"Employing AfiLab™ for commercialized real time, on-line milk separation according to its clotting properties"

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Abstract

The composition of raw milk for a required dairy product has a direct influence on yield, taste and on process optimization. For cheese manufacturing, these are determined mainly by the level of milk constituents and it's coagulation poperties, i.e., rennet clotting time (RCT) and curd firmness (CF). These variables are influenced by many factors such as genetics, diet, stage of lactation, parity, environment and health. Moreover, these factors vary between cows, during lactation, between milking sessions and during the milking of an individual cow.

Large scale dairy plants control milk quality by scaling milk payment according to solids level (fat and protein) and SCC as well as bacteria counts. This is based on daily retrospective evaluation of the milk quality regarding the herd udder health status and the level of milk constituents incorporated into the cheese.

A new approach for quality control of bulk tank milk is offered, in which the milk's coagulation properties - Afi-CF, are evaluated by the AfiLab™ in real time during the milking session. The milk is channeled into two different bulk milk tanks according to a predetermined cutoff. The cutoff is derived from dairy's production required quotas for liquid and cheese products. In this case, tank A contains milk optimized for cheese production and tank B contains milk destined for liquid products.

The potential of commercial cheese production optimization employing real time milk separation by the AfiLab™ was studied during 9 months in a commercial dairy herd which consisted of ~100 Israeli Holstein cows. Milk was separated by AfiLabs on the farm during the milking sessions from every individual cow into the two bulk milk tanks A or B according to its Afi-CF coagulation properties and several dairy products thus produced were compared to non-separated milk.

At the dairy, the set value of protein to fat ratio of the production vat was decided and fat was separated. After pasteurization, cheese was manufactured according to the standard dairy procedures and yield was calculated as kg cheese produced from 100 L of milk. Cheese yield increased along with Afi-CF cutoff level increase from 3.8% at a cutoff level ~70:30 (A:B) up to 14.4% at Afi-CF cutoff level ~20:80. No signifecant difference in SCC was found between the milk in the two bulk tanks. This information is of utmost importance since it clearly demonstrates the ability of the Afilab™ to provide the dairy with milk of higher potential yield for cheese production.

Keywords: on-line milk analysis, coagulation properties, milk separation.

Introduction

Yield and quality of dairy products such as yoghurt and cheese correlate to the chemical composition of the raw milk. The cheese yield formula of van Slyke has long been used by the dairy industry as well as scientists for predicting cheese yield (Brito et al., 2002; Emmons and Modler, 2010; Fenelon and Guinee, 1999; Verdier-Metz et al., 2001). The formula employs milk solids concentrations for predicting cheese production yield per required moisture level. However, the solids quality and its contribution to yield are not addressed in the formula. It has been shown that different batches of milk containing the same concentrations of solids, fat, protein and even casein will result in different cheese yields (Law and Tamime, 2010). This quality is manifested in the clotting parameters of the milk, i.e., rennet clotting time (RCT) and curd firmness (CF) (Fleminger et al., 2011; Leitner et al., 2006; Merin et al., 2008).

The chemical composition of milk produced in the udder is influenced by factors such as climate and season, animal feed, age and breed of cow, stage of lactation and health status of the animal. In modern dairy farming operations, at any given time the animals in the herd differ in stage of lactation, physiological conditions, hormone levels, health status etc. Thus, the milk properties of each individual animal have direct implications on the bulk milk. Consequently the bulk milk represents milk with an average composition of all the individual milked animals. The approach of optimizing vat's milk quality by payment according to somatic cells count (SCC), solids level (fat and protein) and bacteria count in the vat is retrospective and therefore limited. However, the coagulation properties of the milk, which are of major importance in cheese production, are not addressed. The economical goal of cheese making is to maximize yields through the efficient incorporation of milk constituents in the cheese while minimizing constituent's losses in the whey. Therefore, milk processors invest vast efforts in vat milk fortification to a higher level of protein for increasing cheese yields and reducing production costs. Such a fortification is achieved by addition of milk solids (up to 14–17% dry matter in certain products) or by membrane concentration and fractionation of milk proteins (e.g., ultrafiltration, microfiltration and reverse osmosis).

Modern dairy farms are characterized by a high level of automated computerized data acquisition by sensors installed in the dairy parlor or on the individual cows. These data are utilized in the management system for decision making in high precision farming. The AfiLab™ milk spectrometer (Afimilk, Afikim, Israel) provides on-line information on each cow's milk yield, milk composition and clotting parameters in real time during the milking session (Leitner et al., 2011a, 2012, 2013). Such a device when installed in a milking parlor equipped with two parallel milk lines and two bulk milk tanks, has the potential of controlling the milk properties in the two bulk milk tanks A and B, based on its on-line properties for cheese making and for other milk products and fluid milk.

The objective of the present research report is to evaluate the economic potential of real time milk segregation as performed by the AfiLab™, based on its coagulation properties – Af-CF for higher cheese yield of the milk in the production vat in a commercial dairy.

The concept of "management by exceptions" for optimizing production of large herds is becoming common among producers of herd management systems. The reported research supplies insight into the potential of applying this concept, higher in the hierarchy of optimizing the performance of the produced milk. In this approach "management by exceptions" is applied on each quota of milk as it is being milked.

Experimental

The experiment was conducted in a dairy manufacturing Gouda type cheese in vats of 2000 liters along with a variety of other milk products such as soft cheeses and other hard cheeses. The dairy milk supply came from an adjacent dairy farm consisting of ~100 Israeli Holstein cows producing approximately 4000 liters of milk daily. The dairy parlor was equipped with two individual milk lines and milk releasers feeding two bulk milk tanks (Tank A and Tank B). AfiLab^{TM} installed at each stall controlled a valve channeling the milk to the appropriate bulk tank according to real time analysis of its Afi-CF clotting parameters. The quality of the milk in Tank A was controlled to optimize production of hard and semi hard cheese products while Tank B was supplied with raw milk for soft cheese and other products such as yoghurt and labnah. The research was conducted over 9 months and the major product evaluated was Gouda cheese.

Methods

The system was programmed to deliver any given ratio of Afi-CF cutoff level from the total expected production volume of milk in the production vat. The ratio was determined by a cutoff level set by the operator according to fat, protein and Afi-CF, where the latter corresponds mainly to curd firmness (Leitner et al., 2011a). The cutoff Afi-CF for a test-day cheese production was calculated to obtain the desired volume of milk per required product based on the past 3 days performance milk production of the herd. The software for the project was manufactured and operated by Afimilk personnel. Before cheese processing, fat was separated in the dairy to obtain a predetermined protein to fat ratio (PTF), as set by the dairy technologist. At every step of the cheese production process a sample was taken to determine its composition by the Israel Cattle Breeders Association laboratory (Caesarea, Israel).

Gouda cheese

Gouda is considered as a semi Hard Cheese (maximum 39% moisture) internally ripened by bacterial fermentation. The cheese is made from cultured milk that is heated until the curds firms and whey is separated. Some of the whey is then drained, and warm water is added. This is called "washing the curd", and creates a sweeter cheese, by removing some of the lactic acid. About 10% of the mixture is curds, which are pressed into circular molds for several hours. These molds are the essential reason behind its traditional characteristic shape. After pressing, the cheese is soaked in a brine solution, which gives the cheese and its rind a distinctive taste. The cheese is dried for a few days before being coated with wax to prevent it from drying out and then it is aged. Depending on age classification, it can be aged a number of weeks to over seven years before it is ready for consumption. As it ages, it develops a caramel sweetness and sometimes has a slight crunchiness from salt-like calcium lactate or tyrosine crystals that form in aged cheeses. After 24 months of aging, sodium chloride crystals start to form around the outside casing of the cheese.

Raw milk from the bulk tanks, A or B, according to the production plan was transferred to the dairy plant in the morning. At the dairy, the set value of PTF ratio of the production vat was decided and the fat was separated by centrifugation. After pasteurization, cheese was manufactured according to the standard dairy procedures and yield was calculated as kg cheese produced from 100 L of milk and compared by introducing the constituent's levels into van-Slyke's equation.

The composition of the raw milk at the different set cutoff levels and control milk is given in Table 1.

Table1. Raw milk composition transferred to the dairy according to the set target values (milk tank A and milk tank B).

Milk type	n	Raw milk composition ($g\ L^{-1}$)					
		Fat	Protein	Casein	Lactose	Urea (%)	SCC × 10^3
B 25% (-25%)	2	23.5±0.2	32.5±0.2	23.8	51.1±0.6	0.029±0.005	150±26
Control (100%)	12	37.1±1.6	32.7±0.6	24.1±0.3	48.1±1.3	0.026±0.003	303±71
A 70-76% (75%)	5	43.7±2.2	33.8±0.8	24.8±0.6	49.3±0.8	0.032±0.004	286±80
A 36-50% (45%)	8	48.8±1.2	34.9±0.9	25.8±0.9	49.5±0.5	0.024±0.003	298±64
A 21-28% (24%)	3	50.7±0.7	35.8±0.2	26.5±0.3	50.3±0.5	0.028±0.002	264±67

Milk composition changed when increasing the set cutoff value of Afi-CF (from the control to A 21-28), the value responsible for channeling milk into tank A (Table 1). The most important component in cheese making is protein, mainly casein, which increased by ~ 0.7 – 1.0 $g\ L^{-1}$ per cutoff step. It is important to note that the increase in casein (which in general comprises ~74-78% of the protein) was similar to the increase in protein. In addition, fat was increased in a higher ratio, probably due to the general equation set for achieving a certain Afi-CF cutoff value (Fig. 1). The increase of fat which is over the desired PTF ratio is separated in the dairy before manufacturing. Thus, the possible inclusion of an upper limit threshold for fat in the separation algorithm should be considered. Special attention should be paid to the other measured values such as lactose, urea and SCC, which do not vary between the different set Afi-CF cutoff values and the control milk. This is of major importance as it proves that the milk does not change in compositional measures, which could have had a negative effect when introducing the system to potential dairies.

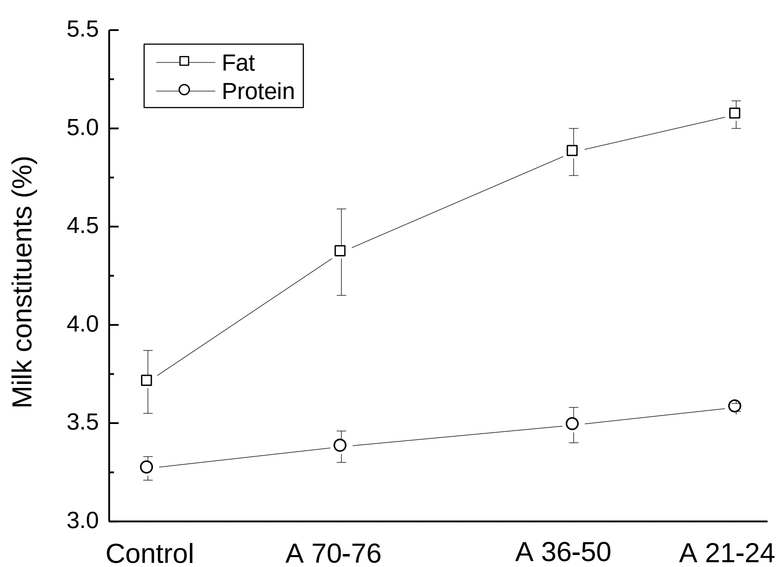

Figure 1. Increase in milk solids, fat and protein in raw milk according to set Afi-CF cutoff level.

The composition of the standardized milk for cheese production, the yields of kg cheese per 100 L and the expected yield calculation according to van-Slyke equation are presented in Table 2. During standardization, none of the parameter's values significantly changed including the major important constituents - protein and casein, while fat concentration was reduced. These findings support the aforementioned assumption that the AfiLab™ segregates milk without changing the components associated with lower milk price such as SCC, and it only increases protein and fat levels. The milk does not lose any of its constituents after the standardization and pasteurization processes. Cheese yield, the major factor tested in this project, increased along the level of Afi-CF setup from 3.8% at cutoff level of ~70 channeled to tank A up to 14.4% at Afi-CF cutoff level of ~22 (Table 2 and Fig. 2).

Table 2. Standardization of milk composition, yield in kg/100 L milk and according to van-Slyke's equation, according to the set target values (milk tank A and milk tank B).

Milk type	Standardized milk composition ($g\ L^{-1}$)					Cheese yield (kg/100 L)	Fat corrected Cheese yield (kg/100 L)	Van Slyke yield (kg/100 L) (42% moisture)	Protein efficiency (%)
	Fat	Protein	Casein	Lactose	SCC ($\times 10^{3}$)				
Control	33.5	32.4	23.8	48.3	265	10.47	10.47	10.53	0.0
A 70-76%	35.1	33.6	24.4	49.4	232	10.93	10.87	10.98	1.4
A 39-50%	39.7	34.6	25.4	49.3	239	11.80	11.45	11.91	4.9
A 21-24%	34.9	34.7	25.3	49.1	196	11.89	11.98	11.11	10.4

An additional quality property attributed to high yield coagulating milk is addressed to as "protein efficiency". This property represents milk caseins ability to aggregate. This property is crucial to the "on-line Milk Separation" concept since it cannot be fortified at the dairy. There are few methods for post-production evaluation of this property (theoretical and experimental). None of them are very reliable.

In the present work we derived the protein efficiency from the modified van-Slyke equation for cheddar cheese yield prediction:

$$y = \frac{(\%\,fat \times 0.9 + \%\,protein \times 0.829 - 0.1) \times 1.09}{1 - M}$$

where: y=expected yield, and M = cheese moisture.

In the derivation of protein efficiency from the van-Slyke equation, expected yield is replaced with the actual yield (y') and the protein efficiency would be the difference between the van-Slyke designated protein contribution to the actual contribution:

$$efficiency = \frac{\frac{y' \times (1-M)}{1.09} - \%fat \times 0.9 + 0.1}{\%protein} - 0.829$$

Although not tested, it is also possible that the quality of the cheese improved. It should be noted that using such milk does not change any of the standard cheese making procedures at the dairy, which means that for the same volume of milk, labor, vat size etc., the dairy is gaining up to 14.4% yield in kg cheese.

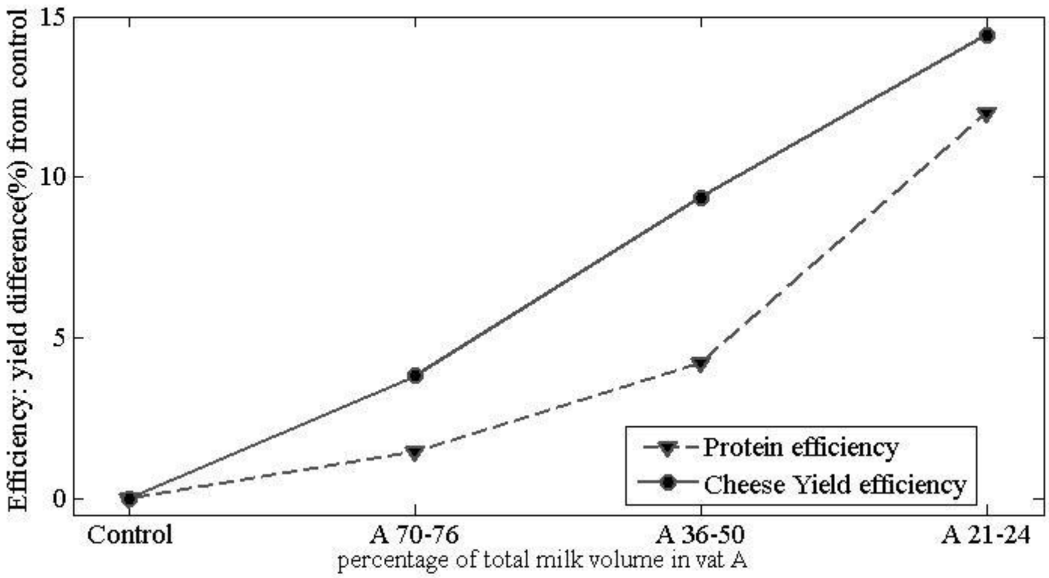

Figure 2. Cheese yield efficiency and protein efficiency in percent yield for different Afi-CF separation cutoff levels (milk channeled to tank A).

It should be noted that a great variation of milk clotting parameters was found between different individual cows and during the milking session. This information has been found to be relevant in classifying the quality of milk at the individual gland and the whole animal udder level, with regard to milk clotting properties and cheese production (Leitner et al., 2004a, 2004b, 2011a,b, 2012; Merin et al., 2008).

Milk delivered by each of the milked cows at every selected target segregation level was diverted into both bulk milk tanks, A and B. Depending on the selected target level different proportions of milk were diverted from each cow to one of the tanks, where the amount that flowed into bulk tank A (higher Afi-CF) as a percent of the whole milk volume was higher when Afi-CF cutoff level was lower. This resulted in lower proportions of milk from fewer cows that were diverted into bulk tank A when Afi-CF cutoff level increased (Fig. 3).

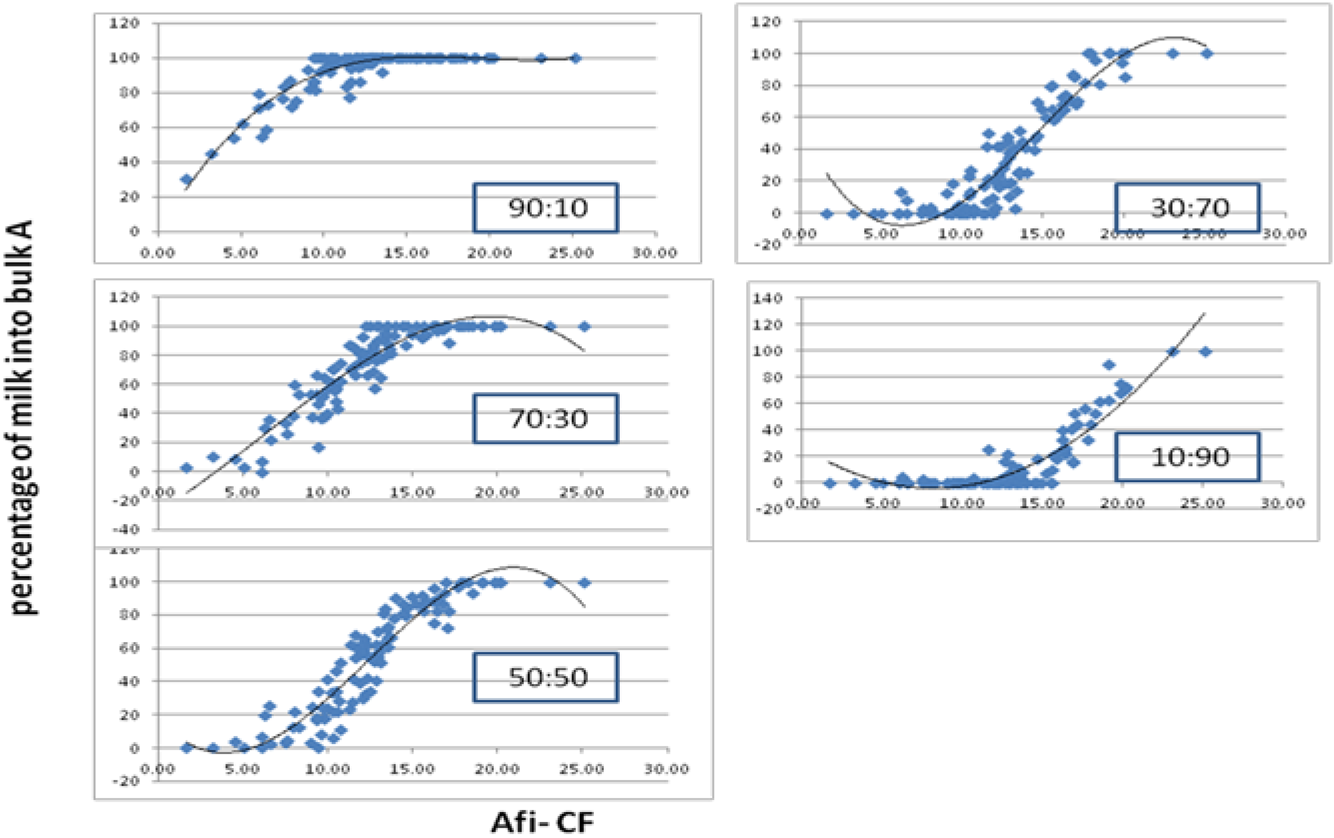

Figure 3. Distribution of cows according to the milk diverted into bulk milk tank A. Each Figure represents a different Afi-CF cutoff level. (Y axes: percent of total cow's yield in bulk tank A, X axes: Afi-Cf value of total cow's milk).

Discussion

The above findings clearly indicate that Afilab™ provides opportunities for on-line segregating and channeling milk into a large variety of dairy products. Cheese yield per volume of milk is increased according to the Afi-CF set value and reached as high as 14.4% yield increase in production of Gouda cheese. The increase was also demonstrated with three more cheese varieties: Parmesan, Mozzarella and Camembert type cheeses (data not shown). Fat separation before cheese making at the dairy provides opportunities for producing other high or low fat products, depending on the dairy's diversity. As it can be seen in table 1, additional economic value in processing can be gained by channeling the milk in bulk tank B to products requiring low fat such as yoghurt or drinking milk.Quality changes of raw milk for cheese, not only between cows and days in lactation but also from day to day and during the milking session, makes this concept of milk fortification economically superior to any other mechanical or artificial approach at the dairy plant. Therefore, the ability of on-line milk separation during each milking of individual cows optimizes the raw milk without added labor cost on the farm. The cutoff Afi-CF for cheese production was calculated to obtain the desired volume of milk per required product. However, in large operations, the cutoff needs to be calculated using more than one set of consideration, since variability exists among farms and therefore all Afilabs™ of all farms need to be synchronized, as well as milk storage capabilities on each farm.

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