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Effect of Ensiling on the Specific Methane Yield of Maize

Professional literature often states that methane yields from silage are higher than with fresh plant material. The results of the investigation presented here prove that through ensiling forage maize, only a slight increase in specific methane yield is attained. When drying silage, losses of fatty acids and alcohols occur (through drying at 105°C). If the measurement of organic matter remaining, after the volatile solids are lost is not corrected, then the specific methane yield is substantially overestimated.

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Keywords

Biogas, energy crops, renewable energy, maize, silage

The German association of engineers' guideline VDI-4630 and the DIN guideline 38414 - section 8, provide rules and procedures for assessing the biogas yields of different organic materials [4]. Nevertheless the data published by different institutions and laboratories are often non-comparable and therefore constrain their use for biogas plant's planning [3].

The crop material used for the determination of the specific methane yields is either fresh (dried or undried) or ensiled. Taking into account alone this factor, one can justify the discrepancy between values published by different institutions and laboratories.

During ensiling microorganisms bring about the decomposition of the carbohydrates (simple sugars, di- and oligosaccharides) present in the substrate mainly into short chains fatty acids and alcohols.

In the biogas production process, the specific methane yields are expressed in norm liter/kg VS. The determination of the total solids (TS), from which the volatile solids content is derived, takes place at 105 °C. At this temperature a considerable share of the produced volatile compounds (fatty acids and alcohols) gets lost, so that the reference value "VS" of the silage differs to that of the fresh crop material (non-ensiled). In animal nutrition it is common to correct the total solids content of silage by taking into account these volatile solids' losses. [5] provide adequate methods for the correction of the TS content silages. The exact correction of the TS requires the determination of the volatile compounds (fatty acids, alcohols, ammoniac), on both the fresh silage and the dried samples (at 105°C).

The objective of this investigation is to assess the influence of ensiling on the methane yield of maize by comparing the specific methane yields of both silages and fresh crops on the same reference basis (corrected volatile solids) and consequently evaluate the overestimation when the correction factor is ignored.

Material and methods

This investigation was conducted using two energy maize varieties of different maturity levels (Variety 1 with the FAO-index: 280 and variety 2 with the FAO-index: 600). The maize varieties were harvested on October 7th 2005. The samples were divided in four different fractions as follows:

1. "fresh dried": drying at 60°C, milling with a hammer mill (sieve diameter 1 mm)
2. "fresh": deep frozen and reduced to small pieces using a lab mixer
3. "fresh silage": ensilage took place in a preserving jar, reduced to small pieces using a lab mixer straight after the silo was opened
4. "dried silage" drying at 60°C, milling with a hammer mill (sieve diameter 1 mm)

The digestion process was conducted according to the "Hohenheim biogas yield test" (HBT) [1, 4]. The volatile compounds (fatty acids, alcohols, etc.) were analysed using the HPLC. The total solids' correction was achieved using the exact method proposed by [5].

Results and discussion

At the harvest maize variety 1 had a higher total solids 'content of 31 % in comparison to variety 2 which reached scarcely 21 %. The total solids content of the silages was for both varieties lower than that of the fresh material and differed from that of the fresh crop material of 5.2 % and 10.6 % for respectively variety 1 and 2. After the correction, the TS of the maize silages were barely lower (1.7 % and 0.9 %) than that of the fresh crop materials. No butyric acid was found in the silages. This proves an optimal ensilage process. In fact butyric acid is a metabolite of saccharolytes (clostridium) that possess the ability to degrade lactic acid and protein [2]. *Figure 1* shows exemplarily the volatile compounds in the silage of maize variety 1. In addition, it shows how the volatile com-

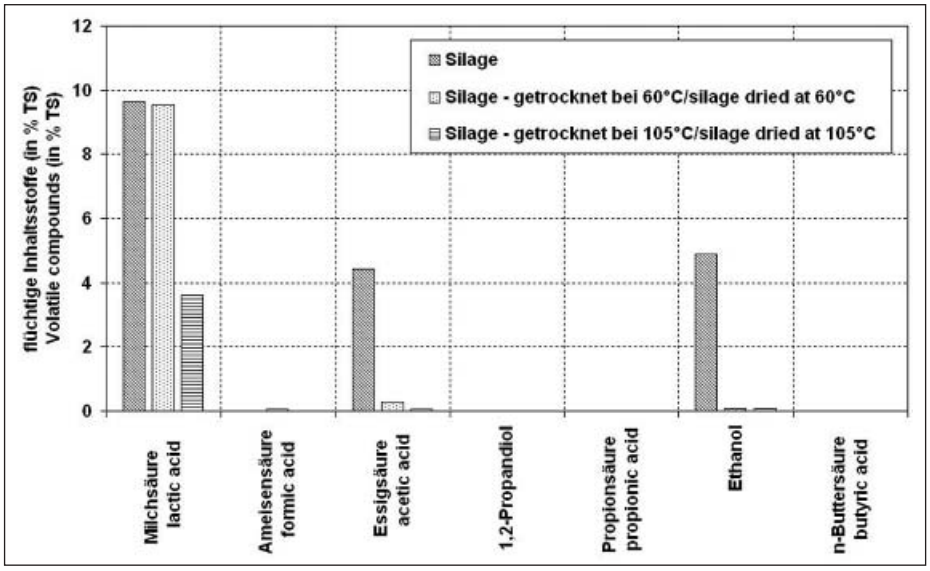

Fig. 1: Volatile solids' profile in the silage of the maize variety 2 (FAO-Index 600)

pounds profile change as the silage is dried at both 60 °C and 105 °C. Ethanol and acetic acid show a very high loss risk. In fact ethanol was lost to more than 98.36% at 60 °C, while acetic acid was lost at a relatively lower level (93.24% at 60 °C and 98.42% at 105 °C). The level of lactic acid in the fresh silage was substantially the same as in the dried silage at 60 °C, deflecting of only 0.93 %. At 105°C, 37.61% of lactic acid was found in the dried silage. Actually during silage drying the evaporation of fatty acids, as well as that of other evaporable substances depends of the pH with an exception for lactic acid. In fact lactic acid is not lost to the same extend as other fatty acids. Secondly it undergoes condensation reactions through which it is turned into lactids, which are not determinable with the usual analysis procedures anymore. Therefore for correction purposes, an empirical value of 8% loss is attributed lactic acid [5].

The composition of the evaporable compounds' profile in the silage was found to vary with the maturity level. At the low TS level (21%) more evaporable acids and alcohol are formed and the share of acetic acid and alcohol increases. Hereby is the expected evaporation loss potential higher and hence the TS correction even more crucial.

In *Figure 2* the specific methane yields of the late maturing maize (variety 2) are shown exemplarily; whereby the differently conditioned variants are compared one another. Moreover both variants "fresh silage" and "dried silage" are compared between them with and without the volatile solids' correction. The specific methane yield of the "fresh" crop material (undried) varied between 0.345 and 0.351 Nm^3/ kg VS. The specific methane yields of the fresh dried (at 60 °C) crop material were of 0.340 and 0.345 Nm^3/kg VS, and hence were lower than that of the fresh undried variant (1.5 and 1.7%). The undried silages showed overestimated yields with 0.381 and 0.398 Nm^3/kg VS. The yields were 5 to 10% higher as long as no correction was made.

With the correction, the specific methane yield of the Silages was between 0.360 and 0.363 Nm^3/ kg VS; representing 2.6 and 5.5% more yield than the fresh undried crop material. Consequently one can conclude that ensilage as a kind of pre-hydrolysis improves only in a limited scope the digestibility of the silages. This is more likely as the microorganisms stop almost completely their activity as soon as the pH in the silage is lower than four. Moreover, there is no indication in the literature that ensilage brings about a substantial decomposition of complex fibers. Therefore a clearer and distinct increase of the absolute specific methane yield of silages is unlikely.

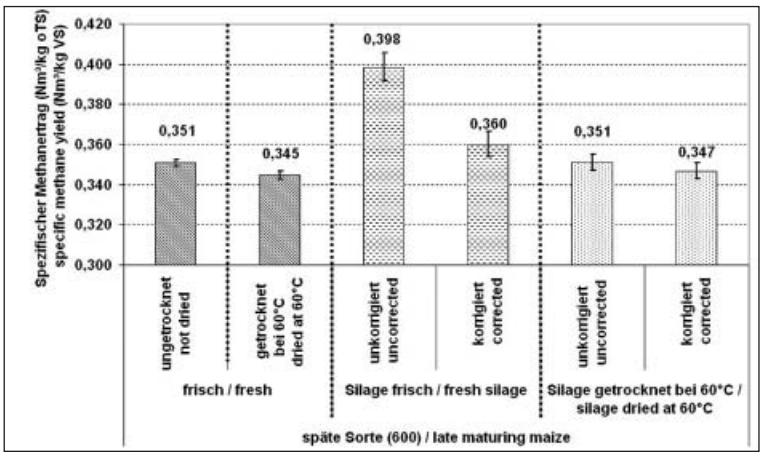

Fig. 2: Specific methane yield of differently pre-treated energy maize (FAO – Index 600) with and without volatile solids' correction

Literature

Books are marked with •

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