32

ANAEROBIC TECHNOLOGY FOR TREATMENTOF CONCENTRATED WASTEWATER FROM ESTONIAN FOOD INDUSTRIES

H.MÖLDER
V.BLONSKAYA
Tallinn Technical University, Estonia

ABSTRACT

Anaerobic wastewater treatment technologies are used throughout the world for effective treatment of a wide variety of industrial wastewater, in particular for the wastewater from the food industry. This type of wastewater is rich in easily biodegradable carbohydrates and has a relatively low content in suspended solids. As an example, the anaerobic bio-degradation of organic matter in wastewater (cheese whey) was studied on a laboratory – scale Upflow Anaerobic Sludge Blanket Reactor (UASB). This wastewater was found characterized by high COD concentration, from 58.000 to 72.000 mg/L. The digester efficiency during the treatment process of cheese wastewater at various organic loading rates (0.5 – 16 kg COD/m^3 · day) was studied and its performance was assessed by monitoring the pH value (6.8 –7.3) and biogas production (up to 24 L /day). The investigation has demonstrated that the process of anaerobic degradation was sufficiently effective for COD removal.

KEYWORDS

Food industry; cheese whey; biodegradable organic; anaerobic treatment; UASB-reactor.

INTRODUCTION

The food industry is one of the major contributors of wastewater pollution. Estonia has 70 small enterprises of the food industry, some of them have very small flow rates (some m^3 per day). Today (1999) some of enterprises are pumping their wastewater to the wastewater treatment plants of towns and others have local treatment plants. In many cases the local treatment plants are rather old and work inefficiently. The quality of wastewater varies according to the branch of industry and mill type, but all wastewater from food industries

https://doi.org/10.15626/Eco-Tech.1999.032

contains an organic matter which is easily biodegradable. Most of effluents are also rich in phosphorus and nitrogen, mostly originating from raw materials or products, but some also from washing. As seen from Table 1, pollutant concentrations in municipal wastewater discharge are substantially higher of the limiting permissible concentrations, especially BOD_7 and phosphorus. The average wastewater concentrations are: BOD_7 – 1177 mg /L, SS –261 mg /L, phosphorus –19,1 mg /L, nitrogen – 57,9 mg/ L and ratio BOD : N : P is 100 : 4,9 :1,6.

TABLE 1 The characteristics of the food industry effluent

Industry	Number of enterprises	Effluent Q, m^3/day	Average concentration of pollutants				
			pH	BOD mg/L	SS mg/L	P_{tot} mg/L	N_{tot} mg/L
Slaughterhouses	2	15–500	6.0	1100	144	13	85
Fish	20	15–745	7.1	953	425	30	93
Dairies	16	5–3800	7.1	830	507	15	90
Cheese	6	61–660	–	1002	253	23	63
Meat	7	16–4400	7.6	575	375	16	78
Potatoe chips	1	334	–	1557	–	35	35
Yeast	1	587	–	6000	100	17	100
Bread, muffin	9	15–70	7.3	901	455	8.5	2.9
Starch	2	16–300	–	718	150	10	50
Alcohol:	2	50	8.9	269	104	14	41
beer	6	35–500	7.3	675	288	9.6	55
drinks, wine	4	60–353	9.3	1113	229	44	56
spirits	3	100–590	6.95	615	101	13	4
Limiting admissible concentration if discharged into public sewerage			6.5–8.5	375	500	10.5	100

The temperature of wastewater is higher than that of municipal waters. Wastewater from the food industry contains proteins, fats, lactose, etc. Full utilization of all wastes on spot and their reuse at the manufactures are naturally the best method for most food industry enterprises. But these technologies are rather complicated and expensive for use in small enterprises. A biological wastes treatment may be a good alternative in such cases. In Estonia, in the majority of cases aerobic processes are used for municipal and industrial wastewater treatment. However, the wastes of food industries are categorized as medium strength organic wastewater, requiring an intensive amount of energy for aeration. Besides, a large amount of waste sludge is generated from these aerobic processes. On the other hand, anaerobic treatment technologies are used throughout the world for the effective treatment of a wide variety of industrial wastewater. The main advantages of the anaerobic treatment are (Malina, 1992): low production of biological sludge, high treatment efficiency, low capital cost, no oxygen requirement, methane production (potential source of fuel), low nutrient requirement, low operating cost.

The comparison of an anaerobic and aerobic processes is shown in Figure 1.

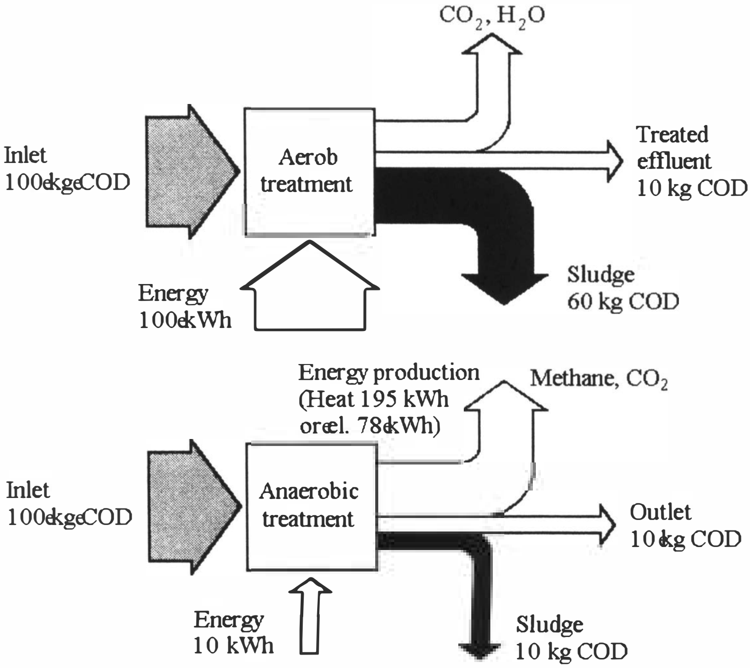

Fig. 1. The comparison of an anaerobic and aerobic processes

Figure 2 summarizes the many anaerobic designs that are currently in use for full-scale treatment applications (Sutton, 1990).

Anaerobic Treatment Technologies

Suspended Growth — Supported Growth

Complete Mix Digester — Anaerobic Contact — Fixed Bed Process — Expanded/Fludized Bed Process

Hybrid

Upflow Anaerobic Sludge Blanket — Anaerobic Lagoons — Upflow Sludge Blanket /Fixed Bed Reactor

Fig. 2. Commonly used full-scale anaerobic treatment processes.

Table 2 summarizes the main parameters of the anaerobic treatment processes in the wastewater of the food industry (Hanging,1996; Kalyuzhnyi,1991, 1997; Lettinga et. al. 1997; Seyfried, 1997).

TABLE 2 Main parameters of the anaerobic treatment processes in the wastewater of the food industry

Industry	Type of the reactor	Wastewater concentration, mg COD/L	Load, kg COD/$m^3 \cdot$day	HRT, Day	Effect of treat-ment, %
Beer	UASB	1300–4600 45000	1.4–14.9	5.6–9	75–80
Starch	H	4500	4	228	97
	AF	10000	10.8	10	80
	UASB	8000	15	18	90–95
Potatoes	AF	7500	8	24–26	80–93
	H	28000	11.6	16.3	70
Dairies	FB	1600	7	24	80
	H	3000–33000	2	20	70
	UASB	3200	12	65	85
Cheese	FB	40000–70000	22	2.4	70
	AF	3600	8–15.6	96–120	82–85
	H	3000–4500	216	85	90
	UASB		3.5–15	6–8.2	92–95

UASB – Upflow Anaerobic Sludge Blanket
H – Hybrid
AF – Anaerobic Filter
FB – Fixed Bed Processes

The best step is the local wastewater treated with the UASB process. The UASB process is the most economical system and may be used for various types of wastewater from the food industry. Advantages of this type of reactor are: to provide a polishing effect to the effluent, start–up time of reactor is short, well-established anaerobic treatment systems, to prevent the washout of viable bacterial matter. This type of reactor is characterized by the highly flocculated, well settling, compact methano-genic sludge granular, resulting in a very high biomass content (Gavala, 1998).

MATERIALS and METHODS

Milk processing is the largest sector of the food industry in Estonia, and therefore it was necessary to search an environmental friendly solution for its wastes. Anaerobic treatment of highly concentrated waste of the cheese industry was studied at the laboratory pilot–plant. The experi-mental pilot plant consisted of five-litre volume packed bed reactors, a sedimentation tank, a feed tank, and a gas collection tank (Figure 3). Temperature was maintained by an electric heating mat wrapped around the external wall of the reactor. The COD, N_{tot}, P_{tot}, dry matter, alkalinity, volatile fatty acids of wastewater and effluent were measured twice a week. Flow rates, biogas production rate and effluent pH were measured daily.

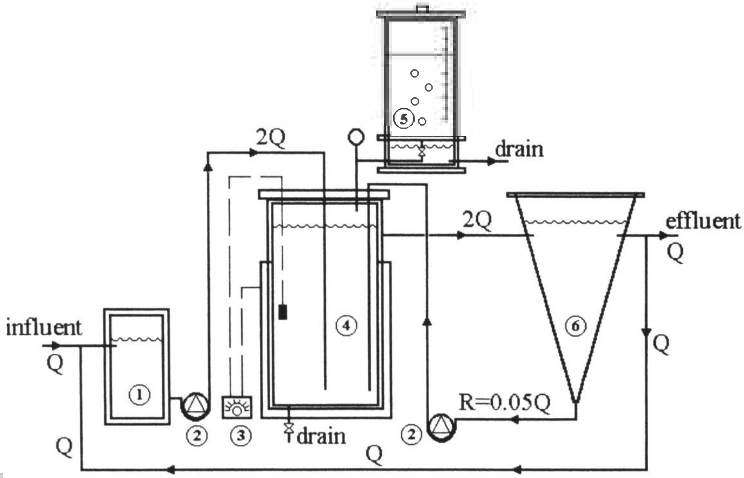

Fig. 3. Scheme of an anaerobic digester

1 – feed tank	4 – anaerobic reactor (volume - 4.8L)
2 – pump	5 – gas collection tank
3 – temperature control	6 – sedimentation tan

The chemical characteristics of the studied wastewater whey from the cheese industry was : COD 58.800 – 73.100 mg/L; dry matter 56.000–72.000 mg/L; pH 3.8–6.3; N_{tot} 760–1.420 mg/L; P_{tot} 368–720 mg/L

RESULTS and DISCUSSION

The efficiency of the anaerobic treatment process is mainly determined by a proper start-up of the reactor. UASB reactor started up with granular sludge (20 % of the volume of the reactor) from one of the full-scale plant working at the sugar industry. The initial sludge loading rate was well below approximately 50% of its maximum potential during the first week. A slowly rising load (5% a week) did not create any problems. It should be noted that the HRT applied was usually shorter than five days, considered (Yan et. al., 1993) as minimal admissible HRT to achieve stable operation of anaerobic reactors treating raw cheese whey. Main operating conditions for the UASB reactor were :

Days of experiment	1.03.98.–2.07.98. 1.09.98.–3.03.99.
Temperature	35 – 37 $^{\circ}$C
Sludge load	0.5 – 16 kg COD/ $m^3 \cdot$ day
HRT	2.5 – 12 days
Gas production	0 – 24 L/ day 0 – 0.814 L/g $COD_{removed}$
Reduction of COD	53 – 98 %

The effluent pH was kept at 6.8 – 7.3, due to the chemical buffer in the wastewater. Figure 4 shows the change of main parameters during the experiments. Biogas production and composition were measured throughout the experiment. The gas produced was composed of 78% methane, 20% carbon dioxide and 2% nitrogen, which was comparable to the figures reported in literature. The gas production rate increased line- arly with an increased COD load. Figure 5 shows that maximum digester COD removal efficiency 98 % was achieved before the load 3.5 kg COD/ m^3 · day. When increasing the influent COD concentration to 32.948 g /L (load 7.44 kg COD/ m^3 · day), the COD removal efficiency was reduced to 70% with a mean COD effluent concentration 15.60 g/L. Figure 6 shows the relationship between the organic load, biogas production and HRT.

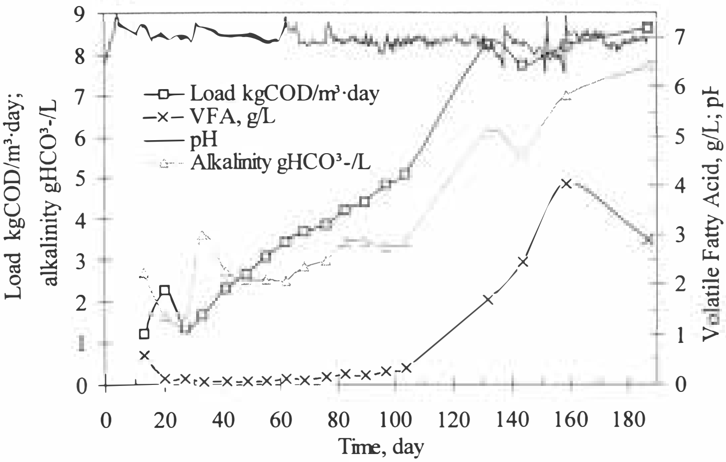

Fig. 4. Organic load, pH, VFA, and alkalinity changes time

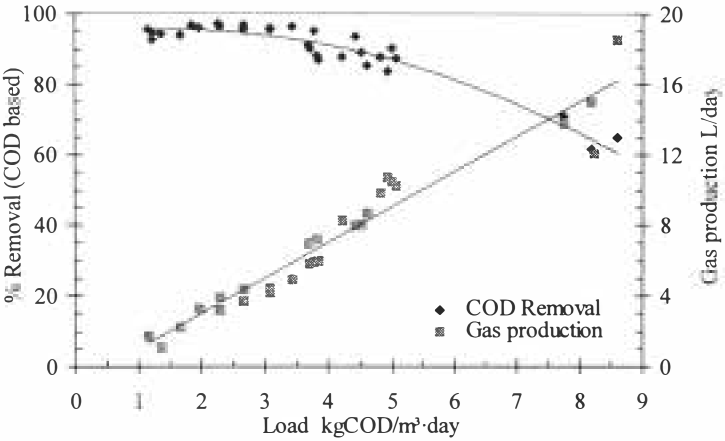

Fig. 5. Relationship between COD removal efficiency, gas production, and organic load

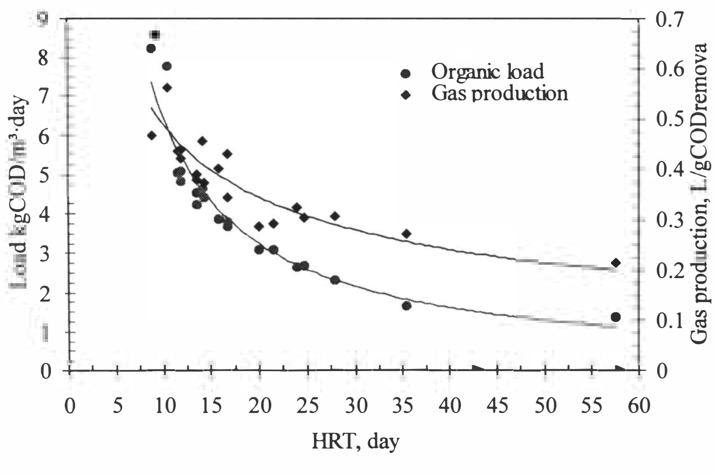

Fig. 6. Relationship between organic load, gas production and HRT

The results of the experiment are summarized in Table 3 .

TABLE 3 Wastewater quality after treatment

Parameters	Concentration mg/ L
COD	2767
Dry matter	6.33
Alkalinity	2770
Volatile acids	943
N_{tot}	438
P_{tot}	69

The maximum COD removal was achieved with a relationship between fatty acid and alkalinity of 0.2, such as for a well-balanced system. When increasing this relationship from 0.6 to 1.0, the COD removal efficiency was reduced from 80 to 45 %. Anaerobic treatment with the UASB reactor was very effective for removing the biodegradable organic matter, but not for removing phosphate and ammonia. The effluent concentration of P and N was increased from 38.5 to 79 mg/L P_{tot} and from 190 to 638 mg/L N_{tot} during the experiments.

CONCLUSION

The investigation of the cheese industry wastewater treatment has demonstrated that the process of anaerobic degradation can be successfully for COD removal. The UASB reactor proved to be a very reliable unit throughout the year. No problems occurred with restarting the UASB reactor when there had been a standstill over a period of some weeks. The optimum parameters for treating cheese whey wastewater, such us

organic load	before 7.5 kg COD/m^3·day
HRT	10 days
treatment efficiency	70–98% COD
temperature	35–37 °C

may be recommended. The treated cheese whey may be directed to the municipal treatment plant.

ACKNOWLEDGEMENT

The authors express their appreciation to the Estonian Science Founda-tion for their financial support (GRANT 3427).

REFERENCES

Gavala H.N., Kopsinis H., Skidas I.V, Stamatelatou K., and Lyberatos G. (1997). Treatment of dairy wastewater using a UASBR. In : *Proc. 8 th. International Conf. on Anaerobic Digestion.,* vol 3, 4p.

Hanging Y. and Guowei G. (1996) Biomethanation of brewery wastewater using an anaerobic upflow blanket filter. Cleaner Prod., 4, (3-4), pp. 219-223.

Kalyuzhnyi S.V., Danilovitsh D.A., and Kozhevnikov A.H. (1991). *Anaerobic Biological Wastewaters Treatment*. M. Reports of Science and Engineering, Series Biotechnology, 29, pp 1-155. (In Russian).

Kalyuzhnyi S., Martinez E.P., and Martinez J.R. (1997). Anaerobic treatment of raw cheese whey wastewater in laboratory and pilot UASB reactoris. In: *Porch. 8th. International Conf. on Anaerobic Digestion.*, Vol 3, 4p.

Lettinga G., Field J., Lier J., Zeeman G., and Hulshoff L. W. (1997). Advanced anaerobic wastewater treatment in the near future. Wat.Sci: Tech., 35 (10), pp.5-12. DOI: https://doi.org/10.1016/S0273-1223(97)00222-9

Malina I.F. and Pohland F.G.(1992). Water Quality Management Library. Volume 7. Design of Anaerobic Processes for the Treatment of Industrial and Municipal Wastes, USA. 214p.

Seyfried C.F. and Austermann-Haun U. (1997). Full-scale experiences with the anaerobic pretreatment of industrial wastewater in Germany . In: *Porch. 8th. International Conf. on Anaerobic Digestion.*, Vol 1, 8p.

Sutton P.M. (1990) *Anaerobic Treatment of High Strength Wastes: System Configurations and Selection, Presented at Anaerobic Treatment of High Strength Wastes*, University of Wisconsin Milwaukel, Milwaukee, Wisconsin.

Yan J.Q., Lo K.V., and Pinder K.L. (1993). Instability caused by high strength of cheese whey in a UASB reactor. *Biotechnol. Bioeng.*, 41, pp. 700 –706. DOI: https://doi.org/10.1002/bit.260410704