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Thermo-mechanical Pre-treatment of Ripe Triticale for Biogas Production

Investigations are presented of ripe triticale's straw and grain, which were in one case wet thermo-mechanically treated and in the other case twice dry pre-treated and then digested in laboratory scale biogas batch tests. The results of measuring the methane concentration in the biogas and the concentration of volatile fatty acids in the 30-litre-biogas fermenter are discussed.

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Keywords

Anaerobic digestion, co-fermentation, thermo-mechanical treatment, triticale

Literature

[1] VDI-Richtlinie: Vergärung organischer Stoffe. VDI 4630; Beuth Verlag GmbH, Berlin, April 2006

The use of energy crops for biogas production in Germany is well established since the amendment of the German renewable energy sources act (EEG) in the year 2004. Therefore the determination of specific methane yields and the dry matter yields of various energy crops became a matter of interest. Furthermore the optimal processing, from the harvest to the anaerobic digestion of biomass, is important for profitability of biogas plants.

Because of the need for optimization the influence of the pre-treatment of grain and straw of ripe triticale on the biogas and methane formation was investigated within the scope of the research project „Optimization of biomass supply for innovative energy recovery schemes".

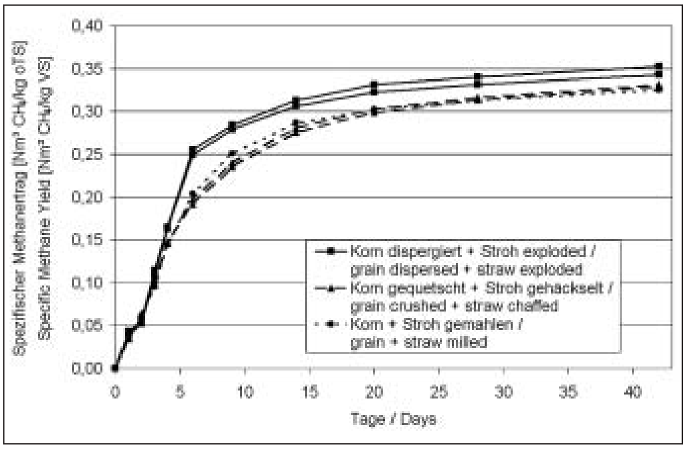

Fig. 1: Specific methane Yield (Nm^3 methane/kg volatile solids (VS)) of ripe Triticale (grain + straw) pre-treated in three different techniques

The aim of the experiment was to investigate the variation of the specific methane yield and the speed of microbiological degradation of biomass with an increasing degree of disintegration of biomass. Furthermore the pH-value and the fatty acids were determined in the digesters filled with various pre-treated triticale in order to estimate the possible influence on process stability of a continuous co-fermentation processes.

Pre-treatment of biomass

The triticale was harvested at full ripe stage with a dry matter content of 86 % and 90 % for grain and straw respectively. Starting with whole grain and roughly chopped straw three pre-treatment methods were investigated (*Table 1*).

Variants 1 and 2 were dry pre-treatments, using a cutting mill (1 and 10 mm sieve) or a grain crusher. For variant 3 the grain and additional water were dispersed over 15 minutes with a laboratory scale disperser „Ultra Turrax T50". The chopped straw of method 3 was mixed with water and pumped into a 400 litre-pressure tank operated at 6 bar and a temperature of 155°C. These conditions were kept constant for an hour, after this the pressure was released explosively. The thermo-mechanical pulping is also called steam explosion or in combination with biogas plant "Thermal Pressure Hydrolysis" - TPH.

Table 1: Techniques of the pre-treatment of ripe triticale´s grain and straw

	grain	straw
1	crushed	chopped, 10 mm
2	milled, 1 mm	milled, 1 mm
3	dispersed	thermo-mechanical pretreatment (exploded)

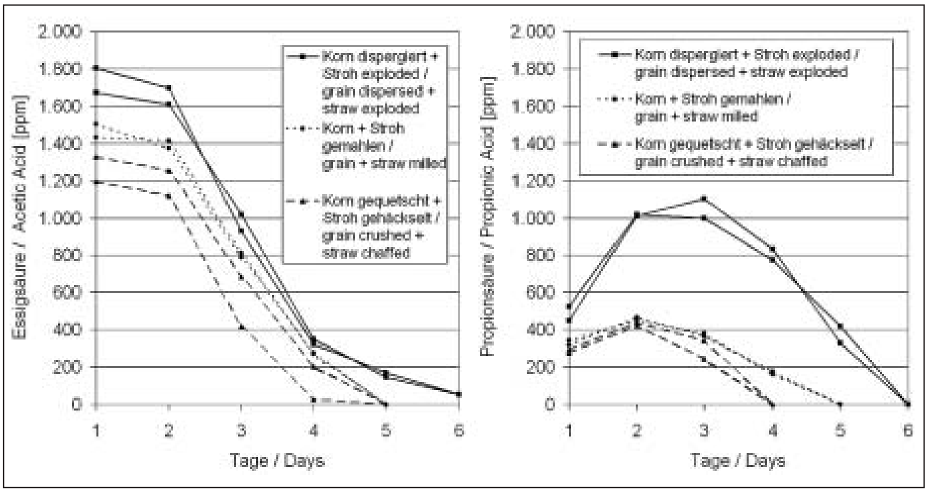

Fig. 2: Concentration of acetic and propionic acid (ppm) in the batch-procedure

Co-fermentation tests

The mixtures of triticale grain and straw in each of the methods were digested in the 30 litre-batch test inoculated with pre-digested cattle manure. The dry matter of the whole sample consisted of 46 % grain and 54 % straw for all variants.

The investigations were carried out in accordance to the guidelines "VDI 4630 - Fermentation of organic materials" [1] of The German Engineering Association (Verein Deutscher Ingenieure - VDI) at a temperature of 37 °C over 42 days with two replications of each method. The quantity of the biogas was determined with a flowmeter and the quality was analysed with a photometric sensor ten times and the pH-value and fatty acid concentration were determined.

Results and Discussion

Results of specific methane yields presented in figure 1 are calculated from the biogas yields and the methane concentration. The triticale was fermented as whole plant (grain + straw) in 30 litre-digesters. Only one replicate for variant 2 "milled grain and straw" was considered for further interpretations due to equipment failure.

The two dry-mechanical pre-treatment methods showed very similar progressions in the formation of biogas. Final values of the specific methane yields were 0.330 m^3 CH_4 kg^{-1} VS for "grain crushed + straw chopped" and 0.325 m^3 CH_4 kg^{-1} VS for "grain + straw milled". The watery processed type "grain dispersed + straw exploded" had a yield of 0.348 m^3 CH_4 kg^{-1} VS and a final value by 5 % higher after 42 days. Furthermore, this method yielded 0.327 m^3 CH_4 kg^{-1} VS after only 20 days, which was the same level as the other methods' final values.

The progressions of the volatile fatty acids acetic acid and propionic acid are shown in *Figure 2*. The state of scientific knowledge is that the anaerobic fermentation is phased into four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The concentration of acids reflects the balance of the interaction between many different species of bacteria of the four stages. A high acid concentration indicates a temporary imbalance, for propionic acid between acidogens and acetogens respectively between acetogens and methanogens for acetic acid.

The wet pre-treated method showed higher concentrations of acids and a higher specific methane yields than the other methods. This wet process might have increased the surface area, making the anaerobic digestible material better available to bacteria.

The concentration of acetic acid in all variants decreased marginally on the second day. The concentration of propionic acid increased noticeable especially for the wet pre-treated variant.

From the third day the total volatile fatty acids diminished. By the sixth day nearly no surplus fatty acids were determined.

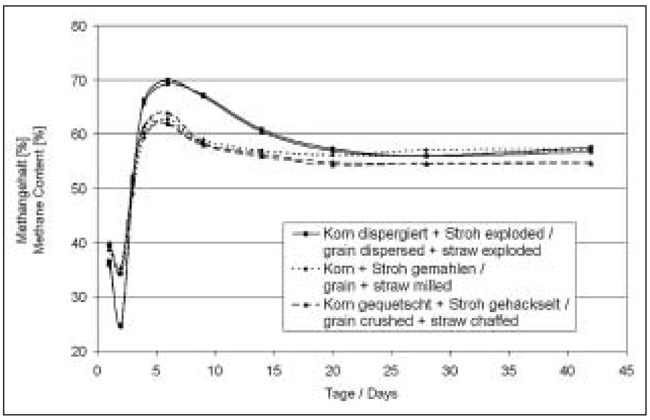

Fig. 3: Methane content in the biogas (%) – batch-procedure

The methane contents of the biogas are shown in *Figure 3*. The concentration of methane varied most for variant "grain dispersed / straw exploded". One reason for that could be an increase in speed of hydrolysis. On the sixth day the peak of methane concentration for all variants was achieved.

The pre-treated material was investigated separately for grain and straw in the Hohenheim Biogas Yield Test (HBT). The results of this additional experiment showed that the increase of specific methane yield of the wet pre-treated method was caused by a raise of the digestibility of straw alone (data not shown). Nearly no effects in degradation of grain were observed for either wet or dry pre-treatment techniques.

Conclusion

The method "grain dispersed + straw exploded" showed a higher methane yield and an increase in speed of anaerobic degradation compared to the dry-mechanical pre-treatment methods of triticale „grain crushed + straw chopped" and "grain + straw milled".

The dry pre-treated straw is hardly and slowly biodegradable, the thermo-mechanical pre-treated straw is more easily degradable. Under conditions of practice it should be dosed carefully. The "feeding" should be done several times a day in small amounts to avoid an uncontrolled acidification, hence an inhibition of the methanogens.

Initial calculations for the additional energy consumption of the laboratory scale steam explosion system led to the conclusion that the additional energy input is higher than the corresponding output compared to the output of milled straw. Only a considerably reduction of process water and the use of waste heat of other processes could reduce the additional energy input of the wet thermo-mechanical pre-treatment in future. Thus there might be a chance to exceed the energy gain of the dry pre-treated variants.