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Dual Use of the Biogas Process:

Disposing of Contaminated Grain Batches while Simultaneously supplying Energy

Investigating Biogas Potential by Comparing two Fermentation Technologies

The Food and Agriculture Organization of the United Nations (FAO) estimates that up to 25% of world food production is contaminated by mycotoxins and around 1,000 million tons of food and feed are lost every year due to mycotoxin contamination. The focus of an interdisciplinary project at the University of Hohenheim is to research a practicable, economical and ecological possibility for disposal, where the Fusarium spores are deactivated and mycotoxins are reduced. The current research is funded by the Agency of Renewable Resources (FNR).

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Keywords

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Literature

Literature references can be called up under LT 07421 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Fusarium (pathogen of Fusarium Head Blight) and its toxic intermediate catabolic product, DON (Deoxynivalenol) are prominent for their high grade of deterioration on cereal products. They can be toxic to humans and animals even in low concentrations. These intermediate catabolic products, the so called Mycotoxins, are under certain conditions being produced by Fusarium on the living host plant, as well as on the stored crops. Deoxynivalenol (DON, or Vomitotoxin) is a Mycotoxin produced by different field moulds, mainly through Fusarium graminearum and Fusarium culmorum. DON comes upon grain and cereals, particularly in wheat, barley and maize. Frequently DON occurs in combination with other Fusarium-toxines, e.g. Zearalenon, Nivalenol (and other Trichotheceenes) as well as toxins of the Fumosines-group. On productive livestock a DON-exposition leads to absence of appetite, feed refusal and vomiting, combined with a simultaneous decrease of weight gain. Pigs are demonstrably the most sensitive species regarding the negative effects of DON. Depending on the compound class, mycotoxins can be acutely or chronically toxic on the human organism. Symptoms of effective poisoning comprise liver and kidney damage, impairment of the immune system, skin and mucous membrane damage or hormonal effects, such as fertility disorders. After it's ingestion as food- / feedstuff DON is going to be metabolised via Deepoxidation and Glucuronidation into its derivative (Deepoxynivalenol). This decomposition product is about 24 times less toxic than the starting substance. A carry over effect of DON and /or it's metabolite into comestible textures, milk, eggs and meat is very low, but cannot be completely precluded.

Legal Situation and objectives of the project

To prevent these toxins from being spread into the human food chain, the European Community launched a directive, providing maximum levels of contaminants ((EC) No 856/2005). The amendment is basically focusing on Deoxynivalenol (DON), Zearalenone (ZEA) and Fumonisines. For DON, the following maximum loads are authorized for unprocessed cereals and amount to 1250 µg/kg. At that time the planned application (food- or feedstuff) is established. Thereby cleaning, drying and sorting are not considered as task specification. A further directive (EG) No.1068/2005 obliges the member states to control the content of contaminates, based on risk assessment.

There was also determined that products offered for intervention, are classified as, i.e. is durum and soft wheat, and as feedstuff, i.e barley and maize. Referring to this, DON counts as an unwanted substance in feedstuffs, and is hence subject for interdiction of blending. Hence a feasible, economical and repeatable method for analysing the Mycotoxin is necessary.

There is need for action regarding potential usage. A sustainable utilisation beyond the food chain in the direction of ethanol production must be excluded, due to the accumulation of DON in the by-product. The intermixture of moulded crop residues into soil is only practical for non conservation cultivation, to avoid reinfection. To find alternatives, the FNR launched a project to acquire the potential of the anaerobic fermentation process regarding an inactivation of the moulds by a simultaneous decomposition of the toxin throughout stabile process behaviour.

Potential assessment by comparing systems

Since the implementation of the "Act on Granting Priority to Renewable Energy Sources" the predominant agricultural biogas techniques are in a flux. As slurry was over many decades the principally used digested substrate, nowadays solid- phase fermentation of energy plants is in great request. Less reactor volume, less process energy, less transport capacity and less outdoor emissions are some of the considerable advantages. Admittedly the state of the art of the installation engineering is subjected to restrictions. The mixing strategies and the loading as well as the unloading techniques are not transferable to liquid digestion systems. Therefore the applied research as well as the industry is focused on special technologies, allowing a high total in solid content (up to 50 % DM).

Therefore several test series have been conducted according to the directives VDI 4630 [7] and DIN 38 414 [8]. The biogas potential of differing dry matter contents as well as the varied process guiding (continuous and discontinuous system) is to be determined for possible inhibition. A monitoring and risk assessment of the spores within the residuals has to be sampled in parallel. The determination of microbiological activity rate was proved at bench scale unit for charges of contaminated wheat in appearance of whole grains and ground flour in batch processes in solid as well as in liquid fermentation processes. An appraisal of the biogas generation was set up in two different lab scale units. Further a method of analyzing the toxin content throughout the whole fermentation process was designed to find evidence about the prospective detoxification effect of the microbiology, because the transfer from the toxin into the crop can not be excluded [9].

The mini-batch fermentation based on the Hohenheim Biogas yield test has been described in detail [10]. The Laboratory solid phase digesters have been configured in 2004 [11] and provided a basis for pure research pertaining solid phase fermentation. The 10 cylindrical reactors were established in a stainless steel finish with a volume of about 60 L and for solid material of around 50 L. Two water benches for the circulated arrangement for maintaining temperature are installed and the temperature of 37° C in the reactor is continuously controlled by PT 100 thermocouples. To avoid loosing thermal energy, polystyrene insulation is encasing the reactors and all relevant tubes. The process water is collected in a hopper reservoir on the reactor base, and sprinkled over the biomass fill by an electrical pump. To disburden sample taking, a three-way cock is added in the percolate recirculation tube and after at least 15 minutes of recirculation, the liquid can be sampled. According to descriptive trials the disposed substrate was moulded material of a trial. The concentration of the toxin averaged 20.000 µg/kg and the Fusarium infestation was tested on 100 %.

Table 1: Analyses of fermentation process analyses

Operation	Operation temperature	Substrate	Arrangement of inoculation	Duration of fermentation	Evidence of complete inactivation
Batch, Liquid-fermentation	mesophil (37°C)	mould-free material	isolated spores	0 - 96 hours	3,5 hours
Batch, Liquid-fermentation	mesophil (37°C)	moulded material	naturally infected cereals	12 hours - 35 days	12 hours
Batch, Liquid-fermentation	thermophil (53°C)	moulded material	naturally infected cereals	12 hours - 35 days	12 hours
Batch, solidphase digestion	mesophil (37°C)	moulded material	naturally infected cereals	12 hours - 35 days	12 hours

Results of the biogas process

Neither the fermentation in solid-phase digestion systems, nor the mini batch fermentation showed an inhibitory effect of the biological degradation process, compared to the toxin-free material. In conjunction to the results of the HBT one can conclude as follows: With the start of the fermentation trial the population of common anaerobic bacteria is marginal and solitary fractionally adapted. Until the fourth day the development phase is found secluded. Therefore the micro organisms score the highest grade of their performance, involved with the highest methane yield. Compared to the reference material (toxin-free) a debased methane yield of the solid phase digestion was determined, as well as for the liquid fermentation. This refers to the decline of the relevant high-energy-level components starch and sugar. These components are being “dissimilated” by the fungi on the field or even past the harvest.

Interpretation of the microbiological investigation

Within the scope of determining the vitality and the sporulation capacity, an established determination method of fungi with an optimum supply of the smoothed samples was conducted (in this case whole wheat grains) [12]. The results are shown in *Table 1*.

Most of the findings could be figured out by the considerable advantages of the HBT (variance of the process parameters and high investigation capacity). The application of isolated spores (synthetic solution with a concentration of 106 colony building units / ml) performed a sufficient deactivation of the germination ability after a digestion-term of 3.5 hours. The process temperature showed no effect on the deactivation. The trial run of solid phase digestion clarified the conditions after 12 hours, which denotes the first unloading time.

Interpretation of the toxin monitoring

The developed method of DON determination within manure and dung showed very good recovery rates [9]. The findings of our investigation showed a decomposition effect. It can be expected that the toxin is degraded by effects of decarboxylation enzymes of the manure, respectively intrinsic micro organisms.

Outlook

For Germany there is an infected quantity of approximately 3.8 Mio. t/a. According to the results presented, these substrates could be decontaminated in cofermentation. By the disposal of the beyond-limits food- and feedstuff, two essential advantageous results arise: The disposal is supposed not to cause ethical conflicts of supply of food vs. alternative energy production. Furthermore the operator of the biogas plant can substitute the use of immaculate grain with a consequent disposal of moulded material, which has economic benefits through lower expenditures for the substrate.

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