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EVALUATING THE POTENTIAL PRODUCING BIOGAS FROM WHEY, A BY-PRODUCT DERIVED FROM DAIRY

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Abstract

Biogas production from cheese whey as an energetically rich product that can contain more than 50 g/ L lactose was investigated. Whey, a by-product derived from the dairy industry, represents an optimal as primary material for biogas production by anaerobic methanogenic fermentation, compatible with liquid manure. In the analysis performed, it was concluded that whey development fulfills all the conditions favorable environment bacterial anaerobic digestion. Whey, having an organic carbon content of 0,798% was used. In our study, AD batches consisting of whey, and 4% inoculum, in 5 l bench top digester were conducted. Our results indicate biogas yields over 1000 cm^3/ L fermentation medium. The concentration of main components in biogas was measured as well. Conclusion – anaerobic digestion of cheese whey is acceptable, with acidification substrate provided in the first phase.

Key words: *anaerobic digestion, biogas, methanogenic bacteria, whey.*

INTRODUCTION

Dairies are industries with high potential for environmental pollution. Pollution is the result of the waste from the process of obtaining the cheese, the main waste whey resulting from coagulation of milk. Whey is the liquid which remains after the removal of caseins from milk and is characterized by a high organic content (BOD5 approx. 50 g / l to the limit of 0.3 g / l of a normal water).

Worldwide is an absolute recipes in individual processing technologies and whey separation. Worldwide is an absolute recipes in individual processing technologies and whey separation. Only half of the whey produced worldwide is employed for human food or animal feed. The rest, by discharging to the environment, put complicated pollution problems exacerbated by the fact that a liter of whey has a biochemical oxygen demand (BOD) 50,000 mg / l, compared with 300 mg / l for affluent discharged from urban centers.

Due to the high cost of treatment whey treatment plants in some countries practice the use of whey for irrigation of agricultural land and pastures, or discharge into streams or oceans.

At first, the use of whey as a fertilizer may present some advantages, but in time, progressive mineralization of soil causes difficulties in cultivating plants. The main objective of the project is to develop, implement and promote technologies and equipment for treating whey in compact stations to reduce the environmental impact of industrial activities milk processing. Cheese production is an important part of the dairy industry in the European Union as more than 40 % of the European Union (EU) milk is processed into cheese [1]. In the milk quota year 2008/2009 milk delivered to the dairies reached 133 621 102 tons [2]. There are a lot of varieties of cheese resulting in different cheese making technologies, but in average the final volume of whey is about 85- 90 % of the volume of the processed milk. It can be estimated that more than 45 million tons of cheese whey each year are produced in the EU. Whey has already been utilized directly as animal feed, processed for human consumption or used as field fertilizer, but usage of whey for energy production is not widespread. Although whey has sufficient biogas potential it is complicated substrate for biomethane production due to the process instability

The main components of cheese whey are: lactose (44-52 g·l-1), protein (6.1-6.6 g·l-1), fat (0.2-0.3 g·l-1) and minerals (5-7.9 g·l-1) [3]. Under anaerobic conditions lactose (main component of whey solids) is rapidly broken down into short chain fatty acids – acetic, propionic, butyric and other acids. As whey has little or no buffering capacity, pH drops dramatically inhibiting activity of methanogens what results in low gas yields with a low methane content [4; 5]. To control the optimal pH level for methanogenic bacteria several techniques have been described. Scientists of ten propose to co-ferment whey together with substrates with sufficient buffering capacities [5; 6; 7]. Ghaly and Ramkumar used a pH measurement and control system which consisted of a computer controlled pH electrode and peristaltic pump. At prescribed time intervals (30 min.) pH was automatically measured and compared with the setpoint of pH 7. If pH was lower than 6.9 the peristaltic pump added basic solution – 2.5 N NaOH [5]. Ghaly and Ramkumar reported biomethane production of 0.51 vm·vr -1·d-1 (vm – volume of methane, vr – volume of reactor, d – day) in the two stage continuous anaerobic digester with the loading rate 10 l·d-1 (hydraulic retention time (HRT) 15 days) [5]. According to Kavacik et al. codigestion of cheese whey and dairy manure in continuous fermentation with HRT of 5 days and 8 % of total solids resulted in 0.906 vm·vr -1·d-1 [6]. In the continuously stirred pilot reactor the methane yield of 2.2 vm·vr -1·d-1 of diluted poultry manure and whey mixture was reported by Gelegenis et al. [4].

As described above organic carbon is measured before inoculation and after fermentation has finished ~ 50 days.

Cominio et al. investigated biogas potential of cow manure and whey biomass mix and achieved 211.4 lm·kgvs -1 (lm – liters of methane, kgvs – kg of volatile solids) [7].

MATERIALS AND METHODS

Raw materials

The raw materials used to construct the fermentation batches are:

Whey the liquid that remains after the casein and milk fat were removed and is characterized by a high organic content (BOD5 approx. 50 g / L, compared to the limit of 0.3 g / L of an ordinary water), fresh dairy cows manure collected in the day of starting the experiment

The manure represents an important source of microorganisms for biogas fermentation.

Table1 – *Characteristics and chemical composition of cheese whey*

Characteristic	Unit	Value
COD	mg/ L	60 000
Lactose	g/ L	50
TS	g/ L	55
VS	g/ L	49
Proteins	g/ L	2.2
Phosphate	g/ L	0.6
Ca	g/ L	0.02
pH		5,5 – 6,6

1. Pretreatment of the raw material and experimental pattern

a. *Unpretreatement biomass*

The seed material was obtained from anaerobic batch reactors used for seed material cultivation in own laboratory. Diluted cow manure was used as the initial substrate. Fresh inoculum from the batch reactor, witch produced biogas with average methane content of 60 % was used for the startup procedure**.**

b. *Physicochemical pretreatment*

Whey mixed to fresh manure were pretreated by a combination of thermal and alkaline pretreatment: the biomass soaked in 2% NaOH was autoclaved 30 minutes at 121 ^{0}C. The biomass was afterwards washed with 10% H_2SO_4 until pH 6.5 and with 12 equivalent volumes of water in order to remove the inhibitors resulted during pretreatments.

c. *Determination of organic carbon* Organic carbon content in the substrate is calculated by the amount of dichromate consumed for the oxidation of anhydride. Anhydride excess dichromate is titrated with a solution of 0.2% normal Mohr salt in the presence of a redox indicator.

The indicator used in titration of the excess oxidant was orthophenanthroline whose turn from blue to red is easier to follow. The equipment used consisted of:

- Magnetic stirrer (magnet wrapped in glass or plastic)
- Porcelain crucible with a diameter of 20-25 cm
- Burette Mohr salt halfmicro

As reactive 1,485g and 0,695g orthophe-nanthroline using ferrous sulfate is bringing to volume in a 100 ml volumetric flask. The way of working is to add 5-6 drops of indicator titrating with Mohr salt solution drop by drop until the solution turn from blue-green to scarlet red. It is considered that recovery of organic carbon is done in the normal range when oxidizing reagent consumption does not exceed 75% of the added.

RESULTS AND DISCUSSIONS

In this research, the UAPB was continuously operated with HRT of 6 to 24 h.

Experiment was conducted over a period of 49 days following distinguished periods: from the beginning until day 11

Day 11 - Day29

Day 29- Day 37

Day 37- Day 49

early in the biogas production increased gradually decreasing as the microorganisms have adapted to the acidity of the whey.

The bioreactor was successfully started with HRT of 24 h, and then the removal rate was gradually increased.

While the HRT was decreased stepwise to 16 h, maximum film was built on the surface of packing. The lactose concentration at downstream drastically dropped to zero.

The COD and lactose in the effluent gradually increased as the retention time decreased stepwise

The bioreactor was successfully started with HRT of 24 h, and then the removal rate was gradually increased.

While the HRT was decreased stepwise to 16 h, maximum film was built on the surface of packing. The lactose concentration at downstream drastically dropped to zero.

The bioreactor was successfully started with HRT of 24 h, and then the removal rate was gradually increased.

CONCLUSIONS

1. Anaerobic digestion of local cheese whey in a bioreactor is acceptable.
2. Usage of pH control should be considered in anaerobic digestion of local cheese whey in a bioreactor is acceptable.
3. Smaller volume of reactor should be considered.

4. The novel anaerobic bioreactor with high performance was able to handle the high organic load.

Figure 1. Laboratory plant for biogas production

Composition of biogas production during different periods of the experiment

Period days	CH_4%	CO_2%	O_2%	H_2S ppm
0-11	56,2	16,8	4,8	83
11-29	65	22	2,9	178
29-37	53	23,3	3,8	176
37-49	62	18,6	3,4	76

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