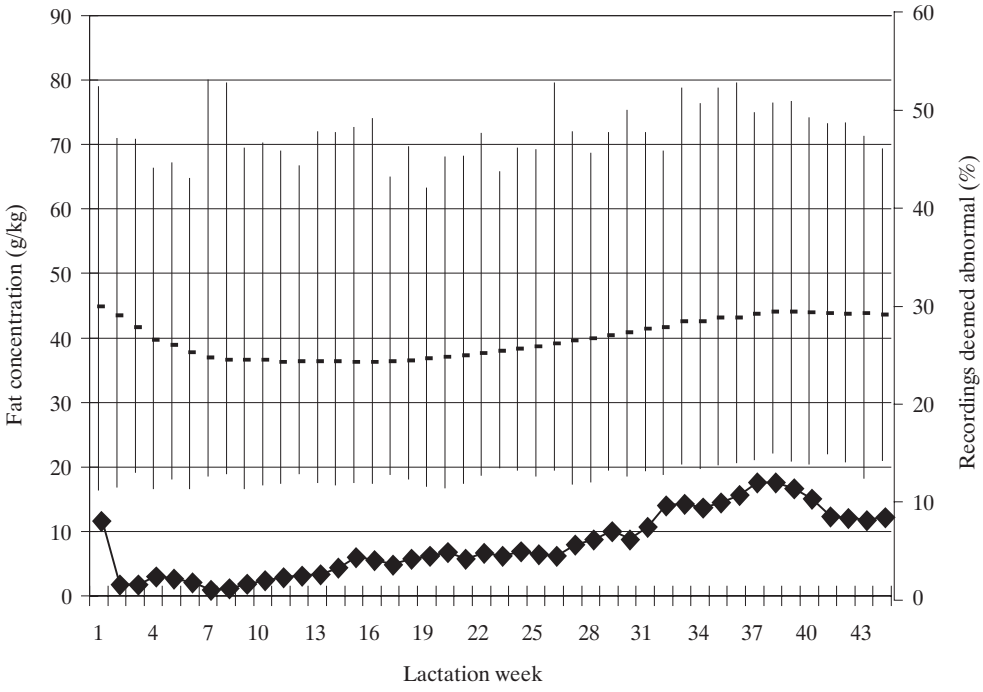

Figure 2. Percentage of fat concentration recordings per lactation week declared abnormal (-◆-) and the mean (--) and range (|) of fat concentration values for each week of lactation.

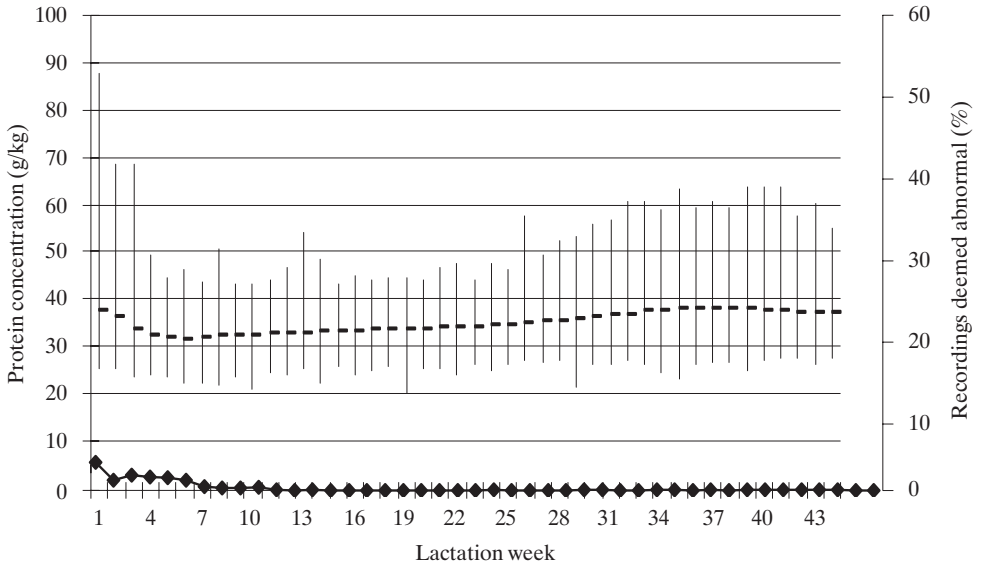

Figure 3. Percentage of protein concentration recordings per lactation week declared abnormal (-◆-) and the mean (--) and range (|) of protein concentration values for each week of lactation.

tively homogeneous with respect to protein concentration (average coefficient of variation is 8.5%) while this is not true for fat concentration (average coefficient of variation is 14.8%). It is evident in Figure 2 that the incidence of abnormal recordings of fat concentration rises from week 29 onwards and begins to decrease again from week 40. For protein concentration (Figure 3), 91% of the abnormal recordings in the first 2 weeks of lactation and 77% of those in the first 3 weeks of lactation were declared abnormally high.

The proportion of abnormal recordings in manually and electronically milk-recorded data were calculated and compared for milk yield, fat and protein concentration. It was found that for milk yield, 2.9% of the electronically recorded and 3.4% of the manually recorded values were declared abnormal. Thus, there was no difference between manually and electronically recorded milk yield data. For fat concentration, 2.7% of the electronically recorded values and 5.5% of the manually recorded values were declared abnormal ($P < 0.001$); while for protein concentration 0.002% of the electronically recorded and 0.003% of the manually recorded values were declared abnormal, again not different.

Discussion

In this study, more milk yield and fat concentration values were declared abnormal than values for protein concentration. This is similar to other studies (Klopcic *et al*., 2003). Of all the recordings declared abnormal, 25% were in the first 2 weeks of lactation. For the most part these are likely to be attributable to the normal course of events expected immediately post calving. Although it was not within the scope of this study to determine the causes of abnormal records it is likely that there are at least five sources: 1) manual or human errors in sampling, 2) mechanical/equipment sampling errors, 3) cow

factors associated with the general wellbeing or stage of lactation of the cow, 4) post sampling treatment that may result in a sub-standard milk sample being presented for analysis in the laboratory, and 5) the ability of the method outlined to identify genuine abnormalities rather than artefacts of the biological data. The adherence to strict guidelines (IDF, 1996) and checks in place internationally and in Ireland (ring testing) should ensure that the laboratory testing procedures are unlikely to be a significant source of abnormal records. However, such procedures are not infallible.

Milk yield

The highest percentage of abnormal milk yield values occurred in the first week of lactation (Figure 1). Issues influencing the variation in milk production at this time are likely to include cow factors such as milk let down in the first few days, stress of parlour introduction, removal from calf, change of diet, dietary upsets, calving problems, etc. (Larson, 1985; Wicks, Carson and McCoy, 2003). The fact that the proportion of abnormal records that were abnormally low was higher (96%) for first lactation cows than for second (66%) or later lactations (75%) suggests that first calvers are more highly variable in terms of milk let down at the beginning of lactation. Other contributing cow factors include the inability of the cow, immediately post-calving, to consume sufficient energy to sustain lactation (Mackle *et al.,* 1999; Buckley *et al.,* 2003; McGuire *et al.*, 2004).

After lactation week 2 the level of abnormalities declined substantially and as the ratio of abnormally low to abnormally high recordings was approximately 50:50 a high proportion of these abnormalities are likely a result of recording errors; misreported yield or animal identification, or faulty recording equipment etc. The slightly higher incidence of low recordings may be due to cow factors such as oestrous behaviour (Stevenson, 1999), mastitis (Harmon, 1994) or poor health.

At the end of lactation an increase in the incidence of abnormal recordings was also evident, albeit to a much lower extent compared to early lactation. At this stage 57% of the abnormal recordings were deemed abnormally low. Factors such as stage of lactation, production potential, pregnancy status, and changes in nutrition are likely to be the primary influences contributing to the variation at this time (Whittemore, 1980; Mepham, 1983; Webster, 1983; Dillon, Ryan and O'Donovan, 1999).

Fat concentration

As well as accurately reading the weight of milk produced by each individual cow at evening and morning milking, a representative sample must be obtained for compositional analysis. Milk fat is the most variable component in milk (Whittemore, 1980; Mepham, 1983). Because it is in suspension in milk rather than in solution, as is the case for milk protein, the risk of getting a non-representative sample is logically greater. Appropriate agitation is critical to obtaining a representative sample; insufficient or excessive agitation can lead to uneven distribution of fat or free fat and hence are likely to be the source of many abnormal recordings. However, other factors may also contribute. The high proportion of abnormal recordings in the first week is most likely due to the fact that at the beginning of lactation (days 1 to 3) milk tends to have about twice the normal concentration of fat (Whittemore, 1980). Thereafter the proportion of abnormal fat values drops and tends to stabilise and gradually increase again in late lactation (Figure 2). This is similar to the findings of Wiggans *et al.* (2003). At week 29 there is a quite sudden increase in the incidence

of abnormal recordings. This appears to coincide with an increase in the variation in fat concentration at this time. This is likely to be a stage of lactation effect (Whittemore, 1980). Mastitis or elevated somatic cell counts are associated with a decrease in fat concentration (Harmon, 1994) due to reduced synthetic activity of the mammary tissue.

The fat concentration in milk can vary from 2% at the beginning of milking to 4% in the middle, and 8% at the end (Whittemore, 1980; Larson, 1985). Thus, the extent to which the cow is milked out will influence the fat concentration for a given 'milking'. As milk fat concentration is very variable sufficient agitation is critical. If the milk is not agitated properly in the jar/meter the milk fat concentration will be low due to the fact that the fat has risen to the top of the jar/meter and usually the sample is taken from the bottom. Insufficient agitation may occur during milk recording due to inadequate agitation time or as a consequence of insufficient vacuum getting to the jar/meter during the agitation process – the latter being influenced by the transfer time between cows.

The milking interval between the AM and PM milk recordings will also influence milk fat concentration. The principle of sampling is on the basis of proportionate volumes of evening and morning milk. Where the intervals are unequal milk fat tends to be higher after the shorter milking interval. This is due to the residual milk being high in fat as indicated above (Whittemore, 1980; Larson, 1985). The effect of milking interval may be overcome by the use of appropriate sub devices (sample dippers; IDRC, 1995), but the practice is open to operator error. However, the effect of milking interval as determined by the position at which individual cows enter the milking parlour cannot be accounted for. Over-filling of the sample bottle will lead to fat sticking to the lid, thus significantly reducing the concentration of fat in the sample. Other sources of abnormal milk fat readings associated with operator error may include 'missed cows' sampled from an unrepresentative sample, e.g., the last milk to leave the jar, hand milking into the sample bottle after machine milking is completed or a sample provided from a different cow etc.

Apart from the challenges presented by the milking/sampling processes in the milking parlour, milk fat concentration is also sensitive to post-sampling treatment of the sample. Collection depots in Ireland tend not to have refrigerated storage facilities. Samples are generally analysed in the laboratory within 4 to 5 days of milk recording. The correct procedure in Ireland (IDRC, 1995) requires the addition of a preservative, containing an oxidising agent, to the milk sample immediately post sampling to avoid deterioration of the sample (Bertrand, 1996). It is imperative that the preservative is uniformly distributed throughout the sample. If sufficient preservative is not present throughout the sample, e.g., preservative not added, not enough preservative added due to broken tablets caused by a faulty dispenser, or inadequate inversion of the samples to encourage even distribution, milk samples are prone to souring, particularly during warm weather. Additionally, the analysis of milk post sampling may be complicated by factors such as creaming (gradients in fat due to differences in densities between the fat and plasma phases of milk (Deeth and Fitzgerald, 1976, 1978; Kammerlehner and Kessler, 1980).

Stage of lactation *per se* has been highlighted as a possible contributor to the increase in abnormal fat recordings as lactation proceeds. The rapid increase in fat concentration in late lactation may cause a problem at the limits (i.e., increasing the

probability of being abnormal) which may also be exacerbated by feeding regimes across herds. As this problem only occurs with fat concentration data, it may be a reason to treat fat concentration differently to milk yield and protein concentration. One way of overcoming this problem would be to use a predetermined percentage of recordings to be deemed abnormal, e.g., let 2% of recordings be abnormal. However, this is not very practical if numerous unusual recordings are found in one herd. Another approach would be to use different limits for different stages of lactation. This would be easily implemented; however this study focused on the limits that are outlined by ICAR (2002).

The higher incidence of abnormal fat recordings with mature cows is likely consistent with the fact that older cows tend to have higher milk volumes thus reducing the chance of obtaining a representative sample due to the difficulties posed to adequate agitation.

Protein concentration

As the protein concentration of milk is generally more consistent than fat concentration (coefficient of variation values 8.5% and 14.8%, respectively), it follows that fewer abnormal recordings were highlighted. Like fat concentration the initial peak illustrated in Figure 3 is associated with the expected high concentration of fat and protein at this time. Like fat, at the beginning of lactation milk tends to contain a very high concentration of protein, approximately five times the normal concentration (Whittemore, 1980). Figure 3 also shows that there was a large variation in milk protein concentration at this time and in the last few weeks of lactation, while in mid lactation it is less variable (Whittemore, 1980; Schutz, Hansen and Steuernagel, 1990). This coincides with the distribution of abnormal recordings (Figure 3). Only 0.003% of the protein recordings were declared abnormal. As protein concentration is little affected by protein intake, depression only occurs in cases of severe protein under-feeding. However, the energy concentration of the diet affects the protein fraction most (Whittemore, 1980). Grass quality, concentrate, supplementation and forage (e.g., grass silage) can substantially influence milk protein concentration and variation but this is less than its effects on fat concentration or milk yield (Chamberlain and Wilkinson, 1996).

Observations on the method outlined

When the interval between the previous normal recording and the one that was being tested was greater than one month, it was observed that the predicted values for the milk yield, fat and protein concentrations increased exponentially with time. Thus, the values predicted were implausible. This problem was not noted by Wiggans *et al*. (2003). To eliminate this problem the recording being examined was compared to the herd mean value adjusted for *DIM*.

Comparison between manually and electronically recorded data

The difference in the incidence of abnormal recordings between manually and electronically recorded data for fat concentration is most likely explained by human error in the critical agitation procedure. If the milk is not agitated properly in the jar/meter the milk fat concentration will be low due to the fact that the fat has risen to the top and that the sample is being taken from the bottom.

This is the first time that an objective method has been used to identify abnormal recordings for milk yield, and fat and protein concentrations in Irish milk recording data. The results clearly show

that the incidence of abnormal recordings varies with stage of lactation and method of sampling. However, the sources of these errors can be explained: it is inevitable that errors will occur when humans and technology are involved. However, being able to detect the errors and understand the abnormal recordings will give a greater insight into milk sampling and as a result will improve the whole milk recording procedure. The method outlined in this study abides by the guidelines outlined by ICAR (2002) and is therefore very suitable for use in Ireland.

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