A new approach to perform analysis of milk components incorporating statistical methods adapted in a real time sensor

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Summary

New sensors emerging from technological breakthroughs avail higher resolution of data. A configuration for on-line real time acquisition of milk components is presented. Within this apparatus, a new developed milk analyser is installed at each milking stall.Acquisition of milk components such as fat, protein and lactose is performed in the same automated configuration that milk weight is acquired by milk meters and at the same time resolution. Means to address the value of the new acquired data are offered.

***Key words**: On line milk analysis, Milk meter, Automated data collection system.*

Introduction

The basic production unit of the dairy industry is the cow. Management of the dairy farm requires monitoring a heterogeneous collection of basic production units. The key for managing heterogeneous ensembles lies in making decisions based on the collection and evaluation of different observables regarding the individuals which constitute the ensemble. Modern dairy farming evolves around data and the means to collect it. Manual observation and recording is gradually being replaced by automated collection and recording of data that is available with new emerging technologies.

Milk recording is a main element for monitoring production. It involves measuring the milk weight and its components. Currently, milk weight recording is automated and performed by electronic milk meters. However milk components recording is still performed manually.

This paper presents new technology for automated milk components analysis and recording.

In this approach, on-line milk analysers (Afilab^{TM}) developed in S.A.E. Afikim and A.R.O (Figure 1), are installed in the parlour at every milking stall. The system records milk composition of every cow in real time during the milking session.

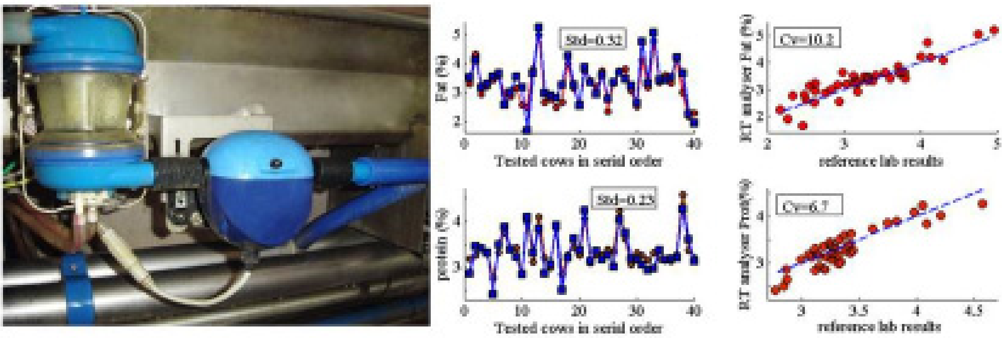

Figure 1. The real time milk analyser installed in the parlour on the milk-pipe ollowing the milk meter (left panel). A comparison between the RT analyser and the reference lab is presented (middle and right panels). Top: protein. Bottom: fat. Middle panel: y axes represent component concentration, X axes represent cow's milk sample, the line represent RT analyser results and the reference lab results. Right panel: X-axes represent lab results, Y-axes represent RT analyser result.

The advantages of this new milk analyser are:

- Free flow.
- Non-interfering measurement.
- Continuous real time acquisition of milk components.
- Data is acquired automatically for the individual cow during its milking.

The evolution of milk recording began with the Dairy Herd Improvement (DHI) in the USA as data recording source for herd management in 1920's. It was followed by the proportional mechanical flow milk meters in the early 1960's and the electronic milk meters in the late 1970's. The last essential step of the identification and PC data collection was introduced in the 1980's.

The new on line milk analyser is another step in the progress of in-parlour milk automated recording scheme. The new sensor presented couples the "lab" to the milking parlour allowing daily real time automated measurements of milk components at each stall.

Multiple sampling compared to periodic sampling

Currently, analysis of milk components is not performed daily. A periodic test is conducted manually at intervals of 4-6 weeks. On a periodic test day, milk samples are collected from every individual in the herd and sent to a chemistry lab for analysis.

An "In-parlour at every stall" sensor is required to be robust, low cost and easy to maintain. These demands impose some treadoffs. The main one lies in the accuracy of the sensor which is inferior to that of the lab. Its strength arises from two major advantages it has over the current method: automated collection of the measured data and the frequentness of the measurements.

Automated data recording is objective, accurate, consistent, effortless and accessible. Therefore, these two advantages of the sensor compensate for the trad-offs derived from its robustness.

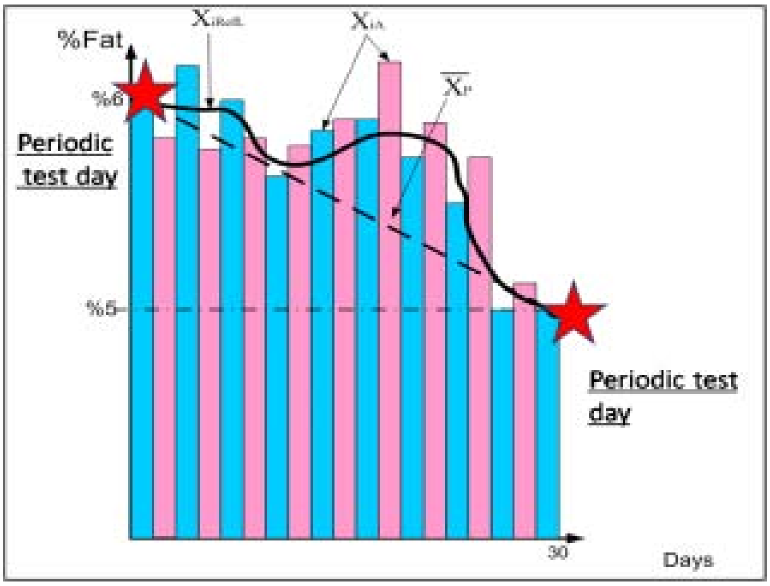

Figure 2. An illustration of the multi-sampling approach compared to the periodic test day. X-axes represent time, Y- axes represent fat concentration. Each bar represents a daily analysis performed by the RT analyser. The stars connected by the dashed line represent the periodic test day analysis. The full line represents the real fat value.
The true picture is given by integrating over the continuous line representing the true fat value at each day. The sum of the bars and the integral of the dashed line represent multiple sampling and periodic test days' approaches, respectively.

A mean to compare low accuracy multiple sampling to single high accuracy sampling is required. The concept of such a comparison is illustrated in figure 2. The compared is the average milk fat of a cow for a duration of 30 days.

The following equations are offered to derive the accuracy needed from a device performing multiple measurements to match a device performing a single accurate measurement:

σ_T^2 - the general total variance of any measurement system

σ_p^2 - the average of all the cows variances in that period of time

σ_L^2 - the variance of the lab accuracy

σ_c^2 - the total variance between cows

σ_A^2 - the total variance of the RT analyzer and n – the number of multiple measurements (number of milkings) of the RT analyze.

Assuming all variables are independent, eq a. describes the total variance of an evaluation of a periodic test (the way it is performed today)

a. $\sigma_T^2 = \sigma_C^2 + \sigma_P^2 + \sigma_L^2$

If we neglect the error of the lab, eq b. describes the total variance of the suggested system with the multiple measurements of the RT analyzer:

b. $\sigma_T^2 = \sigma_C^2 + \frac{\sigma_P^2 + \sigma_A^2}{n}$

From the equality of a. and b. we can subtract from both of the equations .

equation c is derived from the equality of b. and a.

c. $\sigma_P^2 = \frac{\sigma_P^2 + \sigma_A^2}{n}$

is extracted from equation c and determines the variance to be permitted for a number of n multiple measurement of the new method with respect to a single measurement.

d. $\sigma_A^2 = (n-1) \cdot \sigma_P^2$

In this approach, the required accuracy from multiple measurements to properly address the current periodic measurement is dictated by:

- Duration between test days.
- Total variance between samples of the individual.
- The average variance of all samples for a given duration.

The variance of the measuring system must be smaller than the variance of the measured ensemble in the given time.

In a research reported here (Maltz, 2007), an attempt was made to determine the required accuracy from a multiple measurement system to properly represent a single measurement system. In this research (A.R.O farm Israel 2006, 88 Holstein cows), milk samples from three daily milking sessions these cows were sent to the reference lab for a duration of 10 days.

Figure 3 demonstrates the maximal fluctuations in fat concentrations during this period of time for all the cows. The mean standard deviation of all 88 cows was 0.57% for fat and 0.36% for protein. The mean peak-to-peak fluctuations per cow of this herd for that duration was 2.16 % for Fat and 1.55% for protein.

Evaluation and maintenance

This new apparatus for milk analysis differs from the current methods. Means to evaluate its performance should be determined to assure the value of the data acquired in this method is not inferior to the current method.

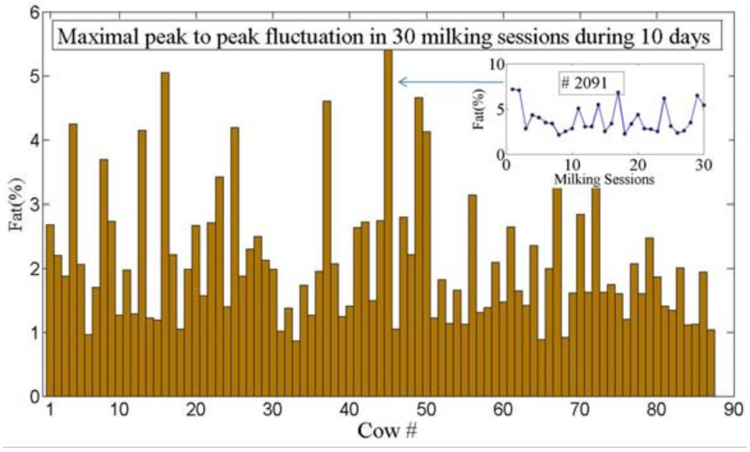

Figure 3. The maximal fat(%) fluctuations per cow over 30 milking sessions in 10 consecutive days. Y axes - fat(%) X-axes - Cows. Insert: the fat(%) fluctuations over 30 milking sessions for cow2091(emphasized by arrow). X-axes milking session, Y-axes: fat concentration.

A pragmatic viable approach is needed for evaluation, maintenance, surveillance and control of the global system for real time in parlour milk analysis. This approach should consider a multiple-sensor system (as opposed to the current method the sensor is not a stand-alone analytic device but part of an automated data collection system) like the milk meter and fat sampler (see configuration in figure 4.).

The following principles are offered for such a framework:

- Analyzing devices are coupled to ICAR approved milk meters and ID.
- Statistical ensemble for the evaluation of a single device should be large enough to represent normal dispersion.
- Evaluation of concentration analysis of RT devices should be a comparison to ICAR approved Lab test.
- Sample for comparison should represent directly the cow's milk. (Not from an ICAR approved fat sampler).
- The main evaluation parameters should be based on average deviation and variance of errors (similar to evaluation of fat samplers and milk meters).
- Required accuracy of device should be derived from the natural fluctuations of milk components concentration between different cows at a defined duration.
- The evaluation of the global system is acquired by performing the same evaluation as that of one device on the herd.

Within the above principles, figure 4 demonstrates evaluation of the milk analysis of the total parlour as it shows the mean error of 10 milking sessions for each cow with respect to the reference lab. This mean error represents the error of the total system and includes the natural variance between the different analysers since cows are not designated to permanent stalls.

Since the analysis method is based on multiple sensors it enjoys the advantage of the system conducting checking over its self. This allows more flexible calibration and validation requirements. This principle is demonstrated in figure 5 (Left panel). A malfunction at a single stall is detected when all the cows that are being milked at that stall have a large deviation from their three days running average.

When the deviation from average occurs for a single cow at a stall or for the total herd (Right panel) then there would be no malfunction in the analysis but a real change in the milk butterfat is detected.

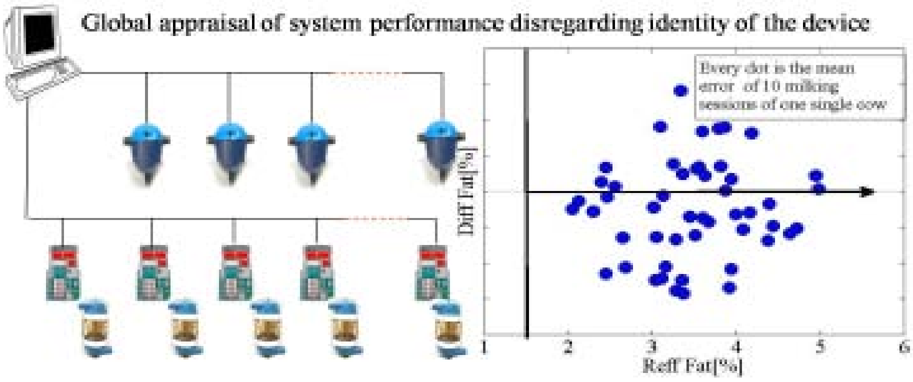

Figure 4. Left - The configuration of an automated in-parlour milk weight and analysis system including ID, milk meters and RT milk analysers at each stall linked to a central computer.
Right - An example for evaluation of total parlour performance(the configuration on the left. The fat analysis mean error of the system. Mean error over ten consecutive milking sessions for each of the individuals comprising the herd.

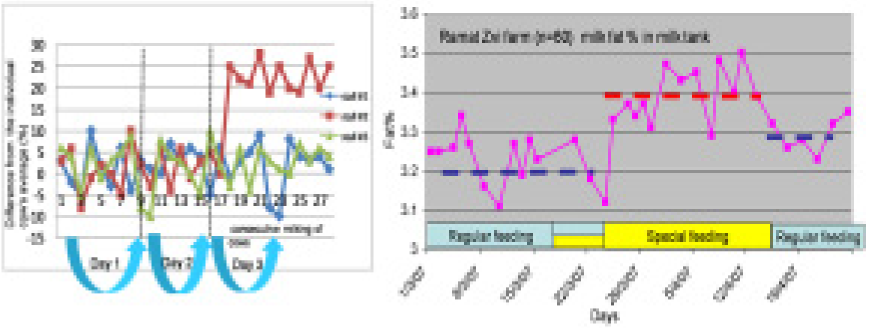

Figure 5. Left panel – follow up in time of the deviation from the fat average of cows at three different stalls shows a malfunction of the device at stall 2 at day 3(X-axes days and cows, Y- axes the difference of each cow from its running three day average. Right panel – fat(%)(over a year) in the milk tank as calculated by the RT analysers- shows real changes of fat(%) for the herd due to change of feed.

Conclusion

The approach presented here for milk analysis evolves from the automated milk recording approach employing electronic milk meter identification and PC data collection.

Addressing this new approach for milk analysis should be different then the protocol used for the current method. The data of interest collected by the system is milk analysis of the individual cow and since this is a multi-sensor system the evaluation should be made upon the performance of the total system and not a single sensor. The guiding principles to address it should evolve from the guiding principles used to address the milk meter and fat sampler since it employs the same configuration.

The high resolution of the data acquired may in the future contribute much more applications than the traditional uses for milk components periodic analysis. This is due to the fact that a low resolution motion picture may unravel a story that cannot be observed in a high resolution snapshot.

References

Maltz, E. 2007. Private communication.