In-line milk analysis: animal health monitoring for improved dairy farm management decisions

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Abstract

Afilab™ (by afimilk) is a real-time, online milk components analyzer that delivers data for each cow, on a per-milking resolution, enabling strict daily monitoring. The information collected allows for prompt preventive health treatment, which in turn improves milk production and fertility performance.

Field trials were conducted in the years 2006-2012 at four commercial Israeli dairy farms with 700-900 milking cows each. In these studies calving cows were tested 3-4 times a week for blood β-hydroxybutyric acid (BHBA) levels during 1 to 10 weeks periods. Afilab™ data of milk fat to protein ratio (FPR) were analyzed for different thresholds of FPR over different periods of time compared to BHBA results.

Based on these studies, a combined model that allows for effective farm management decisions was developed. This model offers a list of ketotic cows to be treated with an adequate level of specificity (85%-55%) and sensitivity (85%-55%). Moreover, thanks to Afilab™ data, it will be possible to establish a definite FPR threshold beyond which cows’ production and reproduction performances decline unless proper treatment is provided.

Keywords: online milk analysis, milk components, ketosis, beta-hydroxybutyric acid

Introduction

The last 5 decades of genetic improvements and selection of dairy cows by milk traits have placed milk production as top priority when allocating energy in a cow’s body, even at the cost of harming basic needs of existence and reproduction.

In order to produce milk, a cow’s body requires three times more energy than the energy required for maintenance (Cook, 2008). When a cow is unable to consume adequate energy from food, there is an excessive mobilization of adipose tissue, i.e., loss of body condition scoring (BCS), indicating a cow is in a negative energy balance (NEB).
The functional activity of various tissues, especially of the liver is impaired by NEB. Amongst other essential functions, the liver plays an important role as a primary source of insulin-like growth factor-I (IGF-I) that stimulates development and ovulation of ovarian follicles (Butler, 2012). As loss of BCS becomes more extensive, the reduction in conception rate to artificial insemination (AI) becomes greater. Low concentrations of IGF-I before and after calving are associated with a failure to conceive, despite repeated services (Wathes et al, 2009). Conception rate decreases about 10% per 0.5 unit BCS loss (Butler, 2012).

Nir – Markusfeld and Ezra (Unpublished) conducted a study (2013) that included 316,255 lactations (2nd or higher), of 163,554 cows, from 1,896 herds, calving in the period between 2002 and 2010. It was found that the adverse effects of NEB on fertility increased with time from calving, the LSMeans differences between ketotic and non-ketotic cows were -3.67% & 6.81% for conception rate (CR) to first AI and open >150 days in milk (DIM) respectively and those for cows with FPR>1.4 vs. those with FPR≤1.4 were similar, -3.03% & 6.63%. Milk yield of cows with either diagnosed ketosis or FPR>1.4 was lower than of those without the traits and culling rate was higher.

Changes in a cow's physical status or nutrition elements have significant biochemical cost that is reflected in the composition of body fluids and especially in milk. Some of the body fat degradation products, like other resources, are directed straight to the udder. This causes an increase in milk fat content. Other fat accumulates in the liver causing excessive ketone bodies production and Ketosis. Ketones are detectable in the blood far earlier than in urine. Increase in ketones (BHBA) in blood or ketones (acetone) in urine, does not occur at the same time as changes of FPR in milk. Blood Ketones elevation can happen 1-2 days after milk FPR elevation (Schcolnik et al. unpublished, 2006).

During early lactation animals are at a much higher risk for ketosis and fatty liver. The common methods for detecting excessive increased levels of ketone bodies are by cow-side tests in the urine, blood or milk. However, since cow's ketone bodies concentration in body fluids depends on metabolic processes characteristic of each cow, feeding time, sampling time and ration composition may affect the results. Hence continuous measurements of FPR as a specific indicator for excessive body fat mobilization in time of NEB, can constitute a practical tool for herd screening of NEB and ketosis.

Afilab™, based on an optical sensor, measures milk composition (fat, protein and lactose) for each cow, during every milking. The objective of our research was the development of a model based on Afilab™ data of real-time milk composition, in order to detect ketosis.

Materials and Methods

In a preliminary study meant to determine an optimal blood sampling time for diagnosis of ketosis, we measured blood ketone levels of 18 cows (5-45 days in milk), at three different times (06:00, 13:00, 20:00) during one day. Cows with beta – hydroxy-butyric acid (BHBA) above 1.4 nmol / L were considered ketotic (Figure 1).

For the development of an Afilab™ data based model, we conducted field trials in the years 2006-2012 at four commercial Israeli dairy farms with 700-900 milking cows each. In these studies, the blood of postpartum cows (5-60 days in milk) was sampled for BHBA levels.
In the first study cows were blood tested for 3 days every week in two day intervals, during a 10 week period. In the other studies cows were tested 4 times a week on consecutive days, during 7 weeks, 3 weeks and 1 week periods. In the first two studies blood samples were tested in a veterinary laboratory, while in the other two studies blood samples were measured cow-side by Precision Xtra® (Abbott) with blood ketone test strips. All cows identified with ketosis symptoms (BHBA > 1.4 mmol/L) were drenched with Propylene-Glycol only at the end of each week, after sampling. Each cow that was treated was culled out of the experimental group (not sampled again). At least two weeks before and during the study, no food additive to prevent ketosis was provided to cows either before or after calving.

Afifab™ data of milk fat to protein ratio (FPR) were evaluated by different calculated FPR thresholds, for different periods of time, compared to BHBA results. In the different models that were tested, cows with BHBA above 1.4 mmol/L were considered ketotic. Analysis was performed by JMP® 10 (SAS Institute Inc.). Since we did not yet find an optimal model proven for its high sensitivity and high specificity concurrently, it is necessary to compromise. Therefore in the application we use two models, one with high sensitivity (>80%) and the other with high specificity (>80%).

In the selected two models, Sensitivity is determined by daily FPR (milk weighted average of morning, noon and evening milkings). A diagnosis is considered positive when daily FPR is higher than the threshold calculated for each cow (default FPR > 1.4). Specificity is determined by daily FPR (milk weighted average of morning, noon and evening milkings) of each of the last three days. A positive diagnosis is when daily FPR of each one of the last 3 days was higher than a threshold calculated for each cow (Reference value BHBA > 1.4 mmol/L).

Results

For the effective measurements it was necessary to determine the optimal blood sampling time for diagnosis of ketosis. In a preliminary study during morning measurements we found two cows out of 18 with symptoms (BHBA > 1.4 mmol/L) of ketosis (11%), while during afternoon and evening measurements the number of cows with the symptoms increased to five (28%) and six (33.0%) respectively (Figure 1). However, no single measurement included all the affected cows together. We concluded that single measurements are not a sufficiently effective means for monitoring and preventing ketosis and negative energy balance in cows.
Figure 1. Average blood concentration of beta-hydroxy-butyric acid (BHBA) and the number of cows with ketosis, during three different testing times throughout the day, in 18 cows postpartum.

Table 1 shows the blood BHBA results, which were evaluated for different thresholds over different periods of time (either daily or averaging the results of several days). Each row represents a different model from the same database; number of cows and ketosis rates, varies according to availability of the dataset required for each model. Based on daily FPR data, a combined model that allows for effective farm management decisions was developed. This model offers a list of ketotic cows to be treated with a practical level of specificity (85%-55%) and sensitivity (85%-55%). Currently a diagnosis according to AfiLab™ data is based on a combination of tests of sensitivity and specificity with different thresholds based on multiple measurements.

Table 1. Results of different models for AfiLab™ data of milk FPR.

<table>
<thead>
<tr>
<th>Number of cows</th>
<th>Number of ketosis events</th>
<th>rate of ketosis</th>
<th>Sensitivity(^1) (%)</th>
<th>Specificity(^2) (%)</th>
<th>Accuracy (%)</th>
</tr>
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<tbody>
<tr>
<td>106</td>
<td>14</td>
<td>13</td>
<td>50</td>
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\(^1\) true positive rate
\(^2\) true negative rate
Conclusions

A transition period directly and indirectly affects fertility, production and survival in the subsequent lactation. Milk fat to protein ratio (FPR) has been shown to be beneficial in the prediction of reproductive efficiency in dairy cows (Podpecan et al. 2010)

Our studies show that AfiLab™ can practically monitor and detect the changes of milk components at any time and thus allow monitoring, diagnosis and effective treatment of metabolic disorders such as ketosis in dairy farms. Our findings have a practical implication presenting two alternatives for the farmer: first, while using the high sensitivity model, he gets a daily list of cows for treatment composed of more than 80 percent of ketotic cows in the risk period (5-60 DIM) with less than 50 percent of "healthy" cows (that might receive unjustified treatment). Second, while using the high specificity model, the farmer gets a daily list of cows for treatment composed of more than 60 percent of ketotic cows in the risk period (5-60 DIM) with less than 20 percent of "healthy" cows.

We started this research with the goal of identifying Ketosis effectively to ensure timely treatment. This goal was achieved. In addition, we found we have a solid base for real time identification of negative energy balance, which is a direct indicator of the cow's health status even before keton bodies are present. In our next phases we aim to pursue this direction as a means for timely identification of cows that are in need of treatment. AfiLab™ provides high resolution daily per cow data about fat mobilisation and negative energy balance.

References


