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Production of Bioplastics from agricultural Waste, Mainly Banana Peels, “*Musa Sapientum*”, Using Batch Reactor

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ABSTRACT

The limited future availability of petroleum, with the environment and waste management, has thus brought people's concern into more sustainable alternatives to replace petroleum-derived plastic. Therefore, the production of bioplastics is the breakthrough innovation to solve the environmental issues by using renewable and degradable natural resources and to provide more cost-effective bioplastic. The objective of this study is to investigate the new and effective process in the production of bioplastics from agricultural waste mainly banana peels. The starting point of this work followed some previously published work without solid output, and then it was improved by changing the procedures, like the introduction of a batch reactor to further concentrate the paste and the incorporation of new additives (Based on Experiments). However, The main experiments in this study were carried by mixing the banana peels and heating in a water bath reactor for at least two hours, the obtained paste was then mixed with relevant additives to obtain the final bioplastics product; The additives include Hydrochloric Acid (*HCL*) to break the bonding, Sodium hydroxide (*NaOH*) in order to neutralize the pH up to 7, Sodium Bicarbonate (*NaHCO₃*) to react with acidic components in the paste, releasing carbon dioxide, which causes expansion of the paste and forms the characteristic texture and grain. The propane- 1, 2, 3-trial (Glycerol) is used in the experiments functions as a plasticizer. Other additives were added to develop or improve the plasticity of the material such as gum Arabic and U-POX Oil. This process produced a wide range of bioplastics samples with different properties such as texture, hardness and coherence. It was found that when the Sodium Bicarbonate, Glycerin, Acetic acid, U-POX Oil, and Gum Arabic ratios increase the produced bioplastics were extracted easily and become more flexible. The obtained results showed that Bioplastics has already formed before entering the oven with self- separation occurring (white color). Characterization was carried out by FTIR analysis, The **FTIR spectrum** was obtained at the wavelength in the range of Spectra standard range of cellulose showed that the peaks at 3354.0 and 2900.7 cm^{-1} , the peaks observed at 3417.63 and 2927.74 cm^{-1} for the final paste after drying or (untreated bioplastics), also observed at 3379.05 and 2929.67 cm^{-1} for the bioplastics from banana peels final product or (treated bioplastic), also a band around 1060 cm^{-1} confirms the **structure of cellulose**. In order to verify that the obtained product is a bioplastic a real polymer, the thermal cracking process was carried, The Thermal degradation of thermoplastic polymers occurs during processing at temperature 293°C, led to the lost weight of 70%, surprisingly; the obtained material then converted to fuel, indicated to classified as light naphtha which might be a new area of research. The research concluded that **bioplastics could be practically obtained from Banana peels using a batch reactor based on Spectra standard range of cellulose**. The research recommends conducting further studies on the use of the material as a biofuel producer, through the thermal cracking process.

Keywords: Banana peels, Bioplastics, Biodegradable, Biobased, Biofuel, and Batch Reactor.

1. INTRODUCTION

Environmental pollution is one of the serious problems faced by humanity and other life forms on our planet today. The plastic industry is considered as one of the most important industries which manufacture polymer materials commonly called plastic and used in a range of industries including packaging, building, etc ^[1]. However, the use of too many plastics results in massive harmful effects. It takes a long time to degrade which is estimated at about 500 years to degrade and will become toxic after decomposed^[2]. On the other hand, the world's awareness of the depletion of natural resources and pollution issues is increasing over the past few decades. Due to the environmental hazard on all organisms and the pollution that happens in all-natural resources such as air, water, plants, and soil pollution and the limitation of the number of fossil resources on our planet, the future cannot depend on petro-plastics. All fossil products should be replaced by bio-based products. The petro-plastics are one of the fossil products which should be replaced by bio-based plastics. As a consequence, research efforts have been developed at different levels to find alternative solutions. Bioplastics contribute by lowering the dependence on fossil fuels and reducing carbon dioxide emissions. Bioplastics can be defined as bio-based plastics and/or biodegradable plastics ^[3]. One of the important classifications of plastics is thermoplastic and thermosetting polymers. Bioplastics are plastics derived from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, wood chips, food waste, agricultural by-products, also from used plastic bottles and other containers using microorganisms. Bioplastic is transparent, flexible,

durable, a great barrier and also heat resistant. There are three types of bioplastics: 1. Starch-based bioplastics, 2. Cellulose-based bioplastics and 3. Protein-based bioplastics. Bioplastics are used for disposable items, such as packaging, crockery, cutlery, pots, bowls, and straws. Beyond structural materials, electroactive bioplastics are being developed that are used to carry electric current. Biopolymers are available for coating paper rather than the more common petrochemical coatings. Low energy costs to manufacture bioplastics. Various agro wastes that have the potential to be used as bioplastics are bagasse, corn cob, cellulose, sago pith waste and chitin, also banana and potato peels. The trend of agro-waste as the source for bioplastics production is rising due to the relatively lower cost and easily available. However, the utilization of agro-waste for the development of bioplastics is still limited due to the unsystematic and low cost-effective waste management system, limited data on waste generation, and low production yield compared to food feedstock. It is believed that the prospect of agro-waste as feedstock for bioplastics will improve with the advancement in biotechnology and government intervention. Government, public, industrialists and researchers should synergize to realize the commercialization of agro waste-derived bioplastics ^[1]. Based upon the above views; the objective of this study is to find the best way and more effective additives material that added to improve and enhance the textures' of the produced biodegradable plastic from agricultural waste (agro-waste) or by-products namely thermoplastics starch "**banana peels starch**", as a substitute for the conventional plastic. The material used in manufacturing the bioplastic, banana peels, was chosen because it is one

of the fruits that are very rich in starch ($C_6H_{10}O_5$), which consists of two different types of polymer chains, called amylose and amylopectin, made up of adjoined glucose molecules that are bonded together forming the plastic as shown in the figure below. Currently, the peel stems and leaves of the banana (80%) simply discarded without further processing whereas waste of banana peel containing polymers such as lignin, cellulose, hemicellulose, and pectin. Banana peel also contains cellulose amounted to 18.71%. Cellulose is a linear polymer consisting of 300 to 15.000 D-glucose linked by bonds β -(1, 4) glycosidic. The empirical formula of cellulose is $(C_6H_{10}O_5)_n$. The cellulose has a uniform surface and forms a layer of fiber-like pore structure. Porous solid has the ability as an adsorbent that can be used as adsorb pollutant in the environment. In addition, the functional groups $-OH$ in a banana peel can be exploited to adsorb pollutants. Cellulose as an adsorbent for wastewater treatment has the advantage of most abundant organic polymer, stable to chemicals, biodegradable, non-toxic, and inexpensive. Besides that, cellulose has thermal stability, the degradation of cellulose led to the lost weight of 90% around 393 to 723 K^[4].

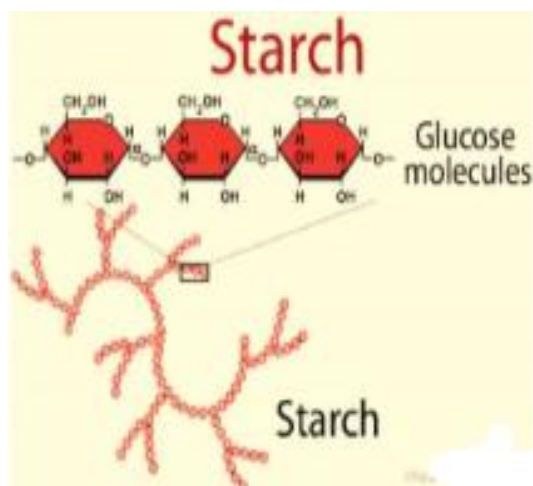


Plate (1): Polymer chain^[4].

The banana fruit's peel were selected for this experiment as an example of starchy agricultural residues which can be processed for the production

of bioplastics, because it is a waste material rich of starch ($C_6H_{10}O_5$), -according to Songklanakarin Journal of Science and Technology^[4], the proximate composition of a banana peel is shown in **table 1**.

Table (1): Compositions of a Banana Peel

<u>Items Content (g/100 g dry matter)</u>	
Protein	8.6±0.1
Fat	13.1±0.2
Starch	12.78±0.9
Ash:	15.25±0.1
Total dietary fiber	50.25±0.2

2. MATERIALS AND METHODS

2.1. Raw materials & Instrument:

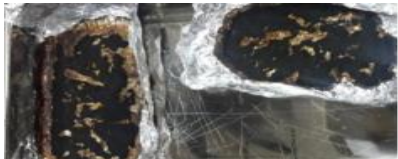



In this study, Banana peels were used as an example of starchy agricultural residues which can be processed for the production of bioplastics. In the experiments and the processing of waste to bioplastics. All measurements were made as precisely as possible. For safety precautions, surgical gloves were worn throughout the experiment. The experiment was conducted in the Department of **Chemical Engineering** Unit Operations Laboratory, at the **University Of Khartoum, in 2017**, and the following **Materials** were used: **Fresh banana peels** were collected from the university cafeteria. The **chemicals and additive materials** were including: **Hydrochloric Acid (HCL) - Sodium Hydroxide (NaOH) - Sodium Bicarbonate (NaHCO₃) - Acetic Acid- Propane-1, 2, 3-trial (Glycerol)-Gum Arabic-U-POX Oil**. On the other hand, the following **Instrument** were used: **Stainless steel knives, measuring cylinder''1000 and 50ml'', Beakers'' 1000 and 50 ml '' digital mass balance''PGW 4502, Max 4500g d=0.01g, ae ADAM'' model'', Petri dishes, Filter mesh, Bunsen burner ''IKATHERM HCT'' model, , Commercial Blending''Waring (W) model'', Refractometer''KARL KOLB German'' model, Stainless steel Batch Reactor''Kuhlwasser-Entleerung Reaktionskessel'' German model, Oven'' Heraeus'' model.**







2.2. Experimental Runs Conducted


In the current work, for production of bioplastics, some preliminary steps have been taken and then final production of bioplastic was done. We carried

out more than **10 experimental** runs for the production of bioplastic. Each time we change the **Procedure Strategy** also, the **amount and types of Chemicals and additives materials** till reached the optimum production **as shown below in table 2:**

Table 2: The used materials and Approach Method in each experiment

EXP.NO.	Approach Method	Used Material for Producing Polymer	Properties of produced Bioplastic With Photo
<u>1</u>	Previously published work (Preparation of Banana peels with added chemicals like Sodium Bicarbonate -HCL NaOH, before boiling process for 30min., then the peels were completely dried, and, using a mixer the peels were squashed until a uniform paste obtained.	-25g of banana paste -5ml of (0.5N) HCL -2ml glycerol -0.5 N NaOH	- Textures:semi-Hard. - little coherent to some extent.  Plate (2): Trial one final product.
<u>2</u>	This procedure is improvement for the previous work by changing the procedure by Introducing a batch reactor to further concentrate the paste and incorporation of new additives. Many samples were done until reached to specific additive materials type and quantity.	-40 g of the paste. - 3ml Glycerol. -10ml Acetic acid. -1teaspoon U-POX oil.	- Textures: semi-Flexible. - It's molecules coherent extent.(not pure) - Thickness: semi-superfine  Plate (3): Trial two First sample final product.
<u>3</u>		-25g of banana paste -3ml HCL. -3ml NaOH. -3ml Sodium Bicarbonate. -3ml Glycerol. -5ml Acetic acid.	- Textures: Sticky. -little coherent to some extent.  Plate (4): Trial two second sample final product.
<u>4</u>		-25g of banana paste -3ml HCL. -3ml NaOH. -3ml Sodium Bicarbonate -3ml Glycerol. -1teaspoon U-POX oil	-Textures: Sticky. -little coherent to some extent.  Plate (5): Trial two Third sample final product
<u>5</u>		-25g of banana paste -3ml HCL. -3ml NaOH. -3ml Sodium Bicarbonate. -3ml Glycerol. -5ml Acetic Acid	- Textures: semi-Flexible. - It's molecules coherent extent.(not pure) - Thickness: semi-superfine.

		-1teaspoon U-POX oil.	 <p>Plate (6): Trial two fourth sample final product</p>
<u>6</u>		-25g of banana paste -3ml HCL. -3ml NaOH. -3ml Sodium Bicarbonate. -3ml Glycerol. -10ml Acetic acid. -1teaspoon Gum Arabic.	- Textures: Sticky. -little coherent to some extent.  <p>Plate (7): Trial two fifth sample final product</p>
<u>7</u>		-25g of banana paste -3ml HCL. -3ml NaOH. -3ml Sodium Bicarbonate. -3ml Glycerol. -5ml Acetic acid. -1teaspoon U-POX oil. Note: yellow color before entering oven.	-Textures: Sticky. -little coherent to some extent.  <p>Plate (8): Trial two sixth sample final product</p>
<u>8</u>		-25g of banana paste -3ml HCL. - 3ml NaOH. -3ml Sodium Bicarbonate. - 3ml Glycerol. - 10ml Acetic acid. -1teaspoon U-POX oil.. - 1teaspoon Gum Arabic Note: open brown color. Before entering oven.	-Textures: very flexible -It's molecules coherent with shiny. -Thickness: semi-superfine.  <p>Plate (9): Trial two seventh sample final product</p>
<u>9</u>	Here was changed in the amount of specific additive materials which were reached from trial (2).	-25g of banana paste -10ml HCL. -10ml NaOH. -10ml Sodium Bicarbonate. -10ml Glycerol. -10ml Acetic acid. -1teaspoon Oil. -1teaspoon Gum Arabic.	-Textures: very flexible -It's molecules coherent with shiny. -Thickness: semi-superfine.  <p>Plate (10): Trial Three first sample final product</p>
<u>10</u>		-25g of banana paste -5ml HCL. -5ml NaOH. -5ml Sodium Bicarbonate. -5ml Glycerol. -5ml Acetic acid. -2teaspoon Oil. -1teaspoon Gum Arabic	-Textures: very flexible -It's molecules coherent with shiny. -Thickness: semi-superfine.  <p>Plate (11): Trial Three second sample final product</p>

<p>11</p>		<p>10ml HCL. 10ml NaOH. 10ml Sodium Bicarbonate. 10ml Glycerol. 10ml Acetic acid. 4teaspoon Oil. 1teaspoon Gum Arabic. Note: self separation occurs and bioplastics formed.</p>	<p>-Textures: very flexible -It's molecules coherent with shiny. -Thickness: thickness was scaled by a Vernia and was 2ml ,semi-superfine.</p>  <p>Plate (12): Trial Three Third sample final product</p>
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2.3. Methods

I. Preparation of Banana Skins

1. Bananas peels were sliced and weighted using stainless steel knives.



Plate (13): Slices of Banana Peel.

2. **869g** of banana peels were mixed well with **800ml** of distilled water until get a homogeneous mixture of textures and then weighted.



Plate (14): Commercial Blending.

3. **1604g** of the mixture was added to the stainless steel batch reactor that consists of a tank with an agitator and integral heating/cooling system related to under vacuum system to contain Safely the products in the vessel under relatively low pressures and temperatures to provide some Degree of mixing, to both agitate the reactants and aid in the heat transfer, from vessel walls to the contents. This process was needed to increase the concentration, improve the paste textures and get the best results which are reading and recording from the Refractometer.



Plate (15): Batch Reactor System

4. The concentration rate of the mixture was read by a Refractometer before entering the batch Reactor at the initial time, and then takes it from the batch reactor during the operation by using an Injection to withdraw the sample after each period of time until obtained the acceptable results at temperature 60°C.



Plate (17): Refractometer

Table (3): Concentration Rate

Time/hr	Conc. Rate	Temp °C
Initial	2.5	Room temp at 30
2	5	60
2:30	6	60

5. The final 726.30g of paste product from a batch reactor was reached, to the required textures and concentration after two and a half hours of operation, which became ready for testing and development through additive materials to get the bioplastics.

6. **1 Liter** of distilled water was added to **100g** of the paste to aid the filtration mesh process; in order to determine the particles size distribution of granular material, so the mesh sieves were used in series in which, each member sieve was selected to

Pass particles approximately smaller in size than the previous sieve.

Table (4): Mesh size of the Grain

Mesh size/micro	Weight after filtration /g
595	27.71
420	10.38
250	1.98
180	0.89
150	0.8



Plate (18): Filter Meshes.

II. Production of Polymer

The production of a polymer was conducted to, preparing of chemical materials, then added chemicals and other additives to the mixture, as follow:

1. 25g of the paste was placed in a 50 ml beaker.



Plate (19): Sample of Paste.

2. Hydrochloric acid (HCl) was added to the paste and, stirred manually to; break the bonding, followed by Sodium Hydroxide (NaOH) in order to; neutralize the pH up to 7.



Plate (20): Paste after first two Chemicals added.

3. Then, Sodium Bicarbonate (NaHCO_3) was added, in order to react with acidic components in the paste, releasing carbon dioxide as the vapor rising, which causes expansion of the paste and forms the characteristic texture and grain. Followed by Acetic acid to the mixture.



Plate (21): Paste after Sodium Bicarbonate added.



Plate (22): Paste after Acetic acid added.

4. Mixture of the additives like (Gum Arabic, Glycerol, and U-POX Oil) was added to make as a plasticizer, developing and enhancements the paste, so when added to the mixture. With good stirring the self-separation occurred, and the bioplastics has formed a white color; which is indicator for cellulose bioplastics.



Plate (23): Self-separation from the mixture and, bioplastics formation.

5. Then the bioplastics was put it in the Petri dish and entered to the oven at 60°C until drying.



Plate (24): Bioplastics in Petri dish final product.

3. RESULTS AND DISCUSSION

Bioplastics have formed already before entering the oven with self-separation occurred. Then after exiting from the oven the paste was separated for two Petri dishes, and the paste thickness was scaled by a Vernia and was 2ml thickness. **Plate 25** shows the bioplastics from banana peels final product result.



Plate (25): Bioplastics from banana peels final product.

✓ **REACTION MECHANISM**

The properties of bioplastics produced from each experiment are presented in **Table 2**. It was found that when the Glycerin ratio increases the produced bioplastic becomes more flexible, also when introducing the U-POX Oil and Gum Arabic with ratio increase the properties of bioplastic improved and self separation with white color occurs.

It is emphasized that presence of HCl and NaOH in proper concentration is consider to be a controlling factor for its strength. The hydrochloric acid is used in the hydrolysis of amylopectin, which is needed in order to aid the Process of film formation due to the H-bonding amongst the chains of glucose in starch, since amylopectin restricts the film formation. The sodium hydroxide

in the experiment is simply used to neutralize the pH of the medium. Acid hydrolysis changes the physiochemical properties of starch without changing its granule structure. Hence, vinegar was added to the mixture to cut off those branches to make a linear polymer called amylose. If the bioplastic is just made from this amylose, then a very hard bioplastic will produced. If the amylopectin content is higher in the starch, the recovery of starch decreases.

✓ **Glycerol as a Plasticizer**

Plasticizers or dispersants are additives that increase the plasticity or fluidity of a material. The dominant applications are for plastics, especially polyvinyl chloride (PVC) glycerol, Sorbitol. The properties of other materials are also improved when blended with plasticizers including concrete, clays, and related products such as: **U-POX Oil and Gum Arabic**. Plasticizers make it possible to achieve improved compound processing characteristics, while also providing flexibility in the end-use product. Glycerol (also called glycerin) is a simple polyol (sugar alcohol) compound. It is a colorless, odorless, viscous liquid that is sweet-tasting and non-toxic^[5].

3.1. Analysis of Bioplastics

3.1.1. Fourier Transform Infrared (FTIR) Spectroscopy analysis:

The FTIR spectra were recorded on an attenuated **total reflection Fourier transform infrared (ATR-FTIR)**. To analyze the chemical changes of the samples before and after production of polymer (additives material) stage, using a **Perkin-Elmer FTIR spectrophotometer**. FTIR spectral analysis with the model **FTIR-8400s** was performed within the wave number range of **500 – 4000 cm^{-1}** . Here The FTIR technique was made in the central

laboratory-center campus at the University of Khartoum, as shown in plate 26, this used to study the main functional groups present in the banana Peels before and after production of polymer (paste and bioplastic). The main functional groups on the cellulose are $C - H$ stretching vibration and hydrogen bonded $O - H$; cellulose is a long chain of β - glucose.



Plate (26): FTIR device

Results of FTIR analysis:

The **FTIR spectra results** showed that the peaks observed at 3417.63 and 2927.74cm^{-1} for the final paste after drying (untreated bioplastic), also observed at 3379.05 and 2929.67cm^{-1} for the bioplastic from banana peels final result (treated bioplastic), also a band around 1060cm^{-1} that represents the $C - O$ and $C - H$ stretching vibration, confirms the structure of cellulose. As Shown in plates 27, 28.

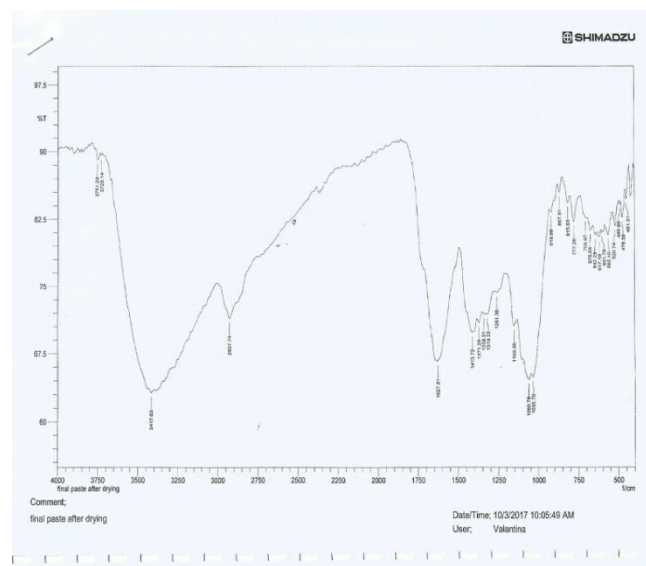


Plate (27): FTIR spectra results for final paste after drying

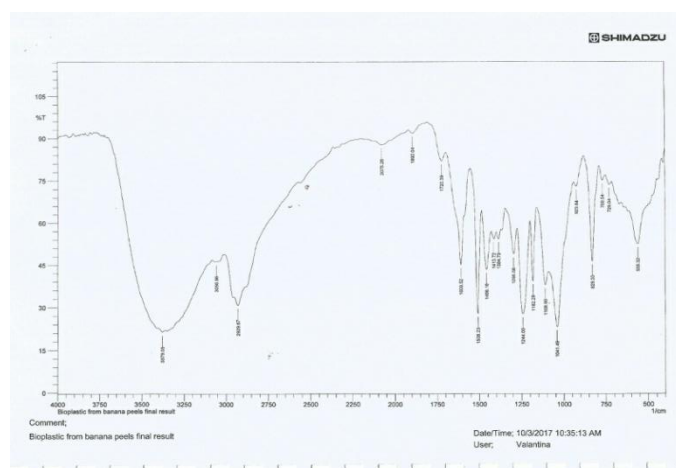


Plate (28): FTIR spectra results for bioplastics from banana peels final product.

✓ **Discussion:**

The FTIR spectra standard range of cellulose showed that the peaks at 3354.0 and 2900.7cm^{-1} ^[6], the peaks observed at 3417.63 and 2927.74cm^{-1} for the final paste after drying (untreated bioplastic), also observed at 3379.05 and 2929.67cm^{-1} for the bioplastic from banana peels final result (treated bioplastic), also a band around 1060cm^{-1} that represents the $C - O$ and $C - H$ stretching vibration, Furthermore the increase in the intensity of these groups indicates to the increase of the crystalline of the samples, as shown in plates below. From these data, the two main groups of cellulose are on relatively equal **absorption area range, confirms the structure of cellulose.**

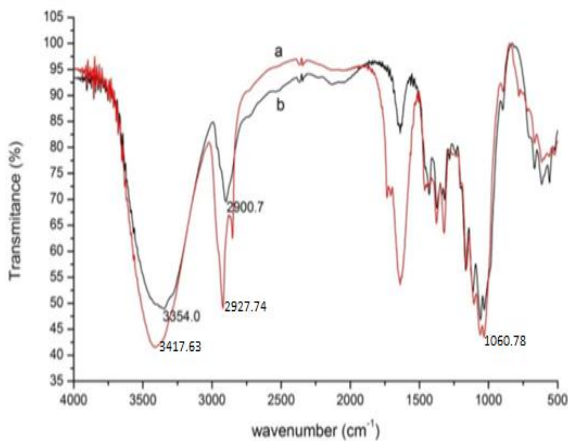


Plate (29): Comparison between the standard cellulose IR with final paste after drying^[6].

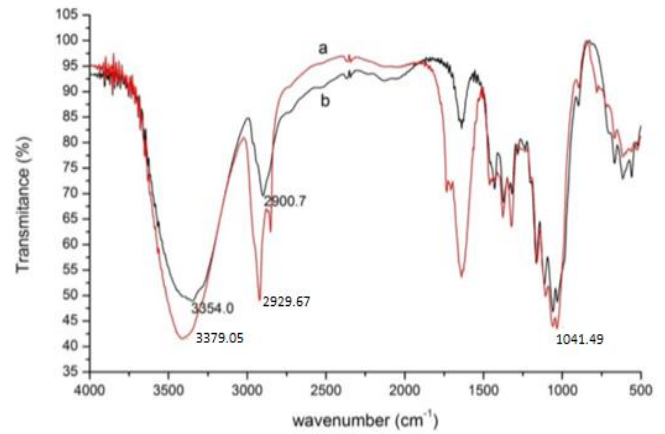


Plate (30): Comparison between the standard cellulose IR with bioplastic from banana peels final product^[6].

3.1.2. Thermal cracking analysis:

In order to verify that the obtained bioplastic is a real polymer, the thermal cracking process was carried. Thermal degradation of thermoplastic polymers occurs during processing at temperature when the polymer is transformed from solid to melt. The **Thermal cracking process** was carried in the Unit Operations Lab at the University of Khartoum, The pieces of equipment of the process were designed, which consisting of the semi-batch reactor with the heater, related with the condenser that condensed gases to liquid oil. The temperature was reading with the thermocouples, as shown in the plate 31.



Plate (31): Semi-batch reactor pieces of equipment

The samples were weighed and entered inside the semi-batch reactor, then the heater was opened, the sample was began heated slowly, the vapor was raised and the condenser condenses the Vapor and transferring part of it to liquid oil, some of it exit as gases, and the other was combustion as ash, as shown in the plate32.



Plate (32): Outlet of the device for the sample

✓ Thermal cracking Results:

The process of the sample was taken about an hour until all the polymer is transformed from solid to melt at 293.3°C.



Plate (33): Liquid oil final product for the sample.

✚ Discussion

Thermal degradation starts primarily when thermal energy removes a **hydrogen atom** from the polymer (R_1-R_2). This generates a radical indicated by ($R_1-R_2\bullet$), where the \bullet is a reactive electron and R is an organic substituent or Polymer fragment. This radical is unstable and reactive and it can do at least eight different things to achieve lower energy as shown in Table 5^[7].

Table 5. Reactions of Radicals Produced by Thermal Degradation

Dissociation	$R_1-R_2\bullet \rightarrow R_1 + R_2\bullet$	The radical may cause the polymer chain to break into two parts. The two parts can be two polymer chains, or it can be one polymer chain and one small molecule
Reaction with other species	$R_1-R_2\bullet + C \rightarrow R_1-C + R_2$ or $R_1-R_2\bullet + C \rightarrow R_1-R_2-C$	The radical can react with another molecule (C) (especially oxygen) in which a break in the chain may accompany
Isomerization	$R_1-R_2\bullet \rightarrow R_3-R_1\bullet$	The polymer can rearrange its structure
Ionization	$R_1-R_2\bullet \rightarrow R_1-R_2^+ + e^-$	The polymer can kick off an electron forming an ion
Deactivation	$R_1-R_2\bullet + R_1-R_2 \rightarrow R_1-R_2 + R_1-R_2$ +energy dissipation	The radical can be deactivated by reaction with another radical and give off energy in the form of heat
Intramolecular energy transfer	$R_1-R_2\bullet \rightarrow R_1-R_2$	The radical can rearrange to another part of the same molecule
Intermolecular energy transfer	$R_1-R_2\bullet + R_3-R_4 \rightarrow R_1-R_2 + R_3-R_4\bullet$	The radical can transfer to another neighboring polymer molecule
Luminescence	$R_1-R_2\bullet \rightarrow R_1-R_2 + \text{light}$	The radical can give off energy in the form of light

The final appearance of the liquid oil result for the sample was separated into two layers, one was on the top, dark color, high viscosity and low density, also the other layer has a yellow color and high density so it's in bottom, as shown in **plate 33**. This result raised some questions for the reason of separation for two layers, also the secret of high viscosity and others, was thought it maybe fuel the dark layer, and another layer may Be water because it's a high density. So to answer this question and to ensure, must be made, gas chromatography test (GC) to recognize the component on the fuel. The tests were carried at the petroleum laboratories, research, and studies (PLRS).

✓ Results of GC analysis:

The results of the gas chromatography and mass-spectra analysis (GC-MS) with flame ionization detector (FID), was confirmed to the expectation and the top layer was a fuel then recognizing to components in the fuel which indicate to classified as the naphtha light fuel, and the dark color back to some reason on the process may be not complete pyrolysis, also the bottom layer was a water. As shown in plate 33.

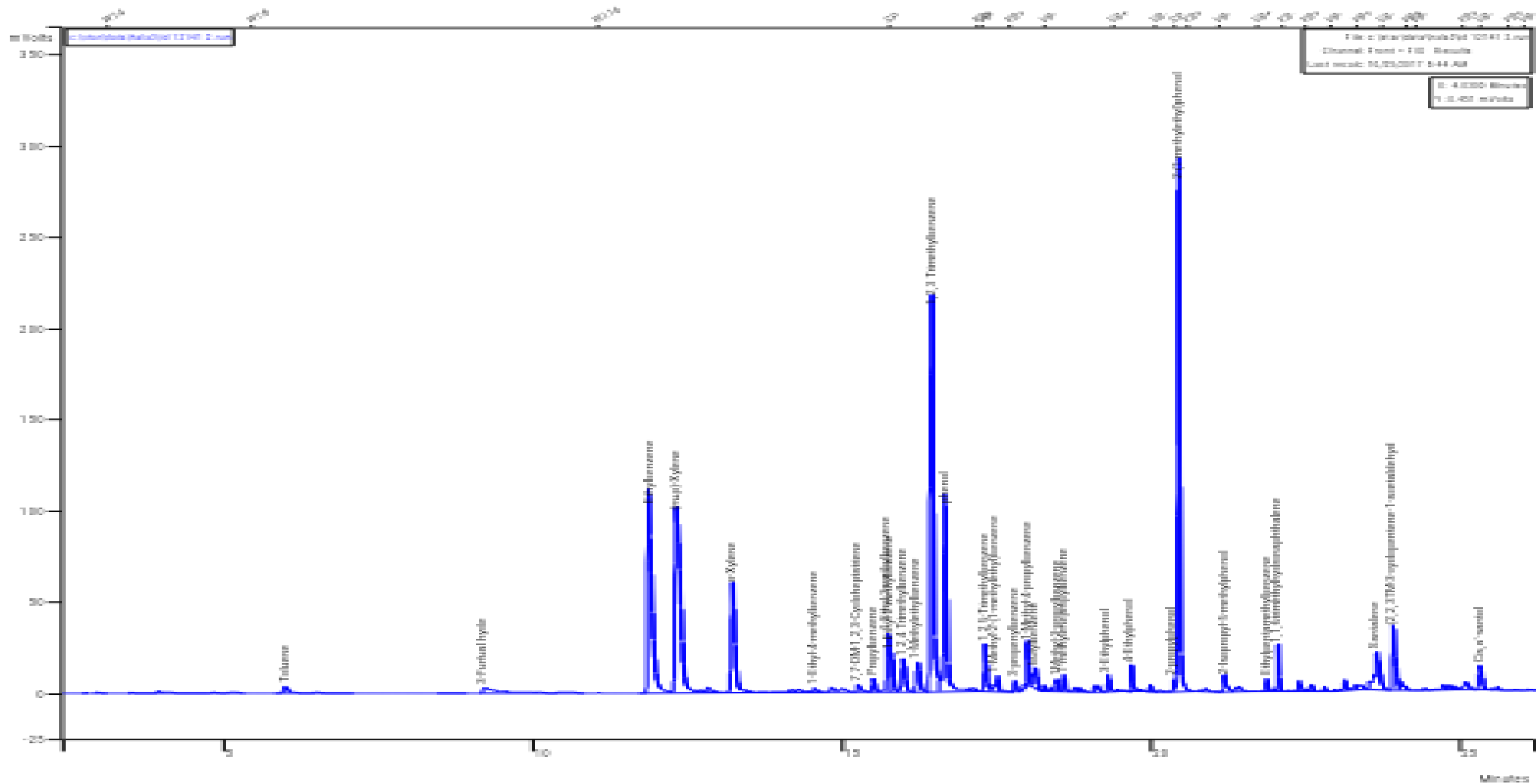


Plate (34): FID Chromatogram result.

4. Conclusions

The current report is an effort towards the synthesis characterization of natural polymeric materials. Certainly, the research is a long way to go for their economic and environmental benefits.

Many experimental trials were carried until some specific properties were reached as shown in table 2. Those trials include addition of materials, which added in suitable amounts, set impart the required properties. The starting point of this work followed some previously published work and then it was improved by changing the procedures, like introduction of batch reactor to further concentrate the paste and the incorporation of new additives as shown in table 2. However, we conclude that:

- ✓ The batch reactor helps in increasing the concentration, improve the paste textures and get the best results without changing in the structure of the banana peels.
- ✓ Glycerin makes the chains of starch slip along each other which makes the bioplastic material more flexible. Therefore, the more glycerin is used the more flexible bioplastic is produced, and vice versa the less glycerin is used the harder bioplastic is produced.
- ✓ Sodium Bicarbonate (NaHCO_3) was added, in order to react with acidic components in the paste, releasing carbon dioxide as the vapor rising, which causes expansion of the paste and forms the characteristic texture and grain.
- ✓ Vinegar breaks the starch chains into smaller sizes which make them more manageable while creating the bioplastic.

- ✓ U-POX oil and Gum Arabic helps in enhancing and improving the quality of produced bioplastics.

Finally it is reconfirmed that a bioplastics could be obtained from Banana peels by using Batch Reactor with other additive materials. However, the thermal degradation occurs at 293°C. But further research is to be conducted to obtain other products like a biofuel, through thermal cracking process.

A research on the utilization of wastes for producing an economically added value should look for the so called green engineering and it is everybody's role to look for the dual purpose of keeping the environment clean and enhance economical benefits at the same time . So these types of projects need more experimental and research to improve and develop the eco-friendly final products and to upgrade the environment by reducing amounts of pollutions and eventually keep the environment clean from those wastes.

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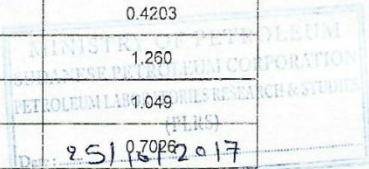
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Appendix

Sample Type: Fuel from Banana peels
 Sample Code: GC/1017/000665 Report number: 0021141
 Sample ID: 0021141 Date/time report: 25/10/2017
 Customer Name: Student
 Customer Ref: _____
 Date / Time Received: 22/10/2017

Component Name	Method	Unit	Result
Toluene	CG-FID	Wt%	0.4453
3-Furfural hyde		Wt%	1.049
Ethylbenzene		Wt%	12.37
(m+p)-Xylene		Wt%	14.54
o-Xylene		Wt%	5.884
1-Ethyl-4-methylbenzene		Wt%	0.2563
7,7-DM-1,2,3-Cycloheptatriene		Wt%	0.3971
Propylbenzene		Wt%	0.5260
1-Ethyl-3-methylbenzene		Wt%	2.200
1-Ethyl-2-methylbenzene		Wt%	1.378
1,2,4 Trimethylbenzene		Wt%	1.597
1-Methylethylbenzene		Wt%	1.339
1,2,3 Trimethylbenzene		Wt%	18.31
phenol		Wt%	8.368
1,2,5-Trimethylbenzene		Wt%	1.672
1-Methyl-2-(1-methylethyl)benzene		Wt%	0.6759
3-propenylbenzene		Wt%	0.4203
1-Methyl-4-propylbenzene		Wt%	1.260
butylbenzene		Wt%	1.049
1Methyl-3-propylbenzene		Wt%	



<ul style="list-style-type: none"> ● TEST (S) Has lhave been subcontracted ,please refer to PLRS for details ● No part of this report can be reproduced except full in any form or by any electronic or mechanical including photocopying and recording without awritten pemission of the issuing laboratory 	Reported by: <i>Tawkeg</i>
	Sig.: <i>[Signature]</i>

(F-04-22)

TEST REPORT

Component Name	Method	Unit	Result
1-methylenepropylbenzene	CG-FID	Wt%	0.4900
3-Ethylphenol		Wt%	0.4203
4-Ethylphenol		Wt%	0.6344
2-propylphenol		Wt%	0.2586
2-(1-methylethyl)phenol		Wt%	15.13
2-isopropyl-5-methylphenol		Wt%	0.6518
Ethylpentamethylbenzene		Wt%	0.3908
1,1,6-trimethylhydronaphthalene		Wt%	1.067
Santalene		Wt%	2.687
(2,2,3TM-3-cyclopentene-1-acetaldehyd		Wt%	2.605
Cis,a'-santol		Wt%	1.217

MINISTRY OF PETROLEUM
 SUDANESE PETROLEUM CORPORATION
 PETROLEUM LABORATORIES RESEARCH & STUDIES
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 Date: 25/10/2017

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(F-04-22)

Plat (35): GC report (page2)

❖ **Calculations of yield:**

- The bioplastics were weighted before the process and was **28g**
- The liquid oil bottle was weighed with it and without it and was

● With it was **134.41g**

● Without it **117.78g**

➤ $134.41 - 117.78 = 16.63g$

● **16.63 g** represents the net liquid oil inside bottles

❖ **Then the yield production =**

Sampleweight – gasesandashformed/sampleweight..... (1)

❖

➤ $28 - 16.63 = 11.37g$

● **11.37g** represents the gases and ash formed.

● **8.6g** represents the ash formed

● **Then 2.77g** represents the gases formed

● **Using Eq(1) to obtained the yield production=**

➤ $28 - 11.37/28 = 0.594 = 59.4\%$

➤ **59.4%** represent the net yield of liquid oil percentage