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Constituent determination of crops in the round baler

Knowledge about value-giving ingredients in crop products becomes more and more important in agriculture. An accurate determination of the constituents during the harvest can help making decisions regarding the harvest strategy, storage life and quality classification of products on site. So far there are no practical possibilities to capture all important ingredients of plant material on agricultural machines during harvest. Therefore, bench tests were conducted on the basis of near-infrared spectroscopy with grass, wilted grass and hay. The obtained results provide a well-founded basis on which further analyses, especially with the objective of the application on the round baler, are based on.

Keywords
Round baler, constituent determination, moisture detection, near-infrared spectroscopy, NIRS

Abstract
Landtechnik 66 (2011), no. 3, pp. 180–182, 4 figures, 5 references

Owing to the advancements in genetic engineering and the related increase of performance in animal husbandry, the requirements placed on roughage quality in agriculture have risen substantially. The quality of forage and silage is determined, for example, by its content of dry matter, crude protein, crude fibre, energy, water-soluble carbohydrates or its buffering capacity. These values depend on the composition of the wilted crop stored in the clamp as well as its process of fermentation. For the farmer to positively influence the production process, the constituents must ideally be available at harvest time. Since the dry matter content and the quality parameters of the crop are subject to significant fluctuations, a random sampling of the crop cannot deliver any conclusive results [1; 2]. Therefore, a sensor is required which continuously and with no further loss of time, monitors the content of moisture and constituents during harvest. This is the only way to make quick and correct in-situ decisions, which also contributes to the optimisation of the agricultural work process.

In the past, moisture monitoring in high-moisture crops such as wilted forage were impaired by the amount of measurement errors caused by the equipment [3; 4]. A satisfactory solution to this problem was first found in near-infrared spectroscopy (NIRS), which today serves as a means for determining the moisture content in the forage harvester during green forage harvest [5]. Another advantage of NIRS is that the content of other constituents (e.g. crude protein, crude fibre, water-soluble carbohydrates) may also be monitored.

Therefore, the goal of the authors' research was to develop an NIRS system for round balers which monitors the content of moisture and value-giving constituents during harvest. This report describes the operations and results regarding moisture detection.

Materials and methods

Equipment and test setup

The work began by developing and building a test rig used to simulate the material flow within a round baler. The multipurpose design of the test rig permitted the examination of both bulk and baled crop materials. The variety of its operating modes served to emulate and analyse different mounting locations within the round baler.

The base of the test rig is a steel frame with a centred wheel rim and tyre mounted on a pivotable stub axle. Fixed to the rim is a screen printing plate used to accommodate the bale (**figure 1**). The rotation of this platform is enabled by a friction wheel and a hydraulic motor driving the tyre. The rotating speed of the platform can be adjusted using the hydraulic drive unit.

Measurements conducted on round bales can be done tangentially (**figure 1**) or radially (**figure 2**).

The measuring head can be moved on its support in both radial and tangential setups, enabling the bale to be measured along almost its entire round and flat sides. The pressure pushing the measuring head against the bale can be adjusted using appropriate ballasting weights. When measuring bulk crop, a ring-shaped bin is mounted on the platform instead of the round bale (**figure 3**). In order to compress the crop as it would be done in front of the bale chamber, an adjustable guide plate with a ballasting weight is mounted in front of the sensor head.

The crop moisture measurement was conducted using an NIR spectrometer with a separate measuring head. The spectrometer has a wavelength range of 400 to 2,200 nm, which extends into visible range.

Sample materials and test procedures

All of the sample materials were taken from test plots at Dresden University of Applied Sciences (HTW Dresden). The moisture testing was carried out on fresh cut grass or rye grass, wilted grass or rye grass and hay to ensure the availability of a broad moisture range. The measurements were conducted over several months, incorporating different vegetation conditions in the examinations. Identical modalities were maintained in all processes and within the test setup, ensuring consistent conditions for measurement.

Before the measurement, the sample materials were cut and wilted. Then, depending on the configuration of the test rig, they were either baled with a round baler or used as bulk crop. The measuring head was pushed against the bale or bulk crop at a predefined pressure, then the test rig platform was set into rotation. The sensor unit was connected to a computer to facilitate recording of the spectra. A dedicated software was used to trigger and control the measurements and to record the spectra.

In each measurement the bale or bin were rotated by two full rotations in an attempt to scan the largest possible amount of material in the measuring profile. Therefore, one measurement consisted of several partial measurements with a variety of spectra in a seamless sequence.

After each measurement, a sample of the crop was taken to determine the crop moisture reference content using the standard oven-drying method. Then the remaining plant material was removed from the test rig, spread on a flat surface, left to dry briefly, and measured again. The entire procedure was repeated a number of times. The gradual process of drying enabled the analysis of a broad moisture range.

Data evaluation

The spectra created in the tests were averaged using the Unscrambler® statistics software (by Camo) while the reference values from the drawn samples were assigned to their respective spectra. Also in use were several data pre-treatments (e.g. scatter correction) and an outlier elimination. Then the calibration methods and statistical measures were calculated, e.g. Standard Error of Calibration (SEC) and Standard Error of Cross Validation (SECV), on the basis of Partial Least Square Regression (PLS). Validation of the values was done by using a 10 % randomised internal validation. An external validation was not conducted due to the low number of samples.

Results

The results of the moisture measurements in bulk crop are set out in **figure 4.** The calculations were performed using approximately 300 samples after data pre-treatment. For the values presented, the calculated SEC was 2.81 % and the SECV

Fig. 1

Assembling of test rig with tangential sensor mounting

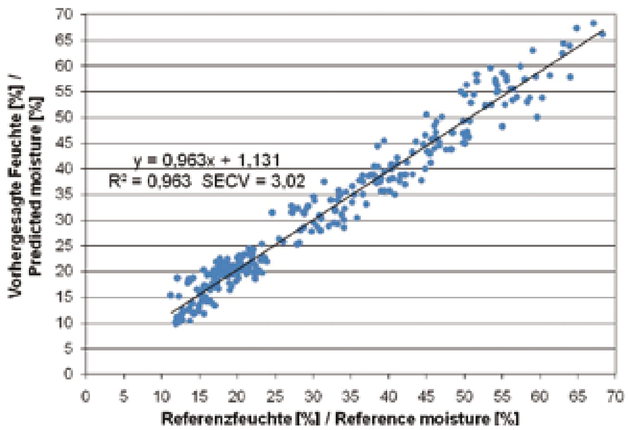
Fig. 2

Measuring head installation for radial measurements on bales

Fig. 3

Test rig for measurement of bulk crop

Fig. 4



Predicted moisture contents as a function of the reference moisture contents

was 3.02 %. The coefficient of determination (R^2) is 0.96. The undervaluation (bias) in the samples was very low. The evaluation of the bale measurement results, however, yielded higher discrepancies.

Conclusions

In spite of the low number of samples and technically immature calibration methods, the results nearly reach the accuracy level of on-line moisture measurement in the forage harvester (approx. ± 2%). The measurements benefit from the conditions during examination of the bulk crop: the plant material passes underneath the sensor at a consistent speed and with no change in direction. This is different in the tangential measurement along the round side of the bale. Due to the corrective movements of the sensor head caused by the uneven surface of the bale, there are fluctuations in the contact pressure between bale surface and sensor head. In extreme cases, there may be interferences by ambient light distorting the measurement. This is not the case when analysing the flat side of the bale, which is even and smooth. Nonetheless, the results obtained here are somewhat less favourable. This may be due to the structure of the material, as the rotation of the bale and the friction of the crop on the inside of the bale chamber cause the stems to align, whereas in bulk crop the stems are positioned at random. This negative impact may probably be reduced by further expanding the calibration methods. Another critical point is the assembly of the measuring head on the bale chamber side wall. In addition to the supposed decrease in measuring accuracy, it must be noted that the measuring head is not constantly in contact with new crop. The baler follows a serpentine path over the window in an attempt to provide even feeding of the bale chamber (in favour of a cylindrical bale shape). This causes parts of the material already measured to be scanned again. Therefore it is preferable to centre-mount the sensor head in front of the bale chamber. The impact of ambient light, debris and vibrations on the measurements is yet to be clarified.

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Acknowledgements

The project described in this report was supported with funding from the German Federal Ministry of Education and Research under the project number 1722X09. The author is responsible for the contents of this publication.