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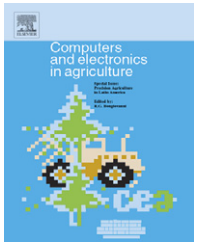

Near-infrared spectroscopic sensing system for on-line milk quality assessment in a milking robot

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ABSTRACT

A near-infrared (NIR) spectroscopic sensing system was constructed on an experimental basis. This system enabled NIR spectra of raw milk to be obtained in an automatic milking system (milking robot system) over a wavelength range of 600–1050 nm. Calibration models for determining three major milk constituents (fat, protein and lactose), somatic cell count (SCC) and milk urea nitrogen (MUN) of unhomogenized milk were developed, and the precision and accuracy of the models were validated. The coefficient of determination (r^2) and standard error of prediction (SEP) of the validation set for fat were 0.95 and 0.25%, respectively. The values of r^2 and SEP for lactose were 0.83 and 0.26%, those for protein were 0.72 and 0.15%, those for SCC were 0.68 and 0.28 log SCC/mL, and those for MUN were 0.53 and 1.50 mg/dL, respectively. These results indicate that the NIR spectroscopic system can be used to assess milk quality in real-time in an automatic milking system. The system can provide dairy farmers with information on milk quality and physiological condition of an individual cow and, therefore, give them feedback control for optimizing dairy farm management. By using the system, dairy farmers will be able to produce high-quality milk and precision dairy farming will be realized.

1. Introduction

Dairy farming is labor-intensive and involves many tasks such as feeding, milking, livestock management, feed crop production and manure treatment. Large-scale dairy farmers manage their livestock in groups, a system known as herd management. However, monitoring the milk quality of each cow and managing each cow according to milk quality and physiological condition, a system known as individual cow management, is also essential for optimum production of high-quality milk. Milk quality is greatly affected by the physiological condition of cows. Therefore, assessment of milk quality of each cow is necessary for individual cow management (Svennersten-Sjaunja et al., 1997). Recently, there has been a need for an automatic on-line method that will enable dairy farmers to assess milk quality of an individual cow during milking.

Near-infrared spectroscopy (NIRS) is a nondestructive method for quality evaluation. Advantages of NIRS include, but are not limited to, the fact that on-line measurement can be performed rapidly, pollution-free and without pretreatment. NIRS has been widely used in quality evaluation of foods and agricultural commodities including rice (Kawamura

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et al., 2002, 2003; Natsuga and Kawamura, 2006), wheat (Natsuga et al., 2001) and satsuma mandarins (Miyamoto et al., 1998). NIRS has also been used to assess milk quality (Sato and Yoshino, 1987; Tsenkova et al., 1999, 2001; Natsuga et al., 2002), but it has been difficult to apply NIRS to real-time on-line monitoring of milk quality of an individual cow during milking.

An experimental, on-line, near-infrared (NIR) spectroscopic sensing system has been constructed to assess milk quality. Kawamura et al. (2007) reported that the NIR spectroscopic sensing system can be used for real-time assessment of milk quality during milking with sufficient precision and accuracy. Based on these results, the NIR spectroscopic sensing system was installed in an automatic milking system (a milking robot system). A milking robot is a system that performs voluntary milking for cows (i.e., each cow deciding milking time and milking interval) at any time during the day without the requirement of human labor. Milking robot systems have been available commercially since 1990s, and the use of these systems has improved herd management. However, in the milking robot system, a sensing system to examine milk quality and physiological condition of the individual cow is needed.

In this study, the precision and accuracy of the NIR spectroscopic sensing system for assessing milk quality during milking by a milking robot system were validated.

2. Materials and methods

2.1. *Near-infrared spectroscopic sensing system*

An experimental, on-line, NIR spectroscopic sensing system for assessing milk quality of an individual cow during milking was constructed. The system consisted of an NIR spectroscopic instrument, a milk flow meter, a milk sampler and a laptop computer (Fig. 1). The system was installed in a milking robot system (Astronaut, Lely Industries NV, Maasland, Holland) with the milk being bypassed from the teat cups to a milk jar (Fig. 2). Raw milk from the milking robot continuously flowed into the milk chamber of the spectrum sensor and flowed out through an outlet pipe for surplus milk to the milk flow meter. The volume of milk sample in the chamber was about 230 mL. The optical axes of a halogen lamp and an optical fiber were set at right angles to each other at the same levels (Fig. 3). The spectrum sensor acquired spectra of diffusion transmittance (interactance) through the milk. The diffusion transmittance spectra were recorded in the wavelength range of 600–1050 nm at 1-nm intervals every 10 s during milking (Table 1). Six continual spectra were averaged to obtain a spectrum for 1 min.

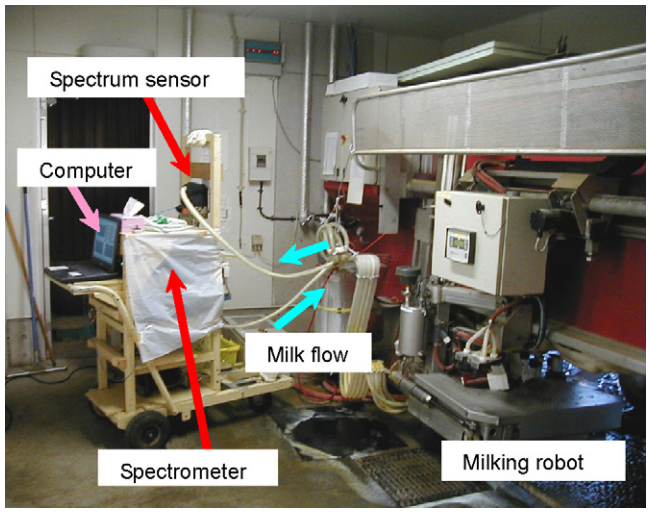

Fig. 2 – On-line near-infrared spectroscopic sensing system installed in an automatic milking system.

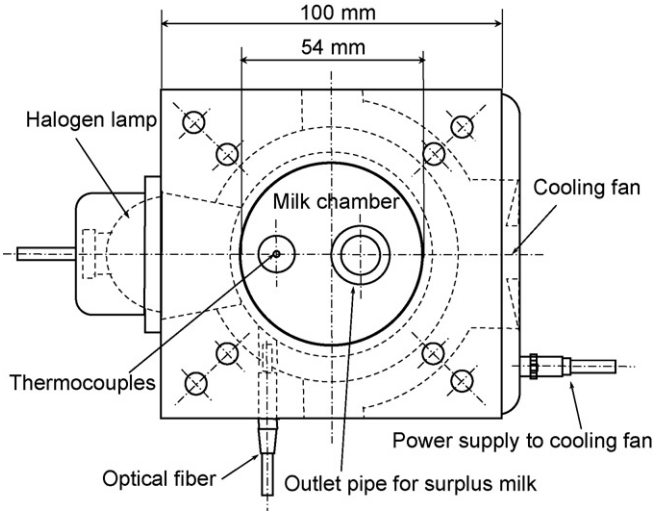

Fig. 3 – Plane view of the near-infrared spectrum sensor.

2.2. *Cows and milk samples*

Seventeen Holstein cows in the stage of early lactation to late lactation were used in the experiment (Table 2). The experiment was conducted all day and night on 20th and 21st October 2003. Milking was automatically started whenever a cow walked into the milking robot. Milk samples were collected from the milk sampler every minute during milking. The experiment was conducted to cover variations in milk

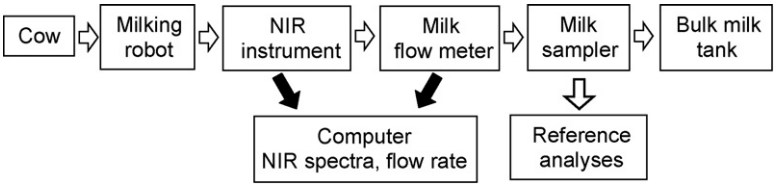

Fig. 1 – Flow chart of an on-line near-infrared spectroscopic sensing system for assessing milk quality in an automatic milking system.