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Influence of Sample Presentations on Quality Measurement using NIRS on Forage Swathes

Comprehensive and precise geo-referenced quality measurement data at forage harvest is the basis for optimised animal feeding, site specific fertilising and avoiding storage losses, as well as increasing the forage quality. For quality measurement Near Infrared Spectroscopy sensors can be used. However, unlike under lab conditions, the parameters for sample presentations under field conditions are instable and are fluctuate widely. Through making experiments on a specific test bed, the influence of changing measurement conditions on measured spectra was investiga-

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Keywords

Forage quality, Near Infrared Spectroscopy (NIRS), sample presentation

Literature

Literature references can be called up under LT 06216 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Using site specific farming to optimise the cost-benefit ratio (economical goal) and to increase the environmental sustainability (ecological goal) [1] requires the acquisition of many process parameters. In doing so, it is necessary to measure, process and evaluate these parameters in real-time enhancing the process quality.

To date, systems recording data about the quantity and the quality of materials predominantly were tested and partially implemented on combine and forage harvesters [2, 4]. Up till now, quality measurement in forage crops is tested and used on small experimental harvesting systems [5]. But on common farm forage processing chains, sensor-based measurement systems for site specific quality information are not provided so far. Implementing this technique can help to decrease forage material losses, which are estimated between 5 to 30 percent (for forage and hay) [7]. The knowledge of detailed quality information in all steps of the forage processing chain (mowing, harvest, storage and feeding) can be used to minimise losses and to increase the efficiency and quality of forage production.

Measuring quality data in lab analysis, Near Infra-Red Spectroscopy (NIRS) is applied increasingly [3]. Adjusted hard covered and water proofed NIRS-sensors are particularly suitable for the installation on mobile harvesters. Thus NIRS sensors were already integrated in combine and forage harvesters.

[6] describes the on-field analysis as a quasi-continuous measurement with an automatic sample feeding. This way, the analysing method is brought to the material - not vice versa – to get high-frequent quality information of many samples in a short time period. An additional benefit of this method is avoiding as well sampling failures as samples age.

Near infrared spectroscopy (NIRS) and sample presentation

First of all, in-field NIRS-sensors detect diffuse reflection of a sample as spectra information by an opto-electronical measuring method. Using this spectra information in a mathematical model, quality parameters – mainly substance contents – of the material can be estimated.

The quality of sample conditioning and the way the sample is presented to the sensor is named sample presentation. It is a central influencing factor of the accuracy estimate and for this reason on the error of measurement as well.

In labs sample conditioning is done by defined measurement standards. This means that the sample presentation is standardized. Bringing the NIRS method to in-field processes, the preliminary purification, homogenization or drying of the sample material is mostly impossible. In fact, new additional sources of irritation such as variations in the intensity of light, temperature or humidity occur. All these disturbing factors have to be cleared by a real-time standardizing of sample presentation (technical approach while sampling) or by an elimination of influences in the value estimation model (mathematical approach after sampling).

Using mobile NIRS systems on harvesters with bypass pre-condition, a higher quality of measurement by a more homogeneous sample presentation is expected. But bypass systems may potentially strongly interfere with the process technique. A mechanical problem in the bypass-system can endanger the application-safety of the whole harvesting process.

Without a bypass, the NIRS sensor systems have to measure at the standing crop or directly at the pre-conditioned material flow. At nearly all steps of the forage harvesting process (mowing, conditioning, swathing and harvesting) the forage is conditioned as a swath. Thus, realising a NIRS sensor system for on-swath quality measurements can be used very effective and flexible.

Approach

The implementation of a prototype for geo-referenced online quality data measurement

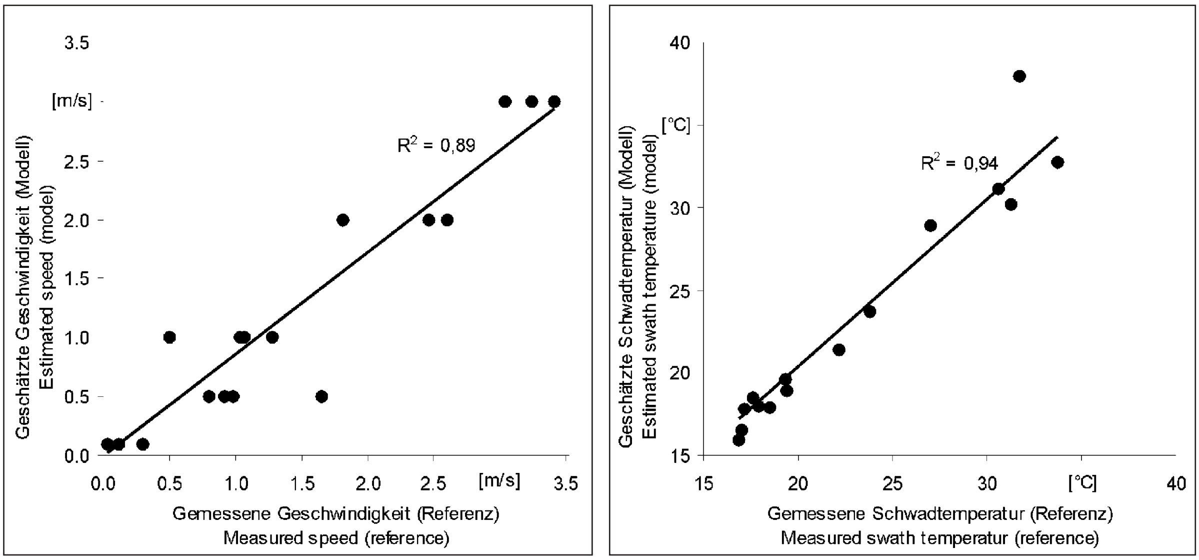

Fig. 1: Measured reference and estimated values from spectra of relative sensor speed and swath temperature

at forage swathes shall be based on a four-stage concept:

1) Determining of the general applicability of NIRS acquiring quality information of forage.
2) Analyzing the influence of a varying sample presentation at continuous swath measurements on the measuring results.
3) Adopting estimation models to quantify the substances of content in the wind-rowed forage. The goal is to eliminate disturbing environmental effects by mathematical corrections, based on additionally measured or calculated parameters.
4) Logical and technical integration of this new measuring method "NIRS on swathes" in the harvest process chain.

The general applicability of the NIRS-method measuring the forage quality (step 1) is already confirmed and well-introduced in labs.

The focus in this paper is the migration-effects from the lab to the in-field conditions (step 2). Especially the individual influences of separate parameters of the sample presentation (actual state of the forage, material position related to the sensor, light, temperature, humidity and relative speed) were checked. To get a reliable spectra information, reproducible test bed experiments were conducted. The results of the experiments were analysed with existing calibration models, calculating forage quality on the basis of NIR-spectra.

Developing new calibration models specialised for "mobile NIRS on swathes" (step 4) is required, the task for future projects. As part of this, also the implementation of an in-field prototype measuring system must be carried out.

Results

At first, a suitable test bed was developed to ensure the reproducibility and the accuracy of the simulated in-field measurements. In this test environment, a NIRS-sensor (ZEISS CORONA 45 NIR) was guided in repeated experiments over a swath, where the relative speed as well as the surface pressure were controlled. For these first experiments, the swath was simulated by a set of small hay or straw H.D.-bales because of the easier handling (maintains surface texture, only a minimal change of substance of content).

Additionally to the spectra, the following six environment parameters of sample presentation were acquired during each run of each trial:

- Relative speed between sample material and sensor unit
- temperature of the ambient air
- temperature of the swath surface
- humidity of the ambient air
- disturbing light irradiation (sunlight)
- material type and its way of to be stored

The data were analyzed with the software WINISI (developed by InfraSoft International). On base of the data, six estimation models were generated, each with all spectra data and focussed on calculating the values of one of the six environmental parameters. The significant effect of one environmental parameter is verified, if the estimation model based on its NIRS data is able to forecast the quality and the quantity of its effect in a backwards way out of one spectrum. Within the model, by a multivariate regression method, correlations between the measured environmental parameters (e.g. the temperature of the ambient air) and the spectra information are searched for. Using the correlations found, environmental parameters can be estimated using the model. For model validation the measured parameters as well as the estimated parameters are compared using the regression coefficient.

Figure 1 shows the regression coefficient as a statistical ratio and the xy-plot for the graphical illustration of two selected parameters "relative speed between sample-material and sensor-unit" and "temperature of swath surface."

All parameters of sample presentation show a correlation coefficient higher than 0.94, except the parameter "relative speed of the sensor-unit" (0.89). There, due to the strength of the dominant water interference, specific sections of the spectra correlate with the strength of the parameters "humidity", "temperature of the ambient air" and "temperature of the swath surface". This explains the significant influence of these three parameters of the sample presentation on the spectra.

Conclusions

The described experiments show the significant influence of the sample presentation parameters on the measured spectra. But further tests have to ensure the relevance of these significant influences before starting the developing of a suitable in-field calibration model. It has to be verified if these significant influences also have disturbing effects on the accuracy of model-estimated In addition to the environmental parameters also quality parameters such as the dry matter content and other substances of the swath material have to be collected. Validation of existing calibration models for substance of content estimation will show the relevance of varying environment influence during swath measurement.