Journal of Applied Research in Science and Humanities

Waste recycling in the light of sustainable development

Doha Abdalla Mohamed, Habiba Ahmed Said, Hebatalah Sayed Abd elhamed, Heba Mahmoud Abdalla, Huda Ali Abdelsamia, Nada Emad Ali

Supervisor: El–shimaa Ibrahim Abdelhalem, Lecturer of physical chemistry, chemistry department

Ain Shams University, Faculty of Education, Program Arabic Science

Abstract

This study aims to highlight the necessity of sustainability in the field of recycling solid and liquid waste, such as damaged fruits and their peels (bananas, apples, oranges) as well as used oils. These waste samples were chosen due to the high production of such waste primarily from households' food leftovers, as well as from restaurants and juice production companies. This poses a significant risk to the environment and humanity, leading to environmental pollution and the emission of greenhouse gases. Therefore, there is a critical need for the safe disposal of this waste through recycling. The waste was recycled and utilized in the production of biofuel and biodiesel, both of which are clean, renewable energy sources that do not harm the environment, thereby achieving the concept of sustainability. The experiment's results indicated the emission of biofuel, which consists mainly of methane gas. Additionally, the biodiesel was identified through tests of its density and ignition.

Key Words:

Recycling – Biofuel – Anaerobic Fermentation – Biodiesel

1.Introduction:

Today, countries around the world strive to achieve zero-waste or minimal-waste societies in the context of an economic shift toward the philosophy of sustainable development and the right of future generations to present natural resources. The misuse of these resources, their harmful environmental impact, and the depletion of fundamental components are among the most pressing issues facing the world. Additionally, the problem of accumulating solid waste and its exacerbation, along with the emergence of sustainable development dimensions, has led to considerations on how to dispose of this waste.

Humanity is currently facing several environmental dilemmas, which challenge human creativity to find sustainable solutions to protect the environment. One of these challenges is the need to produce energy from renewable sources rather than fossil fuels. It is expected that the demand for such renewable energy will increase in the future, becoming more commercially significant. There are methods for converting biomass into biofuel and biodiesel, especially as fossil hydrocarbons become rare and expensive. In recent years, there has been increasing interest in reducing the production costs of biofuel. Thanks to international efforts, the problem of accumulating solid waste has turned into a valuable resource, and this sector has developed significantly. Thus, urban waste has become valuable, and biofuel and biodiesel may be among the promising alternatives to petroleum-based fuels.

2. The Theoretical Framework

Recycling is a crucial process for waste disposal, as the accumulation of waste leads to significant problems that harm the environment and humanity. Recycling allows us to benefit from waste in the light of sustainability. There are many advantages to recycling waste, including repurposing waste in an environmentally friendly manner, which reduces the damage that would occur if these different types of waste were not recycled.

With the continuous growth and increase in the world's population, there is a constant pressure on the limited resources and their sufficiency for this increasing number. We have a responsibility to adopt the "reduce, reuse, and recycle" approach regarding resources and waste. The global priority is not only to mitigate the negative impact that has already occurred but also to meet the need to produce more energy for a population expected to exceed 10 billion by 2050. All of this must be achieved using as few traditional means of energy sources as possible, reducing emissions of polluting gases, and disposing of solid waste(Duque-Acevedo et al.,2020,2). On a global scale, agriculture produces, on average, 23.7 million tons of food daily. This increase has led to further pressure on the environment (Ferdeş et al., 2022,2). The generated waste has become enormous, with the pressure on landfills reaching a dangerous level(Mu et al., 2020,3) (Parthiba Karthikeyan et al., 2018,3) According to studies, the amount of food waste generated in advanced and developing countries is approximately 107 kg/person/year and 56 kg/person/year, respectively. This clearly shows that higher living standards generate larger amounts of waste(Dung et al., 2014,309) (Lipinski et al., 2016,8). There are various types of waste, including solid waste, liquid waste, construction waste, and food waste, which consists of animal or plant origin residues from various foods prepared in the kitchen. It also includes fruit and vegetable residues, used oils, and others, sourced as mentioned from households, restaurants, food companies, and food delivery companies, constituting a large proportion of waste(Oelofse & Nahman, 2013,83) (Kell, 2019,3) .These wastes can be recycled to produce biofuel and biodiesel. Biofuel or biogas is energy derived from living organisms, whether plant or animal. It is considered one of the most important renewable energy sources, produced by the decomposition of organic matter through anaerobic fermentation. Biofuel is a renewable and environmentally friendly energy source, with sources producing biogas existing for a long time. Many countries have used plants and cow dung,

with the United States being one of the countries that focused on anaerobic fermentation as an approach to producing biofuel (Garba and Sambo,1995,36-44) (Sagagi et al., 2010,115). Biofuel production technology is one of the most important technologies today. Biogas can be used to meet energy requirements, while organic residues are considered useful fertilizer. Biogas is a type of renewable energy that can be produced from the decomposition of animal and plant waste, consisting of methane, carbon dioxide, and rare impurities such as hydrogen and hydrogen sulphide, as well as some nitrogen (Heeb,2009,5) (Deressa et al., 2015,65). The production of methane during anaerobic digestion of biodegradable organic matter depends on the quantity and type of material added to the system. Therefore, food residues, fruit and vegetable waste(Deressa et al., 2015,65), and used oils can be subjected to certain conditions to produce biogas. Biogas is a gaseous substance similar to natural gas and can be utilized in several ways. It has different combustion and composition characteristics compared to natural gas, requiring a different set of prerequisites for combustion(Meggyes & Nagy, 2012,67-68). Biogas is odorless and colorless, burning with a clear blue flame(Scano et al., 2014,22) . As for biodiesel, it is produced from recycled used oils, such as waste from hotels, restaurants, households, and other food industries, which are simply dumped into rivers or injected into the ground, impacting the environment. Used cooking oil can be used to produce biodiesel, which can be used as a substitute for fossil fuels like diesel oil. Used cooking oil is a raw material for biodiesel production (Fariku et al.,2007,2443)and can be converted into biodiesel because its chemical composition contains fatty acids. When it reacts with alcohol and using simple technology, it becomes biodiesel(Ullah et al., 2009,3290). Several studies have been conducted on the production of biodiesel from used cooking oil. Biodiesel is made from used cooking oil and methanol using potassium hydroxide as a catalyst (Gnanaprakasam et al.,2013). Biodiesel is produced through a process called transesterification or methanolysis, which involves the alcohol reacting with the oil in the presence of a base catalyst such as potassium hydroxide to produce glycerine and biodiesel (Yaakob et al., 2013)

3.Methods of Research and the tools used

The materials and equipment used in this study.

Fruit remains and spoiled fruits (orange, apple, banana) - Yeast - Calcium carbonate (chalk) - Cannula device -Adhesive - Empty 5-liter plastic bottle - Liquid soap - Glass beaker 250 ml - Flame (lighter) - paper towel - pH meter - Used oil - Potassium hydroxide - Methanol - Separating funnel - Heater and stirrer-Thermometer-Scale

Methodology and Experimental Procedures:

The appropriate initial sample for anaerobic fermentation to produce biofuel was selected. This sample included spoiled fruits and their peels, specifically apples, bananas, and oranges. Yeast and a quantity of calcium carbonate were added. A device was designed for the anaerobic fermentation of the spoiled fruits and their peels as shown in Fig.1, consisting of a tightly sealed plastic bottle with a cannula for controlling gas release. After designing the device for anaerobic fermentation, the prepared fruits and peels were placed in the bottle, followed by the addition of yeast and

calcium carbonate, and the mixture was thoroughly mixed. The pH was adjusted to 6.5-7 (Deressa et al., 2015). The bottle was tightly sealed, and the closure was confirmed with adhesive. A hole was made in the cap to insert the cannula, which controlled the gas flow, and the cannula was closed to prevent the escape of the produced gas. The device and its contents were left in a warm place for a period ranging from two to two and a half months. Every week, the system was monitored, mixed, and checked to determine if biofuel was produced. A test was conducted to detect the presence of gas. First, a soap solution was prepared and exposed to the produced gas by opening the cannula, resulting in many bubbles in the soap solution as shown in Fig.2, indicating the presence of gas. Additionally, a flame was applied to the gas exiting the cannula, causing the flame to glow blue. Another sample chosen for recycling and conversion into biodiesel was used cooking oil from the household, as illustrated in Fig.3. A 60 ml sample of used oil was prepared, purified, and filtered thoroughly to achieve a high degree of purity free from any impurities. The used oil was then heated to a temperature of 55°C. Meanwhile, 0.5 grams of potassium hydroxide were mixed with 12 ml of methanol thoroughly. Once the oil reached the required temperature of 55°C, the potassium hydroxide and methanol mixture were added to the hot oil. The entire mixture was left on a stirring device for an hour, then allowed to sit for 24 hours. It was observed that the mixture separated into two layers: a dark lower layer and a light upper layer, which is the biodiesel layer, as shown in Fig.4. The biodiesel layer was separated using a separating funnel, as depicted in Fig. 5, and its absolute density was measured by determining the weight and volume of the resulting biodiesel. Additionally, its flammability was tested.

4. Results of Research

In the fruit sample experiment for biogas production, biogas is generated through bacterial action in the biological degradation of organic materials under anaerobic conditions (without the presence of air), known as anaerobic fermentation. Composition and Characteristics of Biogas: Biogas is a mixture of gases that primarily consists of the following: Methane (CH_4): 40-70% by volume,Carbon Dioxide (CO_2): 30-60% by volume,Other gases: 1-5% by volume, including: Hydrogen (H_2): 0-1% by volume Hydrogen Sulfide (H_2S): 0-3% by volume In this experiment, the biogas production process was monitored as the anaerobic fermentation of the fruits and their peels takes a considerable amount of time to complete. The biogas production was tracked periodically over the duration of the experiment. To test for the presence of gas, a simple method was used: a soap solution was prepared, and the cannula hose connected to the gas inside the bottle was opened. It was observed that when the cannula valve was opened to allow the gas to escape, many bubbles formed in the soap solution, indicating the presence of gas. Additionally, the produced gas was exposed to a flame, and it was found that the gas flared up and turned blue, indicating the presence of methane.

Regarding the recycling of the used oil sample for biodiesel production, biodiesel was produced as shown in Fig. 6 through the process of transesterification of the used oils. The biodiesel was verified by measuring its absolute density, which was found to be 0.86 g/mL. Comparing this value with the reference density of biodiesel recorded in previous studies, which is 0.856-0.890

g/mL, it was found that the measured value is acceptable and accurate, indicating that the produced substance is indeed biodiesel (Sarno & Iuliano, 2019, 81).

Figure (1): The apparatus and tools used in the anaerobic fermentation process.

Figure (2): Bubbles observed when the gas produced from the cannula was exposed to the soap solution.

Figure (4): Separation of biodiesel and glycerin layers after 24 hours

Figure (3): Used oil sample

Figure (6): Produced biodiesel

Figure (5): Separation of biodiesel using a separating funnel.

5 Interpretation of Results

Through the recycling of apples, oranges, and bananas via anaerobic fermentation to produce biogas, the bubbles observed during the gas detection test, along with the blue flame colour, indicated the presence of biogas, primarily consisting of methane. This confirms the successful completion of the anaerobic fermentation process, which is influenced by various factors including the selection of fruit types, fermentation conditions, temperature, and the duration of the process, as well as the presence of bacteria that facilitate the decomposition of organic matter in the fruit. The type of fruit used plays a crucial role. Apples are generally astringent or slightly alkaline. They contain a lot of fiber, water, and natural sugars, but they are somewhat alkaline due to their nutritional composition. Using apples in the experiment could help balance the acidity of the environment, especially if other fruits used, such as oranges, are more acidic.

Bananas are alkaline fruits. They are high in potassium and magnesium, which are alkaline minerals that can help in neutralizing acidity. Therefore, using bananas in this experiment can help in adjusting the pH, making the environment more conducive to fermentation. Thus, the choice of fruit was appropriate. Temperature is another crucial factor in fermentation, with the optimal conditions being around 25-30°C.The use of yeast in this experiment can positively impact biogas production. Yeast, a type of fungi, is typically used in fermentation processes that convert sugars into alcohol and carbon dioxide, among other compounds. In this case, yeast can aid in breaking down the organic residues in the fruits by secreting enzymes that convert the sugars in the residues into methane and carbon dioxide, thereby increasing the amount of gas produced. Regarding the sample of used oil for biodiesel production, it was found that by measuring the density of the upper layer after separation, it matches the reference density values for biodiesel mentioned in previous studies. This indicates the formation of biodiesel through the transesterification process, which occurs in the presence of potassium hydroxide as a catalyst. Potassium hydroxide is used to increase the reaction rate and improve the yield of biodiesel or increase the quantity produced. The oil was heated to a temperature not exceeding 60°C to prevent the evaporation of the methanol used. Methanol was chosen for its lower cost and faster reaction with the oil sample and potassium hydroxide. Under these conditions, the triglycerides in the oil reacted with methanol in the presence of the catalyst, resulting in the production of methyl esters and glycerol. Methyl esters, which are biodiesel, have properties suitable for use as fuel in car engines, making them the main product, while glycerol is a secondary product.

6. Conclusion

For the sake of achieving sustainable development principles and in light of the significant consumption and accumulation of waste, communities around the world, especially in advanced countries, have resorted to dealing with this dilemma by recycling and benefiting from waste. The study has found a way to safely dispose of waste in an environmentally friendly manner, achieving sustainability by producing biofuel and biodiesel, which are energy sources derived from biomass, especially plant biomass and used oils, respectively. They are among the most important renewable energy sources, unlike other natural

resources such as oil, coal, and all types of fossil fuels.

Acknowledgement

All praise is due to Allah, the Lord of all worlds, with praise that befits His majesty and great power. I send blessings and peace upon our Master Muhammad, the truthful and trustworthy, upon his pure and good family, and upon his righteous and noble companions. It is the right of blessings to be thankful, and the least that can be said for kindness is gratitude. I express my deepest gratitude and immense appreciation to all those who guided and helped me in completing this research. I especially thank my supervisor, Dr EL-Shaimaa Ibrahim Abdelhalem, who illuminated the path for me with her extensive knowledge and sound guidance. Her valuable instructions were the main factor in the completion of this research. I ask Allah to prolong her life, keeping her a shining beacon in the world of knowledge and among scholars.

References and Sources

Deressa, L., Libsu, S., Chavan, R. B., Manaye, D., & Dabassa, A. (2015). Production of Biogas from Fruit and Vegetable Wastes Mixed with Different Wastes. Environment and Ecology Research, 3(3), 65–71.

Dung, T. N. B., Sen, B., Chen, C. C., Kumar, G., & Lin, C. Y. (2014). Food waste to bioenergy via anaerobic processes. Energy Procedia, 61, 307–312.

Duque-Acevedo, M., Belmonte-Ureña, L. J., Cortés-García, F. J., & Camacho-Ferre, F. (2020). Agricultural waste: Review of the evolution, approaches and perspectives on alternative uses. Global Ecology and Conservation,22.

Fariku, S., Ndonya, A. E., & Bitrus, P. Y. (2007). Biofuel characteristics of beniseed (Sesanum indicum) oil. African Journal of Biotechnology, 6(21),2442–2443.

Ferdeş, M., Zăbavă, B. Ştefania, Paraschiv, G., Ionescu, M., Dincă, M. N., & Moiceanu, G. (2022). Food Waste Management for Biogas Production in the Context of Sustainable Development. Energies, 15(17).

Gnanaprakasam, A., Sivakumar, V. M., Surendhar, A., Thirumarimurugan, M., & Kannadasan, T. (2013). Recent Strategy of Biodiesel Production from Waste Cooking Oil and Process Influencing Parameters: A Review. Journal of Energy, 2013, 1-10.

Heeb, F. (2009). Decentralised anaerobic digestion of market waste Case study in Thiruvananthapuram, India, (March).

Kell, C. J. K. (2019). Anaerobic Co-Digestion of Fruit Juice Industry Wastes with Lignocellulosic Biomass by. Stellenbosch University, (April).

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., & Searchinger, T. (2016). Toward a sustainable food system Reducing food loss and waste. World Resource Institute, (June), 1–40.

Meggyes, A., & Nagy, V. (2012). Biogas and energy production by utilization of different agricultural wastes. Acta Polytechnica Hungarica, 9(6), 65–80.

Oelofse, S. H. H., & Nahman, A. (2013). Estimating the magnitude of food waste generated in South Africa. Waste Management and Research, 31(1), 80–86.

Parthiba Karthikeyan, O., Trably, E., Mehariya, S., Bernet, N., Wong, J. W. C., & Carrere,

H. (2018). Pretreatment of food waste for methane and hydrogen recovery: A review. Bioresource Technology,249,1025–1039.

Sagagi, B., Garba, B., & Usman, N. (2010). Studies on biogas production from fruits and vegetable waste. Bayero Journal of Pure and Applied Sciences, 2(1),2–6.

Sarno, M., & Iuliano, M. (2019). Biodiesel production from waste cooking oil. Green Processing and Synthesis, 8(1), 77–82.

Scano, E. A., Asquer, C., Pistis, A., Ortu, L., Demontis, V., & Cocco, D. (2014). Biogas from anaerobic digestion of fruit and vegetable wastes: Experimental results on pilot-scale and preliminary performance evaluation of a full-scale power plant. Energy Conversion and Management, 77, 22–30.

Ullah, F., Nosheen, A., Hussain, I., & Bano, A. (2009). Base catalyzed transesterification of wild apricot kernel oil for biodiesel production. African Journal of Biotechnology, 8(14), 3289–3293.

Yaakob, Z., Mohammad, M., Alherbawi, M., Alam, Z., & Sopian, K. (2013). Overview of the production of biodiesel from Waste cooking oil. Renewable and Sustainable Energy Reviews, 18, 184–193.