Interrelation between composition and near infrared spectra of milk, blood plasma and rumen juice of lactating cows

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Introduction

Near infrared (NIR) spectroscopy has been examined as a reliable method for the investigation of biological material. It is a suitable method for the determination of milk composition and mastitis diagnosis.[1–6] NIR has been used for better understanding of the kinetics, the rate and extent of degradability of different forages in the rumen.[7–9] NIR has the potential to estimate microbial nitrogen content[10] and voluntary fatty acids in the rumen. Analyses of whole blood and blood plasma have also been done by NIR.[11,12]

There are links in the cow's biosystem between bioprocesses in the rumen, blood composition and quantity and quality of the produced milk.[13] Near infrared spectra of dairy cow's biological liquids could provide information for her physiological condition.[14]

The purpose of this investigation was to determine interrelations between milk composition and near infrared spectra of rumen juice and blood plasma and between near infrared spectra of milk and rumen juice and blood plasma components, respectively.

Materials and methods

Thirty-two samples of milk, rumen juice and blood were taken simultaneously from 16 lactating Holstein cows, included in a feeding trial. The diet contained corn silage, Italian ryegrass hay, alfalfa hay, commercial concentrate mixture and different kinds of protein supplement—fishmeal, corn gluten meal, roasted soybean meal or soybean meal. The crude protein from the protein supplement was from 20 to 30% of the total crude protein in the diet. The diet was adjusted to fulfill the maintenance and production requirement level. Each cow was used to test two different protein supplements. Samples of rumen juice were taken four hours after morning feeding.

Milk samples were analysed for fat, crude protein and lactose content by Milko-scan (Foss-Electric A/S, Hillerød, Denmark), that has been accepted as a reference method and for true protein, casein and milk urea nitrogen (MUN) by classical laboratory methods.[15]

Acetic acid, propionic acid and butyric acid content of the rumen juice were determined by liquid chromatography as described by Jouany[16] and pH values of rumen content were measured immedi-

Near Infrared Spectroscopy: Proceedings of the 9th International Conference

Table 1. Range of chemical composition of tested samples

Sample type	Parameter	Minimum	Maximum	Average
Milk	Fat, %	2.00	5.47	3.41
	Crude protein, %	2.88	4.05	3.32
	Casein, %	2.18	2.87	2.62
	True protein, %	2.74	3.87	3.17
	MUN, %	1.40	3.10	2.00
	Lactose, %	4.12	4.93	4.54
Blood plasma	Albumin, %	2.87	3.58	3.25
	Glucose, mg dl^{-1}	45.9	72.7	61.6
	BUN, %	11.3	21.2	15.9
Rumen juice	PH	5.4	6.5	6.27
	NH_3–N , %	2.2	18.8	8.42
	acetic acid, mol%	50.4	64.6	58.6
	butiric acid, mol%	16.9	36.1	23.1
	propionic acid, mol%	11.1	19.0	14.7

MUN: milk urea nitrogen, BUN - blood urea nitrogen
NH_3N: ammoniac nitrogen

ately after sampling, using a pH meter. Ammonia nitrogen (NH_3–N) content was determined by the microdiffusion method of Conway.[17]

Blood plasma samples were analysed by the auto-analyser, Hitachi 7070, for albumin, glucose and blood urea nitrogen (BUN).

Transmittance spectra of non-homogenised milk, rumen juice and blood plasma with a sample thickness of 1 mm were obtained by NIRSystem 6500 spectrophotometer (Foss NIRSystems, Silver Spring, MD, USA) in the wavelength range from 700 to 2500 nm at 2 nm interval and were recorded in the linked computer as absorbance, i.e. log (1/*T*). Prior to spectral analysis each sample was warmed up to 40°C in a water bath.

A commercial program, Pirouette Version 2.6 (Infometrics, Inc., Woodinville, WA, USA,) was used to process the data. The spectral data of milk, rumen juice and blood plasma were transformed into principal components (PC) by principal component analysis (PCA). In the next step, multiple linear regression was used to determine the correlation between principal components and tested chemical parameters.

Results and discussion

Statistical data of the standard chemical analysis for examined samples: milk, rumen juice and blood plasma components, are presented in Table 1. Single cow milk, rumen juice and blood plasma spectra are shown in Figure 1. PCA of spectral data for milk, rumen juice and blood plasma, respectively, showed that the first ten PC's of each set of samples accounted for about 99.9% of the total variation. These first ten PC's were selected for further investigation.

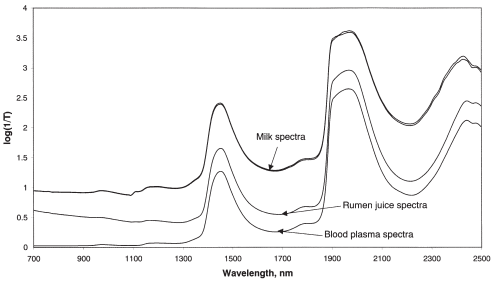

Figure 1. Single cow milk, rumen juice and blood plasma near infrared spectra.

Table 2. Correlation between the first ten principal components of rumen juice spectra and milk components and wavelengths with highest correlation coefficients

Parameters	*R*	Wavelengths with highest correlation coefficients (nm)
Fat, %	0.750*	726,1960,1984,1448,2460
Crude protein, %	0.703	1088,902,2470,1972
Casein, %	0.826**	2218,2206,2102,2146,2072
True protein, %	0.698	1878,2340,2208,2318,1408
Milk urea N, %	0.665	2466,1974,1958,1898,2406
Lactose, %	0.593	2310,2270,1882,2348,2202

Statistically significant at: * $P < 0.05$, **$P<0.01$

Milk composition

The results of correlation analysis between the first ten PC,s of rumen juice spectra and milk composition are shown in Table 2. The wavelengths with the highest correlation with respective components are presented there, too. Statistically significant correlation ($P > 0.05$) was obtained for casein and fat content. A relatively high correlation was obtained for total protein and true protein content. The lowest was the correlation with lactose content of milk.

Correlation between the first ten PC's for blood plasma spectra and milk composition are shown in Table 4. The correlation was statistically significant for casein content. High coefficients of multiple correlation were found for fat, total protein and true protein content, too.

Rumen juice composition

The correlation between the first ten PC's of milk spectra and rumen juice composition was highest for propionic acid and ammoniac nitrogen content. (Table 3)

Blood composition

Statistically significant was the correlation between milk spectra and blood urea nitrogen and albumin content of blood plasma—*R* was 0.731 and 0.718, respectively (Table 5).

Table 3. Correlation between first 10 principal components of milk spectra and rumen juice components and wavelengths with highest correlation coefficients.

Parameters	*R*	Wavelengths with highest correlation coefficients (nm)
pH	0.625	768,2450,2426,1954,1258
NH_3-N, %	0.697	2338,2312,2306,2328,1890
acetic acid	0.565	838,824,2464,2450,1968
propionic acid	0.732*	1086,2450,1884,1408
butyric acid	0.672	1882,1086,1410,2286,2336

Statistically significant at: * $P < 0.05$

Table 4. Correlation between the first 10 principal components of blood plasma spectra and milk components and wavelengths with highest correlation coefficients.

Parameters	*R*	Wavelengths with highest correlation coefficients (nm)
Fat,%	0.698	2144,2198,2064,1972,1584
Crude protein, %	0.685	2140,2346,1142,2198,2064,
Casein, %	0.728*	2130,2312,1192,1722,1488
True protein, %	0.683	2144,2346,1144,1202,1972
Milk urea N, %	0.546	1922,1976,1444,1728,1112
Lactose, %	0.534	1924,1930,1952,1978,1720,

Statistically significant at: * $P < 0.05$

Table 5. Correlation between the first 10 principal components of milk spectra and some components of blood plasma and wavelengths with highest correlation.

Parameters	*R*	Wavelengths with highest correlation coefficients (nm)
Albumin, %	0.718*	2450,2432,1942,1414,1968
Glucose, mg/dl	0.361	1228,2468,1910
Blood urea nitrogen, %	0.731*	2042,1500,2006,1940,2352

Statistically significant at: * $P < 0.05$

Conclusions

The results showed that there are valuable interdependencies between milk composition and near infrared spectra of rumen juice and blood plasma of a dairy cow and *vice versa*. This fact would enable better understanding of the interaction between different physiological processes in lactating cows. Simultaneously, near infrared spectral data acquisition of bio liquids could allow *in vivo* analysis of physiological conditions and feed back optimisation. Further investigation is necessary to define how the assigned wavelengths correlate with each of the tested components, respectively.

Acknowledgment

This work was supported by the Programme for Promotion of Basic Research Activities for Innovative Bioscience (PROBRAIN) of Ministry of Agriculture, JAPAN. The authors are grateful to GL Science Inc., Japan for providing the software Pirouette Version 2.6.

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