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Synthesis of Biobased Plastic from Agriculture Waste: Banana Peels

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Abstract. The production of bioplastics from banana peels instead of conventional petroleum-based plastics is seen as a successful solution to increase the efficiency of the plastics industry, at a lower cost than common plastics, lower carbon footprint and eco-safety. The project's prototype represents the process of producing bioplastics from banana peels and tests the tensile strength shelf-life detection and efficiency of the produced plastic. The results showed that the plastic produced with the optimum resident time to hydrolysis was 15 min for the sample, the weight of bioplastic formed when adding (0.5 N) HCL and (0.5 N) NaOH solutions was 5.6 g, while 3.8 g formed of bioplastic when adding (0.1 N) HCL and (0.3 N) NaOH. The best plastic formed in trial 4 with a weight of 17 g of paste, thin, light in colour, has elasticity and strength and did not show any signs of decay after 2 months. The worst trial we present in trial 5 plastic formed, which was thicker than in trials 2 and 3 and dark in colour, lost its strength, showed signs of decay after 1 month and the lowest weight of the paste in addition, the characterized and weight of bioplastic formed in trial 4 has 17 g of paste and was thin, light in colour and strength very strong, not shown any signs of decay after 2 months. The tensile strength for the neutral sample was 0.4086 N/mm^2 at the residence for 15 min. It has been shown that bioplastic produced from banana peel contains many nutrients and minerals. The bioplastic product contains after lab analysis a high amount of the composition of the fiber, NPK, organic matter and C:N ratio. These results showed the bioplastic produced from banana peels which can be used as food packaging, plates, agricultural pots and soil fertilizer. It is concluded that the use of bioplastics will help in sustainability and is one of the most innovative environmentally friendly materials developed.

Keywords: bioplastic, banana peels, sustainability, agriculture waste

Introduction

Environmental pollution is one of the global problems, especially in developed countries. The most pressing challenge facing the world protecting our planet. Bioplastics have lately gained prominence as a promising means of minimizing the environmental impact of fossil fuel polymers. In comparison to fossil fuel polymers, they have a lower carbon footprint. In Jordan, agricultural food wastes are produced annually in high quantities posing a serious problem, both environmentally and economically (Visco *et al*., 2022). These wastes can be used as secondary starting materials such as banana peels to produce added value products like bioplastics polymer within the principles of the environmentally friendly product.

Environmental pollution is one of the serious problems facing life forms on Earth today. Pollution is a global problem, that affects both developed and developing countries (Noorjahan *et al*., 2022). Bioplastics are materials made from renewable raw materials, they must be biodegradable and compostable in the soil (Yuvaraj *et al*., 2021).

Bio-polymer plastic from banana peels is the most alternative solution that is derived entirely from renewable organic substances based on agriculture food waste and agriculture by-products (Taodharos, 2018). Bioplastics are completely safe and do not have any chemicals or toxins used for manufacturing disposable items, like biodegradable packaging, mulch, pots and straws (Noorjahan *et al*., 2022). This bioplastic is a fully biodegradable bioplastic that can be eventually decomposed and used as soil fertilizer to help other crops to grow and close the carbon cycle. Compared to traditional plastics, biodegradable plastics can break down into carbon dioxide and water within 20-45 days, given sufficient moisture, oxygen and an appropriate number of micro-organisms, whose life expectancy is about a hundred to thousand years (Moshood *et al*., 2022).

Since biobased plastics are created from natural and renewable resources like potato and corn starches, food waste that cannot be eaten and lingo-cellulosic crop

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residue, they are an excellent substitute for synthetic plastics. The qualities and manufacturing costs of bioplastics are significantly influenced by the raw material utilized in their creation. Generally speaking, bioplastics can be composted or biodegraded depending on their composition. It is anticipated that the manufacturing and consumption of such plastic materials will increase in the near future. They have the potential to assist solve numerous environmental issues. As a result, a thorough assessment of these bioplastics is required. (Kumari *et al*., 2023). Bioplastic was examined by Hong *et al*. (2021) as a potential material for food packaging. We talk about the different unique qualities of bioplastic for food packaging. The study also covered several types of bioplastics that are used to package fruits, vegetables, eggs, fish, meats and other items. The primary environmental issues underlying the widespread use of synthetic plastics are their biodegradability and the release of toxins throughout the decomposition process. Thus, the demand for "eco-friendly" plastics is imperative. Disposable products like straws, pots, bowls, crockery and packaging are made of bioplastics. Beyond structural materials, electric current-carrying electroactive bioplastics are being created. Paper can be coated with biopolymers as an alternative to the more popular petrochemical coatings. Low energy requirements in the production of bioplastics. Based on the aforementioned viewpoints, an attempt has been made to use banana peels to create a biodegradable plastic material. The produced bioplastic material has then been characterized using FTIR analysis, a solubility test and a swelling test. (Noorjahan *et al*., 2022)

The outer layer of the banana fruit is called the peel. Fruit can be eaten raw or cooked once the skin is removed and the peel is usually thrown away. An enormous amount of organic waste is produced as a result of this peeling of the banana. Because banana peels are susceptible to microbial destruction, they often make up 30% of the fruit weight and are thrown, which contributes to pollution. Animal feed made from banana peels can also be used to make a variety of other biochemical products. About 15% of green banana peels are starchy. Pectin and cellulose have been reported to be found in banana peels, which makes their appropriate use intriguing from the standpoint of valuing byproducts for non-food purposes in a bio refinery setting, changing. (Ram *et al*., 2020).

The main goal of the current study was to produce biodegradable plastic from banana peels that will substitute the existing commercial plastic. Also, it provides promising methods for optimizing bioplastic production from banana peels. By testing the tensile strength, shelf-life detection and efficiency of the produced plastic. Otherwise, to help save the environment by reducing environmental pollution due to the usage of waste banana peels to produce a new value-added biodegradable plastic. In addition to producing different shapes of bioplastic for different agricultural uses like food packaging to increase the quality and safety of packaged food products and greenhouse pots that can be degradable as fertilizer.

Materials and Methods

Preparation of banana skins. The experiments were done at the same time according to methods described by (Bejena, 2019). Cut banana peel into small pieces and put it in a 500 mL beaker the banana peels were rinsed in 0.5 M $Na_2S_2O_5$ solution for 45 min; $Na_2S_2O_5$ solution acts as a preservative. Then decant the banana peel (under the cupboard). Then, add 375 mL of distilled water in one of the 500 mL beakers, transfer dipped banana peels to a beaker that contains distilled water after that banana peels were boiled in (an 800 mL beaker) of distilled water for about 30 min at 160 °C. After that, the water was decanted from the beaker. Then place banana peels uniformly on the dish with parchment paper and put it in the oven for 30 min at 130 °C. Finally, after the peels were dried, the peel was pureed using a hand blender until a paste formed.

Production of biobased plastic. Banana paste of 25 g is placed in a 50 mL beaker. 3 mL of (0.5 and 0.1 M) HCl was added to the mixture according to the desired pH solution and stirred using a glass rod. HCL was added to break the hydrogen bond among the branched amylopectin which restricts film formation. Then, 2 mL of plasticizer glycerol 10% will be added and stirred using a glass rod for 15 min. Plasticizers were used to improve the plasticity of the material by disrupting hydrogen bonds and spreading the chains apart, which not only increases flexibility but also water vapour and gas permeability. After that, to neutralize hydrochloric acid, (0.5 and 0.3 M) of NaOH wear added according to the pH desired and stirred again, after a desired residence time (15 min) according to (Chandarana and Chandra, 2021). Next, the mixture is spread on parchment paper in an aluminum plate or any bowl or templet, put it in the oven at 130 °C for half an hour or baked till the dry to make the shape. Finally, the tile is allowed to cool and the film is scraped off the surface.

Test the tensile strength. Each sample produced from all experiments was tested for tensile strength. Thickness was detected by the ruler. A visual test of the sample was to detect any perforation, a 2 cm by 4 cm rectangular slice was cut out of the sample for testing. The slice dimensions are kept constant for all samples to ensure uniformity in the testing procedure. Then samples of the same sizes were tested by clamping them and obtained sample between two clamps. The end of the clip is attached to the stand and the other end was a hanging tray for placing heavy objects. The clamping locations are also fixed. When testing for tensile strength, applying the thumb rule for tensile strength testing, the samples are clamped such that 60% of the sample is between the clamps and is our testing region. Weights were added in increments of 10 g each once the sample had been clamped upto 600 g were used. The sample was given a 20 s break in between weight additions to allow for stretching and tearing. This method applies known mass and calculated sample area until the bioplastic that is hanging breaks down (Bejena, 2019).

The following formula was used to calculate tensile strength:

To calculate the force, mass of the hold material in the

$$\text{Tensile strength} = \frac{\text{Weight (N)}}{\text{Cross-sectional area (mm}^2\text{)}} = \frac{\text{Force}}{\text{Cross-sectional area (mm}^2\text{)}}$$

bioplastic times the gravity value (9.81 m/s^2). Using the following mathematical formula as given below.

Force = weight * gravity

Shelf-life detection. The shelf life was assessed by observing changes in the colour of bio-plastic every day. The darkening of the plastic suggested decay. The experiments were trialed six times in order to produce the best quality of bioplastic and were used with different templates to form different shapes for bioplastic in food packaging, plates and small agriculture pots.

To examine the analysis of the components of bioplastic produced from banana peels, the samples were sent to the National Center for Agricultural Research to find out their content, components and mineral content, with the aim of what could be added to the soil if they are used as agricultural pots instead of plastic bags used to grow plants. Three samples of the dough were prepared after forming the bioplastic from banana peels, making sure they were completely dried in the oven at a temperature of 130 °C to get rid of moisture, with a weight of 50 g each sample.

Statistical analysis. Data analysis was performed using SPSS software (SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc). The spearman correlation was used to assess the strength and direction of association between variables. A P value of <0.05 will be statistically significant.

Results and Discussion

The results from this project showed that 25 g of paste was used with the optimum resident time to hydrolysis was 15 min for the sample used in different normality of HCL and NaOH solutions. In Table 1 this illustrates the weight of bioplastic formed when adding (0.5 N) HCL and NaOH (0.5 N) solutions was 5.6 g, while 3.8 g formed of bioplastic when adding (0.1 N) HCL and (0.3 N) NaOH. According to these results, the best normality of HCL and NaOH was (0.5 N). Hydrochloric acid is used in the hydrolysis of amylopectin which was aid the process of film formation because of the H-H-bonding amongst the chains of glucose in starch, since amylopectin restricts the film formation. Also, NaOH was used in this experiment to neutralize the PH of the paste, also adjusting PH with sodium hydroxide (NaOH) that make the plastic flexible differently from convectional plastic, which is following the polymerization process. Similar finding was found in synthesis of biobased plastic from banana paste when mixing the peel's starch with the plasticizer, hydrolyzing agent (HCl) and pH adjuster (NaOH). This gives the plastic its unique flexibility as opposed to convectional plastic, which is created by polymerizing the starch. (Noorjahan *et al*., 2022; Bejena, 2019).

Six trials were made to produce the best bioplastic formed from banana peels and we studied some physical characteristics that are shown in the Table 2. Regarding this experiment, the best plastic formed in trial 4 with a weight of 17 g of paste, thin, light in colour, has elasticity, strength and did not show any signs of decay after 2 months, while the same physical characteristics were present in trial 3 but were thicker than in trials 2 and 4, with a 10 g weight paste. The worst trial we present in trial 5 has plastic formed, thicker than trial 2 and 3, dark in colour, lost elasticity, showed signs of decay after 1 month and has the lowest weight of the paste.

A significant positive correlation between paste weight, degree of colour, elasticity and thickness are presented in the Table 3. The results showed that increasing the weight of the paste increased its flexibility and made it was thin, light in colour. A similar result found according to Prasad (2014) revealed that the bioplastic formed was brownish black in colour, as time in the ground increases, the samples darken. It also becomes fragile over time; the luster gradually decreases. The weight of the sample decreased over time. Also, that samples degrade in soil within 15 days. Bejena (2019) has found that experimental work attempts to relate residence time at different pH values to the tensile strength of bioplastics value and amount of plasticizer. Their results showed that the tensile strength values continue to decrease with a residence time of 5-10 min, the tensile strength increases. For acidic analyses, increasing residence time will result in lower tensile strength due to excessive hydrolysis, but alkaline the analysis showed that the tensile strength varied between 0.1109 and 0.0981 N/mm^2 when the residence time was increased from 5 to 20 min. In the neutral analysis, when the residence time increased from 5 min to 15 min, the tensile strength increased from 0.092 to 0.1445 (N/mm^2). If the plasticizer is used in an amount of 3 mL, beyond this residence time, the tensile strength will be reduced and the plastic.

To calculate tensile strength the following formula was used:

600 g ≈ 5884 Newton
The thickness of the bioplastic is 0.1 mm
= 5884 N ÷ 14400 mm^2
= 0.4086 MPa

The tensile strength for the neutral sample was 0.4086 MPa at the residence for 15 min. This suggests that the optimum hydrolysis time was 15 min for the sample. According to the research paper "Bioplastics- utilization of waste banana peels for the synthesis of polymeric films" by Bejena (2019). The hydrolysis of branched chains of amylopectin, linear chained amylose formed. However, the hydrolysis time increased further, the amylose content decreased albeit slightly, because the amylopectin is hydrolyses to amylase. Further hydrolysis leads to formation of glucose monomers which do not aid in polymer formation. The tensile strength of the bioplastic at various PH values and plasticizer concentrations found to be correlated with residence time. Tensile strength increases from 0.092-0.1445 (N/mm^2) at neutral analysis when residence time increases from 5 to 15 min and at 3 mL of plasticizer. Beyond this residence time, the plastic breaks and its tensile strength decreases as reported by Bejena (2019). According to the research findings in the study "Bioplastics-utilization of waste banana peels for the

Table 1. Weight of bioplastic obtained and normality of the HCL and NaOH solutions

Amount of paste taken (g)	Residence time (min)	HCL	NaOH	Weight of bioplastic obtained (g)
25	15	0.1 N	0.3 N	3.8
		0.5 N	0.5 N	5.6

Table 2. The physical features and weight of bioplastic formed

Number of trials	Residence time (min)	Weight of paste (g)	Characterize
1	15	7	Plastic has formed, a thick, dark colour, lost its elasticity, didn't show any signs of decay after 2 months.
2		9	Plastic has formed, thin and fragile, light colour, has elasticity and didn't show any signs of decay after 2 months.
3		10	Plastic has formed, thicker than in trial 2, light in colour, has elasticity, not shown any signs of decay after 2 months.
4		17	Plastic has formed, thin, light in colour, has elasticity and very strong, not shown any signs of decay after 2 months.
5		5	Plastic has formed, thicker than in trials 2 and 3, dark in colour, lost its elasticity and shown signs of decay after 1 month.
6		8	Plastic has formed, thick, dark in colour, lost elasticity and fragile, still moisture in texture and has not shown any signs of decay after 2 months.

synthesis of polymeric films" by Prasad (2014), there is a decrease in fiber when the amount of NaOH is increased and the diameter in a straight line. Tensile strength naturally decreases as a result of diameter reduction.

The bioplastic formed in our project which can be sustainable at around 1 Kg weight due to its strong tensile strength (0.4086 MPa). Regarded to these results the bioplastic produced from banana peels which can be used as food packaging, plates and agricultural pots.

The results are presented in Table 4. The bioplastic produced from banana peel contains many nutrients and minerals they found Ash fiber (7.9%), organic matter (73.5%), moisture (18.6), NPC (0.4, 39.1, 1.3%) and C fiber (69.85) in the banana peel. According to these results, we can use bioplastic as fertilizer after planting plants and seeds in the soils and it will be degradable and added nutrient composition. Similar findings were reported by Ansari *et al*. (2023) nutritious components found in banana peels include protein, carbohydrates, fats, moisture and ash. Furthermore, they contain large concentrations of bioactive compounds such carotenoids of different kinds (beta, alpha and lutein) and phenolic (flavonoids). Although the peel contains minerals like calcium, magnesium, potassium, sodium, zinc and iron, its main component is starch (18.5%). Wastes are generated in massive amounts due to the huge number of un-used peels which represent about 30%-40% of the fruit mass. (Vinodh *et al*., 2021).

This research provided the scientific basis for the potential of the synthesis of bioplastic from agricultural waste banana peels. In recent years, there has been a growing interest in finding sustainable alternatives to traditional plastics. One such innovative solution is bio-plastic made from banana peels and a fruit renowned for its high starch content. By utilizing the unique properties of amylose and amylopectin, the polymer chains found in banana peels, scientists aim to create a biodegradable and environmentally friendly plastic that could revolutionize the manufacturing industry (Taodharos, 2018).

The best weight of bioplastic formed when adding (0.5 N) HCL and (0.5 N) NaOH solutions was 5.6 g with the optimum resident time to hydrolysis for sample within 15 min in different normality of HCL and NaOH solutions. The same observation was noted in the study of (Chandrana *et al*., 2021). Hydrochloric acid is used in the hydrolysis of amylopectin which aids the process of film formation because of the H- H-bonding amongst the chains of glucose in starch, since amylopectin restricts the film formation. In a study by (Bejena, 2019; Taodharos, 2018) natural starch extracted from palm tree trunks hydrolyze with 0.14 N HCl. During the initial stages of hydrolysis, the amylose content increases, which can be attributed to the fact that due to the hydrolysis of the branched 41 formation of amylopectin and amylose. Also, NaOH was used in this experiment to neutralize the PH of the paste. Hydrochloric acid is used for hydrolysis amylopectin, is required to support the film-forming process due to hydrogen bonding between glucose chains because amylopectin limits film formation. In the experiment, sodium hydroxide was only used to neutralize the pH of the medium. Taodharos (2018) reported that using 25 mL of banana paste results in different plastic forms. Trial 1 shows fragile, thin plastic that decays after a day. Trial 2 forms thicker plastic but loses strength after 3 days. Trial 3 shows similar plastic, while Trial 4 forms thicker plastic without decay for 30 days without any change in strength. The same result was found in the present study the best plastic formed in trial 4 with a weight of 17 g of paste,

Table 3. The association between paste weight and degree of thickness, colour, elasticity and duration to decay

	Weight of paste	
	Spearman correlation	P – value
Degree of thickness	-0.794	0.05
Color	0.88*	0.02
Elasticity	0.93**	.001
Duration to decay	0.393	0.441

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

Table 4. Composition of banana skins

Test name	Result	Unit
Ash	7.9	wt/ wt %
Moisture	18.6	
Organic matter	73.5	
N	0.4	
P	1.3	
K	39.1	
C/N	106:1	%
C. Fiber	69.8	

thin, light in colour which has elasticity and strength and did not show any signs of decay after 2 months. A significant positive correlation between paste weight and obtained degree of colour (r=0.88, P=0.02) and elasticity (r=0.93, P=0.001). The results show that increasing the weight of the paste which increased its flexibility and made it darker.

The tensile strength of the sample increases with residence times from 5 min to 15 min, reaching its maximum at 15 min and decreasing at 20 min, suggesting the optimal hydrolysis time of 15 min for bioplastic production from banana peels. Bioplastic film can sustain a weight near about 2 Kg and has enough tensile strength also reported by researchers (Chandrana *et al*., 2021; Sharmila *et al*., 2021; Gaonkar *et al*., 2018). The banana peels are sources of natural bioactive compounds which is reported by Hikal *et al*. (2022). It can be successfully used in food, pharmaceutical and other industries. Therefore, banana residues may provide new avenues and research areas for the future.

Conclusion

In conclusion, the solution succeeded in achieving the design requirements by producing bio plastic from banana peels that have half the cost of petroleum-based plastic and has higher efficiency. This project advances processes by replacement of all non-biodegradable plastics with biodegradable banana peels, bioplastics offer a significantly reduced carbon footprint versus traditional oil-based plastics, it's a solution for mitigating the impacts of petrochemical plastics on the environment, increasing awareness of sustainable development and management of packaging waste and agricultural pots, the importance of community participation for a greener environment, promote national, regional and international cooperation on proper agricultural waste management. Agricultural foods by-products are produced in huge amounts throughout the year. Effective use of by-products in environmentally friendly industries will reduce pollution. In addition to consumers' preference for environmental-friendly products and government policies toward green procurement and bio-based materials are derived from sustainable and renewable biomass, instead of petrochemicals. The applications of bio-based materials for food packaging, bags, disposable housewares and agricultural pots. To decrease waste, reduce cost, reduce the burden on the agriculture sector and lead to the development of the agriculture sector. These bio-based materials are also environmentally friendly as biodegradable plastic is eventually decomposed and used as soil fertilizer which is more energy efficient than recycling. Collecting banana peels from farmers and markets may contribute to the success of this project. The results of the project will be disseminated among plastic factories to generalize the idea and the farmer also will improve their income as the project and open new doors for their product to sell instead of wasting them.

Authors' contribution. HH is responsible for the study's conception and design, data analysis and manuscript writing.

All the authors contributed equally in searching for the literature and the final version of the manuscript was read and approved by all of the authors.

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Conflict of Interest. The authors declare that they have no conflict of interest.

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