Visible light scatter as quantitative information source on milk constituents

Melentiyeva, Anastasiya; Kucheryavskiy, Sergey; Bogomolov, Andrey

Publication date:
2012

Document Version
Early version, also known as pre-print

Visible Light Scatter as a Quantitative Information Source on Milk Constituents

A. Melenteva [1], S. Kucheryavski [2] and A. Bogomolov [1,3]

Background

Multiple light scattering by colloidal **fat** (1–10 μm) and **protein** (80–200 nm) particles complicates spectroscopic analysis of milk. Visible light region (400–800 nm) with dominating scatter effect is typically avoided.

Our preceding research [1,2] has proved that diffused light by itself delivers quantitative information and can be used for accurate spectroscopic determination of milk fat and total protein in the region 400–1100 nm in the presence of essential variability of fat globule sizes (Fig. 1).

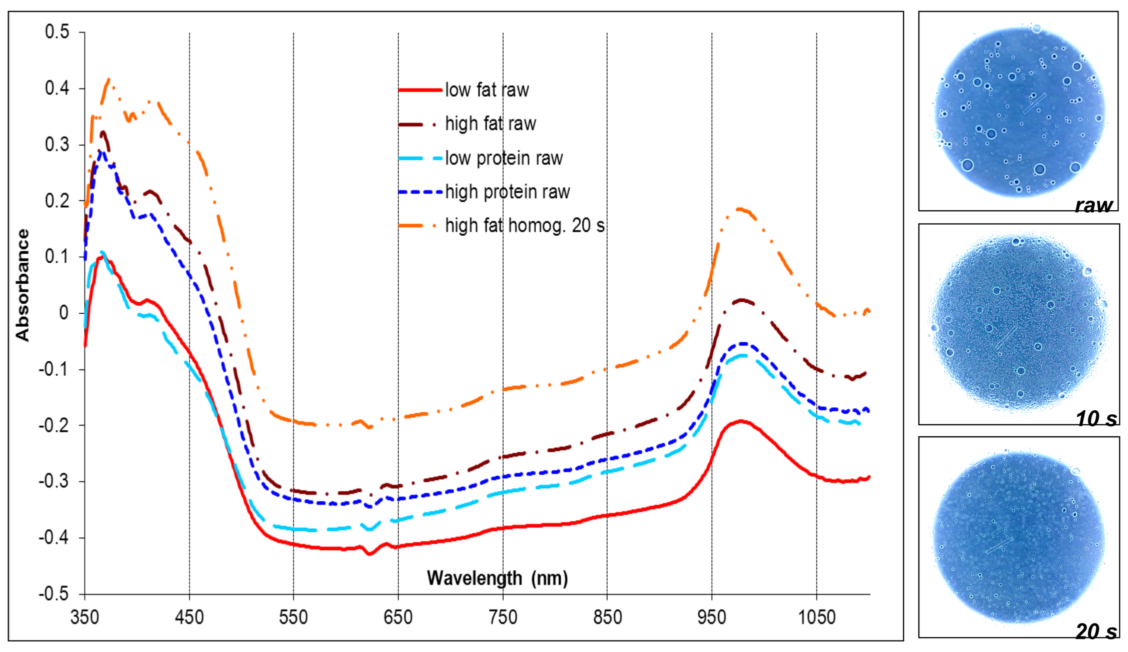


Figure 1 – Spectra of milk samples with different fat and protein content at different homogenization grades

[1] A. Bogomolov, S. Dietrich, R.W. Kessler, Food Chem. 134 (2012) 412–418
[2] A. Bogomolov, A. Melenteva, Chemometr. Intell. Lab. Syst. (2012) submitted

Challenge

Replace spectroscopy with a **low-end detection** technique, such as **digital imaging** combined with multivariate image analysis.

Experimental

Two series of 16 samples with **varying fat and total protein** content were prepared from milk standards of exactly known composition (Table 1) by a **pair-wise mixing** design (Fig. 2). Vis/SW-NIR transmittance spectra were acquired using a 4-mm cavity. To simulate the variation of fat globule sizes each sample was analyzed 3 times: raw and after **two partial homogenizations** for 10 and 20 s with an **ultrasound** processor.

		%Fat	%Protein
F-series	11	2.37	3.47
	22	3.28	3.49
	33	4.24	3.57
	44	5.46	3.61
P-series	11	3.64	3.00
	22	4.00	3.37
	33	4.32	3.66
	44	4.13	4.09

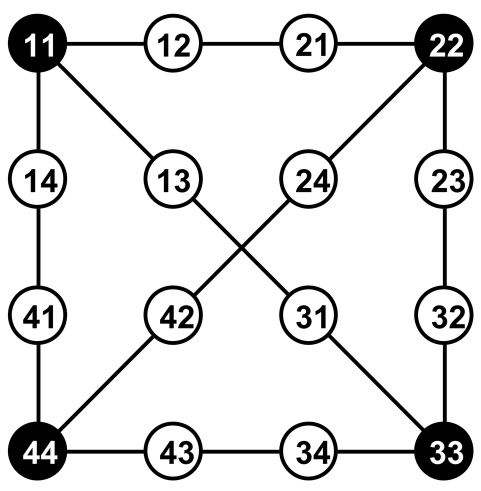


Table 1 – Composition of milk standards used for the preparation of fat (F) and protein (P) sample series

Figure 2 – Pair-wise mixing design for a sample series

Each sample was placed in a Petri-dish and sequentially illuminated from below by red, green and blue LEDs through a fiber cable. The photos of diffusely transmitted light spot on the milk surface were acquired by Cannon 400D using bracketing with five exposition steps, thus, giving 15 images per sample.

Increase of fat or protein content results in a higher light extinction in a sample: compare spot intensities and sizes in Fig. 3. Sample homogenization produces a similar effect.

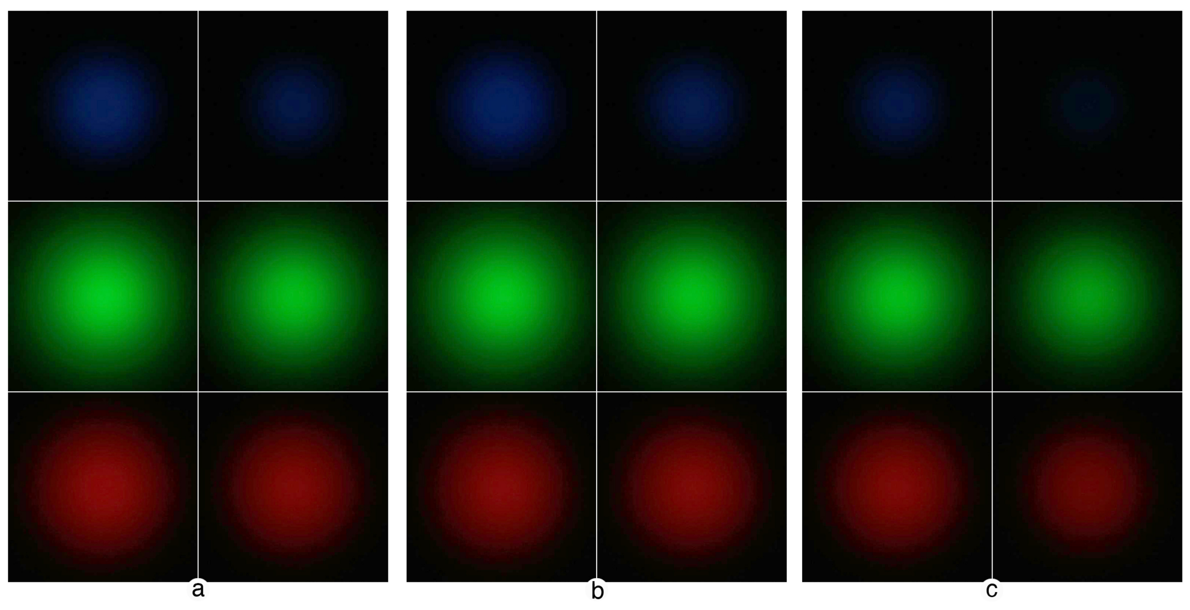


Figure 3 – Photos of samples with smallest and largest fat content (a), with smallest and largest total protein content (b) and sample with smallest fat content before and after homogenisation.

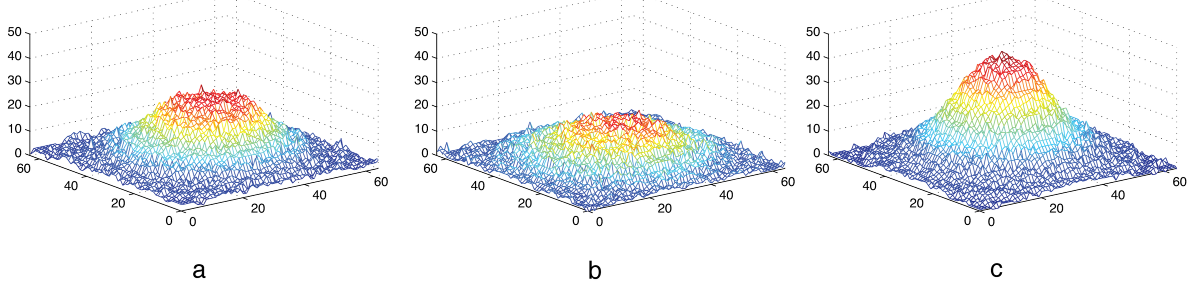


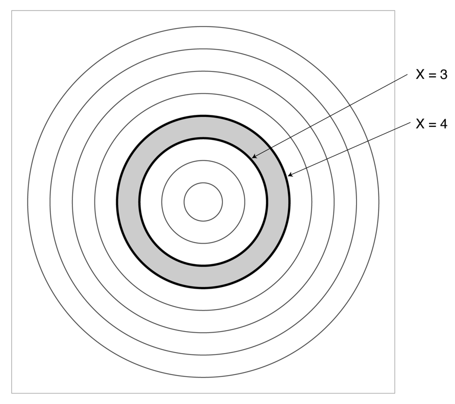
Figure 4 – Difference in light intensities for the green images

However, visual inspection of the images at different light colors reveals differences of fat, protein and homogenization effects; these are in correspondence with spectral differences in Fig. 1. Beside the overal extinction, some differences in radial intensity distribution are observed using the difference images in Fig. 4. Therefore, spatial distribution of diffusely transmitted light should be taken into account by the feature extraction algorithm converting the raw data into a model input.

Results

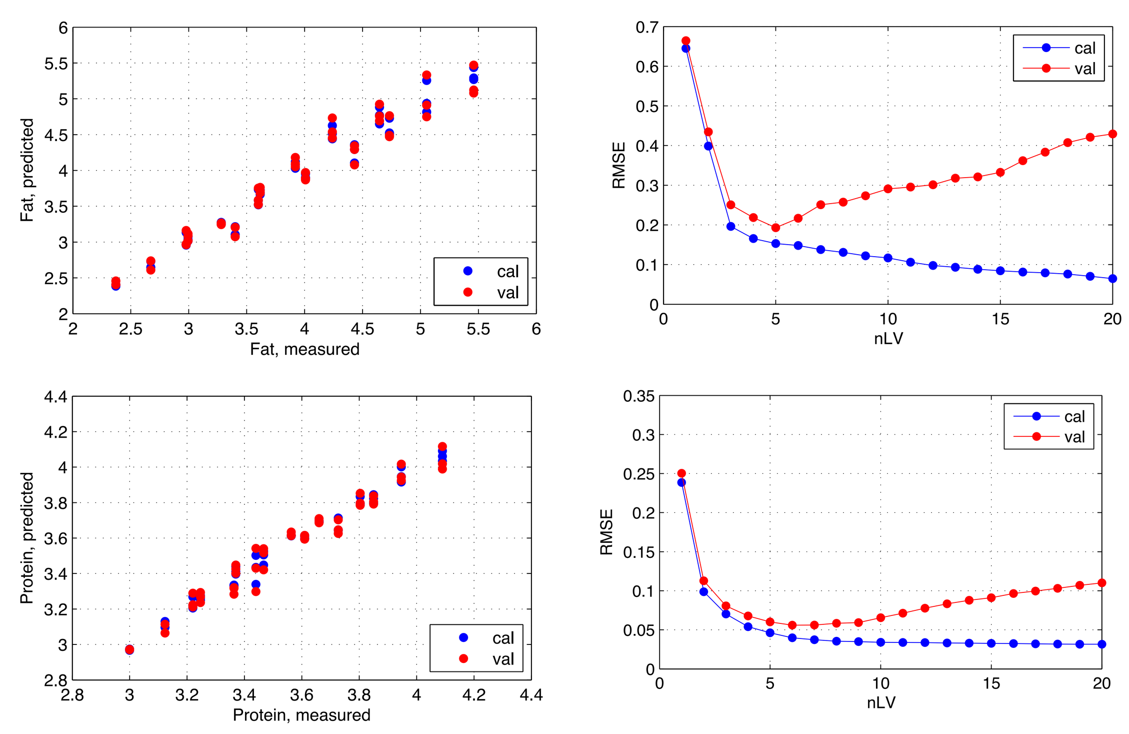
A new feature extraction algorithm, developed for this purpose, calculates average intensity values for N concentric rings built with an equal radius step around the center of a light spot (Fig. 5). N=8 was found to be an optimal resolution for subsequent modeling.

Figure 5 – Scheme of concentric rings based features calculation for N = 8.



The calculated features were used as predictors in PLS regression modells for of fat and total protein content. The best models, obtained after iPLS variables selection are presented in Fig. 6.

Figure 6 – PLS models for prediction of fat (top, RMSECV = 0.190) and protein (bottom, RMSECV = 0.048) content.



Conclusions

Multivariate modeling of conventional digital images enables fat and total protein content prediction in raw milk with a reasonable accuracy. The method is resistant to essential variations of fat globule size distribution.

[1] Samara State Technical University, 244 Molodogvardeyskaya Street, 443100 Samara, Russia, www.samgtu.ru
[2] Aalborg University, campus Esbjerg, Niels Bohrs vej 8, 6700 Esbjerg, Denmark, www.esbjerg.aau.dk
[3] J&M Analytik AG, Willy-Messerschmitt-Strasse 8, 73457 Essingen, Germany, www.j-m.de