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Quality from corn for biogas production – calculation of specific methane yields

To develop a model for the prediction of specific methane yields of corn 258 corn samples were taken and analysed for their raw nutrients and their specific methane yields. An exponential model for the prediction of the methane yield of corn has been developed. The model was able to explain 50 % of the variance in the methane yields of corn samples. The model delivers a new approach for the prediction of the specific methane yield of corn. It differs totally from available models using mainly the method of multiple linear regression. However the new model is also not able to explain the specific methane yield completely.

Keywords
Corn, biogas production, methane yield

Abstract
Landtechnik 67 (2012), no. 5, pp. 354–357, 2 figures, 3 tables, 23 references

The production of biogas from energy crops in Germany has increased steadily during the last 10 years. Due to its high biomass yields and the established production system corn (*Zea mays* L.) has an outstanding position within the energy crops. Because of the high demand for feedstock chopped corn is also traded. The basis for payment is mainly the dry matter yield, other criteria, like Quality, are often not considered, not least because they are unknown. Therefore the present study investigated, if the specific methane yield of corn can be calculated based on the raw nutrients. Several authors investigated the relation of methane yields with raw nutrients during the last years. Amon et al. [1–4] and Kaiser [5] calculate the methane yield using a linear regression, while Weißbach [6] calculates specific methane yields based on fermentable organic matter. He substracts raw fibre as not digestable from the digestable organic matter and assumes the rest is fermented to methane. None of the models can predict the methane yield in an absolutely reliable way, Weißbach [6] gets the most reliable and feasible results. The current models were evaluated based on the available data. Afterwards a new model to calculate specific methane yields was customized.

Material and methods

To analyse various specific biogas yields different varieties of corn were chosen, differing in terms of their ripening group (early, middle early, middle late, late, very late). The ripening types varied strongly with FAO-numbers from 160 to 500, the variety types represented types with dry-down, harmonic and stay green behaviour. **Table 1** shows a summary of the varieties used within the different classes. A total of 76 varieties has been used.

From all varieties samples have been taken at different stages of maturity. The samples were chopped and dried. They were analysed for their biogas- and methane yields using the Hohenheimer biogas yield test (HBT) [7] and for their raw nutrients using the guide lines of VDLUFA [8].

Results

The basic population of the data to investigate a reliable model should show a maximum distribution. **Table 2** shows the variance of parameters in the used material. The tests for normal distribution suggest a good distribution of the data.

Table 1

Number of varieties of each type used

Sortentyp *Variety type*	Reifegruppe/*Ripening group*				
	Früh *Early*	Mittelfrüh *Middle early*	Mittelspät *Middle late*	Spät *Late*	Sehr spät *Very late*
Dry down *Dry down*	4	3	6		
Harmonisch *Harmonical*	8	10	12	4	2
Stay-green *Stay-green*	1	2	6	1	

Table 2

Variation of data used for modelling methane yields

	Minimum *Minimum*	**1. Quantil** *1st Quantile*	**Median** *Median*	**Mittelwert** *Mean*	**3. Quantil** **3rd Quantile**	**Maximum** *Maximum*
XA	2,82	3,34	3,55	3,72	4,00	6,08
XS	15,99	30,44	33,87	33,71	37,67	43,70
Elos/*Esom*	55,05	67,89	70,53	70,38	73,24	78,63
XF	14,49	17,57	18,60	18,86	20,46	27,08
XP	5,40	6,21	6,63	6,91	7,29	9,94
XL	1,31	2,98	3,38	3,24	3,79	4,86
XZ	1,68	4,61	5,32	5,39	6,40	9,85
ADL	0,78	1,45	1,76	1,82	2,21	3,53
NDF	36,09	42,00	43,62	43,92	45,61	54,58
ADF	17,19	21,11	22,36	22,56	24,17	31,24
IVDOM	70,30	74,51	76,15	76,18	78,00	81,58
Methanertrag *Methane yield*	0,30	0,34	0,35	0,35	0,35	0,38

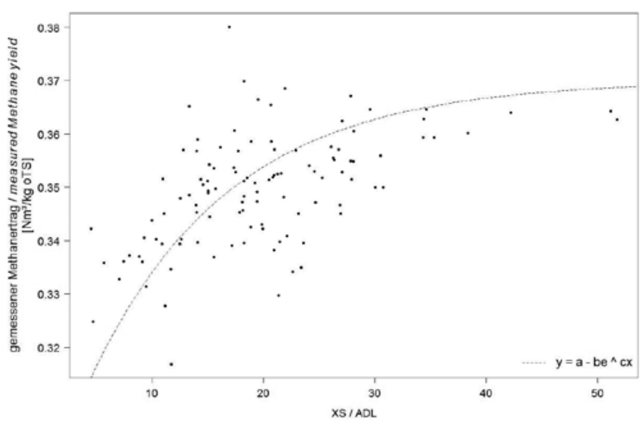
XA = Rohasche/*crude ash*, XS = Rohstärke/*crude starch*, Elos = Enzymlösliche organische Substanz/*Enzyme soluable organic matter*,
XF = Rohfaser/*crude fibre*, XP = Rohprotein/*crude protein*, XL = Rohfett/*Ether extraxt*, XZ = Rohzucker/*crude sugar*,
ADL = Säure-Detergenzien-Lignin/*acid detergent lignin*, NDF = Neutral-Detergenzien-Faser/*neutral detergent fibre*,
ADF = Säure-Detergenzien-Faser/*acid detergent fibre*, IVDOM = In-vitro-Verdaulichkeit der organischen Substanz/*In-vitro digestibility of organic matter*

Model for the prediction of specific methane yield

First step was to evaluate current models based on the collected analyses. Since none of the model delivered a satisfying result, several linear models have been developed, being also not satisfying. Therefore further investigations were done, until a new, non-linear correlation between the methane yield and the ratio of crude starch and lignin could be figured out (**Figure 1**).

Calculation of methane yield with this model, using two independent test sets, resulted in a corelation of 0.515 between calculated and measured methane yield. The range amounts 0.51 to 0.52. As an example the result of the cross validation with two data sets is shown in **Figure 2**.

Fig. 1



Relationship between ratio XS : ADL and the observed methane yields

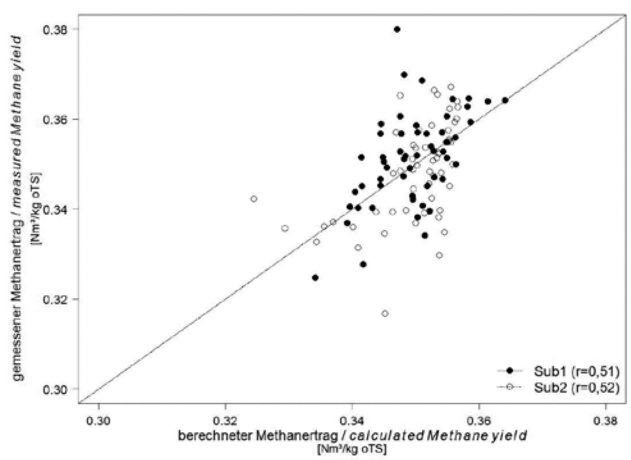
Discussion

The determined model uses the ratio from crude starch and lignin. The model can be distinguished basicly from other models that are mainly determined by linear regression.

Lignin is a for microorganisms undigestable component. It mainly influences the digestibility of material containing lignocellulose [9]. This component is set to the ratio to a fermentable and in a high concentrated component. Afterwards a non linear asymptotic function is fitted to this ratio.

For the given function the maximum methane yields goes asymptotic to 0.38 Nm³/kg oDM. The minimum in this model amounts 0.32 Nm³/kg oDM. This means, the methane yield can

Fig. 2



Comparison of observed methane yields with calculated methane yields for two sample-sets

Table 3

Coefficients of the model Methane ~ XS/ADL according to the function $y = a - be^{cx}$

	Schätzwert/*Estimate*	Standardfehler/*SE*	t-Wert/*t-value*	Pr (> |t|)	
a	0.36459	0.00706	51.643	2e-16	***
b	0.04001	0.00554	7.221	7.09e-11	***
c	-0.05348	0.02595	-2.061	0.0417	*

Signif. codes: 0 = ***, 0.01 = *
Standardfehler der Residuen/*RSE:* 0,0084

theoretically take values between 0.32 and 0.38 Nm^3/kg oDM. This is a considerably difference to other models using linear regression. If for them no scope is given, theoretically the function can give any value.

Also if no starch or lignin is present in a sample, methane can be produced. This corresponds to the minimum value. This value complies mainly with other observations where methane yields of corn can range from 0.25 to 0.40 Nm^3/kg oDM [10–17]. Not one single component can be responsible for the methane production, in fact the components ratio determine the methane production potential.

Darnhofer et al. [18] conclude, that starch has no major influence on the methane production potential and the quality of corn. Although other studies refer the starch a strong influence on methane yields. Experiments digesting single components of the whole crop observed the highest methane yields for the corn cob, while the methane yield of the other parts was clearly beneath the methane yield of the cob [19]. Studies from Eder et al. [20] could confirm these results. But the authors come on experiments on corn whole crops to the conclusion, that ear accentuated types with a high starch content have no significant higher methane yield. They conclude that variety has no strong influence on methane yields [20]. Although they point out results of Heiermann and Plöchl [21], Hertwig and Heiermann [22] and Linke et al. [23] where a positive influence of starch content on methane yield can be observed even though the starch content could not explain the methane yields itself. Linke et al. [23] explain these results with the higher fat content and the higher content of fermentable carbohydrates in the cob. The high lignin content of the rest plant is also supposed being the reason for the reduced methane yield.

Conclusion

Generally multiple linear models seem to be no adequate instrument to explain the complex process of biogas production. The current model seems to be a new approach to calculate specific methane yield. Here the methane yield is determined by the ratio of easy and hard fermentable components, using a non-linear function. It can explain 50 % of the variance in the methane yields. The model could be developed further regarding more data. Also the influence of other factors, like microorganisms should be more attended to. Without concerning these factors a reliable prediction of specific methane yields will remain difficult.

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