All Sciences Proceedings
http://as-proceeding.com/

1st International Conference on Modern and Advanced Research
July 29-31, 2023 : Konya, Turkey

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Case Study: Simulating the Biochemical Decomposition Process of Different Organic Wastes

Ilirjan Malollari*[1], Hasime Manaj[2], Sami Makolli[3] and Rexhina Bazaj[4]

[1,2,4]*Department of Industrial Chemistry, University of Tirana, Tirana, Albania,*
[3]*High Education Institute, UBT, Prishtina, Kosovo*

*(ilir.malo@gmail.com)

***Abstract* –** This paper aims to investigate the simulation of the biochemical degradation process for various types of organic waste. The study focuses on analyzing and understanding how different factors influence the breakdown and transformation of organic materials into useful byproducts, such as compost or renewable energy sources. Through utilizing a computational model, this research offers valuable insights into optimizing waste management strategies with potential environmental benefits.

The growing concern over environmental sustainability has prompted increased efforts towards efficient utilization and disposal of organic waste materials. This paper addresses the need to explore innovative approaches to managing these wastes by simulating their biochemical degradation processes. Case studies showed that anaerobic digestion as an efficient method investigated the application of anaerobic digestion on agricultural waste materials within a rural community. The findings highlighted how anaerobic digestion effectively converted these organic wastes into biogas, reducing greenhouse gas emissions significantly while producing valuable energy resources through methane capture.

It has also been tested that the biodegradation of mixed organic wastes, in contrast to simple anaerobic digestion, or composting is a significant method studied extensively for efficiently decomposing organic waste material. Examining these diverse case studies shows that simulating the biochemical decomposition process of organic wastes is crucial for developing sustainable waste management solutions. Anaerobic digestion proves to be an effective method for reducing greenhouse gas emissions and harnessing energy from agricultural waste materials.

Preliminary findings indicate that variations in temperature significantly impact microbial activity involved in bioconversion processes leading to optimal decompositions within specific ranges suitable for respective type(s) of input material(s). Furthermore, it is observed that maintaining an appropriate balance between carbon-nitrogen ratios plays a vital role in fostering successful transformations while avoiding issues like the leaching of excess nutrients or undesirable byproducts.

Keywords – Biochemical Degradation, Organic Waste Management, Simulation Modeling, Potato Peels, Methane Production

I. INTRODUCTION

The anaerobic digestion process is considered beneficial for treating biodegradable waste as it generates valuable combustible materials and a residue that can be used as soil conditioner or fertilizer. This gas can be used to produce electricity through gas turbines or gas-powered thermoelectric plants in stoves, heating devices, dryers, boilers, or other gas-burning systems, appropriately adapted for such applications [1], [2]. Anaerobic digestion (also known as methane fermentation) is a natural biological process where specific microorganisms decompose biodegradable material in the absence of oxygen. The biogas obtained from this process is a new source of energy used in developed countries. This is an important resource for countries facing economic and ecological issues[4]-[6]. The use of anaerobic fermentation is not a technological or financial problem for developed countries, as they have appropriate resources and means for implementing this technology. This unit was created to study and understand the different processes involved in biogas production through anaerobic digestion, as well as to study the various parameters that influence anaerobic digestion and the resulting biogas value [7].

Anaerobic digestion is a biological process in which organic matter, in the absence of oxygen and through the action of specific groups of bacteria, is broken down into gaseous products or "biogas" (CH_4, CO_2, H_2, H_2S, etc.) along with a mixture of mineral products (N, P, K, Ca, etc.) and hard-to-degrade compounds [8]-[10]. Biogas contains a high percentage of methane, CH_4 (between 50-70%), making it energetically usable through combustion in engines, turbines, or stoves, either alone or mixed with other fuels. Controlled anaerobic digestion by fermentation is one of the most ideal methods for reducing emissions and developing energy from organic waste. Anaerobic digestion can be applied, among others, to agricultural waste and waste from food processing industries. Among these wastes are food residues, organic waste, agricultural residues, crop excesses, etc. These wastes can be treated individually or collectively through co-digestion. Anaerobic digestion is also a suitable process for treating high organic load wastewater, such as that generated in many food industries [11-[13].

The advantages associated with anaerobic digestion are significant reduction of pollutants, mineralization, generation of renewable energy if the gas is efficiently produced and replaces a fossil energy source, reduction of greenhouse gas emissions resulting from the controlled reduction of uncontrolled CH_4 emissions (which generates a greenhouse effect 20 times higher than CO_2), and CO_2 reduction saved by replacing fossil energy. The promotion and implementation of collective biogas generation systems (several farms) and co-digestion allow the implementation of integral management systems for organic waste from different geographic areas, bringing social, economic, and environmental benefits [14]-16].

The process is widely used to treat wastewater sludge and organic waste as it provides a reduction in the volume and mass of the input material. The process of anaerobic digestion begins with the bacterial hydrolysis of the input materials to break down organic polymers such as carbohydrates and make them available to other bacteria. Acidogenic bacteria then convert sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids [17]-[19]. Methanogenic bacteria finally convert these products into methane and carbon dioxide. Careful control of digestion temperature, pH, and feedstock level is essential for efficient material separation; disruptions (turbulence) of digestion can lead to process failure.

Potato Peel Waste - Its Applications in the Food and Biotechnology Industry

Preliminary Information

Potatoes rank among one of the major crops produced worldwide [20]. According to statistics from the Food and Agriculture Organization (FAO), annual potato production exceeded 300 million tons in 2016. Additionally, the food processing industry is one of the most significant businesses that produce a large number of by-products, such as organic waste, that need to be treated and managed to avoid environmental pollution and promote economic growth through their utilization [21]-22]. Potato peel waste, as a by-product of the food processing industry, represents a valuable starting material for the production of economically important substances. Industrial processing generates between 70 to 140 thousand tons of peels worldwide each year. Traditionally, potato peel waste is used as feed for animals, as fertilizer, or as a starting material for biogas production.

Potato peel waste contains various polyphenols and phenolic acids responsible for its antioxidant activities, while fatty acids and lipids exhibit antibacterial activity. Potato peel waste also contains starch (25%), non-starch polysaccharides (30%), protein (18%), acid-insoluble lignin (20%), lipids (1%), and hemicellulose (6%) based on dry weight. The lipid fraction includes long-chain fatty acids, alcohols, triglycerides, and sterol esters. In addition, lignin units are found in the cell walls of potatoes. Potato peel waste is rich in starch (52% dry weight), but the content of fermentable reducing sugars is limited (0.6% dry weight). Consequently, the fermentation of potato peel waste is practically impossible, necessitating initial hydrolysis (enzymatic or acidic) of carbohydrates to increase the content of fermentable reducing sugars [16]-22].

Biotechnological applications of potato peels are widespread in the following fields: biogas production, lactic acid production, polyphenol oxidase enzyme production, biological fertilizers from potato peel waste, biofuels and bio-hydrogen, biosorbent production, etc.

II. MATERIALS AND METHOD

Both digesters have a heating jacket that allows the temperature to be adjusted appropriately for each part of the process and to function within different ranges depending on the microorganisms used. Thus, it can operate in the psychrophilic range (room temperature), the mesophilic range (around 35°C), or the thermophilic range (around 55°C).

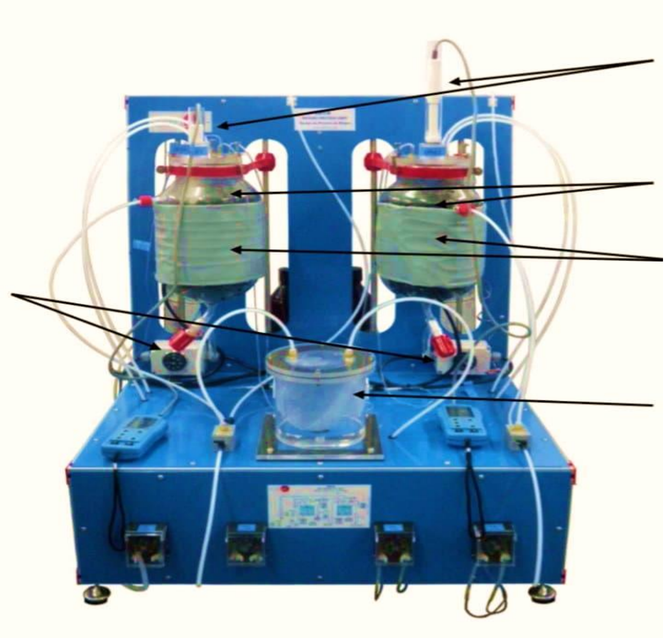

Fig. 1 Computer-Controlled Biogas Process Unit [3]

The unit has four peristaltic pumps that enable the supply of acid and base (introduced into two 1L Pyrex containers placed at the back) to fully regulate and control the pH at each stage of the process. In the case of working with a two-phase anaerobic digestion, one of the pumps transfers the product from one digester to another, passing through a 1L container that collects the excess flow from the first reactor. The control of these pumps allows the various flow rates at which the unit operates to be known.

Two volume tanks are also included for the storage and measurement of the produced biogas volume. The biogas produced flows through a pipe from the upper part of the digester to these reservoirs, where the biogas volume is measured using a water displacement method. Such reservoirs consist of two parts: the upper part is where the generated biogas is collected, and the second part, smaller than the first and located below it, is used to collect the displaced water. Each digester has a temperature sensor and a pH meter.

Their function is to monitor the entire process and study the influence of different control parameters in anaerobic digestion. Finally, the upper part of the volumetric tanks allows the collected biogas to flow through a pipe and pass through a methane (CH_4) measuring sensor.

This sensor allows the methane concentration in such a stream to be known. In this way, the quality of the biogas can be determined depending on the physicochemical conditions in which anaerobic digestion takes place, as well as its value as a renewable energy source.

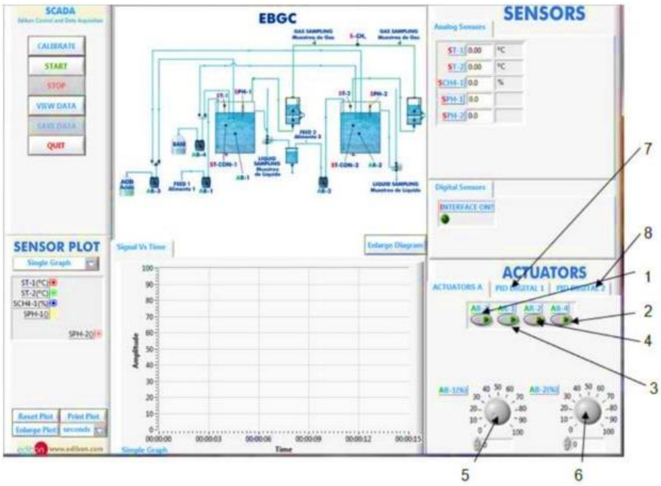

Fig. 2 Software Interface SCADA Presentation for automatic monitoring of the experimental pilot [3].

III. RESULTS : SIMULATION OF THE BIOGAS PRODUCTION PROCESS WITH ASPEN PLUS.

The simulation model of the process was primarily built based on the stages of AD (hydrolysis, acidogenesis, acetogenesis, and methanogenesis). These four phases show how complex compounds are broken down into simpler substances and ultimately into methane and carbon dioxide. Below is the process flow diagram. The method used in this study is the NRTL method, as the involved phases are liquid and gas, and the components are polar compounds.

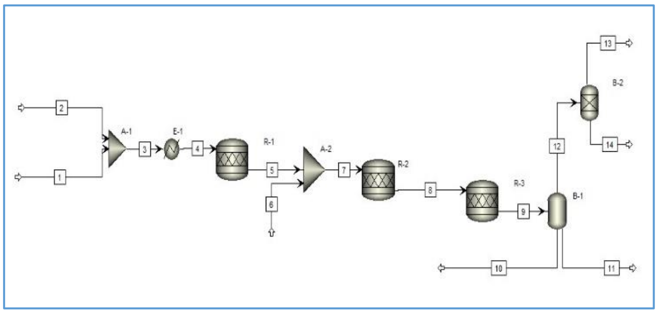

Fig. 3 Flow diagram for the treatment process in Aspen Plus.

Results taken from the simulation An example of complex table 1 is shown below.

Table 1. The dataset was collected by the simulation in Aspen Plus.

															B2
To		A-1	A-1	E-1	R-1	A-2	A-2	R-2	R-3	B1			B2		
Temperature	οC	25.00	25.00	25.00	42.00	42.00	42.00	43.48	42.00	42.00	42.00	42.00	42.00	42.00	42.00
Pressure	bar	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Molar Flow Rate	kmol/hr	0.80	150	150.80	150.80	150.58	0.4	150.98	151.22	151.25	0.99	149.52	0.74	0.51	0.23
Mass Flow rate	kg/hr	208.33	2702.3	2910.6	2910.6	2910.6	6.8	2917.4	2917.4	2917.4	207.4	2693.6	16.4	11.7	4.7
Volume Flow Rate	l/min	5.82	45.31	54.42	55.46	53.78	174.68	54.05	142.48	54.07	6.21	45.28	323.70	224.49	99.21

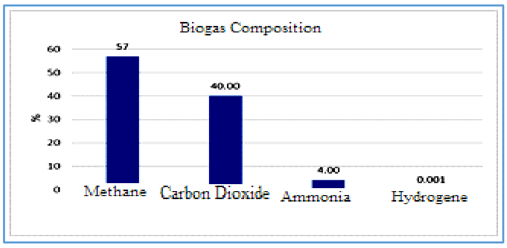

Fig. 4. Biogas composition profited by anaerobic digestion of the waste potato peels, water, and animal manure

Simulation using Aspen Plus with different organic wastes mixtures (See Table 2)

a) *Mixture No. 1:* Raw data and graph. in Fig.5

Table 2. Raw Materials in Mixture 1 used for anaerobic digestion

Kind of Waste	Amount of waste in the Mixture (%)	Humidity %	Dry Matter %	Organic material %	Ash %	C %	N %	C/N
Caw Manure	15.00	11.79	88.21	40.08	59.92	22.27	1.48	15.04
Active Sludge	5.00	70.91	29.08	36.37	63.63	20.21	1.38	14.59
Waste Mushroom	30.00	36.14	63.86	87.42	12.58	48.57	1.36	35.61
Corn Stover	30.00	16.01	83.99	95.83	4.17	53.24	4.24	12.55
Alfalfa	20.00	12.06	87.40	90.85	9.15	50.47	2.50	20.19

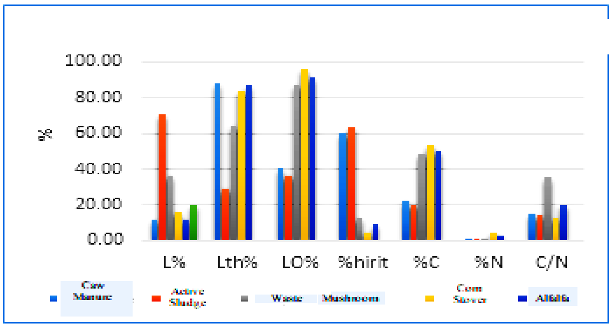

Fig. 5 Raw Materials in Mixture 1 used for anaerobic digestion, and the change in composition during digestion

Statistical treatment of the data from the simulation was presented in Fig. 6.

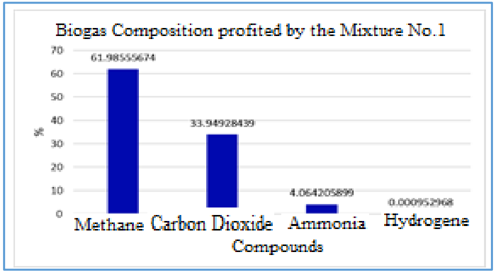

Fig. 6. Biogas composition profited by anaerobic digestion of the waste mixture no. 1.

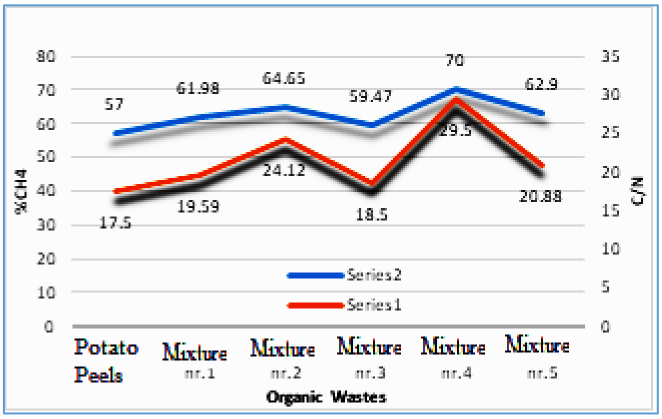

Fig.7 Variability of parameters for 6 experiments.

IV. DISCUSSION

Of all the simulated mixtures, one mixture gives the biogas stream with the largest amount of methane because it contains a high value of the C/N ratio. C/N, as it is shown in Fig.6.

We have performed a series with 6 Mixtures with different compositions, and the results have been different at the end of the procedure of simulation. All these tests have also been performed experimentally in the laboratory of Chemical engineering, and we will present those practical data in another paper to be presented and published!

V. CONCLUSIONS

- Biogas generation through anaerobic digestion is considered beneficial when treating biodegradable waste, as it generates valuable fuel as well as a residue that can be applied as a soil conditioning substance or a fertilizer.
- Numerous global energy needs and the lack of fuels lead to the search for new alternative sources such as chemicals and energy; biomass represents important sources of energy and chemical renewal. Conversion through these methods made biomass can be used in a range of wide as for biofuels, heat, electricity, etc.
- Biogas production goes through a complex anaerobic process that goes through several stages, such as hydrolysis, acidogenesis, acetogenesis, and methanogenesis.
- The optimal conditions for the anaerobic digestion process are thermophilic conditions and mesophilic conditions.
- During anaerobic digestion, in addition to the biogas product, we will also have other products, such as water waste and digestate, which can be used as soil fertilizer due to nutrients.
- Anaerobic digestion process gives higher productivity in thermophilic conditions and in continuous reactors.
- During the simulation of the processes with Aspen Plus, the NRTL method was used because the phases that are present are liquid and gas, and the compounds are polar compounds.
- During the treated mixtures, the most successful mixture is mixture no. 4.
- From the developed simulations, we come to the conclusion that the mixtures that have a high content of the C/N ratio give biogas with a higher amount of methane.
- From the graph built for mixture no. 4, which was the mixture that gave the largest amount of methane content in biogas, we notice that with the increase in the capacity of organic waste, the amount of biogas produced will also increase.

ACKNOWLEDGMENT

The authors appreciate a lot the great help and support of the infrastructure Grant of the Albanian Government (through the National Agency for Scientific Research and Innovation) for the investment to establish the Laboratory of Chemical Engineering, at the Faculty of Natural Sciences, University of Tirana, Albania.

REFERENCES

[1] FAO (2013, 2016) Food Agriculture Organization of the United Nations Statistics Division.

[2] Paleologou I, Vasiliou A, Grigorakis S, et al. (2016) Optimisation of a green ultrasound-assisted extraction process for potato peel (Solanum tuberosum)

[3] Edibon practical exercises manual EBGC/EBGB.

[4] Fatmir Gjyriqi, Ilirjan Malollari, Planifikimi i kapaciteteve, vendeve dhe teknologjive për ngritjen e një rrjrti të shfrytëzimit material dhe eenergjitik të biomasës në shqipëri.

[5] Onyeneho SN, Hettiarachchy NS (1993) Antioxidant activity, fatty acids and phenolic acids compositions of potato peels. J Sci Food Agric 62: 345–350.

[6] Camire ME, Violette D, Dougherty MP, et al. (1997) Potato peel dietary fiber composition: Effects of peeling and extrusion cooking processes. J Agric Food Chem 45: 1404–1408.

[7] Kyzas GZ, Deliyanni EA (2015) Modified activated carbons from potato peels as green environmental-friendly adsorbents for the treatment of pharmaceutical effluents. Chem Eng Res Des 97: 135–144.

[8] Abd-El-Magied MM (1991) Effect of dietary fibre of potato peel on the rheological and organoleptic characteristics of biscuits. Egypt J Food Sci 19: 293–300.

[9] Al-Weshahy A, Rao V (2012) Potato peel as a source of important phytochemical antioxidant nutraceuticals and their role in human health-A review. In: Phytochemicals as NutraceuticalsGlobal Approaches to Their Role in Nutrition and Health, InTech.

[10] Nelson M (2010) Utilization and application of wet potato processing coproducts for finishing
Cattle. J Anim Sci 88: E133–E142.

[11] Liang S, McDonald AG, Coats ER, et al. (2014) Lactic acid production with undefined mixed culture fermentation of potato peel waste. Waste Manag 34: 2022–2027.

[12] Arapoglou D, Varzakas T, Vlyssides A, et al. (2010) Ethanol production from potato peel waste (PPW). Waste Manag 30: 1898–1902.

[13] Mohdaly AAA, Hassanien MFR, Mahmoud A, et al. (2013) Phenolics extracted from potato, sugar beet, and sesame processing by-products. INT J Food Prop 16: 1148–1168.

[14] Sepelev I, Galoburda R (2015) Industrial potato peel waste application in food production: A review. Res Rural Dev 1: 130–136.

[15] Maldonado AFS, Mudge E, Gänzle MG, et al. (2014) Extraction and fractionation of phenolic acids and glycoalkaloids from potato peels using acidified water/ethanol-based solvents. Food Res Int 65:27–34.

[16] Jeddou KB, Chaari F, Maktouf S, et al. (2016) Structural, functional, and antioxidant properties of water-soluble polysaccharides from potatoes peels. Food Chem 205: 97–105.

[17] Liang S, McDonald AG (2014) Chemical and thermal characterization of potato peel waste and its fermentation residue as potential resources for biofuel and bioproducts production. J AgricFood Chem 62: 8421–8429.

[18] Liang S, Han Y, Wei L, et al. (2015) Production and characterization of bio-oil and bio-char from pyrolysis of potato peel wastes. Biomass Convers Bior 5: 237–246.

[19] Prasad AGD, Pushpa HN (2007) Antimicrobial activity of potato peel waste. Asian J Microbiol Biotechnol Environ Sci 9: 559–561.

[20] Sharma D, Ansari MJ, Gupta S, et al. (2015) Structural characterization and antimicrobial activity of a biosurfactant obtained from Bacillus pumilus DSVP18 grown on potato peels. Jundishapur J Microbiol 8: e21257.

[21] Arapoglou D, Vlyssides A, Varzakas T, et al. (2009) Alternative ways for potato industries Waste utilization. In: Proceedings of Proceedings of the 11th International Conference on Environmental Science and Technology, China, Crete, Greece, 3–5.

[22] Fu BR, Sun Y, WANG YX, et al. (2013) Construction of biogas fermentation system based on the feedstock of potato residue. J Northeast Agric Univ 44: 102–106.