Real-time visual/near-infrared analysis of milk-clotting parameters for industrial applications

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The economical profitability of the dairy industry is based on the quality of the bulk milk collected in the farms, therefore it was based on the herd level rather than on the individual animals at real time. Udder infection and stage of lactation are directly related to the quality of milk produced on the herd level. However, improvement of milk quality requires testing each animal’s milk separately and continuously. Recently, it was postulated that online equipment can estimate milk quality according to its clotting parameters, and thus result in better economical return for cheese making. This study further investigated the potential application of the AfiLab™ equipment to provide real-time analysis of milk-clotting parameters for cheese manufacture and cheese yield on quarter (1018) and individual cow (277) levels. Days in milk, lactose, log SCC and udder infection were found to have a significant effect on curd firmness and cheese properties and yield. The results clearly indicate that: (a) the parameter Afi-CF determined with the AfiLab™ is suitable for assessing milk quality for its clotting parameters, a value which is not provided by merely measuring fat and protein content on the gland and the cow levels; (b) bacterial type is the single major cause of reduced milk quality, with variations depending on the bacterial species; and (c) early and late lactation also had negative effects on milk-clotting parameters. Cheese made from the various milk samples that were determined by the AfiLab™ to be of higher quality for cheese making resulted in higher yield and better texture, which were related mainly to the bacterial species and stage of lactation.

Keywords: milk quality, online sensing, clotting parameters, cheese

Implications
This study demonstrates the ability of a visible/near-infrared spectrometer to determine online the quality of milk intended for cheese production. Cheese produced from the milk segregated by the spectrometer according to its clotting parameters resulted in better yield and better texture. The milk segregated by the spectrometer varied significantly in composition and somatic cell count, which were mainly influenced by the infecting bacteria and the stage of lactation of the cows.

Introduction
The dairy industry produces dairy products from bulk milk collected in the farms. The economical profitability of the industry has always been based on the qualities of the bulk milk as tested by the dairy laboratories. Cheese yield is one of the major factors influencing dairy economics and is usually calculated according to various equations (Emmons and Binns, 1990; Emmons et al., 1990; Barbano et al., 1991; Emmons et al., 1993 and 2003; Melilli et al., 2002). The objective of producing the appropriate quality milk for cheese production has been achieved through genetic management and nutrition improvements, which have led to higher cheese yields from the bulk milk tank. However, all of the above have dealt with the herd level rather than with individual animals at real time.

Several studies in goat, sheep and cow milk have shown that the infection status of the animal’s udder (Gonzalo et al., 1994; Auldist et al., 1996; Baudry et al., 1997; Fantuz et al., 2001; Leitner et al., 2004a and 2004b; Merin et al., 2008; Forsbäck et al., 2009) and stage of lactation (Coulon, 1994; Leitner et al., 2011a) are directly related to milk quality, its composition and suitability for cheese making. Thus, some, but not all, bacteria causing mammary infection significantly reduce curd yield and quality, as well as in animals at late lactation. Although the above data are suitable for application on the herd level, it requires testing each animal separately and continuously for clotting parameters. Thus, if a decision to remove the milk from the bulk is made, all the animal’s milk is
removed, although in many cases the low-quality milk can be segregated to one gland only. Moreover, because of various factors, the low-quality milk can be temporarily secreted for a day or even one milking and also only for a small portion of the milk (Forsbäck et al., 2009 and 2010). Recently, it was postulated that online equipment can estimate milk quality according to its clotting parameters, and thus result in better economical return for cheese making (Leitner et al., 2011b).

The objective of this study was to further investigate the potential application of the AfiLab™ (S.A.E. Afikim, Israel) equipment to provide real-time analysis of milk-clotting parameters for cheese manufacture and cheese yield. The first part of the experiment tested the effects of lactation parameters, quarter (gland) and whole udder milk composition and bacterial infection on online sensing of milk-clotting parameters, whereas the second part tested a model of laboratory small-scale cheese production according to the parameters derived from the online AfiLab™ equipment.

Material and methods

The NIR milk analyzer

The analysis was carried out using the new online milk analyzers (AfiLab™) developed by S.A.E. Afikim (Israel) providing real-time online analysis of fat, protein, lactose and milk coagulating properties during milking. The device is a commercial light emitting diode (LED-) based milk spectrometer in the visible (vis)–NIR regime, and it was calibrated at the beginning of the research with reference to the Optigraph as described previously (Leitner et al., 2011b).

Animals

Israeli Holstein cows in a commercial dairy herd of 300 cows, producing approximately 11.500 l during 305 days, were selected for the study. The cows were milked three times daily (at 0300, 1100 and 1800 h) and were fed a typical Israeli total mixed ration containing 65% concentrate and 35% forage (17% protein). Feed was offered ad libitum in mangers located in the sheds. The milking parlor was double-sided parallel equipped with online milking stations with one station containing four AfiLab™ units connected to corresponding four milk meters. All quarters were simultaneously, but separately, milked using the AfiMilk (S.A.E. Afikim, Israel) quarter-milker apparatus, thus allowing online milk analysis of milk components, as well as clotting parameters on the glandular level. The milk was collected for reference sampling and quarter milk yield was established for each tested cow.

Study layout

Before the experiment, all the cows in the herd were sampled for bacteriology by quarter.

Milk samples on the quarter level were taken from seven cows, which were between 30 and 60 days after recovering from clinical infection caused by Escherichia coli.

During November 2009 and January 2010, 143 cows were sampled, focusing on the infected cows. Seven to nine cows were sampled on the glandular and the cow level on each sampling day one to seven times. At milking, udders were cleaned, disinfected and sterile milk samples were collected for bacteriology. Cows were milked by Afimilk online quarter-milker equipment. Quarter milk yield was recorded and the milk was gently mixed; 300 ml from each quarter was taken for analysis of milk composition and milk-clotting parameters, as well as a portion of the samples was taken for small-scale cheese making. The percent milk yield of each quarter of the total milk yield of the cow was calculated and the relative quantity was gently mixed and 300 ml was taken for the test on the cow level.

Milk analysis

In the experiment, days in milk (DIM), days in pregnancy (DIP) and milk quantity (kg/day) were recorded on the day of testing by the Afimilk online data recording system. Bacterial identification was done according to International Dairy Federation (Oliver et al., 2004). Fat, protein, lactose and urea concentrations were analyzed by the Milkoscan 6000, and somatic cell count (SCC) with a Fossomatic 360 (Foss Electric, Hillerød, Denmark). Casein (only for the samples for cheese making) was determined according to ISO (2002). Rennet clotting time (RCT, min) and curd firmness (CF, V) were tested using the Optigraph® (Ysebaert, Frepillon, France) and by the AfiLab™, as described by Leitner et al. (2011b). AfiLab values for curd firmness (AfiLab™ online CF) are further referred to as Afi-CF.

Laboratory small-scale cheese making

Cow’s milk (100 ml) was placed in two 50 ml plastic tubes (CentriStar, Corning, NY, USA). The milk was acidified to pH 6.2 using 0.08 ml of 44% lactic acid along with 0.1 ml CaCl₂ solution (0.01 M). After temperature equilibration to 30°C, 2.5 ml of 1 : 100 diluted coagulating enzyme (Fromase 15 TL; Gist-Brocades nv, Delft, the Netherlands) was added, stirred and left undisturbed to achieve coagulation within approximately 30 min, and the coagulum was left to set for additional 30 min. The curd in each tube was then cut using a spatula and cooked by slowly increasing the water bath temperature to 36°C for 60 min (Kosikowski and Mistry, 1997). The curd was transferred to perforated tubes (2 cm Ø) and flat-bottomed glass tubes filled with water served to press the curd (0.1 kg/cm², 4°C) for 24 h. Curd was weighed after 24, 48 and 72 h to calculate yield according to dry matter (4 h at 105°C). Cheese texture firmness was analyzed using the Texture Analyzer TA XT2 (Stable Micro Systems, Godalming, Surrey, UK; Merin et al., 2008).

Statistical analysis

All statistical analyses were carried out using JMP software (SAS Institute, 2000). The analyzed parameters were RCT and Afi-CF. The parameters were analyzed in two phases: (1) the quarter level and (2) the cow level. The ANOVA models included the udder infection status (US); NBF (no bacteria found) or INFECTED), lactation (first or second and up) and the interaction between them as fixed effects and
interaction; all lactation interaction; d zinc protein; and among the different bacteria was done by the t-test.

Comparison between infection status NBF or INFECTED and among the different bacteria on the analyzed parameters was conducted only for the value Afi-CF. Correlation between Afi-CF and RTC revealed technical problems in the interpretation of the Optigraph results: a value of Afi-CF < 1, which means no coagulation, was recorded at the same time for some of these samples using the Optigraph as a positive value of RCT. Therefore, in calculating the correlation between the two curd firmness parameters, only samples of Afi-CF > 1 were included (Figure 1). Logarithmic regression of r = 0.64 was found with a high variation for Afi-CF between 7 to 18 and RTC.

Lactose, log SCC and udder infection were found to have a significant effect or were interrelated with RCT and Afi-CF, whereas fat and conductivity were found significant only on Afi-CF. There were also two significant interactions of lactation × UIS and log SCC × UIS. The other tested parameters had no significant effect on RCT and Afi-CF.

**Results and discussion**

**Validation of Afi-CF calibration**

The milk samples tested in this study revealed a large distribution of the effects tested, which are summarized in Table 1.

Of the clotting parameters, CF was tested twice: in the laboratory using the Optigraph (CF-90) and online using the AfiLab™ (Afi-CF) with a significant correlation between them (r = 0.687). Therefore, further comparison between infection status and among the different bacteria on the analyzed parameters was conducted only for the value Afi-CF.
values (P > 0.05). There was a significant variance between cows, which represented more than 50% of RCT and 80% of Afi-CF from the total variance in this trial. Log SCC (effect of the bacterial infection) was interrelated with RCT; increase of log SCC increased RCT and decreased Afi-CF. Increase of fat level increased Afi-CF, whereas low lactose level increased RCT and decreased Afi-CF. Conductivity significantly interacted with Afi-CF: increased conductivity decreased Afi-CF. The significant interactions of log SCC and lactation with UIS were because of the different intensity of infections in the lactations and high variation in the infected quarters.

The implementation of the AfiLab™ for online discrimination of milk on the cow level according to pre-decided standards was shown previously in comparison with standard laboratory techniques (Leitner et al., 2011b). The potential application of the equipment for providing real-time analysis of milk-clotting parameters for cheese manufacture and cheese yield was established in this study. RCT and CF are accepted industrial parameters for cheese manufacture and cheese yield was validated the capability of performing the claimed task by the AfiLab™ instrument.

The udder bacteriology condition on the glandular level revealed 80.5% (819/1018) samples free of bacteria and 19.5% (199/1018) infected samples. Of the infected glands, the various bacteria were: E. coli; 21%; coagulase-negative staphylococci (CNS) – 151 (Staphylococcus simulans – 24, Staphylococcus chromogenes – 100, Staphylococcus haemolyticus – 27); Streptococcus dysgalactiae – 27 (Table 2). No significant differences were found in fat and protein content between uninfected and infected glands, hence a combination of fat + protein of all samples were correlated with Afi-CF and Afi-CF range was 'between' 0 and 5.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NBF (819)</th>
<th>S. simulans (24)</th>
<th>S. chromogenes (100)</th>
<th>S. haemolyticus (27)</th>
<th>E. coli (21)</th>
<th>Strep. dysgalactiae (27)</th>
<th>P [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC (×10³)</td>
<td>82 ± 6a</td>
<td>1882 ± 52b</td>
<td>897 ± 210b</td>
<td>682 ± 335b</td>
<td>3772 ± 690a</td>
<td>2446 ± 307a</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>% milk*</td>
<td>100a</td>
<td>88.6a</td>
<td>94.9a</td>
<td>100a</td>
<td>75.2c</td>
<td>85.8b</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>4.09 ± 0.03</td>
<td>3.80 ± 0.16</td>
<td>4.04 ± 0.10</td>
<td>4.04 ± 0.22</td>
<td>4.02 ± 0.19</td>
<td>4.11 ± 0.28</td>
<td>ns</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.47 ± 0.01</td>
<td>3.57 ± 0.07</td>
<td>3.64 ± 0.05</td>
<td>3.60 ± 0.07</td>
<td>3.55 ± 0.08</td>
<td>3.54 ± 0.07</td>
<td>ns</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.89 ± 0.01a</td>
<td>4.50 ± 0.13b</td>
<td>4.75 ± 0.04ab</td>
<td>4.43 ± 0.10b</td>
<td>4.16 ± 0.09c</td>
<td>4.27 ± 0.10c</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Urea (%)</td>
<td>0.035 ± &lt;0.01a</td>
<td>0.034 ± 0.08a</td>
<td>0.043 ± 0.00a</td>
<td>0.034 ± &lt;0.00a</td>
<td>0.025 ± &lt;0.00b</td>
<td>0.032 ± &lt;0.00a</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>RCT (s)</td>
<td>1379 ± 19c</td>
<td>2614 ± 213ab</td>
<td>1690 ± 79b</td>
<td>1941 ± 133a</td>
<td>2263 ± 238c</td>
<td>2257 ± 222a</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Afi-CF</td>
<td>11.93 ± 0.19a</td>
<td>5.71 ± 2.02b</td>
<td>10.52 ± 0.66ab</td>
<td>8.51 ± 1.44b</td>
<td>1.87 ± 0.51c</td>
<td>6.33 ± 1.0b</td>
<td>P &lt; 0.001</td>
</tr>
</tbody>
</table>

NBF = no bacterial finding; SCC = somatic cell count; RCT = rennet clotting time; Afi-CF = AfiLab™ curd firmness.

*% milk – the proportion of quarter’s milk production from cows yield calculated for each cow taking into account front or rear udder glands.

The cow level
On the cow level, 24/143 cows were uninfected in all four glands, whereas when infected, the infecting bacteria were:...
parameters had no significant effect on RCT and Afi-CF values \( (P > 0.05) \). Increased percentage of fat decreased RCT and increased Afi-CF, whereas low lactose level increased RCT and decreased Afi-CF. Log SCC (effect of the bacterial infection) is interrelated to RCT; increase of log SCC increased RCT and decreased Afi-CF. The intensity of DIM effect was different in uninfected cows compared with infected cows; however, as lactation progressed, RCT increased and Afi-CF decreased. UIS had a borderline effect on RCT and no significant effect on Afi-CF because of the high variation in the infected cows.

Milk yield of the uninfected cows was significantly higher than that of the infected cows. Because of the low number of cows each of the staphylococcal-infected bacteria, all were grouped into CNS. SCC was significantly elevated in all the infected quarters with the highest and most significant in \( E. coli \) - and \( Strep. dysgalactiae \)-infected quarters. Lactose level was significantly lower in all the infected quarters compared with the uninfected ones. Urea was significantly lower only in milk from glands infected with \( E. coli \). As a result of all the above, RCT was significantly longer in all the infected quarters but significant from uninfected only in CNS and \( E. coli \)-infected quarters. The Afi-CF was higher in uninfected quarters, but because of high variation in each of the bacterial infection the mean value was not significant. No correlation was found between log SCC and Afi-CF of

**Table 3** Whole udder level milk yield, milk composition and milk clotting parameters of uninfected (NBF), and infected with CNS, \( Escherichia coli \) and \( Streptococcus dysgalactiae \) (mean ± s.e.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NBF (24)</th>
<th>CNS (84)</th>
<th>( E. coli ) (24)</th>
<th>( Strep. dysgalactiae ) (11)</th>
<th>( P ) [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk (kg/day)</td>
<td>35.6 ± 0.76(^a)</td>
<td>31.4 ± 1.1(^b)</td>
<td>29.7 ± 2.02(^b)</td>
<td>31.3 ± 1.64(^b)</td>
<td>( P &lt; 0.05 )</td>
</tr>
<tr>
<td>SCC (x10(^3))</td>
<td>75 ± 7(^c)</td>
<td>464 ± 82(^b)</td>
<td>3200 ± 385(^a)</td>
<td>1301 ± 300(^b)</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>4.081 ± 0.07</td>
<td>4.07 ± 0.10</td>
<td>4.23 ± 0.36</td>
<td>4.05 ± 0.26</td>
<td>ns</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.46 ± 0.03</td>
<td>3.62 ± 0.05</td>
<td>3.57 ± 0.13</td>
<td>3.34 ± 0.09</td>
<td>ns</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.93 ± 0.01(^a)</td>
<td>4.79 ± 0.03(^b)</td>
<td>4.67 ± 0.05(^b)</td>
<td>4.78 ± 0.04(^b)</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Urea (%)</td>
<td>0.036 ± 0.02(^a)</td>
<td>0.036 ± &lt;0.00(^a)</td>
<td>0.027 ± &lt;0.00(^b)</td>
<td>0.031 ± &lt;0.00(^d)</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>RCT (s)</td>
<td>1345 ± 34(^b)</td>
<td>1725 ± 81(^a)</td>
<td>2114 ± 176(^a)</td>
<td>1620 ± 174(^b)</td>
<td>( P &lt; 0.05 )</td>
</tr>
<tr>
<td>Afi-CF</td>
<td>11.76 ± 0.36</td>
<td>10.56 ± 0.73</td>
<td>6.48 ± 1.31</td>
<td>8.01 ± 1.36</td>
<td>ns</td>
</tr>
</tbody>
</table>

\(^a\)\(^b\)^: Parameters within rows with no common superscript differ significantly \( (P < 0.05) \).
uninfected quarters. In contrast, negative correlations were found with each of the bacterial group with the strongest in *E. coli*-infected quarters.

The results of this study reinforce the findings that bacterial infection in general and certain bacteria species in particular are the major causes of impaired coagulation properties of milk from infected glands, either of the gland or the cow level (Leigh and Lincoln, 1997; Leitner et al., 2006; Merin et al., 2008). Of the bacteria species, *E. coli* and *Strep. dysgalactiae* had the major impact; however, it should be kept in mind that all *Strep. dysgalactiae*-infected glands shed these microorganisms, whereas *E. coli*-infected glands were several weeks post proved infection. The resulting effects of the latter bacteria are in agreement with other reports (Le Roux et al., 2003; Moussaoui et al., 2004). Moreover, the results also indicate that impact of bacterial infection within species is inconsistent. Therefore, bacteriology alone is not sufficient for predicting milk quality intended for cheese making. The other major effect on milk-clotting parameters appeared to be the combination of milk volume and stage of lactation (Davis et al., 1999; Silanikove et al., 2005 and 2009; Leitner et al., 2011a). Therefore, bacteriology alone or stage of lactation are insufficient parameters for predicting milk quality intended for cheese making.

**Small-scale cheese making**

Small cheese blocks were produced from a representative part of the milk samples collected for the study. As summarized in Table 4, it shows that regarding SCC and milk composition, the milk samples followed the same trend found for all the milk sampled for the study, as reported above. The parameters that were related to cheese production showed distinct differences arising from the milk origin. RCT was longer according to the different infecting bacteria, with *S. dysgalactiae* being the longest. Afi-CF recorded for the samples revealed decreasing values according to the different bacteria, where *E. coli* resulted in the lowest value. It should be noted that for *Strep. dysgalactiae* and *E. coli* about 50% of the milk samples did not coagulate at all (** in Table 4) indicating a major influence on the milk of these two bacterial species. Curd yield, calculated after 72 h, revealed a significant yield reduction in all cheese made from infected milk, with the lowest from the 50% of the milk of *Strep. dysgalactiae* and *E. coli*-infected animals that did coagulate. The dynamics of water loss from the cheese blocks during 72 h are presented in Figure 4. Of the *Strep. dysgalactiae*-infected quarters, the milk coagulated only in four of the eight cows. Cheese weight was reduced over time in a different manner for the different groups. The cheese made from *Strep. dysgalactiae*-infected milk resulted in the highest initial yield and lost water fast. It should be noted that only four samples of that milk coagulated and resulted in a single cheese block (thus, there are no error bars). Cheese made from milk from quarters infected by CNS resulted in the lowest yield, whereas cheese made from milk of uninfected quarters was intermediate at 24 h. However, the slope of the CNS was steeper (b = −1.8) than that of the uninfected (b = −1.15). Final dry curd in cheese made from 100 ml milk at 72 h showed a significant difference among the three milk sources, 38% lower in *Strep. dysgalactiae* and *E. coli*, and 13% in CNS compared with the uninfected milk. Texture analyzer results at 72 h, as determined from the penetration curves at 3 and 10 mm depth (Merin et al., 2008), showed that cheese firmness was lower for cheese made from milk of infected quarters, whereas *Strep. dysgalactiae*- and *E. coli*-infected milk resulted in softer cheese (Table 4).

The differences in cheese yield in relation to bacterial infection were demonstrated before (Leitner et al., 2006; Merin et al., 2008) and the deleterious effect of the different bacteria was further highlighted in this study. It is assumed that parts of the effects noted in these studies are strongly related to the milk-clotting parameters as influenced by the different infecting bacteria. However, other research papers have pointed out other variables as related to low cheese

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NBF (25)</th>
<th>CNS* (26)</th>
<th>E. coli (5)</th>
<th>Strep. dysgalactiae (8)</th>
<th>P [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC (×10³)</td>
<td>66 ± 13c</td>
<td>537 ± 120b</td>
<td>6376 ± 3357a</td>
<td>2733 ± 746a</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.96 ± 0.17</td>
<td>3.66 ± 0.14</td>
<td>3.34 ± 0.55</td>
<td>3.44 ± 0.76</td>
<td>ns</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.55 ± 0.11</td>
<td>3.57 ± 0.07</td>
<td>3.79 ± 0.18</td>
<td>3.78 ± 0.32</td>
<td>ns</td>
</tr>
<tr>
<td>Casein (%)</td>
<td>2.75 ± 0.08</td>
<td>2.73 ± 0.07</td>
<td>2.81 ± 0.14</td>
<td>2.71 ± 0.21</td>
<td>ns</td>
</tr>
<tr>
<td>% Casein</td>
<td>78.29 ± 0.41c</td>
<td>85.10 ± 0.38b</td>
<td>74.05 ± 0.97a</td>
<td>75.8 ± 0.42a</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.92 ± 0.03a</td>
<td>4.54 ± 0.09b</td>
<td>4.27 ± 0.31c</td>
<td>4.17 ± 0.23c</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>RCT (s)</td>
<td>1393 ± 79b</td>
<td>1864 ± 113a</td>
<td>1809 ± 138 (2/5)**</td>
<td>3348 ± 894 (4/8)**</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Afi-CF</td>
<td>9.54 ± 0.66a</td>
<td>6.75 ± 0.63b</td>
<td>3.58 ± 0.95 (2/5)**</td>
<td>5.56 ± 0.78 (4/8)**</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Dry curd/100 ml milk at 72 h</td>
<td>6.51 ± 0.26a</td>
<td>5.63 ± 0.17b</td>
<td>3.66 ± 0.12 (4/8)**</td>
<td>3.91 ± 0.26 (4/8)**</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Texture meter first (3 mm)</td>
<td>0.44 ± 0.04a</td>
<td>0.38 ± 0.02a</td>
<td>0.16 ± 0.02b</td>
<td>0.22 ± 0.03b</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Texture meter end (10 mm)</td>
<td>0.69 ± 0.03a</td>
<td>0.59 ± 0.02b</td>
<td>0.25 ± 0.03c</td>
<td>0.39 ± 0.04c</td>
<td>P &lt; 0.05</td>
</tr>
</tbody>
</table>

NBF = no bacterial finding; CNS = coagulase-negative staphylococci; SCC = somatic cell count; RCT = rennet clotting time; Afi-CF = AfiLab™ curd firmness.

*Pooled CNS.

**Only x/y Afi-CF > 1.

a/b/Parameters within rows with no common superscript differ significantly (P < 0.05).
yield, such as genetic correlations (Ikonen et al., 2004; Malacarne et al., 2006; Vallas et al., 2010), relative composition of caseins (Wedholm et al., 2006; Penasa et al., 2010) and cows producing noncoagulating milk (Ikonen et al., 1999). As there are no indications on the health status of the cows, or in certain cases cows with at least 10^6 cells/ml and higher were included in the studies, the influence of the presence of infecting bacteria on their findings could not be ruled out. However, Ikonen et al. (2004) suggest that ‘... the loci causing noncoagulation of milk and increasing SCC of milk are closely linked or partly the same’. It is therefore strongly suggested that future studies on the relation of milk quality to its clotting parameters will always be accompanied by a full report on the animal’s gland/udder health status.

The textural properties of cheese produced from milk infected by various bacteria was discussed earlier, where it was reported that the softer texture was noted not only in cheese but also in yoghurt, as well and bacteria were the major influencing parameter. Similarly, loss of water from cheese curd is well known to be influenced by milk quality (Merin et al., 2008).

It is well established that dry matter in milk, mainly fat and protein, are the major components affecting cheese yield, and thus served as the parameters used in the various yield prediction formula (Emmons et al., 1990; Fenelon and Guinee, 1999; Verdier-Metz et al., 2001). This point was further discussed regarding the exact major fraction to be used in the calculations (Emmons and Modler, 2010). Indeed, using such equations on milk coming from uninfected animals during the major part of their lactation, as well as using bulk tank milk resulted in good agreement between experimental and calculated results (van den Berg et al., 1996; Mellili et al., 2002; Emmons et al., 2003). However, a certain number of animals in a herd at each point of time are infected or are at certain physiological conditions that lead to production of milk that deviates from what is accepted as ‘normal milk’ (Pitkälä et al., 2004; Sampimon et al., 2009; Leitner et al., 2011a).

In this study, under one of the latter conditions, for example, udder infection, the empirical equations developed resulted in a lower predicted cheese yield, whereas cheese made from milk of uninfected udders resulted in a somewhat higher yield than the predicted (Figure 5). Hence, Afi-CF was calibrated against the Optigraph values, which gives a predictive value for CF beyond the factors taken into account by the various formulae.

### Concluding remarks

The quality of milk, the raw material for the dairy industry, is the key for high-quality products, repeatability of texture and taste, as well as economic benefit. In modern dairy farming with large numbers of animals, quality control of milk shifts from the individual animal to the bulk milk; that is, SCC, bacterial count, etc. Online milking equipment provides an opportunity to shift back to controlling each individual animal at real time. So far the milking equipment can signal and alert deviation from normal and provide the farmer with tools for a decision-making by monitoring each cow every milking (Katz et al., 2007).

The results clearly indicate that: (a) the parameter Afi-CF determined with the AfiLab™ is suitable for assessing milk quality for its clotting parameters, a value that is not provided by merely measuring fat and protein on the gland and the cow levels; (b) bacterial type is the single major cause of reduced milk quality, however, it is bacteria–species related. In that manner, it is important to realize that S. chromogenes, the most common bacteria causing infection, had only a minor influence on Afi-CF. Moreover, S. simulans, which also belongs to the CNS group, had an effect similar to streptococcus; (c) early and late lactation also had negative effects on clotting parameters (Leitner et al., 2011a). Overall, it is important to note that not all the glands and cows categorized as infected or at late lactation produce ‘low-quality milk’ and also not all the milk from a particular animal is of low quality.
Currently, on the basis of the above study and the previous work of Leitner et al. (2011b), online milking parlor, which will be equipped with two parallel milk lines, has the potential to control the milk properties in the bulk milk tank based on online optical detection of its coagulation parameters by the AfLab™ and to channel it into two separate collecting tanks. Such a system will be able to segregate milk online according to the predetermined needs of the collecting dairy.

**References**


SAS Institute 2000. JMP user’s guide. SAS Institute, Inc., Cary, NC, USA.


