

Reference Study: Increasing Biogas Yield through Addition of Food Waste Moosburg, Germany Waste Water Treatment Plant – Anaerobic Digester

1. Introduction

The Moosburg wastewater treatment plant has one 634,008 gallons anaerobic digester, which was designed to process a maximum 23,775 gallons/day of activated sludge at 3.5% solids. The AD is currently processing 17,170 gallons/day of sludge and producing 39decatherms/day of energy from biogas. The operators would like to better utilize their anaerobic digester to achieve energy self-sufficiency by supplementing their excess AD capacity with high energy food waste. Finsterwalder Umwelttechnik, Yield's European partner, was brought in to simulate & analyze the impact of adding food waste to their anaerobic digesters. The final step was to design the optimal technical and financial solution for the plant.

2. Study Objectives

1. Determine how to increase the overall capacity of the digester
2. Determine how much food waste can be digested with this excess capacity considering the operating parameters of the mixing equipment and nitrogen load.
3. Design a method to remediate the extra nitrogen that is created by digesting the food waste.
4. Determine the expected gas output to assist in sizing the gas generator equipment.
5. Determine the sensitivity of the system to failure

3. Methodology

Traditional methods for analyzing & optimizing the Anaerobic Digestion process consist of experimenting with lab equipment or making process changes in a working plant. This has proved to be very costly and time consuming.

Finsterwalder has developed a computer simulation called BioTip that simulates the anaerobic digestion process. This model and its conclusions have been validated by the

data from many actual WWTP anaerobic digesters. The simulation is able to manage multiple organic streams of material with different loading schedules. Based on the compositions (carbohydrates, proteins, fats, water content) of the material the simulation will calculate the biogas yield, methane yield, concentration of organic acids, the PH value, the buffer capacity, organism concentration and the growth rate. The simulation models the four concurrent AD processes (Appendix A) Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis in 1 minute increments until the system achieves steady state or fails. Retention time has often been difficult to predict, as the AD system is very complex. The model can work with complex inputs and schedule and accurately predict steady state, which aids in determining retention time.

This study utilized the BioTip to simulate two process changes to the Moosburg Anaerobic Digester. One of the areas of investigation was the thickening of the sludge to increase gas production and create excess capacity in the AD. The impact of the addition of 24.2 tons per day of food waste (the available food waste) was also studied.

Simulations Outputs:

1. Biogas Production
2. Methane Production
3. Concentration of Volatile Organic Solids
4. Buffer Capacity – ability of system to keep pH stable

4. Food Waste

The food waste used in this project was comprised of high-energy food processing waste (20% solids) and yields an average of 3.5 decatherms of biogas energy per ton of food waste. The food waste was pre-processed (shredded & screened) and contained about 1% contaminants in the form of plastic particles, grit, sand, and glass fragments less than 2mm. The contaminants were within the design specifications of the AD's contaminant cleaning system and were therefore not considered a problem.

The addition of the food waste increased the AD's total solids to 5.5%, which was above the initial design of the mixing system. The operators confirmed that the mixing system was capable of handling this density without a problem. Food waste is high in nitrogen, resulting in discharge levels greater than the 5 mg/l standard for Germany. Methods for remediating these high levels comprised a significant part of the recommendation phase of this project.

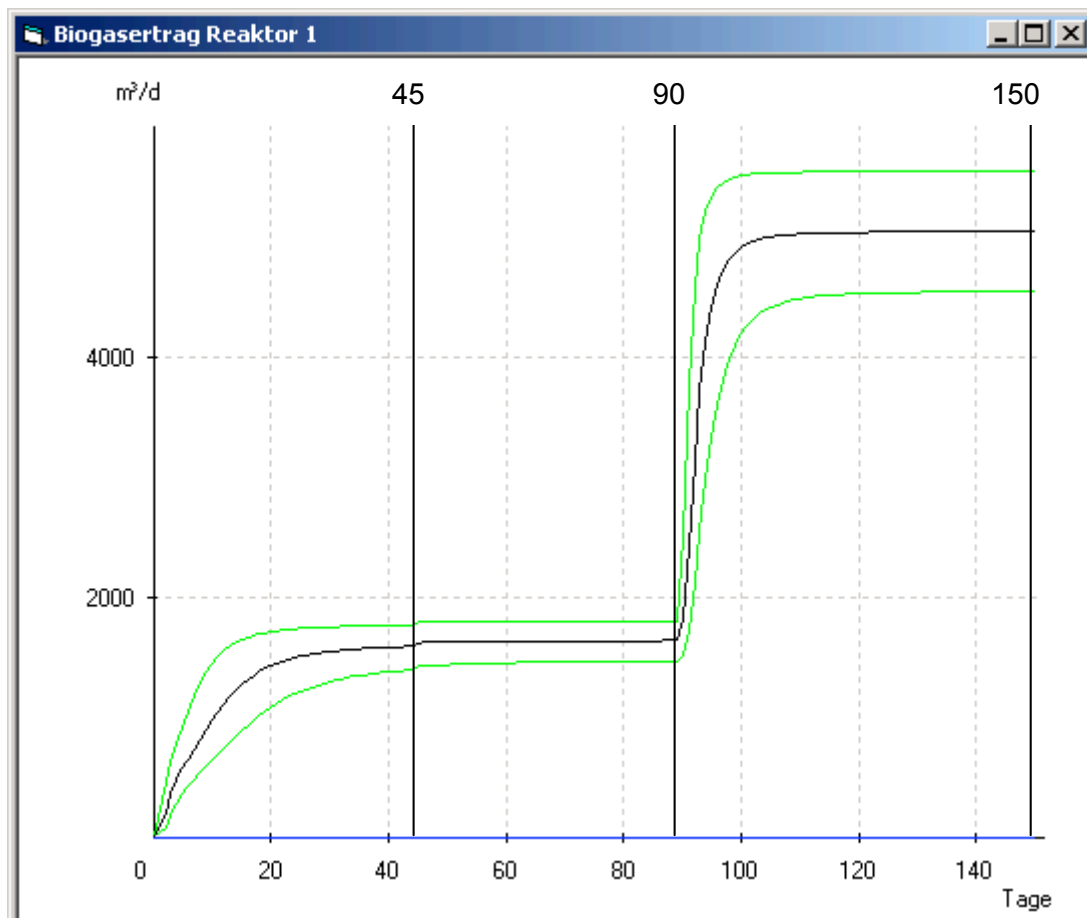
5. Moosburg Simulation

There are over 15 input variables required for a simulation. Some of the more critical variables are listed below. Most variables are entered using a range. The range appears on the result graphs showing the best case, median case and worst case.

1. Food waste Nutrition (carbohydrates, proteins, fats, etc.)
2. Sewage Nutrition (carbohydrates, proteins, fats, etc.)
3. Operating Temperature
4. Feeding schedule
5. Sensitivity to Trace Element supplementation
6. AD capacity

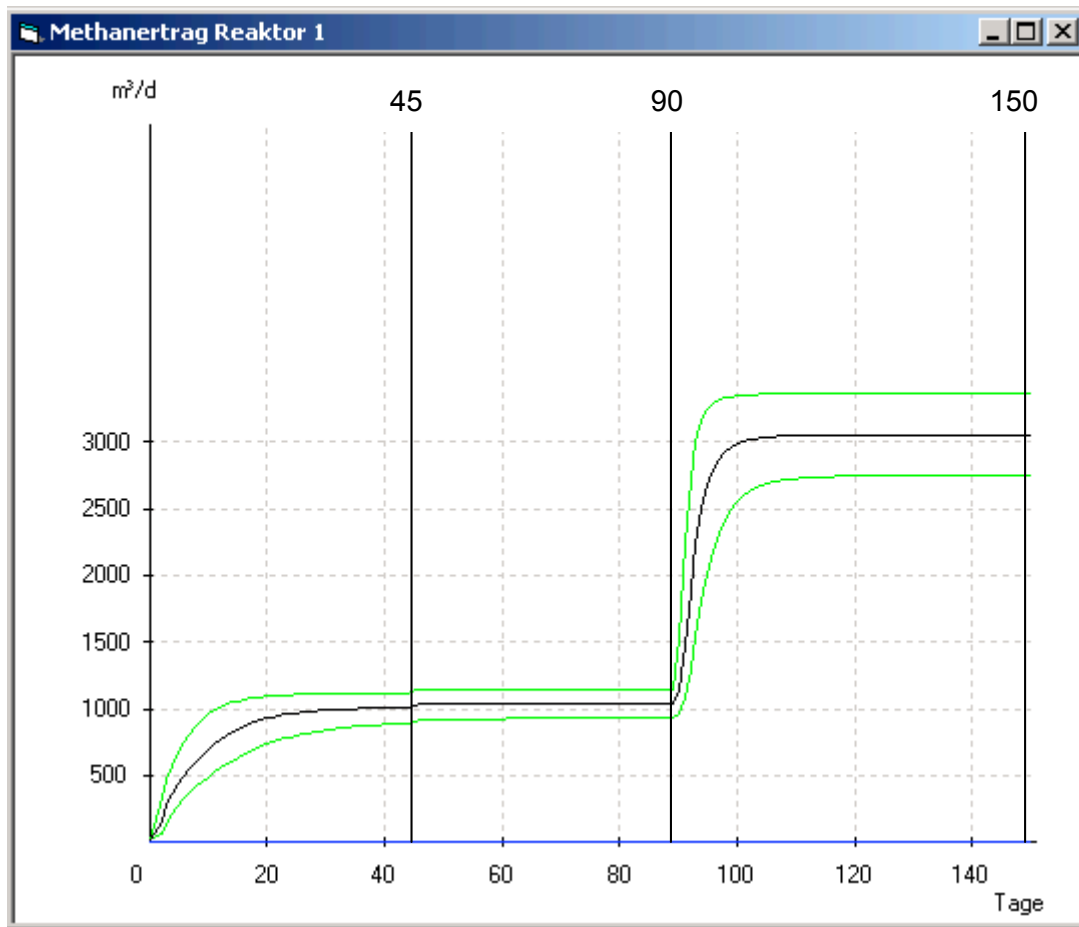
Graphs 2.1 to 2.4 illustrate how the key variables change as process changes are made to the system. The following states are calculated:

- (1) Time slice 0 to 45 days 23,775 gallons /day of non-thickened activated sludge
- (2) Time slice 46 to 90 days 11,887 gallons/day of thickened activated sludge
- (3) Time slice 91 to 150 days 11,887 gallons/day of thickened activated sludge and 24.2 tons of pre-processed food waste



Picture 2.1: Development of biogas yield. The biogas yield depends only on organic part of total solids (Note: Tage =days)

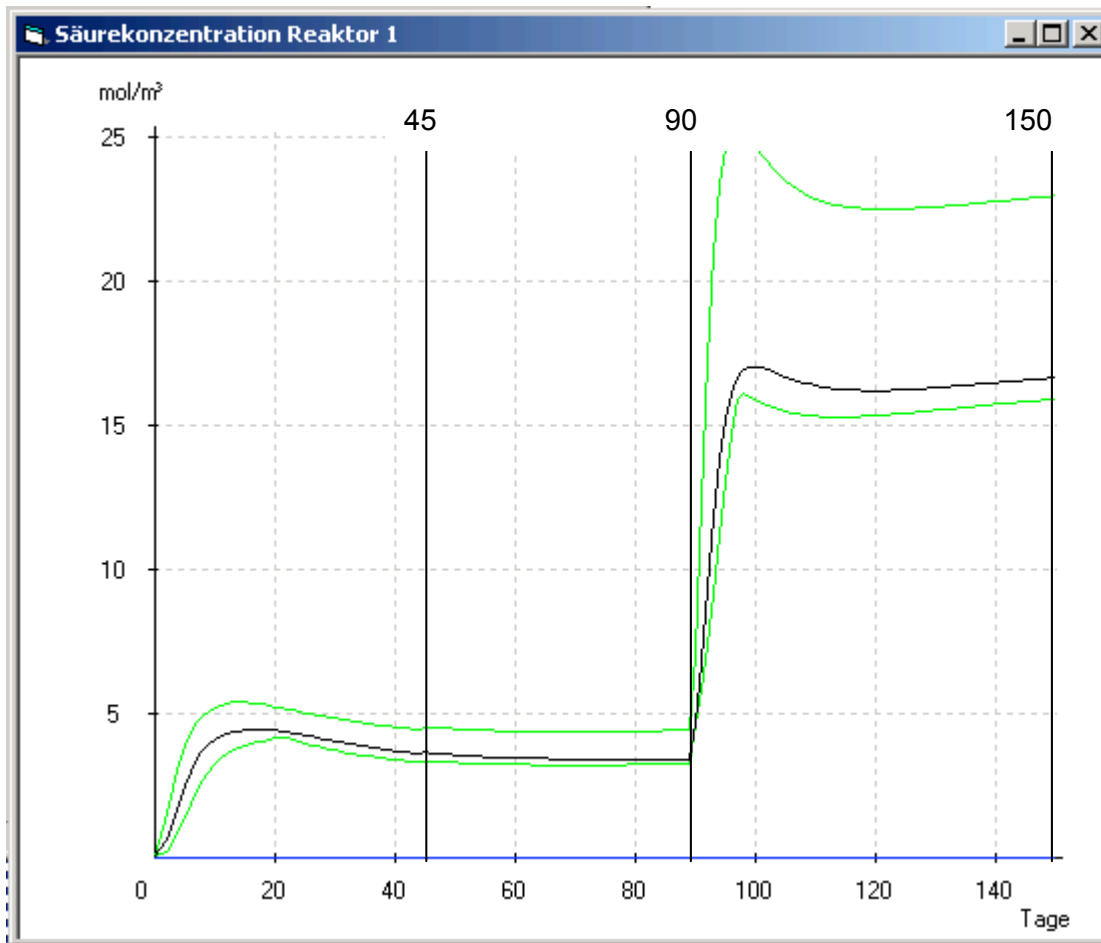
The biogas yield depends only on the organic fraction of the total solids. The size of the digester and the load equates to a 39 day retention time. If the retention time was too short the gas production would begin to fall off but it appears very stable and level which means all the organics degrade completely. Picture 2.1 shows that up to 37 decatherms/day biogas energy can be obtained from activated sludge. Together with the food waste a energy from biogas can yield up to 115 decatherms/day is obtained. The gas yield is based on the input of 8.36 tons/d total solids with the composition shown in table 2.5.



Graph 2.2: Development of methane yield. The methane yield depends on mass and quality of feedstock. In this case, protein content is the most relevant factor. (Note: Tage =days)

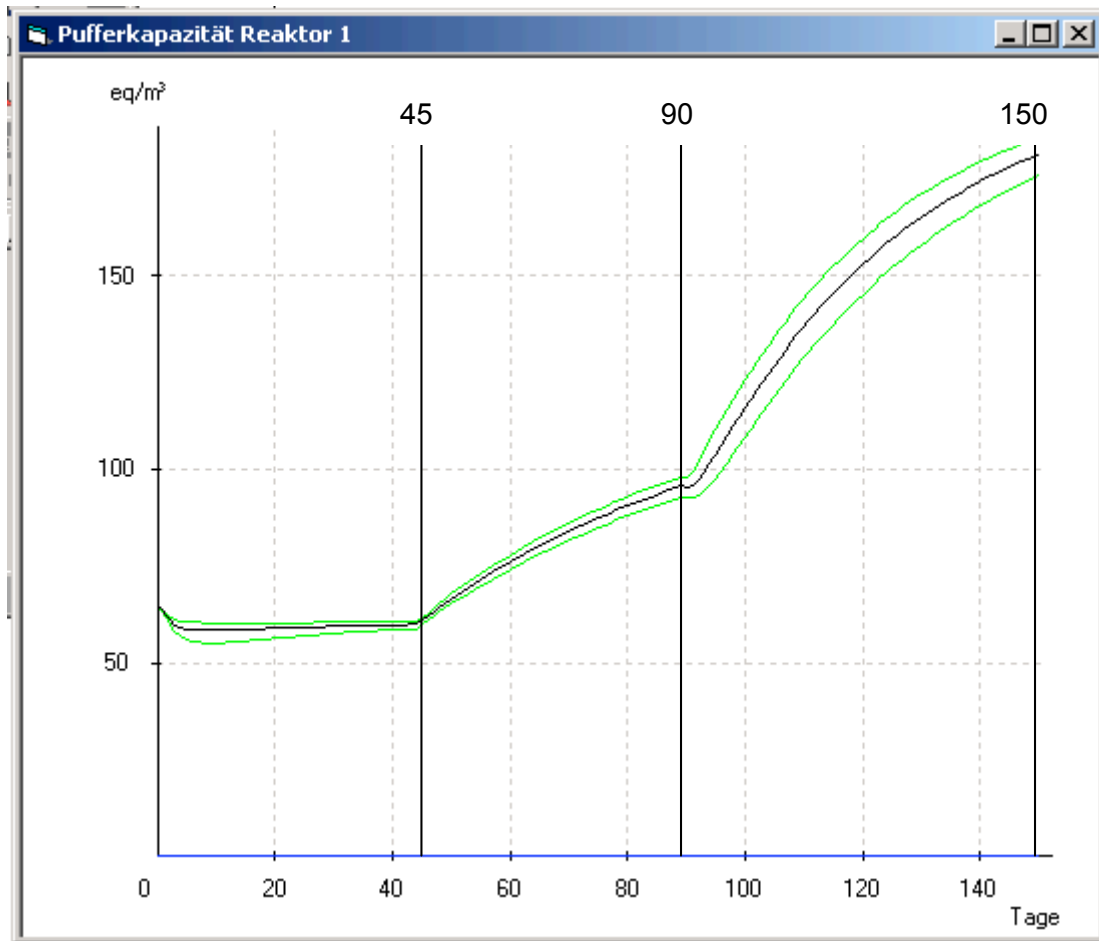
The development of methane yield is similar to the biogas yield. The methane content changes from 63% at the beginning to 62% in the future stage. Methane content is slightly reduced by the higher protein content of the food waste in the future stage.

The energy content of the approximately 111 decatherms of methane yields a combustion capacity of 1.25MW. This equates to an electrical capacity from about 500kW and 500kW of heat generation. 50% of the heat will be used for the digester and the remaining heat will be used by the sewage sludge dryer and to heating buildings of the treatment plant. 350kW of electricity are required to power the plant, the extra 150kW is sold to the electrical grid.



Graph 2.3: Development of concentration of volatile organic acids in the digester. This depends on availability of trace elements and on the mass and quality of the feedstock. (Note: Tage =days)

Although not directly simulated in this model, the concentration of volatile organic acids is very dependent on the availability of trace elements. Trace elements are a part of activated sludge but they are missing in most food waste. It is necessary to supplement a food waste system with trace elements in order to achieve these simulated results. The organic acid concentration at the beginning is lower than 4mol/m^3 , then rises up to 16mol/m^3 at the end. This does not cause any biological instability, because the buffer capacity (graph 2.4) rises at the same time from about 65eq/m^3 over 200eq/m^3 . The rising concentration of volatile organic acids has positive effect for the nitrogen elimination because denitrification needs readily accessible acids.



Graph 2.4: Development of buffer capacity. The buffer capacity describes the ability of the system to keep the pH stable. Thickening the activated sludge and adding food waste causes the buffer capacity to rise. (Note: Tage =days)

The simulation of the biochemical process shows that the biological system in the digester has no problems with the additional waste load. It will be necessary to thicken the activated sludge before digesting in order to allow for longer retention times and better degradation.

Graph 2.5

	Current		Future	
	Sludge only	With Food	Plant design	
Sewage sludge	17,170	17,170	11,887	gallons
Total solids	3.5	3,5	7,0	%
Food waste		16.5	24.2	tons/day
Food waste solids		20%	20%	
Total solids over all	3.9	5.8	8.3	tons/day
Protein content food waste		30%	30%	
Protein content sewage sludge	35%	35%	35%	
Protein content sewage sludge	0.88	0,88	1,2	tons/day
Protein content food waste		1	1,4	tons/day
Total Protein	0.88	1.9	2,6	tons/day
Digester volume	634,008	634,008	634,008	gallons
Biogas energy	30	111	186	decatherms
Mass loss of biogas	.935	3.52	5.94	tons
Retention time	37	31.3	39.0	days

Appendix A

Hydrolysis, Acidogenesis, Acetogenesis, and Methane production

1st Stage: Hydrolysis

Complex substrates (carbon hydrates, proteins and fat) are converted by hydrolytic bacteria (facultative anaerobes and anaerobes) into simple sugars, fatty acids and amino acids.

2nd Stage: Acidogenesis

The short chain fatty acids, simple sugars and amino acids are converted to short chain organic acids(e.g. Acetic acid, acetate, butyric acid) alcohols, hydrogen and carbon dioxide by facultative and obligatory anaerobic bacteria.

3rd Stage: Acetogenesis

Acetate production occurs as the bacteria convert organic acids and alcohols to acetate. The methanogenic bacteria feed on the metabolic products of the acetogens and remove the H ions, which if the ambient concentration got too high would kill the acetogens and thus remove the food source of the methanogens.

4th Stage: Methanogenesis

Conversion substrates such as of acetate, formate, CO₂, H₂, methanol, methyl amine, propionate, butyrate etc. into methane, carbon dioxide, water, hydrogen sulphide and a bit of NH₃ and NH₄.