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Short communication: Variation in the composition and properties of Swedish raw milk for ultra-high temperature processing

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ABSTRACT

The composition and properties of raw milk are of great importance for the quality and shelf life of the final dairy product, especially in products with a long shelf life [e.g., ultra-high temperature (UHT)-treated milk]. The objective of this study was to investigate the compositional variation in raw milk samples before processing at the dairy plant. Moreover, we wanted to investigate the effect of the UHT process on this variation (i.e., if the same variation could be observed in the corresponding UHT milk). The quality traits analyzed included detailed milk composition, counts of total and psychrotrophic bacteria, proteolytic activity, and color, as well as predictive measures of stability (i.e., ethanol stability and heat coagulating time). Samples of raw milk and the corresponding produced UHT milk were collected and analyzed on a monthly basis during 1 yr. Principal component analysis was used to identify months showing similarities and differences with respect to total variation. In contrast to previous studies, we observed only small variations between months and no clear effect of season for the raw milk. For the UHT milk, July and the winter months (December, January, and February) tended to separate from the other months. Quality traits showing significant variation were only to some extent identical in raw milk and UHT-processed milk. A better understanding of the natural variation in raw milk quality will provide opportunities to improve the shelf life of UHT-treated milk products.

Key words: raw milk quality, ultra-high temperature milk, seasonal variation, principal component analysis

Short Communication

The composition and properties of the raw milk are of great importance for all dairy products, affecting the quality and shelf life. In general, raw milk quality traits vary with breed, feed, stage of lactation, and animal health, as well as season (Fox and McSweeney, 1998). In Sweden, calving patterns are nonseasonal, resulting in bulk milk from cows at various stages of lactation all year round (Jordbruksverket, 2012). This will reduce seasonal variation in raw milk composition, although not entirely eliminate it (Auldist et al., 1998). Apart from the lactation stage, feed is the main factor contributing to variation in the raw milk. Swedish legislation specifies that cows should be outdoor grazing for a minimum of 2 mo during summer, and the majority of the cows are fed silage during the indoor period. Milk quality traits reported to vary with season include protein and fat (Lindmark-Månsson et al., 2003; Heck et al., 2009), mineral content (Sola-Larrañaga and Navarro-Blasco 2009), but also several other traits (Gaucher et al., 2008).

Variation in milk composition has a multifactorial background and constitutes a challenge for dairy industry, especially in products with long shelf life (e.g., UHT-treated milk). Globally, UHT milk is an important dairy product, although in the northern hemisphere, UHT processing is less common. With the increasing production of novel UHT milk-based beverages, variation in product stability has led to a growing interest in the effect of raw milk composition on stability during storage. Quality traits considered to have most influence on the stability of UHT milk include pH, calcium, protein composition, urea, and bacterial count, and consequently also the underlying factors giving rise to variation in these quality traits (Williams, 2002).

The composition of milk delivered to Swedish dairies has been previously investigated in 1996 (Lindmark-Månsson et al., 2003) and 2009 (Lindmark-Månsson, 2012). The objective of our work was to investigate the monthly variation in raw milk during 1 yr, including quality traits (e.g., composition, bacterial count, SCC, enzymatic activity, color, ethanol stability, and heat coagulation time). Moreover, we wanted to study if the variation in some of the quality traits was affected by the UHT process. Our hypothesis was that differences

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between raw milk produced during grazing and indoor periods exist and that these differences will persist in the UHT-processed milk.

In total, 22 samples (i.e., 11 raw dairy silo milk samples and 11 samples corresponding to the UHT milk produced from the sampled raw milk) were used in the study. A representative sample of the raw milk was collected on a monthly basis during 1 yr with the exception of August at the Norrmejerier dairy plant in Luleå, northern Sweden. The raw milk, consisting of pooled milk provided from approximately 80 farms located in the surrounding region around the dairy plant, was sampled and transported refrigerated to the Swedish University of Agricultural Sciences (**SLU**), Uppsala. As part of the process, the raw milk was standardized to 1.5% fat and the UHT treatment was performed using indirect tubular heat exchangers at 137°C for 4 s. Samples of the UHT milk were transported to SLU at ambient temperature. Analysis of the raw milk and UHT milk was initiated the day after delivery to SLU, resulting in raw milk samples not older than 4 d, including cold storage on farms and at the dairy plant, and UHT milk samples with an age of 5 to 14 d. Samples were also aliquoted and frozen at −20°C for later thawing and analysis of mineral content, citric acid, urea, and enzymatic activity. All measurements were done at ambient temperature unless otherwise stated.

The content of TS, protein, fat, and lactose in milk was measured by near-infrared spectroscopy, using MilkoScan FT120 (Foss, Hillerød, Denmark). The protein profile was analyzed by capillary electrophoresis, as previously described by Gustavsson et al. (2014). Citrate content was analyzed by HPLC according to the method described by Andersson and Hedlund (1983). Urea was determined using the AutoAnalyzer III procedure (SEAL Analytical GmbH, Norderstedt, Germany) according to Eriksson and Rustas (2014). Calcium, potassium, sodium, and magnesium were analyzed as described in ISO 8070 (ISO/IDF, 2007) using atomic absorption spectrometry (AAnalyst 100, Perkin Elmer, Waltham, MA).

Counts of total bacteria and psychrotrophic microorganisms were enumerated in raw milk samples with colony count techniques according to the NMKL method 86 (NMKL, 1999) and ISO 8552 (ISO/IDF, 2004), respectively.

The CIELAB color space of raw milk and UHT milk was measured with a CM-600d spectrophotometer (Konica Minolta, Shanghai, China). Using this technology, L* indicates lightness ranging from 0 to 100, a* indicates a range from green to red (−60 to +60), and b* indicates a range from blue to yellow (−60 to +60). The pH was determined using an IoLine electrode (SI Analytics, Mainz, Germany). The freezing point of the raw milk samples was estimated using MilkoScan FT2 (Foss, Hillerød, Denmark) and SCC using Fossomatic FC (Foss).

Plasmin and plasminogen derived activity was determined according to the method by Korycka-Dahl et al. (1983), with modifications described by de Vries et al. (2016). Total activity was obtained by activation of plasminogen into plasmin by addition of urokinase and plasminogen derived activity was calculated as the difference between the total activity and plasmin activity. Activities were expressed as U/mL, with 1 unit defined as the amount of enzyme that produces a $\Delta A_{405}{}^{1cm}$ of 0.001 in 1 min at 37°C due to *p*-nitroanilide released from the chromogenic substrate.

Total proteolysis was measured on basis of the reaction of primary amino groups of trichloroacetic acid-soluble peptides and free AA with fluorescamine (Wiking et al., 2002). Equal volumes of milk and 24% trichloroacetic acid were mixed, held on ice for 30 min, and centrifuged at 16,000 × *g* for 20 min at 4°C (Himac CT15RE, Hitachi Koki Co., Ltd., Tokyo, Japan). The supernatant was mixed with sodium tetraborate and fluorescamine, and the fluorescence (excitation wavelength 390 nm, emission wavelength 480 nm) was measured after 18 min in a luminescence spectrometer (LS 55, Perkin Elmer).

Ethanol stability was defined as the highest ethanol concentration added to the sample without causing visual coagulation of the milk when equal volumes of milk and ethanol, at ethanol concentrations ranging between 40 and 100% in 2% increments, were mixed and incubated for 30 min. Heat coagulation time was defined as the time needed for visual coagulation of 0.5 mL of milk in a sealed test tube while being rocked at 130°C (Davies and White, 1966) using the dedicated equipment from Hettich Benelux (Geldermalsen, the Netherlands).

Principal component analysis (**PCA**) was used to identify months showing similarities with respect to the total variation using SIMCA 13.0 software (Umetrics, Umeå, Sweden). Minitab 17 software (Minitab Ltd., State College, PA) was used to calculate Pearson correlation coefficients for selected quality traits. Samples of raw milk collected in June and July were compared with milk collected during the rest of the year to evaluate differences in milk quality traits between outdoor and indoor periods using Minitab 17 software. The *P*-values were calculated by one-way ANOVA (2-sided 95% CI). The same comparison was done for the corresponding UHT milk samples.

To study the variation in Swedish raw milk for UHT processing, PCA for raw milk and its corresponding