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Correction of Dry Matter Content in Sugar Beet Silages as a Substrate for Biogas Production

Volatile organic substances (acids and alcohols) are lost during the process of determining the dry matter (DM) content of silages. Therefore, correction of DM content for the loss of volatiles is necessary. If this loss of volatiles is not taken into account, calculation of both nutrient content and specific gas production leads to false results, causing experimental data to be misleading [5]. The organic matter of sugar beet silages up to one half can consist of volatile fermentation products. Therefore, the substrate-specific biogas yield is only possible to establish if the respective contents of fermentation acids and alcohols of these silages are known. After publication of equations for correcting DM content in maize and grass silages [9, 10], an equation for DM correction for ensiled sugar beets silage is recommended here.

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Literature

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Fundamentally changing economic conditions have made sugar beet quite an interesting substrate for biogas production recently. In order to use sugar beets beyond natural shelf-life, their preservation has attracted significant attention [2, 6]. Against this background, existing knowledge from previous investigations which aimed supplying sugar beets for feeding purposes all year around can be used [3, 4, 11].

Preliminary tests under practical large-scale conditions have shown that whole sugar beets can be stored in the absence of air for a certain period of time [6]. Under anaerobic conditions, metabolic activity of beet tissue ceases resulting in cell death, release of liquid cell content and turning to fermentation as is known from ensiling chopped sugar beets.

To assess preserving technologies for sugar beets, balance trials for establishing the recovery of the biogas production potential from harvest to the biogas reactor are necessary. Inclusion of all volatile products in silages forms a precondition of such balances. The aim of this study was to determine the range of concentrations of individual volatile compounds which may be found in sugar beet silages, and to propose a substrate-specific equation for correction of DM for volatile compounds in these silages.

Materials and methods

Analytical results of 35 sugar beet silages from previous trials [4], which had been completely documented, could be used for this investigation. Those sugar beets were washed, chopped and stored in airtight plastic bags. Storage time varied between 2 weeks and 9 months. To control fermentation, in some of the silages potassium/sodium pyrosulphite was applied for suppressing lactic acid fermentation, in others sodium benzoate was used for inhibition of alcoholic fermentation. Lactic and acetic acids were determined individually, whereas the higher homologues of acetic acid were only analysed as the sum all other acids („butyric acid" according to Lepper-Flieg). Total content of alcohols was determined oxidimetrically and expressed as ethanol.

The analytical results from previous trials were amended by results on 9 samples taken from sugar beets preserved in plastic tubes within the scope of practical testing of this technology [6]. These sugar beets had not been washed and chopped. They were stored for 6 months (December 2007 to June 2008). These samples were submitted to gas-chromatographic analysis for all individual short chain fatty acids and alcohols.

Efforts to determine potentially volatile compounds in the drying residue were not successful as during extraction of drying residues significant amounts of solubilized pectins disturbed the chromatographic analysis.

Results and discussion

All results are summarized in *Table 1*. The average contents for sugar, fermentation acids and alcohols of ensiled sugar beets compared reasonably well with those stored unprocessed under air-exclusion in plastic tubes. Therefore, it was possible to combine all data and further use them as one data set.

The wide range of individual data, however, exclusively results from the previous trials. The reasons for the great variability of analytical data are the varying storage length and fermentation pattern of silages. On the contrary, data on the contents of individual low fatty acids (besides acetic acid) and alcohols (besides ethanol) were obtained only from the recently analysed samples. It could be shown that the concentrations of higher homologues of acetic acid and of ethanol are very small and that those do not have to be taken into consideration individually when correcting DM content. Butyric acid formation does not occur in sugar beet silages. Methanol which is regularly found in preserved sugar beets is most likely to be formed during the process of decomposition of pectins.

If sugar beet silages are stored for longer periods, the vast majority of the sugar is converted by fermentation into lactic and acetic acids, but mainly into ethanol. It is well known that, during fermentation, lactic acid formation goes on earlier than ethanol production [4]. Due to low buffering capacity of sugar beets, only relatively small concentra-

tions of lactic acid are required to reduce pH to below 4, thereby ceasing further lactic acid production. Residual sugar is then converted into ethanol by yeasts which are known to be acid-tolerant. Extend of ethanol fermentation depends on storage length and conditions. The high variability in residual sugar content is associated with the enormous range of concentration of volatile fermentation products. There is an expected close relationship between residual sugar level and ethanol content (*Fig. 1*).

Although volatility of each individual fermentation product could not be measured, it can well be derived from other investigations. As in maize silages, typical pH of sugar beet silages is below 4. Therefore, a volatility coefficient of the total of low fatty acids of 95% can be assumed [9]. Furthermore, volatility coefficient of lactic acid of 8% [1, 7, 8] can also be applied to sugar beet silages. As found in investigations with maize and grass silages [9, 10], alcohols with one hydroxyl group evaporate always completely. Since alcohols with two hydroxyl groups occur only in minute amounts in sugar beet silages, 100 % volatilization can presupposed also for the total of all alcohols here.

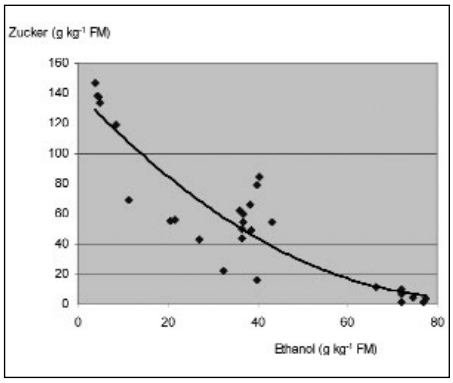

Fig. 1: Decrease of sugar content with increasing ethanol content in sugar beet silages

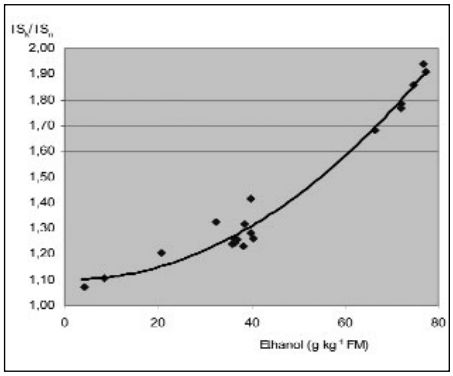

Fig. 2: Relationship between ethanol content and the volatilization losses during sample drying of sugar beet silages, indicated by the quotient DM_c/DM_n

Table 1: Content of sugar, potentially volatile fermentation products and dry matter in ensiled sugar beets (n = 44)

	Content in silages		
	Mean	**Range**	**Standard deviation**
Sugar (g kg^{-1} FM)	59	2 …147	46
pH	3.9	3.5 … 4.5	0.3
Acids (g kg^{-1} FM)			
Acetic acid	7.74	1.70 …17.90	4.18
Propionic acid*	0.04	0 … 0.05	0.01
Iso-butyric acid*	0.52	0 … 0.60	0.10
Butyric acid*	0	0	0
Iso-valeric acid *	0.08	0 … 0.14	0.03
Valeric acid*	0	0	0
Caproic acid*	0	0	0
Lactic acid	11.95	5.90 …28.50	6.30
Alcohols (g kg^{-1} FM)			
Methanol*	1.25	0.02 … 2.79	1.03
Ethanol	37.18	3.80 …77.30	24.34
Propanol*	0.09	0 … 0.14	0.04
Butanol*	0	0	0
1,2-Propanediol*	0.26	0 … 0.50	0.13
2,3-Butanediol*	0.49	0 … 0.59	0.06
Dry matter (g kg^{-1} FM)			
not corrected** (DM_n)	154	88 … 207	44
corrected** (DM_c)	208	169 … 254	77
quotient** DM_c/DM_n	1.352	1.075 …1.939	0.281

*Mean and standard deviation form 9 samples,
** from 35 samples

By means of these volatility coefficients, the DM figures obtained in the common way (DM_n) were corrected for the loss of volatiles (DM_c). The results are shown in the last lines of *Table 1*. On average, the error of DM_n was found to be approximately 35%. The enormous variability of this error is vastly associated with differences in ethanol content, which is demonstrated in *Figure 2* on the basis of the quotient DM_c/DM_n.

Conclusions and recommendations

As dry matter of freshly harvested sugar beets is composed of sugar of about 70% and this is fermented at a variable extent, it follows that a vast and substantially varying proportion of the organic matter of sugar beet silages consist of volatile fermentation products. Therefore, information on substrate-specific biogas yield makes only sense if it is based on corrected DM and corrected organic matter contents, respectively. Complete chemical analysis of silage for volatile fermentation products is the crucial pre-requirement for this approach.

It is recommended to correct the DM content determined in the common way (preliminary drying until constant weight at 60 to 65 °C, followed by final drying at 105 °C for 3 hours) for the loss of volatiles during this process by using the following equation:

$$DM_c = DM_n + 0.95\ FA + 0.08\ LA + 1.00\ AL \quad [g\ kg^{-1}\ FM],$$

where is:

FA = total content of low fatty acids (C2…C6)

LA = lactic acid content

AL = total content of alcohols (C1…C4, including diols).

All analytical data have to be fitted in this equation in the dimension g per kg fresh matter (FM).

As a consequence of correcting the DM content, all analytical parameter which are expressed as part of the DM have to be corrected as well. Those which are directly measured in the dried sample and usually expressed as percent of DM_n (e. g. crude ash) must be multiplied with the quotient DM_n/DM_c. Difference fractions (e. g. organic matter) have to be calculated once more by using the figures expressed as percent of DM_c.

Acknowledgment

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