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The Use of Colour Measurement for the On-Line Determination of Milk Quality during Milking

Automatic milking (AM) requires dependable sensor technology for the reliable detection of obviously altered milk. The determination of the electrical conductivity (EC) of the milk, which has so far been employed, is insufficient for this purpose. The examinations carried out show that the technique of spectral photometry is very suitable for the evaluation of raw milk quality.

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Keywords

Milk quality, udder health, colour measurement

Literature

Literature references can be called up under LT 03411 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Raw milk is a significant and important raw material for the food industry. Its quality is guaranteed by adherence to the Milk Decree.

In automatic milking, the quarter-specific measurement of electrical conductivity (EC) is currently state of the art for the evaluation of milk quality. The use of EC measurement has been discussed by many authors [2; 4; 5] for quite some time. In summary, one can say that EC measurement alone is insufficient for the determination of udder diseases and, hence, a reduction in milk quality. Recent studies by Köhler [6] showed that the combination of several parameters, such as EC, milk flow, and milking intervals, allows the success rate of mastitis detection to be increased in a fuzzy model.

Ordolff and Vijverberg & Espada conclude that diseases of the milk gland also affect milk colour and can be detected using suitable optical systems [3; 7]. The results of their own previous colour measurement trials show that spectral photometry enables colostrum and milk containing blood to be detected [8]. Thus, optical sensors provide another possibility to examine milk quality. A manufacturer of automatic milking systems meanwhile also offers an on-line colour sensor.

Bergann & Schick, however, also determined a very high correlation (R^2 = 0.988 to 0.999) between milk fat content and colour in ultra-high heated milk for consumption [1].

In the studies described below, the individual wavelengths (WL) were analyzed with regard to their dependence upon the fat content in order to allow for colour measurement largely independent of the fat content. In addition, the course of reflectance in the individual milk fractions was examined from the beginning until the end of the milking. Finally, tests were carried out in order to determine to what extent milk from diseased udders can be detected reliably with the aid of spectral photometry.

Material and Method

The studies were carried out in March 2003 using the herd (80% Red and White Holstein, 20% Red Spotted Highland) of the experimental farm Hirschau (TU München-Weihenstephan), which was milked with the aid of the automatic milking system VMS® from the company DeLaval. A specifically manufactured device in the VMS® allowed representative samples to be taken from the milk fractions.

Part A of the trial consisted of the extraction and spectral-photometric examination (64 milkings altogether) of the quarter-specific milk fractions of a selection of 40 animals (with and without secretion disorders). The first fraction consists of the first 500 g of each quarter milking. Due to the experimental conditions, the other milking fractions were milked in steps of either 500 g or

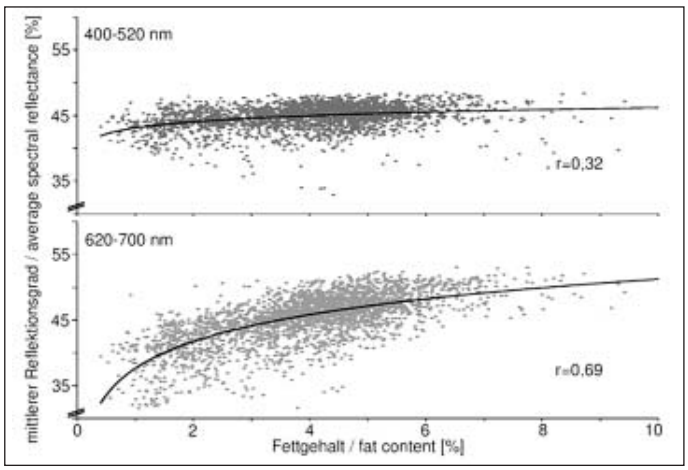

Fig. 1: Average spectral reflectance in the bands 400-520 nm and 620-700 nm versus milk fat content (n=2640 milk samples)

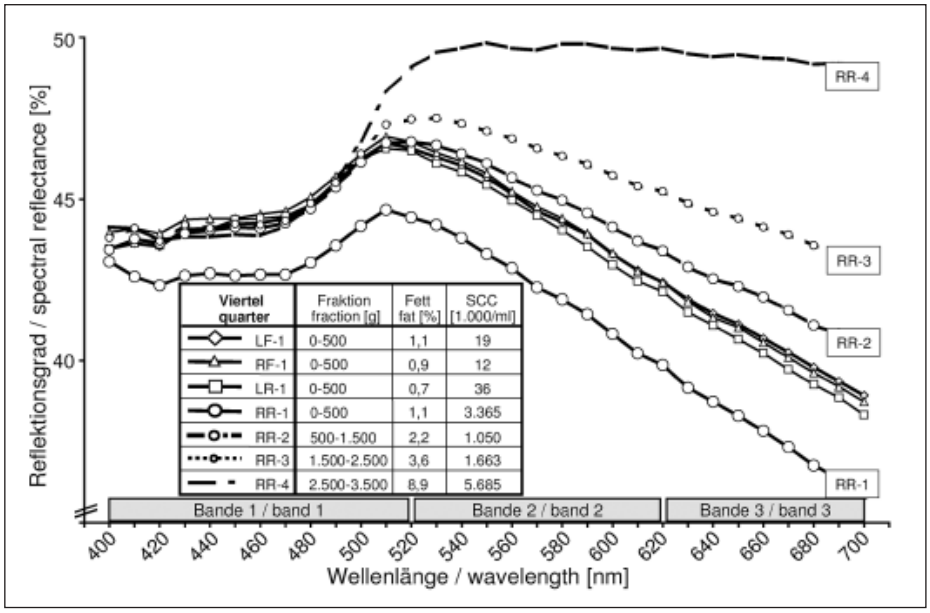

Fig. 2: Spectral reflectance of quarter individual milking-fractions of the udder-diseased cow 497 (4. 3. 2003; 9:46, 17,2 kg of milk)

1,000 g. Since milk ejection caused by teat cleaning could influence the spectral-photometric measurement values, samples were taken both with and without previous udder cleaning.

In part B, samples of the initial quarter milkings (IQM, < 300 g) from 16 cows with healthy and diseased udders were gained and examined by means of spectral photometry over a period of nine days. The usual cleaning- and pre-stimulation routine was skipped during this study. In addition to the number of cells in the initial quarter milking determined during each milking process, the bacteriological examinations of the first and last trial day form the basis of udder health evaluation.

All measurements were carried out with the measuring instrument spectro-color (Dr. Lange GmbH & Co. KG), which features d/8° measuring geometry and a measuring field 8 mm in size. For the measurements in the wavelength band (WLB) between 400 and 700 nm, the illuminant CIE D65 and the 10° standard observer were pre-set, and the milk samples were heated to a uniform temperature of 37°C.

In addition, all milk samples were examined for fat, protein, lactose, and somatic cell content in standard tests carried out in the laboratory of the milk examination ring Wolnzach.

Results

In both series of experiments, the dependence between reflectance and fat content was determined first. The examination of 2,640 milk samples from different fractions and total milkings showed that the fat content was reflected in particular by the red WLB between 620 and 700 nm (band 3) (*figure 1*). Thus, the correlation coefficient between mean reflectance in the spectrum between 620 and 700 nm and the logarithmic fat content is r = 0.69. Reflectance in the WLB between 400 and 520 nm (band 1), however, is only slightly influenced by fat (r = 0.32).

The results of part A show that in udder-diseased animals lower reflectance occurred in the first milk fraction (< 500 g) of the affected quarter, in particular in the WLB between 400 and 520 nm. *Figure 2* shows the first milk fractions of all quarters and the other milk fractions of the diseased quarter „rear right“ (RR-1 to RR-4) as examples of the milkings of cow 497 (4 March 2003; 9:46 a.m.). The non-diseased quarters (LF-1, RF-1, LR-1) do not show any noticeable deviations, while the mean reflectance of the diseased quarter (RR) in the WLB between 400 and 520 nm shows a negative deviation of 4.0% from the reference quarter. The spectral reflectance of the second milk fraction of the diseased quarter (RR-2) (milk ejection has already taken place here) adapts to the spectral reflectance of the healthy quarters in the WLB between 400 and 520 nm. Therefore, it is no longer possible to distinguish the diseased quarter from the healthy ones. The large deviations of the spectral reflectance of RR-1 to RR-4 are caused by the increasing fat content (1.1 to 8.9%).

The analysis of all 64 milkings showed that in normally lactating cows only a very small difference in quarter-specific spectral reflectance in the WLB between 400 and 520 nm was able to be distinguished. In animals with secretion disorders, diseased and healthy quarters can exclusively be differentiated in the first milking fraction (< 500 g, before the beginning of milk ejection) with the aid of spectral photometry. An examination of the influence of the cleaning routine of VMS® on the colour values measured showed that after this examination it was no longer possible to separate diseased quarters from healthy ones. Thus, the negative deviation of the RR quarter (cow 497, 5 March 2003, 5:19 p.m,), for example, diminished to 0.5% (without pre-stimulation 4.0%). Pre-stimulation, such as udder cleaning, thus exerts a negative influence on the detection of alterations with the aid of colour measurement.

Based on the previous results, 280 milkings were examined in part B to determine whether milk from diseased quarters is detected with the aid of the difference method. In these examinations, the quarter which exhibits the highest reflectance in the WLB between 400 and 520 nm served as a reference quarter. Hence, a difference or a relative deviation was able to be calculated for the remaining quarters. At a maximum negative deviation limit of 2%, 85% of the healthy quarters (< 100,000 scc/ml) were classified correctly.

An exceeded limit indicates altered milk quality. Thus, the currently employed method (a deviation of more than 2% in the current milking) enabled 71% of the IQMs which contained more than 500,000 scc/ml or showed positive bacteriological results as well as 80% of all IQMs containing more than 1,000,000 scc/ml to be detected as abnormal.

Summary

The studies show that colour measurement allows milk from diseased udders to be detected. The described method enables the strong influence of the milk fat content on milk colour to be disregarded. The most meaningful results can be achieved if the milk is examined optically in the WLB between 400 and 520 nm before the beginning of milk ejection.

An even better detection rate of sub-clinically diseased quarters and, hence, altered milk quality could be reached by combining these colour values with other parameters (EC, ion concentration) [9].