BIOCHEMICAL TREATMENT OF WASTEWATER FROM CANNING COMPANIES FOR BIOGAS AND DIGESTATE PRODUCTION

N. Bublienko[1], O. Salavor[1], O. Nychyk[1], N. Stetsenko[1]

[1]National University of Food Technologies, Ukraine

3110nb@gmail.com

DOI: https://doi.org/10.20535/2218-930022024313231

Canneries are a powerful source of wastewater. Wastewater is produced at various stages of the technological process and is contaminated with carbohydrates, proteins, fats, etc. Often, such wastewater is not treated or discharged into natural reservoirs incompletely treated. It is advisable to use methane fermentation. This biotechnological process will contribute to the removal of pollutants from sewage. At the same time, biofuel and biofertilizer are also produced. Therefore, research on methane fermentation of cannery effluents to obtain biogas (alternative biofuel) and digestate (plant growth stimulator) is relevant. The purpose of the work is to study the methane fermentation of cannery effluents with the production of biogas and digestate. The work's task is to study the process of methane fermentation of cannery effluents, determine the intensity of gas generation, study the stimulating effect of digestate on plant seeds. The initial COD of the effluents is 4200 mg O_2/dm^3, pH 6.8. The research was carried out in a periodic regime, the loading dose was 30 %. Methane fermentation caused a high efficiency of wastewater treatment. The final value of the COD of the effluents was 500 mg O_2/dm^3. The cleaning efficiency is 88.1 %. The intensity of biogas release was high. Recorded biogas formation of 4 dm^3 from 1 dm^3 of wastewater. The amount of biogas in terms of the amount of initial pollution: 0.95 dm^3/g of COD_{start}. The amount of biogas in terms of the amount of fermented pollution: 1.08 $dm^{3/}g$ of COD_{ferm}. Biogas had a high methane content – 65 – 68 %. Such biogas is used as an alternative biofuel. There is a clear classical interdependence between the reduction of sewage pollution and the release of biogas. Digestate is a valuable fertilizer and seed biostimulator. When seeds were treated with a digestate solution, the growth of roots (by 20 – 27 %), stems (by 21 – 30 %) was accelerated. Germination energy increased by 24.8 % compared to the control experiment.

Key words: *biofertilizer, biogas, canning industry, digestate, environment protection, methane fermentation, wastewater.*

Received: 13 October 2024 Revised: 10 November 2024 Accepted: 10 December 2024

1. Introduction

The canning industry of Ukraine is one of the main ones in the food industry, which provides the population with high-quality products of animal and plant origin.

At the same time, such factories cause a strong negative impact on the environment. Canning plants are a source of wastewater of various compositions, concentrations, and origins. These effluents are generated at most stages of the technological process: transportation, washing, sorting of plant raw materials (vegetables, fruits), processing of raw meat, grinding, heat treatment of semi-finished products, production of marinades, brines, sterilization of finished products, etc.

At some canneries, from 12 to 35 % of raw materials end up in sewage. If a cannery processes not only vegetable but also meat and dairy raw materials, then fats, protein components, etc. get into the wastewater. Often, such wastewater is not treated at all at factories, or is discharged into natural reservoirs incompletely treated, which has a significant negative impact on the environment (Getta et al, 2022, Jayasundara et al, 2023).

Since the COD of wastewater of canning enterprises is higher than 2000 mg O_2/dm^3, it is advisable to use methane fermentation. Such biotechnology will ensure the removal of pollutants from sewage, and will also provide an opportunity to obtain biogas.

Biogas is a biofuel that is an alternative source of energy (Zhao et al, 2021, Tamošiūnas et al, 2022). Biogas (or biomethane from it) can be used for heating the methane tank, the production processes, obtaining electrical energy (Lewis, 2023, Saravanan et al, 2023).

Also, during the bioconversion of organic substances under the influence of anaerobic bacteria, digestate is formed (Le et al, 2024). Digestate has significant concentrations of B vitamins and other biologically active complexes (Sarangi et al, 2022, Angouria –Tsorochidou et al, 2021). Digestate is used as a fertilizer or seed growth stimulant for various crops (Song et al, 2021, Bumharter et al, 2023, Lu et al, 2021).

Research on methane fermentation of cannery effluents to obtain biogas (alternative biofuel) and digestate (plants growth stimulator) is relevant.

The purpose of the work is to study the methane fermentation of cannery effluents with the production of biogas and digestate.

The task of the work is to study the process of methane fermentation of cannery effluents, to determine the intensity of gas generation, to study the stimulating effect of digestate on plants seeds.

2. Materials and Methods

Methane fermentation of effluents from canning enterprises took place in a laboratory installation: a biogas reactor (methane tank) with a volume of 3 dm^3, a gasholder for the accumulation of biogas. The methane tank was placed in a thermostat to maintain the required temperature regime.

Standard methods were used to determine process indicators (Semenova, 2019).

The pH of the environment in the bioreactor was monitored with a pH device of 340. The content of methane and carbon dioxide in the biogas was determined by an accelerated method: passing it through 10 % sodium hydroxide solution (Semenova, 2019).

Biosolution (digestate and tap water) was used to stimulate the seeds. The length of the roots, the height of the seedlings, and the energy of seeds germination were determined.

3. Results and Discussion

At the Department of Ecology and Ecomanagement of the National University of Food Technologies, methane fermentation of wastewater from the food industry and waste (municipal, agricultural, food, etc.) is being researched.

Concentrated wastewater from canning production was fermented in a biogas reactor with a volume of 3 dm^3. The bioreactor was placed in a thermostat (the temperature of the mesophilic regime is 37 ± 1 °C). Activated sludge from the bioreactor of the Yuzefo-

Mykolaiv biogas plant (Ukraine, Vinnytsia region) was used.

Wastewater from the Moshuriv cannery had turbidity, a light yellow color, and a characteristic smell. Chemical oxygen demand (COD) of effluents is 4200 mg O_2/dm^3, pH 6.8. The research was carried out in a periodic regime, the loading dose was 30 %.

Control of purification was carried out according to indicators: COD, temperature, pH, amount of biogas, methane content in it, efficiency of purification. The biogas output was calculated on the number of initial pollutants according to COD and on the number of fermented pollutants.

Duration of fermentation was 3 days. The pH of the culture fluid increased from 6.8 to 7.8. Therefore, the normal course of methane fermentation takes place. Acidification of the liquid was not observed.

Methane fermentation caused a high efficiency of wastewater treatment. The final value of the COD of the effluents was 500 mg O_2/dm^3. Therefore, the cleaning efficiency is 88.1 %.

Gas generation was also investigated. The intensity of biogas release was high. Recorded biogas formation of 4 dm^3 from 1 dm^3 of wastewater.

The amount of biogas in terms of the amount of initial pollution: 0.95 dm^3/g of COD_{start}. The amount of biogas in terms of the amount of fermented pollution: 1.08 dm^3/g of COD_{ferm}.

Biogas had a fairly high methane content – 65 – 68 %. Such biogas is used as an alternative biofuel to ensure the temperature regime in the methane tank or to produce electricity.

There is a clear classical interdependence between the reduction of sewage pollution and the release of biogas.

On the fourth day, the intensity of gas generation decreases significantly, which is explained by the limited possibilities of anaerobic bacteria for complete biotransformation of pollutants. Due to the subsequent minor production of biogas, it is not advisable to continue the fermentation.

For complete sewage treatment, it is possible to recommend the use of traditional aerobic treatment.

The results of the research are shown in Table 1.

The digestate from the methane tank has many biologically active components. Vitamins of group B are particularly important components. The content of vitamin B_{12} reaches 16 – 19 μg/g of dry matter.

Digestate also has valuable components for plants: nitrogen, phosphorus, potassium. Therefore, it is advisable to use digestate as fertilizers, as well as to stimulate plants growth.

We conducted exploratory studies on the use of anaerobically fermented mass as a biostimulator of the growth of seeds of a mixture of lawn grasses (ryegrass *Lolium perenne*, fescue *Festuca glauca*).

Treatment of lawn grass seeds with a bioactive solution was used. This solution was obtained by diluting the digestate with tap water (10 cm^3 of tap water per 2 cm^3 of digestate).

The seeds were soaked in a biosolution for 40 minutes (the ratio of biosolution and seeds is 1:100). In parallel, the seeds were soaked in ordinary water at room temperature in a similar ratio (control experiment).

Treated seeds were placed in Petri dishes boiled and disinfected with alcohol. A thin layer of sand was distributed on the bottom of the cups. Before that, the sand was washed with distilled water, dried in a drying cabinet, and sieved.

Table 1. *Indicators of the process of methane fermentation of cannery effluents*

Duration of fermentation, hours	**COD, mg O_2/ dm^3**	**pH**	**Amount of biogas, dm^3/dm^3**	**The total amount of biogas, dm^3/dm^3**	**The total amount of biogas, dm^3/g of COD_{start}**	**The total amount of biogas, dm^3/g of COD_{ferm}**	**Cleaning effect,%**
0	4200	6.80	0	4.0	0.95	1.08	88.1
12	2500	7.30	1.2				
24	1800	7.40	1.2				
36	1200	7.50	0.8				
48	900	7.70	0.4				
60	700	7.75	0.3				
72	500	7.80	0.1				

25 seeds were added to each Petri dish. Seeds were germinated at a temperature of 20 °C. Seeds were moistened daily.

After 2 days, the length of the roots of the seeds and the height of the sprouts were measured daily.

The obtained data are shown in Table 2.

Table 2. *Changes in seed parameters during the germination process*

Duration of germination, days	**The length of the roots, cm**		**Height of sprouts, cm**	
	with a growth stimulant	**without a growth stimulant**	**with a growth stimulant**	**without a growth stimulant**
2	0.80	0.60	0.35	0.25
3	1.10	0.70	0.90	0.80
4	1.60	1.10	2.10	1.80
5	2.10	1.30	3.20	2.60
6	2.40	1.60	4.50	4.00
7	2.80	2.00	5.60	5.20
8	3.20	2.20	7.40	6.80

After 72 hours from the start of germination, the number of germinated seeds was counted, and the energy of germination was calculated. For seeds not treated with a biostimulator (soaked only in tap water), this indicator was 73 %, for treated seeds – 95 %.

When seeds were treated with a digestate solution, the growth of roots (by 20

– 27 %) and sprouts (by 21 – 30 %) was accelerated. Germination energy increased by 24.8 % compared to the control experiment.

This testifies to the effectiveness of using digestate solutions to stimulate seeds germination.

4. Conclusions

Methane fermentation of technological wastewater of the Moshuriv Canning Plant ensures their comprehensive utilization.

High cleaning efficiency up to 88.1 % is ensured. The final value of the COD of the effluents was 500 mg O_2/dm^3. Traditional aerobic treatment is used for complete wastewater treatment.

Gas generation processes also take place intensively: biogas is formed in the amount of 4 dm^3 from 1 dm^3 of wastewater. The high content of methane in biogas (65 – 68 %) makes it possible to use it as an alternative biofuel.

The byproduct of methane fermentation (digestate) is a valuable fertilizer and plants growth stimulator. This biostimulant significantly improved the process of grains germination (germination energy increased by 24.8 %).

References

1. Angouria-Tsorochidou, E.; Thomsem, M. Modelling The Quality of Organic Fertilizers From Anaerobic Digestion – Comparison of Two Collection System. *J. of Cleaner Production.* **2021**, *304*, 127081. https://doi.org/10.1016/j.jclepro.2021.127081.

2. Bumharter, C.; Bolonio, D; Amez, I.; Martínez, M. J. G.; Ortega, M. F. New Opportunities for the European Biogas Industry: A Review on Current Installation Development, Production Potentials and Yield Improvements for Manure and Agricultural Waste Mixtures. *J. of Cleaner Production.* **2023**, *388*, 135867. https://doi.org/10.1016/j.jclepro.2023.135867.

3. Getta, O. S.; Shestopalov, O.V.; Kulinich, S.S. Environmentally Safe Solutions During Wastewater Treatment After Washing Vegetable Products. Information Technologies: Science, Engineering, Technology, Education, Health, Abstracts of reports 30th International science and practice conf. MicroCAD-2022, Kharkiv, Ukraine, October 19 – 21, 2022; NTU «KhPI»: Kharkiv, 2022; 238. https://repository.kpi.kharkov.ua/handle/KhPI-Press/60324 .

4. Jayasundara, P. M.; Rathnayake, M. Environmental Impacts and Sustainability Assessment of Fruit and Vegetable Waste Valorization Through Life Cycle Assessment (Includes an Overview of Life Cycle Assessment From Laboratory Scale to Industrial Implementations and Social & Economic Sustainability). Chapter 10. *Fruit and Vegetable Waste Utilization and Sustainability*, 2023; 181 – 212. https://doi.org/10.1016/B978-0-323-91743-8.00010-1.

5. Le, T.-S.; Bui, X.-T.; Nguyen, Ph.-D.; Ngo, H. H.; Dang, B.-T.; Le Quang, D.-T.; Pham, T. T.; Visvanathan, Ch.; Diels, L. Bacterial Community Composition in a Two-Stage Anaerobic Membrane Bioreactor for Co-Digestion of Food Waste and Food Court Wastewater. *Bioresource Technology.* **2024**, *391*, Part A, 129925. https://doi.org/10.1016/j.biortech.2023.129925.

6. Lewis, M. Water, energy and wastewater. Chapter 46. *Food Process Engineering Principles and Data*, 2023, 425 – 432. https://doi.org/10.1016/B978-0-12-821182-3.00039-X.

7. Lu, J.; Xu, S. Posttreatment of Food Waste Digestate Towards Land Application. *J. of Cleaner Production.* **2021**, *303*, 127033. https://doi.org/10.1016/j.jclepro.2021.127033

8. Sarangi, P. K.; Singh, Th. A.; Singh, Ng J.; Shadangi, Kr. Pr.; Srivastava, R.K.; Singh, Ak. K.; Chandel, A.K.; Pareek, N.; Vivekanand, V. Sustainable Utilization of Pineapple Wastes for Production of Bioenergy, Biochemicals and Value-Added Products: A Review. *Bioresource Technology.* **2022**, *351*, 127085. https://doi.org/10.1016/j.biortech.2022.127085

9. Saravanan, A.; Senthil, K. P.; Rangasamy, G.; Hariharan, R.; Hemavathy, R.V.; Deepika, P.D.; Anand, K.; Karthika, S. Strategies for Enhancing the Efficacy of Anaerobic Digestion of Food Industry Wastewater: An Insight Into Bioreactor Types, Challenges, and Future Scope. *Chemosphere.*

2023, *310*, 136856. https://doi.org/10.1016/j.chemosphere.2022.136856.

10. Semenova, O.I.; Bublienko, N.O. Environmental Technologies and Equipment: Laboratory Workshop. NUFT, 2019, 55. http://elibrary.nuft.edu.ua/library/DocDownloadForm?docid=379672.

11. Song, S.; Lim, J.; Lee, J.; Cheong, J. Ch.; Hoy, Sh.H.; Hu, Q.; Tan, J. K. N.; Chiam, Zh.; Arora, Sr.; Lum, Ti.Q.H.; Lim, E.Y.; Wang, Ch.-Hw.; Tan, H. T.W.; Tong, Y. W. Foodwaste Anaerobic Digestate as a Fertilizer : The Agronomic Properties of Untreated Digestate and Biochar-Filtered Digestate Residue. *Waste Management.* **2021**, *136*, 143–152. https://doi.org/10.1016/j.wasman.2021.10.011.

12. Tamošiūnas, A.; Khiari, B.; Jeguirim, M. Biofuels production: Biogas, Biodiesel and Bioethanol from Tomato Wastes. Chapter 10. *Tomato Processing by-Products* 2022, 333–370. https://doi.org/10.1016/B978-0-12-822866-1.00003-X.

13. Zhao, Y.; Wei, R. Anaerobic Fermentation Process for Biomethane Production from Vegetable Waste. Chapter 1. *Biomethane Production from Vegetable and Water Hyacinth Waste***.** 2021, 1–62. https://doi.org/10.1016/B978-0-12-821763-4.00001-6

БІОХІМІЧНЕ ОЧИЩЕННЯ СТІЧНИХ ВОД КОНСЕРВНИХ ПІДПРИЄМСТВ ДЛЯ ВИРОБНИЦТВА БІОГАЗУ ТА ДИГЕСТАТУ

Бублієнко Н.О.[1]*, Салавор О.М.*[1]*, Ничик О.В.*[1]*, Стеценко Н.О.*[1]

[1]Національний університет харчових технологій, Україна

3110nb@gmail.com

Консервні підприємства є потужним джерелом стічних вод. Стічні води утворюються на різних стадіях технологічного процесу та забруднені вуглеводами, білками, жирами тощо. Часто такі стічні води не очищають або скидають у природні водойми неповністю очищеними. Доцільним є використання метанової ферментації. Такий біотехнологічний процес сприятиме вилученню забруднень із стоків. Також при цьому утворюються біопаливо та біодобриво. Тому актуальним є дослідження метанової ферментації стоків консервних заводів для отримання біогазу (альтернативне біопаливо) та дигестату (стимулятор росту рослин). Мета роботи – дослідження метанової ферментації стоків консервних виробництв з отриманням біогазу та дигестату. Завданням роботи є дослідження процесу метанової ферментації стоків консервних заводів, визначення інтенсивності газогенерації, дослідження стимулювальної дії дигестату на насіння рослин. Початкове ХСК стоків 4200 мг O_2*/дм*^{3}*, pH 6,8. Дослідження проводили у періодичному режимі, доза завантаження – 30 %. Метанова ферментація зумовила високу ефективність очищення стоків. Кінцеве значення ХСК стоків становило 500 мг* O_2*/дм*^{3}*. Ефективність очищення – 88,1 %. Інтенсивність виділення біогазу була високою. Зафіксоване утворення біогазу 4 дм*^{3} *з 1 дм*^{3} *стічної води. Кількість біогазу у перерахунку на кількість початкових забруднень: 0,95 дм*^{3}*/г* $ХСК_{поч.}$*. Кількість біогазу у перерахунку на кількість зброджених забруднень: 1,08 дм*$_3$*/г* $ХСК_{зброд.}$*. Біогаз мав високий вміст метану – 65 – 68 %. Такий біогаз використовують як альтернативне біопаливо. Прослідковується чітка класична взаємозалежність між зменшенням вмісту забруднень стоків та виділенням біогазу. Дигестат є цінним добривом і біостимулятором насіння. При обробці насіння розчином дигестату відбувався прискорений ріст корінців (на 20 – 27 %), стебел (на 21 – 30 %). Енергія проростання збільшилась на 24,8 % відносно контрольного досліду.*

Ключові слова: *біогаз, біодобриво, дигестат, консервна промисловість, метанова ферментація, охорона довкілля, стічні води.*