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# Determining forage maize dry matter content

## Application of high frequency electromagnetic fields

*With the measurement results from commercially available high-frequency equipment, the dry matter [%] of forage maize from different sources can be precisely measured under laboratory conditions. A satisfactory estimation without knowledge of sample weight and density is not possible with the applied equipment. Contrary to this it appears that a precise estimation of moisture content (g) is possible. The correlation between the actual and the estimated moisture content ran to r = 0.98 with varying sample weight and density when a regression equation was used on unknown samples.*

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### Keywords

Maize, yield mapping, DM content, radio frequency

In the last years there have been many promising concepts presented for the continuous estimation of fresh matter yields in forage. Different systems have also been presented for measuring dry matter content (DM), although no reports are available over satisfactory solutions.

Among the many available methods for determining DM, the high demands required when applying equipment in harvest conditions mean only a few systems can be considered. Of especial interest are methods which utilise the very different dielectric properties of water and organic mass.

Following promising results in limited preliminary trials with forage maize, and full experiments with greencrop [1], from using commercially available high frequency equipment, the work reported here was to test if this method enabled satisfactory DM estimations in a number of maize samples from various sources.

### Methods

During the forage maize harvest 2000 chopped maize from four areas was harvested. Fields 1 (variety Helix, KWS), 2 (Carrera, KWS), 3 (Palermo, KWS) and 4 (Palermo, KWS) belonged to two different farms and were harvested with different machines. The maize was immediately brought into the Institute for Agricultural Engineering, University of Göttingen and there spread out for drying under an „artificial sky“ [2].

Samples from this material were taken and portioned at regular periods. The portions were positioned in the application area of a recently presented [1] high frequency plant from the French manufacturer SAIREM (Lyon). There, a defined amount of power was applied until (as a result of machine-specific adjustment) no more performance was reflected. At this moment the parameters U (current between condenser plates), LP (load position), and TP (tune position), all automatically recorded by the high-frequency plant, were registered. The two last parameters are plant-specific figures presented by the regulating condition of the adjustment network. Following this, the dielectric material characteristics were not measured with this plant, the measured parameters had, however, a direct relationship.

The actual DM was determined through drying in a drying cupboard at 105 °C. The resulting evaluation followed through regression analysis. Here, the main question was to

*Table 1: Estimation of the DM content of chopped maize with various regression functions*

| | Measurement variants | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Sample weight (g) | 50 | 50 | 100 | 100 | 150 | 150 | 184 |
| Sample container (mm)[2)] | 91.0 | 174.5 | 91.0 | 174.5 | 91.0 | 174.5 | 174.5 |
| Sample density (g/cm³) | 0.095 | 0.026 | 0.191 | 0.052 | 0.286 | 0.078 | 0.095 |
| LP[3)] | -0.01 | 0.15 | 0.04 | 0.03 | 0.31 | 0.05 | 0.24 |
| TP | -0.01 | -0.01 | 0.08 | -0.02 | 0.01 | 0.15 | 0.26 |
| U | -0.01 | 0.11 | 0.13 | 0.05 | 0.37 | -0.01 | -0.01 |
| TP,U | 0.00 | 0.12 | 0.39 | 0.07 | 0.42 | 0.21 | 0.26 |
| LP, TP, U | -0.01 | 0.21 | 0.38 | 0.20 | 0.56 | 0.21 | 0.26 |
| LP, TP, U, LP TP $^{-1}$ | 0.15 | 0.23 | 0.39 | 0.24 | 0.59 | 0.21 | 0.28 |
| TP, U (quadrat) | 0.11 | 0.29 | 0.39 | 0.15 | 0.43 | 0.19 | 0.30 |
| LP, TP, U (quadrat)[4)] | 0.33 | 0.46 | 0.39 | 0.23 | 0.57 | 0.33 | 0.29 |

[1)] Precision after adjustments for the number of independent variables ($R^2_{adj.}$). Per variant was investigated 32 samples from farm 1 and 28 samples from farm 2.
[2)] Interior diameter of sample container (Teflon pipe)
Examples for the representative regression equations
[3)] Dry matter content = $\beta_0 + \beta_1$ LP
[4)] Dry matter content = $\beta_0 + \beta_1 LP + \beta_2 LP^2 + \beta_3 TP + \beta_4 TP^2 + \beta_5 U + \beta_6 U^2$

which proportion could the variance in DM be explained through the given measurement results.

At this point the results were presented which, with an applied power of 50 W, were determined with seven measurement variants within a DM range of 31.8 to 51.8%.

### Results

It was clear from the results of the regression analyses *(table 1)* that through including several independent variables the DM could be better explained than through simple regressions. A further improvement was achieved through the use of quadratic equations. In the technological sense it was meaningful that a higher density led to a better evaluation precision. However, there are exceptions to this. Here it has to be considered that a comparison of variants within the same sample mass is influenced by the size of the contact area between electrode and maize (container diameter). Where variants with the same contact area are compared, consideration must be taken of the fact that the variants in the larger sample containers were all only slightly consolidated.

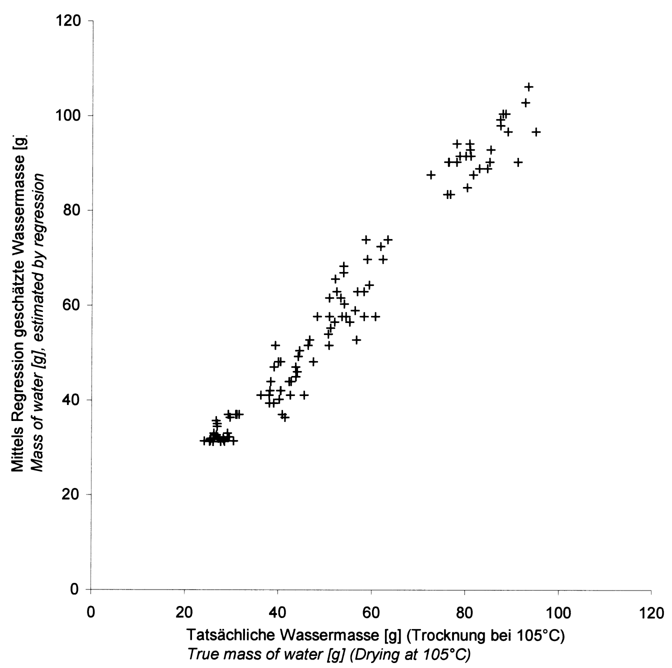
It did, however, remain clear that the resultant correlations did not satisfy the required demands for a dependable measuring system.

The differentiations applies in table 1 pertaining to various measurement variants were not able to be realised in practical harvest application. The DM investigation must take place independently of the material density and weight where the only known factors are transmission performance and size of application area. Because of this, the variants 1, 3, and 5 as well as 2, 4 and 6 were collated in a further evaluation step. Under these conditions the coefficient of determination fell still lower than that given in *table 1*. A satisfactory DM estimate appeared not to be possible with the high frequency equipment under these conditions.

It has already been mentioned that information would be given on promising applications for determining fresh material yield in forage production. When this factor is actually known then knowledge of moisture amount [g] would also give the DM [%]. The use of moisture amount as dependant variable led to a dramatic rise in precision for the described calculations for all variants. Building on this knowledge, the final evaluation step was to test whether exact estimation is also possible with unknown samples.

Data material was collated for this reason and investigated with the measurement variants 1, 3 and 5 with maize from farm 1. From this, a quadratic equation was calculated with U as independent variable and moisture amount as dependant variable. Finally the moisture amount in samples from farm 2 was evaluated with this regression equation. At the same time the data from the measurement variants 1, 3 and 5, as well as a further variant (75) not described here, were applied. *Figure 1* shows the result of this evaluation. With r = 0.98 the correlation between actual and estimated moisture amount was extraordinarily high.

*Fig. 1: Estimating the water content of maize for silage samples from farm 2 using the regression function on the basis of data from farm 1*





### Summary

The results confirm that the use of dialectric material characteristics offers a valuable method for rapid moisture content determination during forage maize harvest. Should such measurements take place independently of material density and weight, the use of the moisture amount as opposed to the DM content as measurement or estimate factor leads to a definite increase in precision.

According to the available results it appears possible with the presented methods to be able to estimate moisture content with sufficient precision, with a given calibration, even with unknown samples. Thus, first of all it should be possible to combine several sensors (fresh mass, moisture amount, temperature) in practical harvest application. Secondly, a continuous bulk evaluation should be possible when DM is known or is constant.

These results were probably not influenced by the fact that a complicated high-frequency plant with full automatic adjustment system was used. Even with an unsuccessful adjustment of the equipment to the material characteristics, mathematically valuable factors should be able to be found that allow a determination of the moisture content.


## Literature


[1] *Snell, H., B. Kulig, C. Oberndorfer, W. Lücke und H. Van den Weghe*: Einsatz hochfrequenter elektromagnetischer Felder zur schnellen Feuchtebestimmung in Silomais und Gras. 58. Internationale Tagung Landtechnik, 10.bis11. Oktober 2000, Münster

[2] *Snell, H.G.J., C. Oberndorfer, A. Kutz, W. Lücke and H. Van den Weghe*: A system for testing plastic film for bunker silage preservation – Design and preliminary findings. Journal of Agricultural Engineering Research 79 (2001), pp. 37 - 45