African Journal of Housing and Sustainable Development (AJHSD)
Volume 4, Number 1
http://ujh.unilag.edu.ng/index.php/ajhsd

Climate Resilience and Global Polyethylene Bag Pollution: Exploring Synthesis of Biodegradable Plastic Bags from Cassava (*Manihot esculenta*) as a Solution

Isaac Byarugaba

School of Biosciences, Makerere University, Uganda.
Makerere, Kampala, Uganda

To cite this article: Byarugaba, I (2023). Climate Resilience and Global Polyethylene Bag Pollution: Exploring Synthesis of Biodegradable Plastic Bags from Cassava (*Manihot esculenta*) as a Solution. *African Journal of Housing and Sustainable Development, 4*(1), pp. 42-48.

Abstract

Plastic bags are polymers of ethylene and are used in almost every aspect of everyday life across the globe for a variety of functions. After their use and disposal, plastic bags have no end-of-life time because of their non-degradable nature, leading to environmental contamination and pollution. As a way of disposing them, thermal treatment is employed but this leads to emissions that increase the concentration of greenhouse gases in the atmosphere, eventually contributing to the climate crisis. Therefore, synthesis of biodegradable plastic bags offers an environment-friendly alternative for conventional plastic bags. A biodegradable plastic bag prototype was synthesized using renewable raw materials with lower carbon footprints. Among such materials was starch obtained from wasted cassava, glycerin and vinegar which served as plasticizers to make the bag flexible and less brittle. The use of renewable raw materials (cassava) with lower carbon footprints in the production of biodegradable plastic bags can therefore be considered as instrumental in reducing plastic bags waste contamination and pollution of the environment thereby contributing towards achieving climate-resilient cities.

Keywords: Biodegradability; Climate resilience; Greenhouse gases

1.0 Introduction

Plastic bags are polymers of high molecular weight processed from petroleum-based raw materials called ethylene (Ismail et al., 2016). These are used in almost every aspect of life worldwide for storing, carrying and, packaging of a wide variety of items and materials (Kaewphan & Gheewala, 2013). Waterproof plastic bags are quite thin and easy to carry, they are also strong, and hold their shape under normal use.

Through chemical reactions, ethylene is obtained from crude oil in a process that emits greenhouse gases such as carbon dioxide which contributes to climate change (Kaewphan &

✉ ibyarugaba@cns.mak.ac.ug

Gheewala, 2013). Plastic bags are non-degradable in nature because they cannot be broken down by microorganisms in the environment when disposed (Sanyang et al., 2016). Consequently, burning and sending them to landfills is resorted to, which contributes to environmental contamination and pollution.

The Impact Forecast estimates that during the production, use and disposal of plastic bags, for every ton, about 3,299kg of carbon dioxide is emitted into the atmosphere resulting into 329,900 million kilograms of carbon dioxide emitted into the atmosphere every year from the 100 million tons of plastic bags used. Whereas for every ton of biodegradable plastic bags, during their production, use and disposal, about 1,189kg of carbon dioxide is emitted; thus in every ton, about 2,110 kg of carbon dioxide emissions are saved, hence contributing severely to climate change.

Muralikrishna and Manickam (2017) define environmental pollution as contamination of the physical and biological components of the earth or the atmospheric system to such an extent that normal environmental processes are adversely affected. Therefore, plastic bags, when disposed, contaminate the physical and biological components of the environment through increased concentration of greenhouse gases (Jones et al., 2013).

Greenhouse gases are gaseous compounds that can emit ultraviolet radiation within a certain thermal infrared range (Fouladi et al., 2020). They can trap the earth's emitted radiation which otherwise escapes back to space to make the earth more habitable through temperature regulation. Thus, high concentrations of greenhouse gases in the atmosphere increase the amount of trapped heat (Borduas & Donahue, 2018). Among the greenhouse gases in the atmosphere are carbon dioxide and, methane which are emitted during the disposal of plastic bags (Yoro & Daramola, 2020).

The United Nations (2018) defines climate change as a long-term shift in temperature and weather patterns that are driven mainly by human activity the burning of fossil fuels. The earth being a complex interconnected system, it is inevitable that changes in one area would influence changes in all other areas hence the need for global climate resilience actions.

The Centre for Climate and Energy Solutions (n.d.) defines climate resilience as the ability to anticipate, prepare for and respond to hazardous events, trends or disturbances related to the climate. It involves how climate change creates-new or alters current-climate-related risks and taking steps to better cope with the risks. To be sure, switching from use of fossil fuels and their products to renewable raw materials and their products, such as biomass-based products with lower carbon footprints, will aid in reducing emissions, leading to climate resilience (Chen, 2013).

Biodegradable plastic bags are synthesized using renewable raw materials. Such bags can serve the same purpose as conventional plastic bags (Wahyuningtyas & Suryanto, 2017). Biodegradation is an irreversible change creating significant change in the structure of a material, thus resulting in the loss of its properties as caused by biological activities such as enzymatic action. Renewable raw materials include agricultural products such as starch extracted from cassava (Jain & Tiwari, 2015). Biodegradable plastic bags are environmentally friendly and can be used as manure or even processed into fertilizers that aid in the increased production of agricultural products thereby aiding food security while boosting production of the raw materials for biodegradable plastic bags.

In most cities in the developing world, almost all aspects of everyday life involve use of plastic bags, most of which are non-reusable and non-degradable after disposal. Plastic bag waste is either collected and incinerated at specific garbage collection centres in an open environment or it is collected and burnt at unapproved places; sometimes such waste is sent to landfills or disposed in water bodies. Whatever the method of disposal, the result is emission of greenhouse gases into the atmosphere.

Given this background, this study contributes to the process of achieving climate-resilient cities through control of plastic bag waste environmental contamination and pollution by explaining the synthesis of biodegradable plastic bags using agricultural products like cassava (Mooney, 2009).

2.0 Literature Review

Today, plastic bags are used almost everywhere and have replaced many conventional materials and products (Geyer et al., 2017). Indeed, global plastic bag production has increased significantly despite vast quantities of the product being discarded daily (Alam et al., 2018). Given their lightness, strength, cheapness and easy handling, plastic bags are one of the most common products worldwide (Kaewphan & Gheewala, 2013).

According to the statistics supplied by Word Counts in 2022, more than five trillion plastic bags are used per year, with a total of 160,000 being used in a second and over 700 being used per year by an individual. In 2015, plastic bag waste accounted for 47% of plastic waste generated globally. If current production and waste management trends continue, roughly 12,000 metric tons of plastic waste would be in landfills or the natural environment by 2050 (Geyer et al., 2017).

Less than 1% of used plastic bags are recycled and the rest is thrown into the environment, never to degrade (Sanyang et al., 2016). The common approach to eliminating such plastic waste is by destructive thermal treatment that itself degrades the environment, leading to negative externalities on human and nonhuman life (Khan & Ghouri, 2011). During the process of eliminating plastic bag waste material, emissions of massive amounts of carbon dioxide occur with other toxic chemicals also being released into the atmosphere (Verma et al., 2016; Yoro & Daramola, 2020). No doubt, two major dangerous greenhouse gases are carbon dioxide and methane being emitted into the atmosphere (Kaewphan & Gheewala, 2013).

As emissions continue to rise, the Earth has become warmer by about 1.1^{o}C than it was in the late 1800's (United Nations, 2018). Limiting global temperature rise to not more than 1.5^{o}C will therefore help in avoiding the worst climate impacts and maintain a livable climate, since the climate change negatively impacts human health (Jung et al., 2018).

Accordingly, transiting to biodegradable plastic bags is now a necessity for the Earth's survival (Jones et al., 2013). Such plastic bags are made from plant materials, which are natural, renewable, abundant and of low cost (Dai et al., 2009).

Globally, projections on the monetary value of biodegradable plastic bags are expected to move from $ 1,470.5 million in 2017 to $2.052.2 million by end of 2022. This is based on worldwide governmental action on minimizing the effect plastic pollution.

Biodegradable plastics can be developed from starch, given its favorable thermoplastic properties, biodegradability, abundance and cheap cost (Shafqat et al., 2021). Moreover, the agricultural waste from which starch can be extracted has been identified as a cheap and renewable raw material alternative (Jain & Tiwari, 2015). This starch is mainly from agriculture wastes like cassava, which has a short life due to postharvest physiological deterioration (Zainuddin et al., 2018).

Worldwide, about 278 million metric tons of cassava were produced 2018, 61 % was from Africa (Tafesse. et al., 2021). More than one-third of cassava produced globally is wasted owing to post-harvest physiological deterioration, hence the abundance of the agricultural waste from which starch can be extracted for use in synthesis of biodegradable plastic bags (Jain & Tiwari, 2015).

During their production, plasticisers are added to increase the plasticity of the material as well as their mechanical properties. They play significant role by forming hydrogen bonds with starch by disrupting the strong interaction between intra and intermolecular hydrogen bonds in starch, improving processing properties and flexibility (Dai et al., 2009). When disposed in the environment, biodegradable plastic bags absorb moisture from the air and microorganisms break it down by biological means in a period between 3-6 months (Momani, 2009).

Therefore, the prevalent use of plastic bags today leads to negative externalities on the climate as well as on urban systems and populations. This calls for the need to promote climate resilience through use of biodegradable plastic bags (Tyler & Moench, 2012).

A number of campaigns have been launched in different countries to reduce excessive use of plastic bags, with some of them having failed and regulations suspended owing to opposition from users. Such regulations have included an outright ban on plastic bags, ban of plastic bags below a specific thickness and size, and imposition of an environment levy on plastic bags (Saidan et al., 2017). The switch to an alternative will therefore contribute to implementation of policies on environmental justice.

3.0 Methodology

The research was done in Kampala, Uganda's capital and largest city. Kampala was selected because it is one of the highly populated districts in Uganda with a high rate of plastic bag use, especially for grocery shopping. According to the National Environment Management Authority, at least 600 tons of plastic bags are consumed every day in Uganda and afterwards disposed of irresponsibly. In the city about 150 tons of waste are generated every day, with only 40% of plastic waste collected and 60% left in the environment, thus causing pollution from eventual burning in an open environment (Monitor, 2022).

3.1 Research Design

The research design was experimental in nature. A prototype for a biodegradable plastic bag was developed from cassava. The cassava was processed and starch was extracted before being used as the main raw material. Other ingredients (glycerin and vinegar) were added to increase the plasticity of the material as well as its mechanical properties. Starch was extracted from cassava roots that were purchased from a market in the city. Glycerin and vinegar were also purchased from chemical stores in Kampala.

3.2 Procedure

Cassava roots were washed and cut into pieces, then grated in a mortar. Distilled water was added to the mortar and the cassava was ground carefully. Subsequently, the material was filtered into a clean beaker. The second and third steps were repeated twice to extract any extra starch. The mixture in the beaker was left to settle and the water decanted, leaving the starch settled at the bottom. Distilled water was then added to the starch extract, which was stirred gently and left to settle before being decanted to obtain starch that was free from all contaminants. Starch was added to water stirred to form a mixture, and this process was followed by addition of glycerin and vinegar. The mixture was stirred further for uniform mixing with application of moderate heat to form a paste that was sprayed on a smooth surface and left to dry in the sun for a period of 24 hours forming a bioplastic film.

4.0 Results

Wasted cassava roots (Figure 1) were grated to extract starch (Figure 2). After addition of distilled water, an emulsion formed to which glycerin and vinegar were added before being stirred to form a mixture. When moderate heat was applied, there was uniform mixing of the content, which formed a paste that was sprayed on a smooth surface (Figure 3). This was then dried to form a bioplastic film (Figure 4).

The bioplastic film formed was flexible, not brittle, on folding. On disposal in open environment, the bioplastic film started to decompose after a period of four weeks. When dropped in water, after a period of two weeks it was observed to disintegrate.

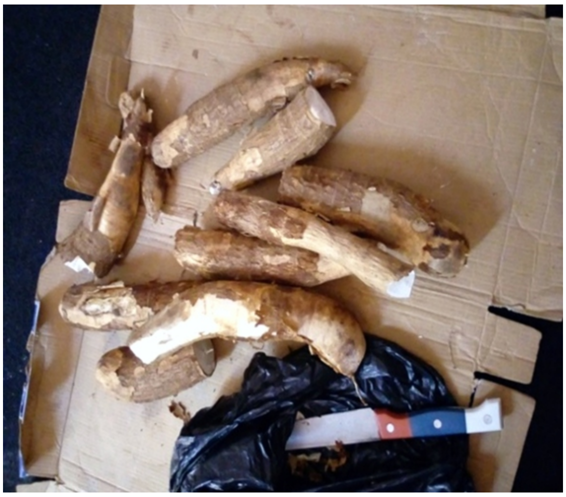

Figure 1: wasted cassava roots

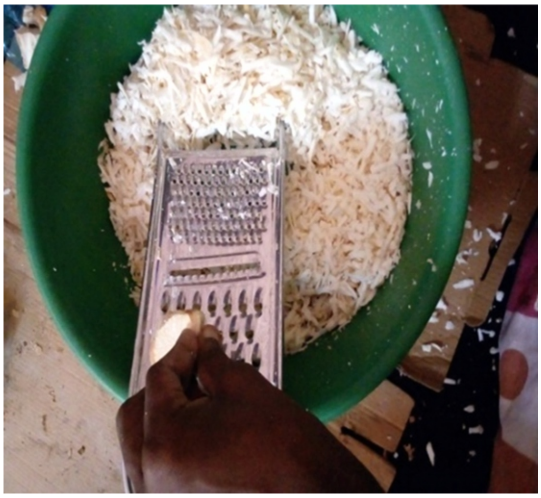

Figure 2: cassava grating to extract starch

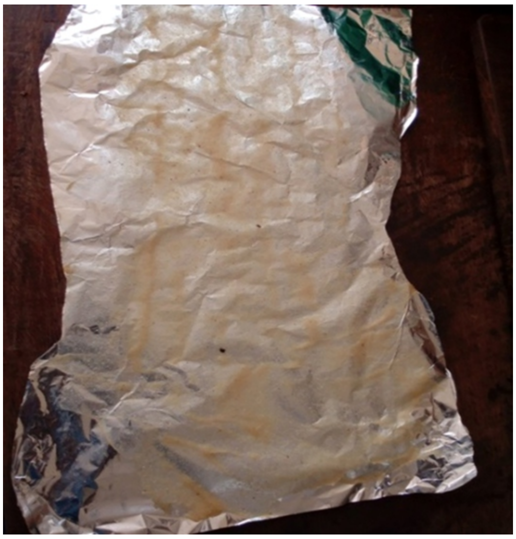

Figure 3: Starch paste on aluminum foil for drying

Figure 4: Bioplastic film after drying

5.0 Conclusion

Nowadays many countries have introduced or are about to introduce policies banning the use of non-degradable plastic bags owing to the contamination and pollution they cause to the environment upon disposal. As part of efforts in this regard, this study focuses on synthesis of biodegradable plastic bags as an alternative to conventional non-degradable plastic bags. Thus, in the bid to achieve climate-resilient cities in the long term, it would be necessary to invest in renewable raw materials with lower carbon footprints (e.g., cassava) in the production of biodegradable plastic bags. Governmental and other authorities must therefore consider making informed decisions regarding environmental policies. It should be noted, however, that this study did not test for the strength and thickness of the bioplastic film produced. It would also be necessary to determine whether other agricultural wastes, e.g., banana pseudo stems and maize kernels, are possible raw materials for biodegradable plastic bags. This study is an invitation for more elaborate processes to test the industrial efficacy of the production of bags from biodegradable raw materials on a wider scale.

There is a high demand for products which only satisfies the user's needs and actively reduce environment pollution, thus the high acceptability of biodegradable plastic bags. The production of biodegradable plastic bags also promotes bioeconomy and circular economy which of recent are at the forefront of industrial production towards mitigating climate change.

6.0 Acknowledgement

The author is grateful to the Department of Plant Sciences, Microbiology & Biotechnology Makerere University and The Climate Launchpad for offering the basics, guidance and mentorship in the due course of developing this research project. My sincere gratitude goes to the Makerere University Biotechnology classes of 2021 & 2022 for their unending support towards accomplishing this milestone.

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