ASEC 2023
The 4th International Electronic Conference on Applied Sciences
27 October – 10 November 2023 | Online
applied sciences MDPI

Online Near-infrared Spectroscopy for the Measurement of Cow Milk Quality in an Automatic Milking System

Patricia Iweka*, Shuso Kawamura, Tomohiro Mitani, Takashi Kawaguchi

Agricultural and Food Process Engineering Laboratory
Hokkaido University, Japan

Dairy farming

Feeding

Manure treatment

Labour intensive

Milking

Livestock management

Herd management

Extensive dairy farmers manage their livestock in groups

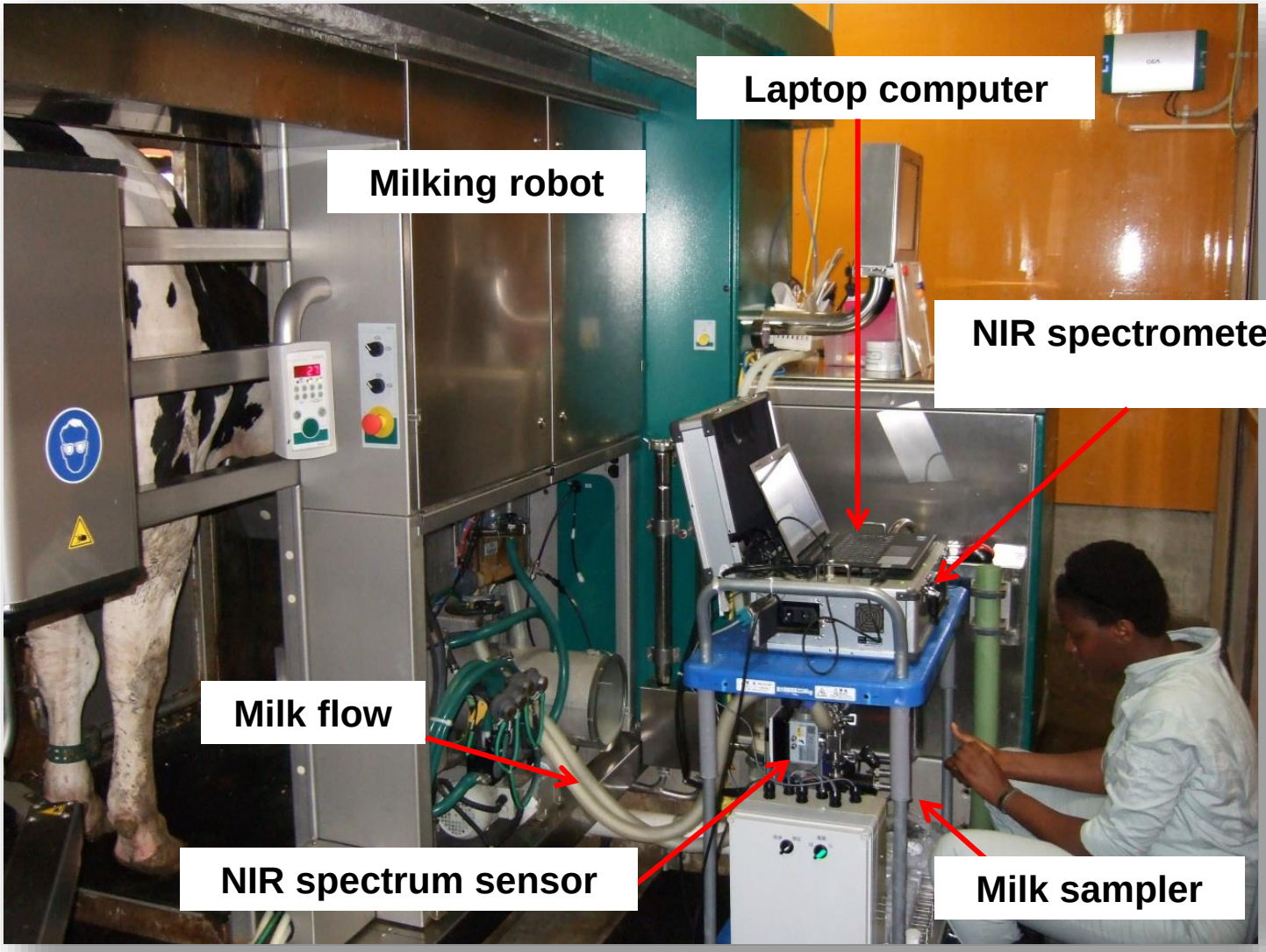
Individual cow management

Monitoring the information of each cow is necessary for the production of high-quality milk

Dairy farmers have very strong need for a system to measure milk quality of individual cow during milking

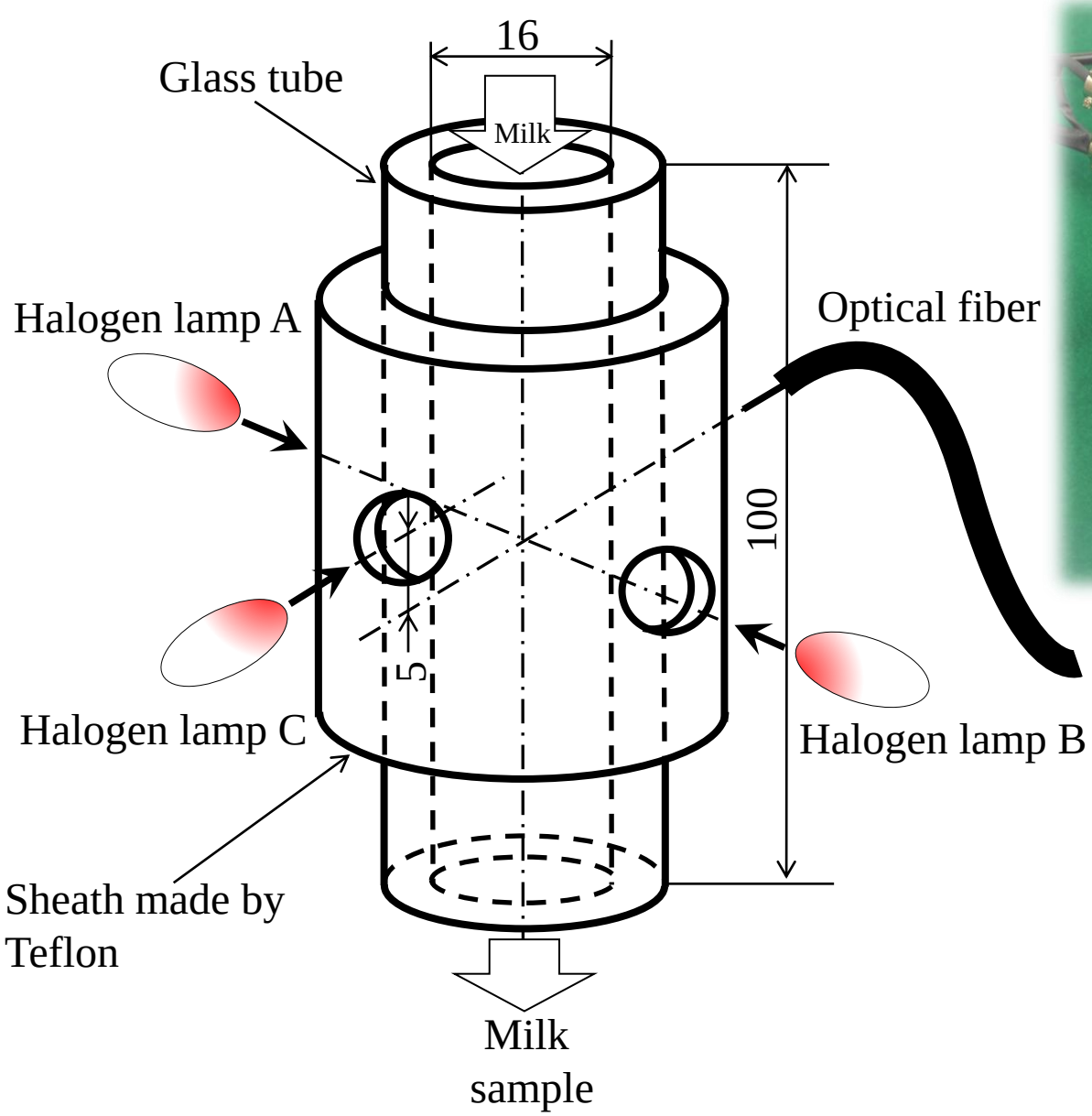
Investigate..

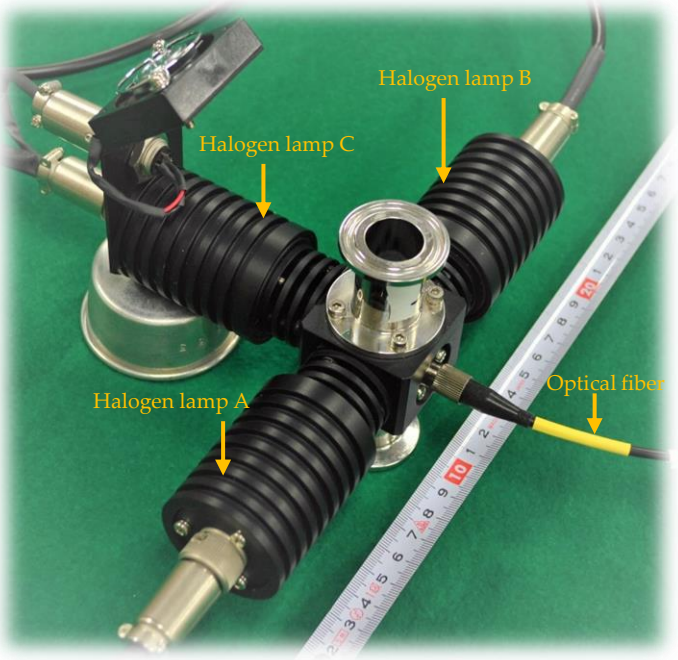
Precision and accuracy of the NIR spectroscopic sensing system for individual cow milk quality measurement in an automatic milking system



Online near-infrared spectroscopic sensing system installed in an automatic milking system

Schematic diagram of the optical system

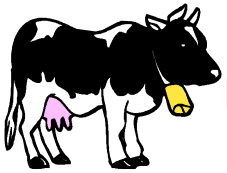




Original NIR Sensor

Spectrum sensor
Milk chamber
Three halogen lamps
Optical fiber

Flow chart of the NIRS sensing system for milk quality measurement in an automatic milking system



Milking robot → NIR instrument → Milk flow meter → Bulk milk

NIR instrument → Milk sampler

Milk sampler → Reference analyses

NIR instrument, Milk flow meter → Computer NIR spectra, flow rate

Volume of milk sample approx. 30 ml at every 20 s

700 – 1050nm wavelength range

NIR spectra and milk flow rate were recorded at every 20 s

= Milk flow

= Milk data

- Fat（%）
- Protein（%
- Lactose（%）
- Solids not fat (SNF) (%)

Milk quality indicators

- Somatic cell count (SCC)（log SCC/mL）

↓

Milk quality
and health status indicator

Reference analyses

- **Milkoscan instrument was used to measure milk fat, protein, lactose, and SNF**
- **Fossomatic instrument was used to measure the somatic cell count (SCC) of the raw milk of 24 Holstein cows**

Reference analysis was carried out by Hokkaido Dairy Milk Recording and Testing Association

Chemometric analyses

All samples were randomly divided into two sample sets.
calibration subset and validation subset

Develop calibration models
using two-thirds of all samples (calibration subset)

Reference data + **Spectra data**

Partial least squares (PLS) method

Calibration models

Validate the precision and accuracy of the calibration models
using one-third of all samples (validation subset)

Validation statistics of NIRS sensing system for milk quality determination

Real-time Milking Accuracy (Every 20 seconds during milking)

Milk Quality items	n	Range	r^2	SEP	Bias	RPD	Regression
Fat (%)	125	0.98-8.54	0.99	0.17	0.01	8.86	y = 1.03 x - 0.11
Protein (%)	125	2.76-4.46	0.79	0.22	0.01	2.16	y = 0.91 x + 0.31
Lactose (%)	125	3.99-4.97	0.71	0.12	0.01	1.86	y = 0.98 x + 0.07
SNF (%)	125	8.15-10.09	0.71	0.25	0.03	1.83	y = 0.92 x - 0.71
SCC (Log SCC/mL)	125	3.70-6.47	0.65	0.44	-0.02	1.69	y = 1.02 x – 0.09

n: total number of validation samples. r^2: coefficient of determination. SEP: standard error of prediction. RPD: ratio of SEP to standard deviation of reference data. Regression line: regression line from predicted value(x) to reference value (y).

Measurement accuracy were almost the same

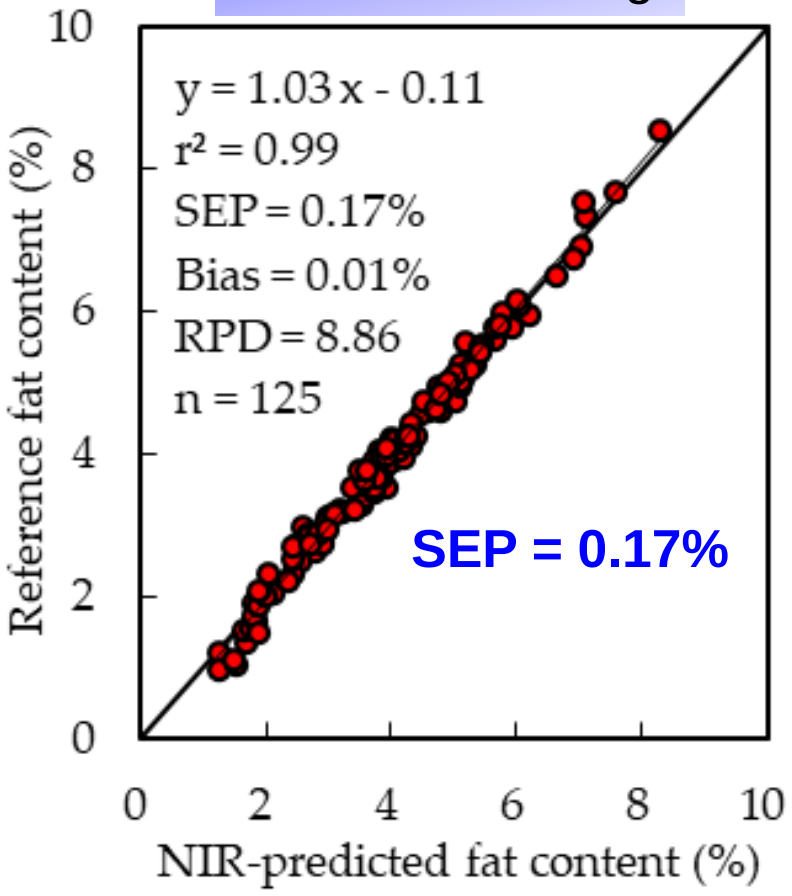
One Milking Time Accuracy

Milk Quality items	n	Range	r^2	SEP	Bias	RPD	Regression
Fat (%)	20	1.96-5.79	0.98	0.15	0.05	6.92	y = 0.98 x + 0.01
Protein (%)	20	2.89-4.17	0.83	0.18	-0.07	2.43	y = 0.96 x + 0.22
Lactose (%)	20	4.22-4.85	0.87	0.08	0.01	2.50	y = 1.22 x - 1.01
SNF (%)	20	8.59-9.82	0.94	0.10	-0.02	4.08	y = 0.96 x + 0.37
SCC (Log SCC/mL)	20	4.00-6.47	0.83	0.36	-0.17	2.12	y = 1.35 x - 1.49

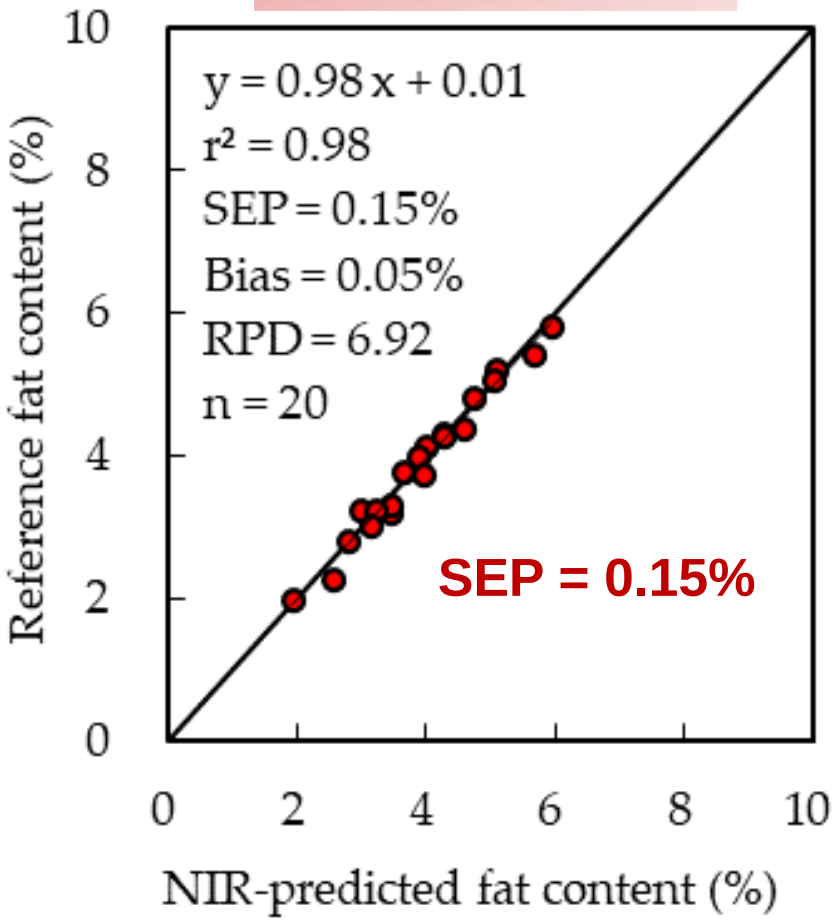
n: total number of validation samples. r^2: coefficient of determination. SEP: standard error of prediction. RPD: ratio of SEP to standard deviation of reference data. Regression line: regression line from predicted value(x) to reference value (y).

Milk Fat Content

Real-time milking



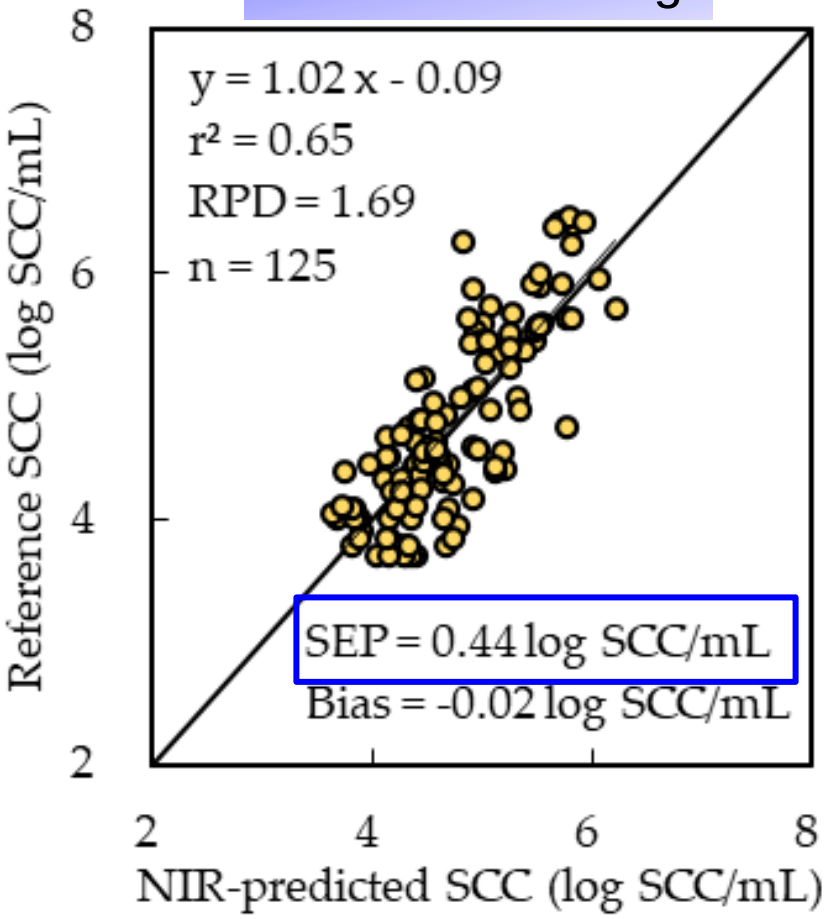
One milking time



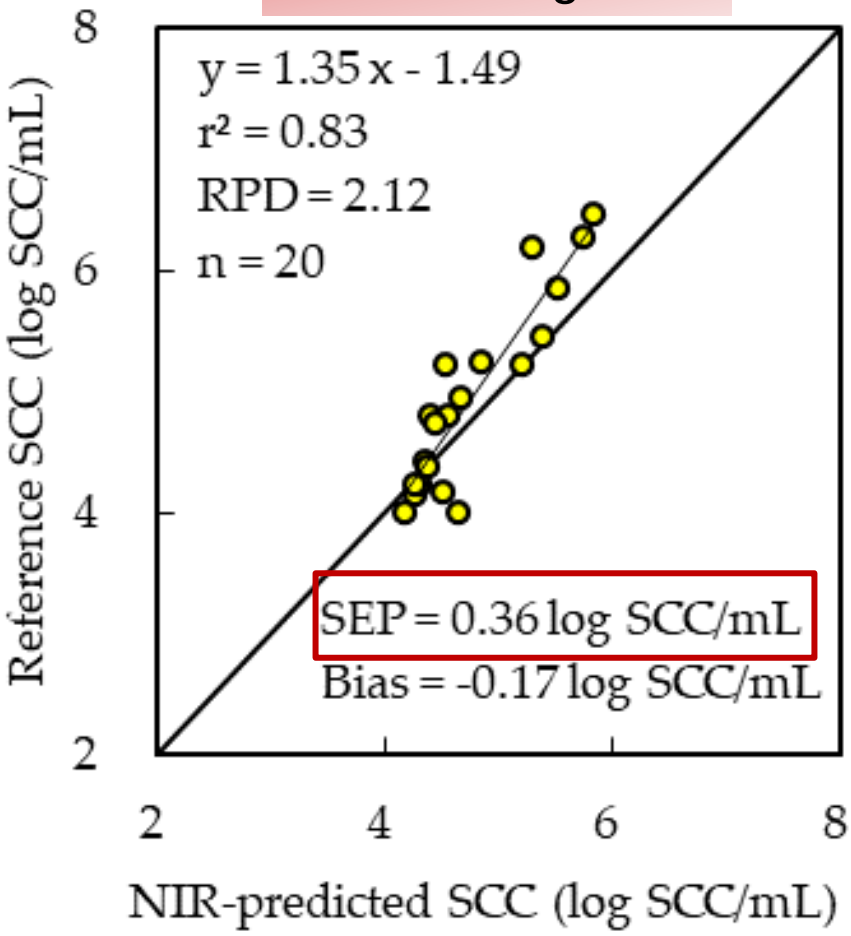
Almost the same accuracy

Somatic Cell Count

Real-time milking



One milking time



Almost the same accuracy

NIR sensing system developed could be used for on-line real-time measurement of

fat, protein, lactose, SNF, and SCC during milking with sufficient precision and accuracy

- Meet the requirement of dairy farmers and veterinarians

- **Rapid** feedback control for upgrading dairy farm **(individual cow)** management

- Relieve dairy farmers of poor cow milk production and economic losses

- **Application of NIR sensing system**

Dairy precision farming

Acknowledgement

Dr. Patricia Iweka,
Hokkaido University

Professor Shuso Kawamura,
Hokkaido University

Professor Tomohiro Mitani,
Hokkaido University

HOKKAIDO UNIVERSITY FOUNDED 1876

NARO
National Agriculture and Food Research Organization

Hokkaido University Dairy Farm

Tukii Moon Well Dairy Farm,
Tochigi Prefecture, Japan

ORION
冷熱と真空でイノベーション

SOMA OPTICS, LTD.