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Determining the Contents during Harvest with a Forage Chopper

Near-infrared spectroscopy (NIRS) can be used to assess forage quality. Rugged NIRS sensors make it possible to use them on agricultural machines. Until now the calibration of these sensors was specifically designed for the respective machines and operating conditions. For use in agriculture alternative calibration methods are needed. One possibility is to gather a wide variance of content concentrations through experimental cultivation with specific variety selection and fertiliser application. The calibrations would then be determined in the laboratory. In order to transfer the calibrations from the laboratory to various choppers, the effects of the different samples were investigated.

Increasing quality consciousness and the desire for better process control require new techniques in agricultural production. Including the NIR online-measurement of the forage ingredients in addition to yield data by the forage harvester does not only extend the knowledge in precision farming, but offers also new possibilities for process control. For years, the near infrared spectroscopy is an essential tool in laboratories for fast and economical assessment of forage quality. Through the development of durable and shock resistant NIR sensors the technical requirements for embedding NIR on harvesting machines are given. Whether and how the NIRS can be used meaningfully on forage harvesters, is subject of a research project supported by the Federal Ministry of Education and Research. The project is carried in cooperation of the Technical University of Dresden, the Federal Agricultural Research Centre (FAL) and the CLAAS company.

Characteristics of the NIR - spectroscopy

The calibrations for the NIR - spectrometers are empiric regression models and usually specific to spectrometers, product and sample presentation. The calibration models must include the variability of breeds, environmental factors and the sample presentation. Additionally the calibration must cover the whole expected range of concentration of the particular ingredient. It is not possible to control all these technological and biological parameters for a calibration by extracting the reference sample directly on the forage harvester.

Solution

The spectrometer CORONA 45 VISNIR, containing a diode array as spectral sensor and produced by the CARL ZEISS company, is used both in the laboratory and on the forage harvester. There are two principles for the integration of the spectrometer into the harvester. One the one hand it could be integrated as a bypass-system, on the other hand it is possible to measure the moving material directly, preferably at the spout of the harvester [1, 2, 3]. The extraction of only a part of the moving material using the "bypass principle" raises the question about the representativeness of the sample. Therefore measuring the moving material directly is the preferred principle in this research project.

An effective calibration is guaranteed by the defined conditions in the laboratory at a downscaled test rig with minimised expense. This way offers the advantage that the variation of the plants - necessary for the development of the calibration - is sufficiently high. Factors, which affect the sample presentation, can be easier analysed and be varied under these conditions. This procedure makes it necessary to guarantee the transferability of the developed calibration models between the downscaled test rig and the farm machine. It requires the development of suitable transmission methods. Therefore in the focus of the investigations are the conditions of the material flow and the influence of varied machine settings and harvesting conditions on measuring results.

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Keywords

Near - infrared (NIR) spectroscopy, quality monitoring, site-specific farming

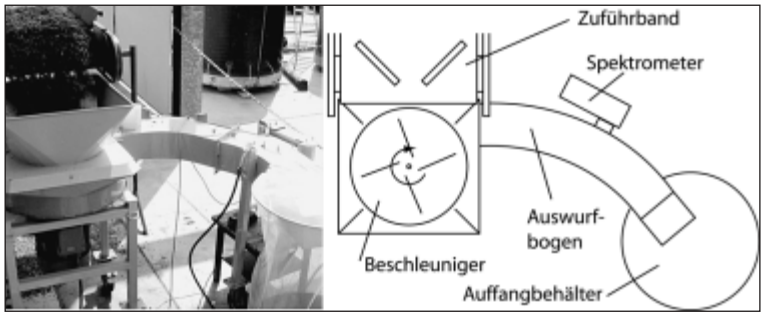

Fig. 1: Device for calibration of a NIR Sensor

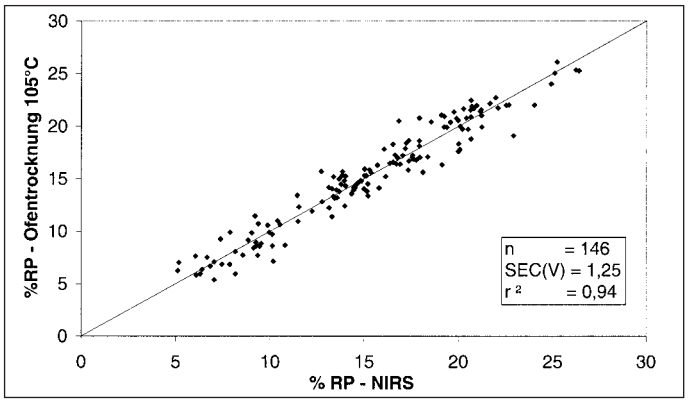

Fig. 2: Result of calibration on the protein content in wilted grass

Calibration in the laboratory

At the Federal Agricultural Research Centre in Braunschweig a test rig has been developed, with which harvested and chopped forage is accelerated and then passes a spout (*Fig. 1*). This accelerator copies the condi tions of measurement in the spout of the forage harvester. The interface between spectrometers and chopped forage is standardised. Thereby comparable conditions both for the measurement at the forage harvester and at the accelerator are guaranteed. The optimal position of the spectrometer along the spout of the accelerator was determined by photographing the flow of material with a high-speed camera. These investigations also have been realised at the forage harvester, in order to guarantee comparable measuring conditions. Basic requirement for developing a calibration is the generation of a sufficiently large sample set. The sample set must be distributed homogeneously over the entire measuring range which can be expected. This is ensured by arranging appropriate field tests in the Federal Agricultural Research Centre with different varieties of the forages grass, clover, red clover, alfalfa and maize for silage with different fertilisation strategies. While grass, clover, and alfalfa are harvested it is possible to give them different states of wilting. The material is collected immediately after cutting, is protected against rain and can be dried gradually. Subsequently the material is chopped. The maize is already chopped during the harvest and has to be cracked only. The samples are collected in a special container after passing the accelerator. Three test samples are extracted from this container for the reference analysis. The reference analyses are carried out in the laboratory of the Federal Agricultural Research Centre. The accuracy of the calibration is represented for protein in *Figure 2*. To transfer the calibration models to the conditions at the forage harvester, global models can be created to consider variation of different spectrometer and of sample presentation. This method is complex. Here it is checked, if using standardising functions can be an adequate method. The basics of this research are experiments, where the same samples were used in the forage harvester and in the laboratory accelerator. In this way the different spectrometers used in the project were deployed, too.

Properties of the material flow in the forage harvesters

Investigations in a test rig at the University of Technology in Dresden focus on the properties of the forage flow, where the conditions in the spout can be reproduced.

For the application of NIRS forage flow separation is of interest. The spectrometer reflects the light at a measuring spot at the surface of the forage flow with a diameter of 20 mm. Because of the forage flow, a small strap of the forage is measured by the spectrometer. To find an answer to the question, if the scanned forage is representative for the whole flow of forage, a testing device was developed. This device divides the flow horizontally or vertically in the flowing direction by using hydraulically operated baffles. Just like in reality at forage harvesters, the spout can be adjusted backwards or to the right or left side. In the trials a mixture of maize silage (40 - 50 % dry matter) and maize kernels (87 % dry matter) was used. The throughput and the ratio of maize kernels to maize silage were varied. The samples from the divided flows were dried in a drying oven. This procedure allows to asses possible separation in the forage flow with respect to water contentor fractions parts with different water content. Therefore the partial flows were compared with the entire flow.

A separation is proven only horizontally across the flowing direction, when spout is swivelled to the side. There was no significant vertical separation. These results have to be confirmed in field tests.

Results

To collect samples from the forage flow in a forage harvester, which are identical to the forage measured by the spectrometer, a sampling system was developed. A baffle leads the entire flow temporarily in a basket after passing the interface of the spectrometer. Baffles and spectrometer are controlled by the same notebook via CAN-Bus to ensure a precise correlation between sample and spectra.

The application of the calibration from laboratory to spectra of samples of grass (first cut 2004) from field resulted a SEP 5% for dry matter after correcting the bias. Assessing this result it must be considered that the variation of the estimated samples is not yet included in the model. Other reasons for the big SEP are the different spectrometers and the presentations of the samples in laboratory and at the forage harvester. Actually, methods to minimise these errors are currently being analysed.

Literature

Books are identified by •

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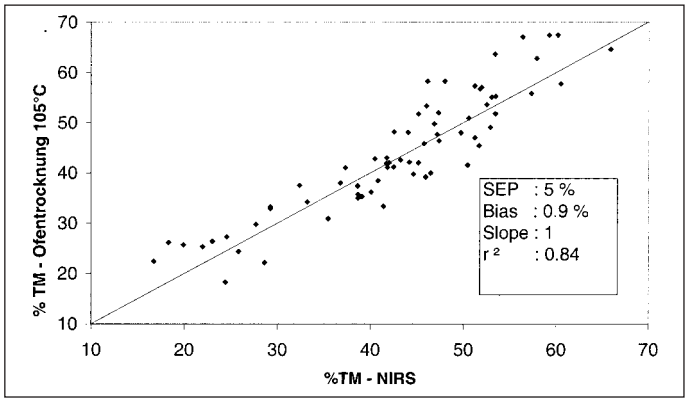

Fig. 3: Prediction of DM-content from spectra of the forage harvester using the calibration from the laboratory