学位論文審査の要旨

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学位論文題名

Development of near-infrared spectroscopic sensing system for online real-time monitoring of milk quality during milking

（搾乳時乳質のオンラインリアルタイム評価のための
近赤外分光センシングシステムの開発）

This PhD thesis comprises 116 pages, 67 Figures, 22 Tables, and 8 Chapters with 2 reference theses.

Near-infrared spectroscopy (NIRS) is a nondestructive system for collecting qualitative information on foods and agricultural products. However, it has been hard to use the NIRS for real-time on-line monitoring of milk quality of each cow during milking. Therefore, the general objectives of this study were (1) to develop a near-infrared (NIR) spectroscopic sensing system for online real-time monitoring of milk quality during milking, (2) to examine potential factors (such as cow individuality, milking season and parity) that may be affecting the high performance of calibration models and to propose possible solutions to achieving high precision and accuracy of the calibration models for each milk quality indicator, (3) to determine milk urea nitrogen (MUN), somatic cell count (SCC) and milk progesterone concentration using NIR spectroscopic sensing system, and (4) to examine the measurement accuracy of the NIR sensing system installed into an automatic milking system.

1. Near-infrared Spectroscopic Sensing System

An experimental online NIR spectroscopic sensing system was designed for the determination of milk quality of each cow during milking. The system consisted of an NIR spectrum sensor, NIR spectrometer, milk flow meter, milk sampler and a laptop computer. Milk spectra with a wavelength range of 700 to 1050 nm at 1-nm interval and milk samples of about 30 mL were collected using the NIRS sensing system every 20 s during milking. Chemometric analyses were carried out to develop calibration models for each milk quality indicator using partial least square statistical method. Spectra data analyses software (The Unscrambler ver. 10.3) was used for the analyses.

2. Measurement accuracy of NIR spectroscopic sensing system for milk quality determination

The results obtained showed that cow individuality, milking season and parity could affect the accuracy of calibration models. The performance of calibration models for each milk quality indicator such as the three major milk constituents (fat, protein and lactose), solids not fat (SNF), moisture content, MUN and SCC for each cow, each milking season and each parity were evaluated and compared. The results indicated that the precision and accuracy level of the calibration model for fat and moisture content was excellent and relatively the same for each milking season considered. However, the accuracy for other milk quality indicators fluctuated for each season. Similar result was obtained for each parity. Lactation stage of the cows was throughout each season. Also cow individuality affected the performance of the calibration models.

3. Contribution to the production of high-quality milk and physiological condition of each cow to meet dairy farmers and veterinarians' requirements

The performance of the NIR spectroscopic sensing system was sufficiently high. Sufficient levels of precision and accuracy for predicting the three major milk constituents were indicated by the high values of coefficient of determination and small standard error of prediction values. MUN concentration was high in grazing season (summer season) compare to non-grazing season (winter season) which is due to the fact that cows were fed with feed of high protein content in summer season. Variation of lactation stage and genetic quality of cows fed diets containing similar level of nutrition, especially of protein, may also affect MUN content. High SCC which is related to seasonal environmental changes showed peak levels during summer season compare to other seasons. High SCC is routinely used by dairy farmers to detect mastitis. Therefore, it is important to monitor the quality of milk constituents, moisture content, SNF, MUN and SCC in real time during milking for different seasons as this would ensure proper individual cow management.

The NIR sensing system was able to determine progesterone concentration at each milking time with almost the same accuracy as the predicted progesterone concentration during milking. Therefore, by taking records of this predicted progesterone value at every milking time and monitoring the continuous changes in progesterone concentration, it is possible to predict each cow ovulation status and diagnose the early pregnancy of each cow. In addition, the precision and accuracy of the NIR spectroscopic sensing system when installed into an automatic milking system was good. Thus, the installation of NIR spectroscopic sensing system developed in this study into an automatic milking system would facilitate the monitoring of milk constituents and diagnosis of mastitis of individual cows in real-time during milking.

Therefore, we acknowledge that the author is qualified to be granted the Degree of Doctor of Philosophy in Agriculture from Hokkaido University.