Diagnosis of physiological abnormalities using adaptive milk spectral model of individual cows

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Introduction

Dairy cow health management is one of the highest priority concerns in any dairy farm. In terms of producing milk with high quality and minimising economical losses, it is very important to detect abnormalities in cow health. Current methods of diagnosing cow health are costly and time and labor consuming. Thus, it is difficult to diagnose disease in individual cows at an early stage. A rapid and low cost diagnosis method is needed to indicate the necessity of an early treatment.

Near infrared (NIR) spectroscopy of biological fluids such as milk has been applied in various fields of dairy science and remarkable achievements have been reported (Tsenkova *et al*., 2001). The advantages of NIRS include speed, simultaneous, non-destructive measurement of a number of milk constituents as well as great potential for analysis. In addition, biological fluids such as milk contain information specifically related to the metabolic and health status of ruminant animals. Some changes in their NIR spectra can be attributed to the disease response of the animals. However, in most cases, the accuracy of NIR prediction models has been strongly affected by the influence of spectral differences coming from cow's individuality.

In this work we propose a rapid method, named the Adaptive Milk Spectral Model of Individual Cows (ASMIC) that, in contrast to existing methods, uses the spectral individuality of the cow for diagnosis. With high accuracy, it has been demonstrated that milk spectra of each cow could be used as an individual marker by combining NIRS and SIMCA analysis. It is proposed that deviation from the normal individual milk spectral model of each cow could be used as a detector of physiological abnormality. Such a deviation would alert the farmer to investigate the reason for such an abnormality.

Materials and methods

A total of 769 individual milk samples were collected from seven Holstein cows accommodated at Awaji Agricultural Technology Institute, Japan. Unhomogenised raw milk samples were collected every weekday morning from day 31 to day 200 of the lactation stage of each cow, over a year period.

All transflectance NIR spectra were taken using an XDS Rapid Content Analyser (Foss NIRSystems, MD, USA) fitted with a quartz cell with a gold reflector. The optical path length was 1mm. The samples were standardised for temperature by maintaining them at 40°C during the acquisition of spectra. The NIR instrument recorded three consecutive spectra for each sample over the wavelength region of 700–1900 nm in 0.5 nm increments. A total of 2307 milk spectra were measured. Additionally, biological information of each individual cow such as diseases, treatment, diet change, estrus and ovulation were recorded.

The proposed Adaptive Spectral Model of Individual Cows, ASMIC, was developed by using milk spectral data acquired for the same time interval right before the day of prediction. The optimum number of consecutive day spectra to be used for model development was investigated. Soft Independent Model of Class Analogy (SIMCA) and a commercial program (Pirouette Version 3.11; Informatics, WA, USA) for multivariate spectral data analysis were used to process the data and to develop models for individual identification.

Milk spectra often exhibit a baseline shift or drift due to variations in sample presentation. In milk spectra, baseline changes are induced mainly by the light scattering due to milk fat globules. Therefore, spectral pre-treatment is an important step in the data analysis. In this study, three types of pre-processing were employed: raw spectra, Savitzky-Golay first and second derivative with window width of 25 points (12.5 nm). Models were developed over three wavelength regions, 700–1098 nm, 1100–1900 nm, 700–1900 nm, and various periods of times, 14 days, 21 days, 30 days and 60 days. They were compared in order to optimise the correct classification rate for the best model. Model prediction accuracy was evaluated using the spectral data from day 91 to day 200.

Results and discussion

The average NIR spectra for the milk samples of each cow in the region 700–1098nm are illustrated in Figure 1.

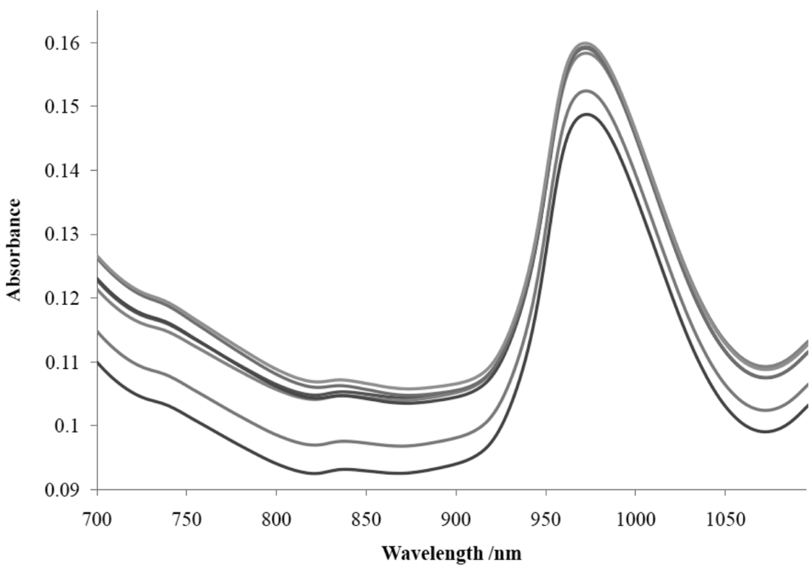

Figure 1. Seven mean NIR spectra in the region of 700–1098 nm of individual milk of each cow.

Table 1. Averaged accuracy of individual cow identification by ASMIC (ASMIC is developed for fixed period of 21 days before the day of prediction).

Math transform	Wavelength region		
	Short (700–1098 nm)	Middle (1100–1900 nm)	Short + Middle (700–1900 nm)
None	14.7%	14.3%	10.8%
1st derivative	88.2%	75.7%	62.1%
2nd derivative	76.9%	71.0%	76.6%

This Figure shows that differences between the spectra of each cow do exist.

The best ASMIC was defined as that with the highest rate of correct classification. Table 1 shows a summary of the ASMIC model results obtained. It can be seen that the best performing models, with the lowest misclassification rate, used first derivative pretreated spectral data in the wavelength ranges of 700–1098 nm.

The derivative pre-treatment is one of the most frequently used in spectral preprocessing. A constant background is removed by transforming the original spectra into first derivative spectra and a linear background is removed by transforming them into the second derivative spectra. Therefore, since the best ASMIC was obtained with first derivative spectra, but not with the second derivative, it would appear that linear background information, such as scattering of light by fat globules in raw milk, is useful for the correct individual identification. The short NIR wavelength region (700–1098 nm) was shown to be the optimal range for classification in this

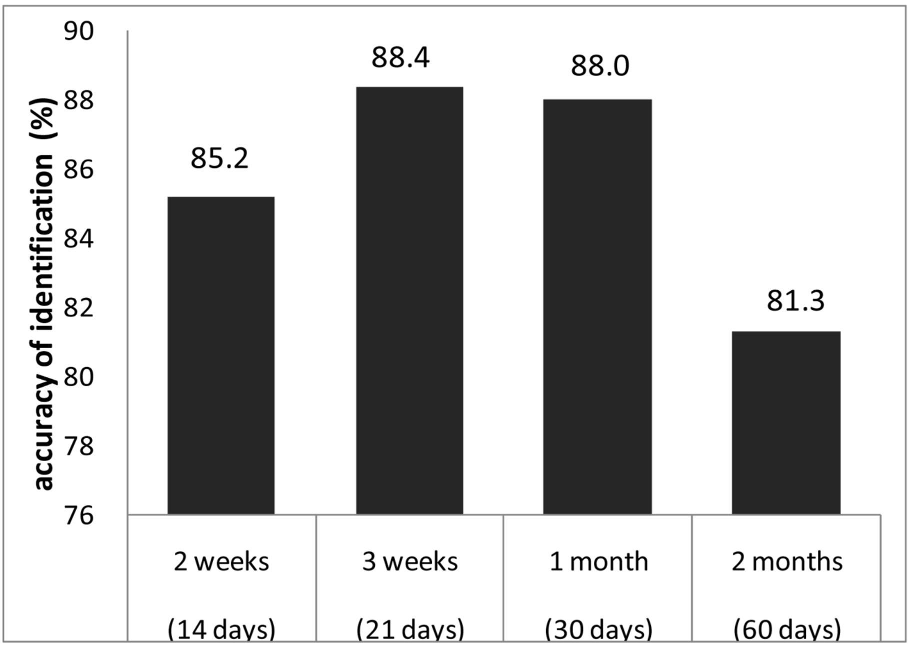

Figure 2. Averaged accuracy of individual cow identification by ASMIC (ASMIC is using the short wavelength region spectra with 1st derivative transformation.

study. Previously published papers give an insight into potential of this region for analysis of milk composition (Tsenkova *et al*.,1999). Because of the high transmittance of light in this region and availability of excellent detectors in this range, it may be possible to construct on-line sensors for the nondestructive determination of the various components and for noninvasive diagnosis based on short-wavelength NIR spectroscopy.

Figure 2 shows that substantial improvement was gained when using a spectral data set covering the last 21 days before the day of diagnosis.

Interestingly, this finding could be related to the estrous cycle of non-pregnant cows, the average length of which is 21 days. Further investigations are needed to understand how this is related to the individuality and physiology of each cow.

When using the best conditions described above, with 95% confidence level, the accuracy of ASMIC classification was 88% correct, which signifies that 12% of the samples were misclassified. In this study no objects with misclassified spectral data have been removed, since the data set represents real world variations. As more samples are included in the data set, better classification results could be obtained.

Mis-classifications were divided into two groups: False Negative, FN, and True Negative, TN. FN represents misclassified cow identification with unknown reason. TN represents misclassified cow identification caused by known physiological abnormality. Figure 3 shows that the average accuracy of abnormality detection was 57%.

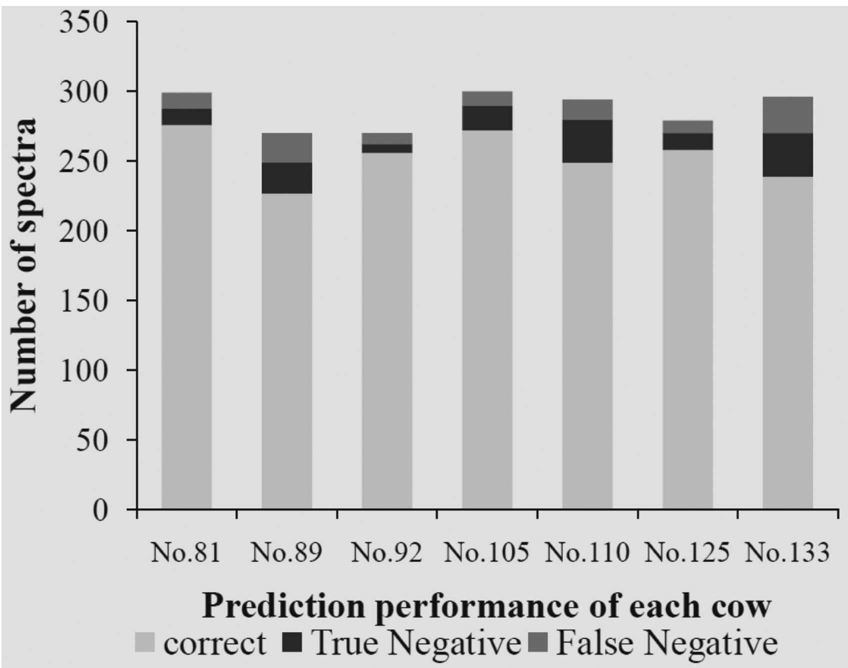

Figure 3. Accuracy of individual cow identification and abnormality diagnosis over the lactation stage period of day 91st to day 200th by Adaptive Spectral Model of Individual Cow (ASMIC is developed for fixed period of 21 days before the day of prediction).

Conclusion

The results show that differences between the NIR spectra of each cow do exist and promising classification can be obtained after optimising spectral pre-treatment. Each deviation of the model, i.e. mis-identification of a cow could be due to physiological abnormalities.

The results represent an important step towards the development of an on-line NIR method for monitoring milking cow's health status in the field. Further detailed investigations are needed to find out the real reason behind each mis-classification and relate it to physiological and other abnormalities.

References

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