Automated daily analysis of milk components and automated cow behavior meter: developing new applications in the dairy farm

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Summary

Two new sensors, an on-line milk analyzer (Afilab™) and a behavior meter (Pedomer+™) were developed in S.A.E. Afikim. The results of applicative research carried out by S.A.E. Afikim Application team and researchers of the Volcani Cente (Israel), are presently described.

A controlled large scaled field trial was carried out in an Israeli commercial dairy herd, milking 800 cows from May/07 through July/07. Daily milk components of the milk analyzer were compared to reference laboratory.

Daily calculated variations of fat and protein in bulk milk between the analyzer and the laboratory were -0.05% to +0.28% and 0.01% to 0.05% respectively. The agreements between the estimated payment returns under Israeli economy corrected milk formulas were -1.1% to 0.0% and allow for a daily follow up of dairy returns. Variations of the estimated daily dry matter intake calculated by the NRC 2001 formula revealed differences of 1.8 Mcal/day and 15 gr protein/day per cow between the analyzer and the laboratory results. Prediction of NEB/ketosis is possible with diverse sensitivity and specificity values depending on the fat: protein ratio cutoffs. The results of the retrospective analysis suggest that further research and interaction with other Afimilk sensors will improve the results.

Applied studies for uses of the behavioral meter showed that behavioral data collected and analyzed may be used as a useful tool for evaluation and detection of stressful situation (e.g. heat stress, noise disturbance, bedding condition). Derived applications would be monitoring housing management, influence of alteration in farm routine or facilities and prediction of calving time.

The author believes that the new sensors will improve management of the commercial dairy herds while further research will allow more practical application and better understanding of the complex dairy cows behavior.

Key words: *Milk analyzer, Behavior meter, Lying behavior, Animal welfare, Milk components.*

Introduction

The structure of the milk industry is going through extensive changes in the last decades. The number of farms is dropping, while the average number of animals in each farm is increasing sharply. As a consequence, monitoring and control of production, fertility, animal health and welfare cannot depend anymore on familiarity of the individual cow. Since the basic production unit in the dairy is still the individual cow, an efficient and precise monitoring approach for dairy farms is required. Familiarity is replaced by an analysis of an ensemble of data which will avail addressing of the individual cow within a large herd. This data must be accurate, reliable and accessible. These requirements dictate automated data collection.

However, though the cow is being addressed individually in terms of health and reproduction in the modern dairy it is not yet being fully implemented in terms of management. One of the reasons is lack of information about the individual cow and another reason may be the lack of means to exploit this information if and when it is provided. Gathering accurate data is not enough anymore. The emerging of new technologies avails new data in higher resolution than ever before. Firms developing new technologies are now required to conduct research to supply applications for advanced use of their newly acquired data.

Two new additional sensors were developed by S.A.E. Afikim, a milk analyzer (Afilab™) and a behavior meter (Pedomer+™) . These sensors are already installed and used in several commercial and research farms. This work summarizes some results of applied research that has been recently performed , by S.A.E. Afikim Application team and researchers of the Institute of Agricultural Engineering, Agricultural Research Organization - The Volcani Center in aim to study and develop meaningful applications for the two newly sensors.

Milk analyzer (Afilab™)

The Afilab™ is a newly device that performs real time analysis of milk solids (fat, protein and lactose) and gives indication of blood and SCC. The technology is based on light scattering off matter, therefore it does not interfere with the milk flow through the pipe nor does it change the milk in any way. The concept is to amplify the laboratory performing periodically (milk test) to the milk line, in each stall at each milking. The data concerning milk components of any individual cow is now available in every milking and during the milking. This resolution shows great differences between and during milking sessions.

Materials and methods

Large filed study was performed by S.A.E. Afikim Application Team in a commercial dairy farm milking 800 cows thrice daily from May/07 to July/07 (Shkulnik *et al.*, 2008, unpublished data) .

Milk components (e.g. % fat, % protein, % lactose, SCC) data as measured by the analyzer were recorded for each cow in every milking, as a reference (gold standard) milk samples were collected from each cow once a week (on a regular day) during noon milking, and was analysed for the same components with laboratory equipment (Combi MilkoScan™, Foss Analytical A/S, DK-3400, Hillerød, Denmark). Blood samples from each cow in the fresh cows group (cows up to 21 days postpartum) were collected three times a week and B-hydroxybutyrate (BHBA) levels (mmol/liter) were measured as a reference for negative energy balance (NEB)/ketosis status. The statistic analysis was performed by statistical software (JMP® 6, SAS Institue Inc., NC 27513-2414, USA).

The described applications are based on the results of this study (only part of the results is presented).

Derived applications

Control of nutritional status of groups and herds – for efficient economical dairy farm, ration evaluation is essential. Eicher stated that the calculated ration is generally easy evaluated. However evaluating the ration that is actually fed and ingested is problematic and general assumptions and approximations have to be made. Eicher summarized "If milk components are utilized in conjunction with herd health program it allows for rapid detection of nutritional changes which may result in metabolic and/or reproduction problems" (Eicher, 2004).

The analyzer data that could be presented at all levels (individual cow, group or herd) and emphasizes any exception, which may lead for an early detection of nutritional problems (e.g. fat, protein or fat/protein ratio decrease or increase).

Comparison analyzer fat and protein percentage with the milk test day of the whole herd revealed differences of -0.05-0.28% and 0.01-0.05% respectively.

Individual feeding – gathering the data daily and individually allow performing an individual feeding program that could be analyzed and corrected if needed, this is particularly important when supplement of additional concentrate feeding is needed (e.g. pasture management and fresh cows or other non homogenous groups).

For example - Using the NRC 2001 formula for predicting dry matter intake of individual lactating cow:

$[DMI(kg/d) = (0.372 * FCM^{0.75}+0.0968 * BW) * (1-e^{-0.192*(wol+3.67)})]$

the newly data now available by the analyzer, together with already existing data (milk production and BW) enables precise calculation of individual cow requirements.

When fat and protein were added to the formula (of an average virtual milking cow) there were differences of 1.8 Mcal/day and 15 gr protein/day per cow between the analyzer and the laboratory (Combi MilkoScan™, Foss) results.

Predictions (diagnosis) of metabolic diseases **–** the correlation between metabolic diseases, as ketosis and Sub Acute Ruminal Acidosis (SARA), with milk component is well-known.

Fat:Protein ratio (FPR) was suggested as potential indicator for energy balance (EB) (Grieve *et al*. 1986), and FPR of 1.35-1.5 was found in different studies as indication for negative EB (Heuer *et al.*, 1999 on the studies of Driksen *et al*., 1997; Geishauser *et al*., 1997; Hamann and Kromer, 1997 and Heuer and Pflug, 1993). Friggens and co. argued that automated sampling and inline milk analysis may improve accuracy of EB determination (Friggens *et al*., 2007).

The agreement between BHBA blood levels with FPR in milk was tested, various cut offs were examined, and some of the results are presented in table 1.

It is clear from the data displayed in table 1. that sensitivity and specificity values depend on chosen fat/protein ratio cut offs and allows farm manager to dictate his cut off.

Table 1. Analyzer FPR versus BHBA (mmole/L) in blood (n=345).

	BHBA>1.4 (31.3%*)			BHBA>2.0 (9.3%)[1]		
FPR	Sensitivity (%)	Specificity (%)	Accuracy (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
>1.2	59.3	56.1	57.1	75.0	54.0	55.9
>1.4	33.3	82.7	67.2	53.1	80.8	78.3
>1.6	11.1	92.4	67.0	25.0	93.0	86.7
>1.8	2.8	98.3	68.4	9.4	98.7	90.4

[1]% of cases with BHBA above threshold (1.4 or 2.0).

The addition of second variable, change in daily milk yield (ΔMY), into the model improved the results (data is not presented). Further sophisticated multivariables models will be developed and have to be tested in the near future.

SARA is defined as extended periods of depressed ruminal pH below 5.5–5.6. (Instead of 6.0 and 6.4) and is a common in modern dairy herds (Nordlund *et al*. 2004 on the study of Garrett *et al*., 1997). The diagnosis is based on primary symptoms (reduced or erratic feed intake, reduced rumination, mild diarrhea, foamy feces), ruminal fluid Ph and production records (e.g. depressed milk-fat content). Nordlund and co. reported that Holstein herds with more than 10% of the cows are with milk fat 2.5 or less are suspected for SARA (Nordlund *et al*., 2004), while Tomaszewski and Cannon, suggested that rumen acidosis is presented when FPR<1.0 (Tomaszewski and Cannon, 1993). This application could not be tested in the study, because this particular farm did not suffer from SARA at this specific period. This issue has to be evaluated in the future.

<u>Follow ups dairies' milk payment</u> – in most countries payment for milk is affected by amount of fat and protein and the level of Somatic Cells Count (SCC). The information is given today by DHI or private milk laboratories and is done periodically or not at all. This routine does not allow daily follow up on the milk income.

Monthly economy corrected milk (ECM) calculated by analyzer compared to calculations based on milk test day using the Israeli formula, of three months showed differences of -1.1%-0.0%. These results enable good follow ups for the farmer in real time.

<u>Retrospective analysis</u> – using the analyzer data (fat and protein) to evaluate the influence of some risk factors (as EB status) on production parameters was done with retrospective analysis model (Model Nir) and was found satisfactory.

Applications under research and development

<u>Early Detection of mastitis</u> – mastitis affects the milk quality and the productivity of the cows, and it has a great impact in the dairy farm (economically and labor's work). Early detection of mastitis (clinical or sub clinical) and rapid treatment have the potential to prevent milk production loss (quantity and quality) and to save labor time and efforts.

Many studies described the correlation between milk components and udder health (Bansal *et al*., 2005; Leitner *et al*., 2004; Ogola *et al*, 2007; Nielsen *et al*., 2005; and Pyorala, 2003). Pyorala suggested lactose and electrical conductivity of the milk as two of the most promising parameters for monitoring subclinical mastitis (Pyorala, 2003).

Our observations in some commercial dairy farms, which already have the analyzer installed, support these studies. Thus, a filed study must be done in order to perform a statistic validation and to develop an application based on the analyzer data.

Application derived from interaction with other sensors – interaction of analyzer's data with information acquired from other sensors including; milk meter (milk production, milk flow, milk conductivity), weight scale (changes of body weight), and pedometers (cow's activity, lying behavior) open new horizons for developing new applications and improving established applications.

Behavior meter (Pedomer+)

The Pedometer+™ is a new leg tag that continuously records activity (steps/hour), lying time and lying bouts. It is based on a 3 dimensional sensor which detects the position of the animal leg. The concept is to determine the routine behavior of the animal (at individual, group and herd levels) and to pinpoint the deviation from the daily routine as a potential indication for welfare, health, fertility, production and stressful events.

Animal welfare and comfort is an emerging issue in modern agriculture driven by consumers and animal organizations. Poor welfare usually leads to greater susceptibility to disease (Broom and Corke, 2002). Weary and Tucker suggested that standing and lying behavior may be a suitable approach when cow comfort is assayed (Weary and Tucker, 2003). Moreover in aim to maintain good health and welfare and high levels of productivity, it is essential that dairy cows have enough time to lie down and rest (Tucker *et al*., 2004). Furthermore blood flow to the mammary gland is increased by 24-28% when cows lay down (Cook 2003 on the studies of Metcalf *et al*, 1992 and Rulquin and Caudal, 1992), and this may improve nutrients delivery to the udder and hence increase milk yield (Cook, 2003)

Materials and methods

The data presented is based on two studies done by groups leaded by Maltz E., from the Agricultural Research Organization - The Volcani Center, and observations that had been performed in commercial farm equipped with the pedometer+™.

Study 1 – Lying behavior of dairy cows under different housing systems – the study was performed in a commercial dairy farm milking 550-600 cows thrice daily. In a first trial, lying behavior of 12 multiparous was recorded in a roofed no-stalls barn, under comfortable thermal conditions. In a second trial, lying patterns of 16 first-calvers cows were monitored in two adjacent barns: a no-stall completely roofed barn (8 cows) and a free-stall completely roofed barn (8 cows). In the third trial, change-over of 4 cows from each group of second trial was done. Activity and performance were monitored by Afifarm management system (S.A.E. Afikim, Israel). Significant differences were evaluated using Student T-tests, unpaired – between groups, paired - between periods and treatments of the same cows (Livshin *et al*., 2005)

Study 2 – Detecting calving time of dairy cows by analyzing activity and feeding behavior – fourteen cows prior calving were allocated each 5 kg concentrates a day that were allowed in 5 equal portions of 1 kg in each of 5 even feeding windows, using computer controlled self feeders. Activity and feeding behavior were recorded and analyzed for the last 7 days prior calving. Activity variables that were measured included number of steps, number of lying bouts and accumulating lying time. The data of each day was compared to those of the previous day and differences were analyzed by paired t-test for significance. Analysis was performed for day time (06:00 – 19:00), night time (09:00 – 06:00) and diurnally.

Derivative application

Cow welfare and comfort assessment – in the result of study 1 and from observations in commercial farms, the lying behavior has a constant pattern during the day, the longest lying periods are during the night hours, and the shortest are at noon time (Table 2). It was found that there is only a 20% range of differences, between individuals in daily lying time, while in activity it can get higher that 100% (Livshin *et al*., 2005). Therefore it was concluded that lying behavior could be considered as a relatively stable parameter, and that any changes from the routine may indicate a stressful situation. We observed sharply changes in lying behavior of the whole herd in response to heat stress and to noisy disturbance (data not presented).

In study 1 the lying behavior was found to be a powerful tool that indicates differences in cow comfort in two different housing systems (Table 3) and therefore may be used as a tool for evaluation of housing management, and influence of alteration in farm routine or facilities.

Table 2. Lying time (mean ± SD) in between milking diurnal intervals of 8cows in no stalls barn and in free stall barn (From Livshin et al., 2005).

Time interval	Lying Time (min)	
	No stall barn	Free stall barn
04:30-12:30	157±42 (29.4)[1]	120±43 (28.1)
12:30-20:30	118±50 (22.1)	108±49 (25.3)
20:30-04:30	258±51 (48.4)	199±50 (46.6)

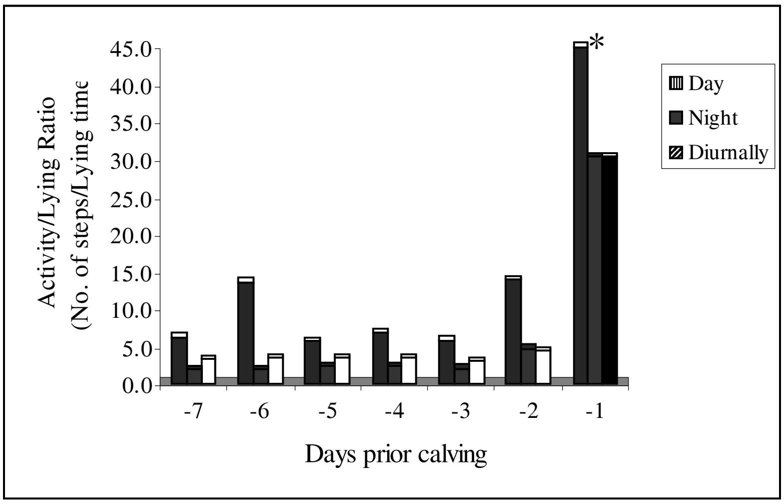
[1]% from daily lying time.

Table 3. Cows lying time (mean ± SD) in between-milkings diurnal intervals of two groups of four cows that were transferred from one type of barn (period 1) to the other type (period 2). (From Livshin et al., 2005).

Time interval	Period 1		Period 2	
	No stall	Free stall	No stall	Free stall
04:30-12:30	153±41[1a]	120±39[1]	178±55[a]	126±55
12:30-20:30	110±45[1]	113±48[1]	148±46[a]	78±43
20:30-04:30	254±51[1a]	180±56[1]	259±58[a]	200±75

[1]Significant difference ($P<0.01$, paired t-test) in lying behaviour of the same cows when transferred from one barn to the other in different periods.
[a]Significant difference (P<0.01, unpaired t-test) in lying behaviour between groups (4 cows) inhabiting different barns within period.

Detecting calving time of dairy cows – the results of study 2 (Figure 1) demonstrated that cow's behavior changes prior calving, the activity of the cows increases and the lying time decreases significantly one day prior to calving. The results showed that calving time can be predicted by measuring these parameters, and therefore may help to plan the daily routine in the farm, and attend to expected difficult calving. In an earlier study it was found that the most sensitive parameter is Activity/Lying ratio (number of steps/lying time) (Maltz and Antler, 2007).



*P< 0.01 day -1 compared to day -2

Figure 1. Activity/Lying ratio in the last 7 days prior to calving, during day time (06:00-19:00), night time (19:00-06:00) and diurnally (Maltz and Antler, personal communication).

Applications under research and development

Heat detection in unfavorable condition – cows in heat are usually restlessness, and tend to increase activity and decrease lying time. In some management condition (e.g. tie stalls) the cows do not have the option to show high activity and hence heat could not be detected via regular pedometers. We believe that monitoring lying behavior changes will enable heat detection in such unfavorable condition. Studies regarding this issue will be conducted in the near future.

Define the best density of milk cows in barns – with the growing demand for milk all over the world, dairy farms are increasing the number of milking cows and hence the density of cows in barns. This overcrowded will induce penalties such as increase in SCC and decrease in ECM (Nir (Markusfeld), personal communication). We are now conducting a research in aim to test the possibility to determine the best density for each barn with the aid of lying and activity behavior and milk production.

Discussion

Efficient management of modern dairy farm requires rapid and accurate data collection and an easy way to exploit this information. Gathering accurate data is not enough anymore, and companies developing new technologies are required to conduct applied research for the use of this new data. Applied research has been conducted in order to develop applications for new acquired data; Data supplied by on-line milk analyzer and behavior meter, developed by S.A.E. Afikim, and some derived applications were presented. Some applications are ready for use e.g. follow ups dairies' milk payment, control of nutritional status of groups and herds, individual feeding, predictions (diagnosis) of metabolic diseases, retrospective analysis, cow welfare and comfort assessment and detecting calving time of dairy cows. While others e.g. early detection of mastitis, heat detection in unfavorable condition, definition of optimal density of milking cows in barns still have to be tested and to be proven.

However, our goal is to develop models consisting of a multivariable integration and analysis of data collected from all sources.

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