Thomas Amon, Vitaliy Kryvoruchko, Barbara Amon, Vitomir Bodiroza, Werner Zollitsch and Josef Boxberger, Vienna

Biogas Production from Energy Maize

At the Division of Agricultural Engineering in the Department of Sustainable Agricultural Systems of the University of Natural Resources and Applied Life Sciences in Vienna, the goal of biogas research is to find measures for improving the efficiency of biogas production. This project focuses on how biogas from energy maize can be produced efficiently and be ecologically sustainable.

Dr. Vitaly Kryvoruchko, Dr. Barbara Amon und DI Vitomir Bodiroza are research partners, ao.Univ.Prof. Dr. Thomas Amon is head of the working group "Animal Husbandry and Environmental Engineering", o.Univ.Prof. Dr. Josef Boxberger is head of the Division of Agricultural Engineering and ao.Univ.Prof. Dr. Werner Zollitsch is head of the Department of Sustainable Agricultural Systems at the University of Natural Resources and Applied Life Sciences, Peter-Jordan Straße 82, A-1190 Wien; e-mail: *thomas.amon@boku.ac.at*

Keywords

Biogas production, maize, methane energy value model, sustainability, renewable energy

Acknowledgement

The investigations were carried out in line with the program "Energy Systems of the Future" – an initiative of the Federal Ministry for Traffic, Innovation and Technology (BMVIT). Financing partners are: Raiffeisen Ware Austria AG, Pioneer Seeds GmbH, Monsanto Agricultural Germany, Limagrain Nickerson GmbH, IPUS GmbH, GE Jenbacher AG, SEEG Reg. Gen.m.b.H, Nawaros GmbH, Schmack Biogas AG.

The production of biogas from agricultural raw materials is becoming more prominent. It is particularly important as a sustainable energy source.

Arable crops, which are increasingly used for biogas production, have until now been predominantly cultivated for human and for animal nutrition. For biogas production, the demands on the quality and composition of the plants are changing. For optimum methane production, genotypes of crops must be found that deliver a high methane yield per hectare and are able to be ensiled. At the same time, mono-crop rotations should be avoided. A wide range of crops as possible must be used for the biogas production [1]. Energy maize is most favourable to be integrated in ecologically optimized crop rotation systems.

Energy maize for biogas production

For biogas production from energy crops, maize as a raw material has the greatest importance. First, maize as a C_4-plant posseses the highest yield potential of all domestic arable crops. Furthermore, harvest-, conservation-, unloading-, and loading systems for maize are technically developed and extensively optimized. Presently the question being intensively discussed is how the optimal energy maize should be characterized for biogas production. Three functions of maize as energy maize can be recognized by:

- Energy maize culture is cultivated and used as the only crop in the vegetation year.
- Energy maize is cultivated as the main crop following an initial crop cover e.g. winter rye.
- Energy maize is cultivated in combination with other crops e.g. sunflower. The goal of the combined cultivation is to improve the silage through the combined harvest of both crops, and simultaneously complement the nutrient inputs, which in turn generate higher specific methane yields and methane hectare yields.

New breeding goals are targeted for energy maize. Energy maize should grow as much biomass over the entire plant as possible and thereby should reach a high specific methane production capacity. In addition, the maize plant should reach a dry matter content of at least 28% at harvest in order to enable safe ensiling without secreting silage effluent. Intensively discussed is by which breeding methods the mentioned breeding goals can be reached most effectively. One strategy pursued, on the basis of proven forage maize lines, the development of more high-performance hybrids [2]. The biomass and methane yields of maize should increase. The underlying hypothesis is that late maturing energy maize varieties enter later into the generative phase than conventional forage feed maize varieties. Thereby, the plants have more time for the development of vegetative leaf biomass and less time for starch development in the cob.

The conventional breeding strategy, on the other hand, suggests that for climatic reasons the maturity spectrum of forage maize already is widely utilized [3]. The use of marginally late maturing varieties appears possible. Next to high biomass yields, one aims to fulfill the range of ingredients necessary for methane fermentation. By breeding methods the components presently available in minimum amounts, including proteins and fats, are being increased and thereby improve gas production. For cultivation, maize varieties that mature marginally later than the customary varieties cultivated for feed should be planted. Very late maturing varieties would increase the cultivation risk without bringing significant advantages in methane yield.

Methane yield from the fermentation of energy maize

The specific methane production of the energy maize samples, preserved as silage, was

Table 1: Parameters of regression function to calculate the methane energy value of forage maize silage with the crude nutrients

Content	Regression Coefficient	Significance
Crude protein (XP)	15.27	0.000
Crude fat (XL)	28.38	0.001
Crude fibre (XF)	4.54	0.000
N-free extract (XX)	1.12	0.008

Quality parameter of the total equation:
R^2 = 0.968; F-value = 1583.027;
Durbin-Watson-value = 1.176;
Level of significance = 0.000; n = 95

measured in the laboratory with Eudiometer instrumentation under controlled conditions. The methodology followed the DIN-standard 38414 [4] and included three repetitions. The methane concentration in the biogas was measured every 2 to 3 days with a NDIR analyzer.

Our experimental results indicate the yield superiority of the medium-late maturing varieties compared to the very late maturing maize varieties.

The question of optimal harvest date of energy maize is important. The varieties should reach their maximum methane hectare yield, when they can be optimally ensiled, which is with a DM content of approximately 30 % in the whole crop.

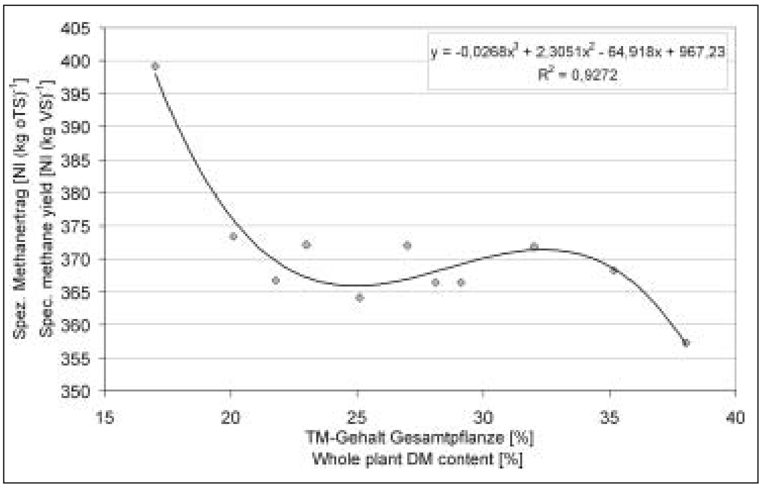

Fig. 1: Biomass yield and methane-ha-yield, specific methane formation ability and dry matter content of the plants at harvest at 5. 10. 2004 (variety comparison experiment Haidershofen 2004)

Methane energy value model for maize

With the methane energy value model, the specific methane capacity of the individual crude nutrients of maize silage in biogas production is determined. An energetic estimation is achieved regarding the methane yield potential of the energy maize silage [5]. The represented equation is the current form to date, calculated from 95 data records (*Table 1*) of maize silage energy content, crude nutrients, and specific methane yield. The equation for the calculation of the methane energy value (MEV) of energy maize follows a multiple and linear regression model in the general form:

MEV (Nl CH4/kg VS) =
x_1 • Crude protein (XP) (Content in % of DM) +
x_2 • Crude fat (XL) +
x_3 • Crude fibre (XF) +
x_4 • N-free extract (XX)

The methane energy values are reported in Nl CH_4/kg VS. Table 1 shows the regression coefficients of the function for the practical calculation of the methane energy value with the determined level of significance for the regression coefficients. The regression coefficients identify the contribution of each crude nutrient to the methane production from maize silage.

The specific model with its regression coefficients is now used to calculate the specific methane production capacity of forage maize silage based on crude nutrients, which are tabulated in the DLG ruminant feed value tables [6]. *Figure 1* shows the calculated specific methane yield of different maize silage, dependent on the dry matter content and the contained crude nutrients.

The calculation result shows that the specific methane production of “unripe” maize silage (dry matter content less than 20 %) is higher than that of “silage-ripe” maize silage (30 – 33% dry matter content). With increasing maturity of the crop, specific methane production decreases. With increasing dry matter content (DM > 22%) methane production levels stays at approximately 370 Nl/kg of VS. With maturity of the whole crop (DM > 35%) the specific methane yield clearly declines. A dry matter content of 30% is optimal to ensile maize. The specific methane yield has an optimum between 30 and 35 % DM. For methane production evidently maize silage from the vegetation stage “beginning of ear development” has a more favorable proportion of ingredients; crude protein, crude fat, crude fiber (cellulose, hemicellulose, lignin), as well as starch and sugar; than maize silage from plants in the “end maturity” vegetation stage where plants have > 55% of their ears and a dry matter content > 38%. The nutrient composition of ensilaged maize in the range of 31 to 34 % DM is most favourable for methane formation. A harvest below 25 % DM of the whole plant is not desirable, because maize silage effluent is formed and tends to smell, and in most cases the biomass production could still increase.

Conclusions and outlook

As our experiences with energy maize cultivation show, breeding strategies for specialized energy maize, based on marginally late maturing forage maize varieties, have been relatively successful. Up until now, conventional varieties with accelerated rate of maturation showed the highest methane hectare yields with simultaneously good ensiling potential of the biomass and high yield reliability. Further research must clarify the roll of the input materials of silage from the whole crop; above all, the roll of crude fibre and starch on the specific methane production capacity. Energy maize can best be used for biogas production, if it is optimally integrated in sustainable, locally adapted, diverse crop rotation systems. The productive capacity (methane hectare yield) of new “energy maize hybrids” must be examined at different locations over several vegetation periods.

Literature

[1] *Amon, Th.*: Biogaserzeugung aus Rohstoffen der Landwirtschaft, Praxisrelevante Neuigkeiten. Energy – Zeitschrift der österreichischen Energieagentur (2005), S. 29

[2] *Schmidt, W.*:. Maiszüchtung für die Energieerzeugung. KWS SAAT AG, Grimsehlstraße 31, 37574 Einbeck, Vortrag anlässlich der Wissenschaftlichen Tagung des Dachverbandes Agrarforschung (DAF) e.V., Braunschweig am 26. und 27.10.2005

[3] *Degenhardt, H.*: Optimierung des Biogasertrages durch angepasste Maissorten und richtiges Anbaumanagement. Feldberater 1/2005, PIONEER Hi-Bred Northern Europe Sales Division GmbH Apenser Strasse 198 21614 Buxtehude; www.pioneer.com (2005)

[4] DIN 38 414: Bestimmung des Faulverhaltens „Schlamm und Sedimente“ (1985)

[5] *Amon, Th., V. Kryvoruchko,B. Amon,W. Zollitsch, K. Mayer, S. Buga und A. Amid:* Biogaserzeugung aus Mais – Einfluss der Inhaltsstoffe auf das spezifische Methanbildungsvermögen von früh- bis spätreifen Maissorten. Bericht über die 54. Tagung 2003 der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs vom 25. bis 27. November 2003. Bundesanstalt für alpenländische Landwirtschaft (2004), S. 59 – 68

[6] DLG – Futterwerttabellen Wiederkäuer. Herausgeber: Universität Hohenheim, 7. Auflage, 1997