NIRS Sensor controlled total-mixed-ration for nutrient optimized feeding of dairy cattle

W. Büscher, P. Twickler, C. Maack

Institute of Agriculture Engineering, Livestock Technology,
University of Bonn, Germany

J. Marquering

B. Strautmann & Söhne GmbH u. Co. KG, Bad Laer, Germany

M. Müller

m-u-t AG, Wedel, Germany

Abstract

Feed mixer are used to feed grass and maize silage together with other components in one ration. It can be used in combination with a transponder system for concentrated feed as well as for feeding of a total mixed ration. The implementation of a measurement system based on NIR-spectrometric sensors to measure DM-content and other nutrients (XP, XL, and XF) should result in a more precise nutrient adjustment of the ration.
To calibrate the measurement system spectra of many different silage samples are taken offline and analysed by wet chemistry. The goal is a good calibration model which can be used in the online measurement system. The NIR sensor and the spectrometer have been integrated in the mass flow of the self-propelled feed mixer. The calibration model is the start point for the online measurement at the feed mixer. The calibration models were validated in online and offline measurement. The tests have been completed and the validation shows good results.

Keywords: Total-mixed-ration, Near infrared spectroscopy, Calibration model, Self-propelled feed mixer, Feed ration improvement

Introduction

The exact regulation of dry matter, energy and ingredients in green fodder has a large advantage in the ration optimization of economical animal nutrition. The production of in-house fodder is connected with varying contents of dry matter,

energy and ingredients in the individual green fodder of each farmer. Even in one silo the dry matter content of the crop differs in a range more than 5%. Control of the feed values concerning the investigations of samples does not fully capture the often high variation in the feed stock. A permanent determination of these parameters can be ensured by the integration of near-infrared spectroscopy (NIRS) in the feed delivery and storage technology.
The near infrared spectroscopy (NIRS) is used in many agricultural ranges. It is a fast and not destructive method to determine substrate-specific characteristics (Stockl et al., 2011). The documentation of contents in case of grass silage and hay in round bales was likewise accomplished on basis of NIRS successfully (Walther et al., 2011). In comparison to the NIRS- measurement in self-propelled choppers the database is less considerable.

Figure 1: NIRS in the mass flow of a self-propelled chopper

Former field tests NIRS in self-propelled choppers came to the conclusion that the DM content can be predicted with only small deviation lower than 2% (DLG 2010, DLG 2013).

Main object of the project "SenToMiRa" is a nutrient optimized total mixed ration for feeding dairy cattle. By installation of a near infrared sensor (MUT-Group) on the material flow at a self-propelled feed mixer wagon (STRAUTMANN). It will be tested to fill and analyze the individual ration components according to the specific needs of the respective performance group. Particularly the in-house basal feed can be analyzed real time regarding the content of dry weight, nutrients and energy content. The adaptation of the ration has to be done by balancing the components depending on the actually measured values of the different parameters. The parameters of the desired ration should be nearly consistent at every feeding time. So with the developed technology it should be ensured that at each time and each feeding place, a qualitatively homogeneous TMR can be offered. This TMR is adapted to the performance level and specific ration requirement of the respective group of dairy cattle.

Material und Method

For a precise measurement of fodder nutrients it is important to have a calibration model based samples of each crop. To get a good calibration model 400 - 500 samples are needed. The samples are measured with the near infrared sensor and connected with the measured nutrients of wet chemistry analyzes. In the project to calibrate the NIRS the first measurements were executed using an offline method by a developed turntable. Figure 2 presents the turntable for simulation and

Figure 2: Turn table with NIRS (Landtechnik Bonn) and Self-propelled feed mixer (Strautmann, 2013)

the self-propelled feed mixer wagon where the near infrared sensor was installed. With a modification the NIR sensor is positioned under the fodder samples. Through this process it was simulated the silage-taking from the silo feed off into the fodder mixer. Reference measurements of dry weight, nutrients and energy content with wet chemistry analysis in the laboratory complete the components for the calibration. The wet chemistry analyses are performed by a certificated laboratory (LKS Landwirtschaftliche Kommunikations- und Servicegesellschaft mbH). By the measurements different samples of each silo surface were taken. These analysis results were used for the basic calibration. In the next step the near infrared spectroscopy system in the material flow on a self-propelled feed mixer wagon was installed.
Figure 3 shows the NIR sensor in the cutter of the self-propelled feed mixer wagon.

Figure 3 near infrared sensor head (left outside, right in side)

Results

Since 2012 the machine has been tested at the experimental and educational center agriculture house Riswick in Kleve. Everyday round about 500 cattle has been fed. Also samples were taken from the silages for the NIR measurements to get more reference date to improve the calibrations of grass silage und maize silage.

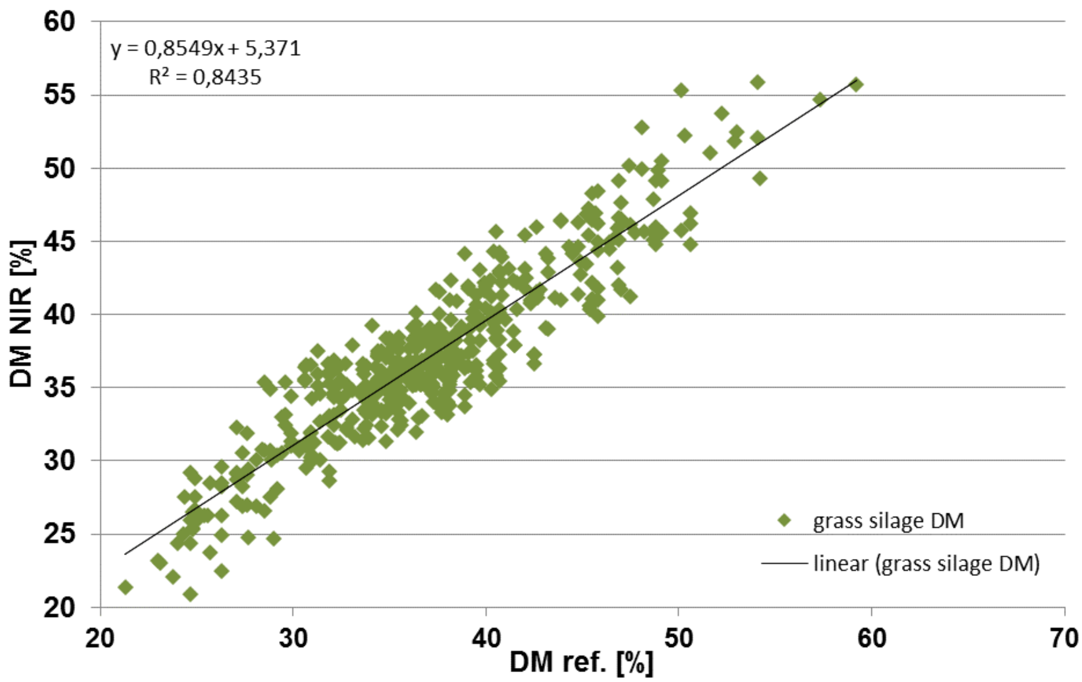

Figure4: Modell „grass silage"; linear regression of DM-content, n= 520

Everyday round about 500 cattle has been fed. Also samples were taken from the silages for the NIR measurements to get more reference date to improve the calibrations of grass silage und maize silage.
Figure 4 shows the dry matter values measured to calibrate the NIRS in case of grass silage. The x-axis gives the reference of DM measured by laboratory. Implemented are the bisecting line across the origin and the linear regression of the scatterplot. The calibration consists of 520 data sets. The RMSECV across all samples is 2.44, which means the mean deviation of the crass validation in [%]. The RPD based on RMSECV is at 2.53 and the SECV 2.81. The SECV is calculated by the RMSECV and the BIAS. The BIAS of 1.93 shows the systematic deviation to the mean value. The calibration has values from 21 up to 59% DM and gives the opportunity of a DM prediction in this Range. To improve the calibration model for grass of low and high DM content, more wet and dry samples to enlarge the data set would be helpful.

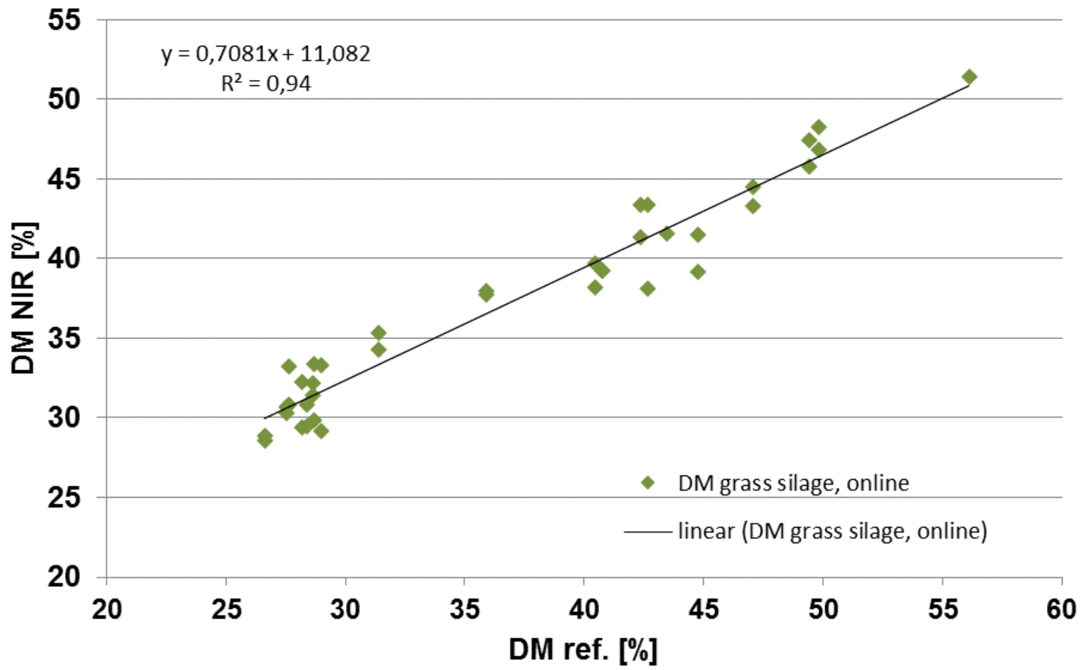

Figure 5: Modell "grass silage"; linear regression of DM-content, Online, Test-Set-Validation, (n=3)

To validate the calibration model of grass silage at the online measurement of the feed mixer wagon 38 samples were used. The silage had DM contents from 26.6 up to 56.1% the arithmetic mean of the reference was 36.8%. The arithmetic mean of the NIRS measurement was 37,1% and the absolute deviation was in average 2,6%, which is 0,5% more than the average deviation of the turn table system with similar samples. The standard deviation is 2.96% and the stability index 0.94. The presentation of the sample to the sensor in the turn table is more consistent compared to the mass flow at the cutter of the feed mixer wagon. This might be one reason because the measurement of DM is more precise.

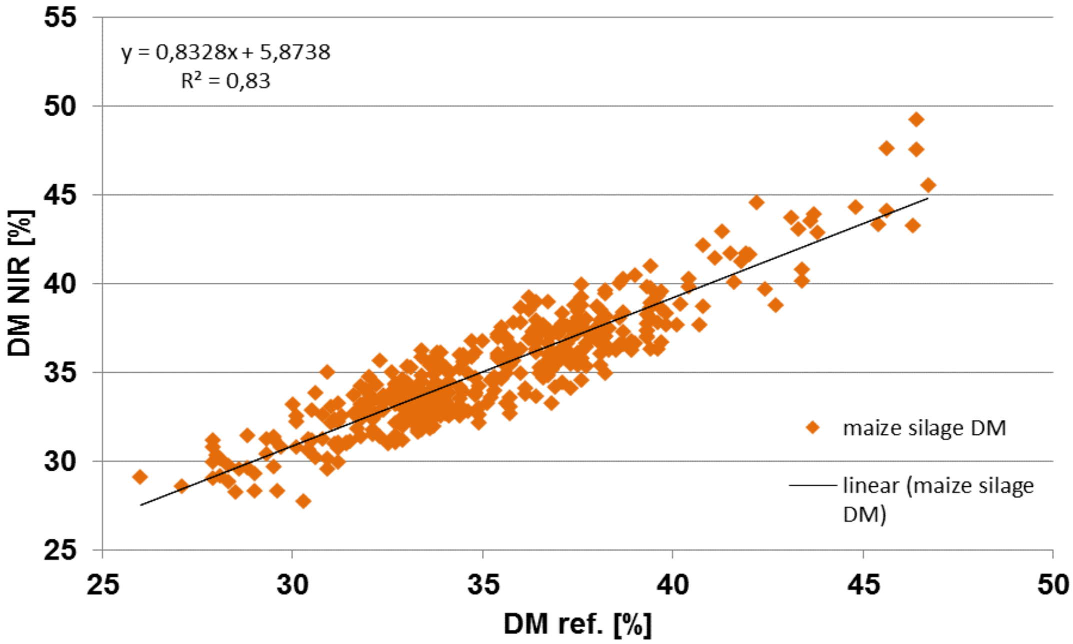

Figure 6 Modell „maize silage“; linear regression of DM-content, n=433

Figure 6 shows the dry matter values measured to calibrate the NIRS for maize silage. The linear regression is implemented in the scatterplot consisting of 433 data sets. The RMSECV across all samples is 1.46. The RPD based on RMSECV is 2.43 and the SECV 1.04. The calibration has DM values from 26 up to 46.7% and offers a DM prediction in this range. The main part of the calibration data is in the range from 30 to 40% DM, which is the range of most maize silages in practice.

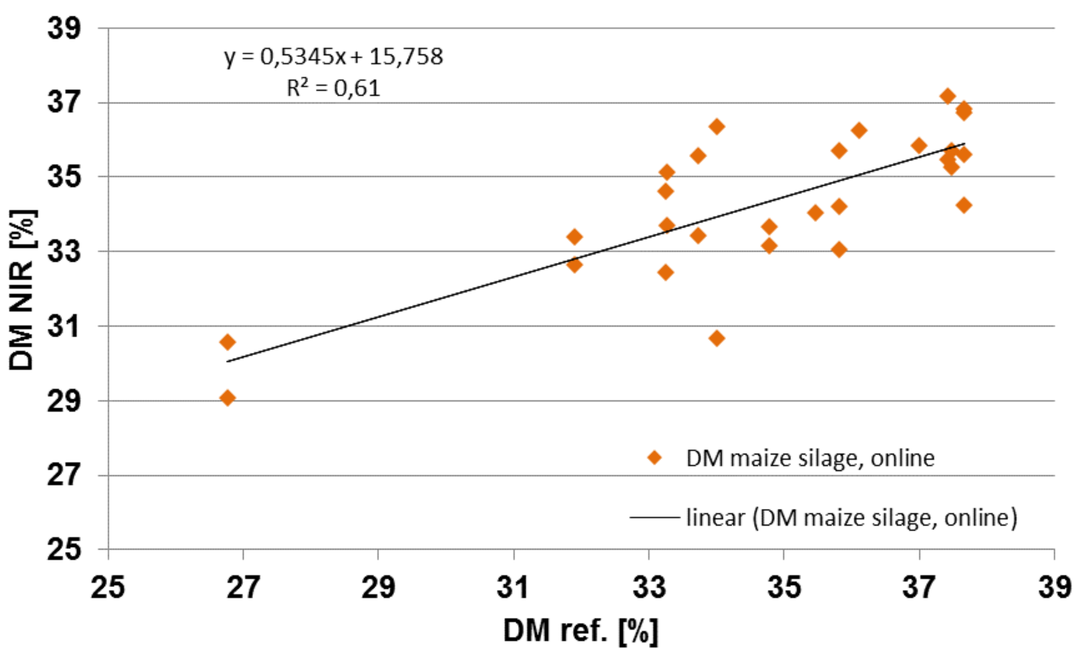

Figure 7: Validation “maize silage“; linear regression of DM content, Online, Test-Set-, n=28

To validate the calibration model of maize silage at the feed mixer wagon 28 samples were used. The silage had DM contents from 26.8 up to 37.7% the arithmetic mean of the reference was at 34,7%. The arithmetic mean of the NIRS measurement was 34.3% and the absolute deviation was in average 1.6%. The standard deviation is at 1.8%. The stability index with 0.61 considerable lower than in case of the offline validation. The distribution of DM contents in the test set was between 32 and 38%, only two samples had low DM contents of 27%.

Table 1: Calibration parameters of TM and nutrients (grass silage)

Parameter	n	RMSECV	RMSEC	RPD (RMSECV)
DM [% FM]	520	2,44	2,07	2,53
XA [% DM]	490	1.47	1.33	1.53
XP [% DM]	477	0,97	0,59	1,3
XF [% DM]	479	0,92	0,66	1,67
XL [% DM]	479	0,4	0,3	1,32

Table one shows the statistic parameters of the Calibration in case of grass for DM, XA, XP, XF and XL. Next to DM the XP content is of interest to adjust the ration in order to the actual values of the silage. The grass silages had contents from 8.5 up to 15.7% with an arithmetic mean of 12.8%. The NIRS measured XP content was from 10.7 to 16.1%. The average absolute deviation was 1.4% and the standard deviation 1.58%. 79% of the samples were in a ±2% range of tolerance. The RPD (1.53) of the validation is lower than for DM and shows in comparison to other applications the need of calibration enhancement.

Table 2: Calibration parameters of TM and nutrients (maize silage)

Parameter	n	RMSECV	RMSEC	RPD (RMSECV)
TM [% FM]	433	1.46	1.17	2.43
XA [% DM]	389	0.36	0.30	1.21
XP [% DM]	396	0,92	0,79	1,36
XF [% DM]	395	1,28	1,09	1,12
XL [% DM]	405	0,37	0,31	1,61

In table two the parameters of the maize calibration for DM, XA, XP and XF are shown.

The XP content in the validation was 5.8 to 8.4 % with an arithmetic mean of 7.5%. The NIRS measured values were from 5.4 to 8.1, in mean 7.2%. The average deviation was 0.8% and the standard deviation 0.92%. 27 of 28 samples were in a rage of tolerance ±2% and 20 even below ±1%. The RPD (1.36) of the validation indicates, that the calibration has to be further improved to get more reliable results.

Conclusion

The integration of an NIRS measurement system at a self-propelled feed mixer gives the opportunity to get an actual information about the silage DM and the content of important nutrients. It is possible to measure the crops in the mass flow after the cutter. The precision of the prediction has to be further improved by enlargement of the calibration data. An additional effect may be reached by an improved crop presentation to the NIRS detector head. In future the measurement of DM and nutrients by NIRS direct on the feed mixer could be used in relation with a feeding test. This would help to answer the question how is the effect of a daily ration adjustment to the actual silage DM and XP content.

References

DLG (2010): DLG-Prüfbericht 5913 F, Harvest Lab – Feuchtemessung in Mais im mobilen Einsatz auf John Deere Feldhäcksler 7550i, Groß-Umstadt

DLG (2013): PB6168F/DLG-Prüfungsnr.:2013-374, Feuchtemessung in Mais Mobiler NIR-Sensor auf einem CLAAS Jaguar 960, Groß-Umstadt

Stockl, A., Oechser, H., Jungbluth, T. 2011. Online-Messung flüchtiger Fettsäuren in NawaRo-Biogasanlagen mittels NIRS. Landtechnik 66 (2011), no.3. Darmstadt. pp. 201-204

Walther, V., Heinrich, K., Wild, K. 2011. Inhaltsstofferfassung von Erntegütern in der Rundballenpresse. Landtechnik 66 (2011), no.3, Darmstadt. pp. 180–182