

Bioplastic formation from wasted paper

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Abstract- Plastics created from fossil fuels are quite widespread in our lives, and we cannot imagine our existence without them. At the same time, they are non-biodegradable and emit greenhouse gases, posing an environmental issue. Biodegradable bioplastic is the solution to this issue. Plastics created from renewable biomass sources, such as vegetable fats and oils, corn starch, pea starch, or microbiota, are known as bioplastics. Bioplastics can be made from a range of sources, including starches, cellulose, and other biopolymers. In this work, we will discuss the production of bioplastics from cellulose, with waste papers serving as our raw material and the pH sensor serving as our feedback control mechanism.

Our research is focused on improving the plastic industry through the recycling of wastepaper, The prototype that we built on a modest scale was made up of three parts. Notably, the method of converting wastepaper into bioplastic was accomplished through chemical treatment using acetic acid (CH₃COOH) and sulfuric acid (H₂SO₄). And three test designs were created; the first and second were successful in producing plastic, but they did not accomplish the intended outcomes. The third one succeeded in meeting the design requirements by creating bioplastic with high efficiency that can be utilized to make plastic. The project is finished after the feedback control system is installed. Meanwhile, our prototype is running automatically, thanks to a DC motor, a water pump, an Arduino, and a PH sensor that measures the pH of the solution and modifies it until it is neutralized. Finally, countries' environmental pollution will be regulated during the large-scale development of our prototype. In addition to expanding the industrial sector.

Index Terms- Paper, Recycling, Esterification, Cellulose Diacetate, Feedback control system

I. INTRODUCTION

Bioplastics are synthetic polymers derived from renewable biomass such as vegetable fats, oils, starch, or microbes. Petroleum-derived polymers, such as fossil-fuel plastics, rely more on fossil fuels and release more greenhouse gases. Some bioplastics, but not all, are biodegradable. Biodegradable bioplastics can deteriorate in either anaerobic or aerobic environments, depending on how they are made. Bioplastic can be manufactured from a variety of materials such as starches, cellulose, and other biopolymers. Bioplastics are widely utilized in packaging, tableware, food packaging, and insulation.

Polylactic acid is the world's second most important bioplastic in terms of volume usage. Polylactic acid is a transparent plastic derived from corn or dextrose. Its qualities are like those of traditional petrochemical-based mass polymers, and it can also be processed using common equipment that is already used to make some conventional plastics. Polylactic Acid mixes of various grades are granulated and used in the plastic processing sector to manufacture films, fibers, plastic containers, cups, and bottles. Polylactic Acid, a plastic substitute made from fermented plant starch (typically maize), is quickly gaining traction as a viable alternative to traditional petroleum-based polymers. Some countries have outlawed plastic shopping bags, which are responsible for much of the world's "white pollution." Bioplastics are now made from corn starch, potato starch, or banana starch, which are all edible to humans and animals. Paper, as we all know, is the world's second greatest producer of garbage, accounting for 17% of total waste, and the third largest industrial polluter of the environment. So, instead of using starch excreted from food items, I recommend employing wastepaper, which is largely constituted of cellulose and is disposed of in the seas. We will look at how to convert wastepaper into biodegradable plastic and how to eliminate errors that occur throughout the process by incorporating a feedback control system in this study.

Paper is made up of short cellulose fibers that can be easily converted into bioplastic by a chemical treatment. So, in this process, cellulose is recovered from waste papers using an acetic acid pretreatment reaction. The cellulose is then esterified with acetic anhydride to produce cellulose triacetate. After removing the acetyl group from cellulose triacetate, it is converted into cellulose diacetate. Finally, bioplastic is created by combining it with acetone or another solvent.

II. MATERIALS

Wasted paper or any source of cellulose as I used filter paper, Acetic acid, Sulphuric acid, Acetone, and Acetic anhydride from a chemicals company, Plasticizers from the plastic industry
The electronic components are Arduino UNO, H-bridge, Water pump, DC motor, Wires, Power supply, Breadboard, LCD, Regulator, And finally Constant & variable resistance from an electronic shop.

III. PREPARATION OF CELLULOSE FIBERS BY ESTERIFICATION

The method has described the preparation of cellulose fibers. 10 grams of cut paper were transferred into a 1-L beaker and treated with 50ml of acetic acid and half a gram of sulphuric acid solution. Then mixed it around for a couple of minutes to make sure that all the paper was wet. The mixture was heated with occasional stirring for 1 h at a temperature range of 60–65°C. it is a pre-treatment process that helps open the normally tightly packed cellulose fibers. This allows the fibers to be acetylated more evenly, and it'll also speed up the reaction. After 1 hour, the pre-treatment is done and now it was time to acetylate it. a mixture of acetic acid and acetic anhydride was added, to cover the top, and put the beaker in a hot water bath for 30 minutes at a temperature range of 60–65°C. What happened here is a reaction between the acetic anhydride and the hydroxyl groups of cellulose. Each glucose subunit has three hydroxyl groups and almost all of them will get acetylated This type of reaction is known as the ESTERIFICATION Reaction, and it leads to the formation of cellulose triacetate Which is soluble in the acid mixture. as the reaction progresses all the paper should slowly disappear. After that take the beaker out of the hot water bath and separate the solution evenly into two round bottom flasks to make two forms of cellulose acetate and to compare the results between them.

The formation of cellulose triacetate

Take one of the round beakers and put it back in the hot water bath and add a stir bar This time though the water bath is slightly hotter, and it's held around 60 C Then pour 25ml of 80% acetic acid into the solution. The other 20% of this is just water and up until this point, everything was completely water free the purpose of adding it now is to destroy any excess acetic anhydride that remains. After the addition keep it here for about 15 minutes and then pour it all into a beaker and slowly mix in about 25ml of distilled water, and a whole bunch of triacetate starts to appear Then on top of this then pour in 200ml more to completely knock out the rest then mix it up well, and let it sit for a couple of minutes To separate the triacetate just dump it into my vacuum filter, and turn on the pump. All the water is quickly pulled out, but unfortunately, this is the beginning of the kind of annoying part. The reaction mixture that I'm filtering off is highly acidic and well this [acidity] gets all absorbed into the cellulose, so just pulling away the water isn't good enough, and there's a whole bunch of acid that's still trapped inside, and then transfer it to the vacuum filter to pull away all of the liquid, and then just like last time put them both in my toaster at low heat for a couple of hours to dry.

The Formation of cellulose diacetate

Using the second-round flask, drop in a stir bar in it and wait for it to warm up to about 60 C then add a dilute mixture of acetic acid with a small amount of sulfuric acid by adding water here as well as sulfuric acid it will be hydrolyzing some of the acetyl groups and converting them back to hydroxyls. run it under these conditions for about three hours Which should on average remove one acetyl group for every glucose unit. the major product will be cellulose diacetate, but sometimes some triacetate will remain unaffected and will form some monoacetate when it's done, Finally, transfer everything to a beaker, and from this point on the workup is the same as the last run. slowly add 25 mils of distilled water with stirring in between in the previous run it seemed like once the precipitate appeared It was there to stay, but this time all Reda's all's back into solution to knock it out. I must add a bunch more water, so pour in 200 mils and mix it thoroughly let it sit for a couple of minutes, and then transfer it to the vacuum filter to pull away all of the liquid, and then just like last time then put them both in my toaster at low heat for a couple of hours to dry.

Testing the powders with acetone

When they're both dry left with some nice hard and crunchy powders, in Any case, I'm gone move on and do a quick test on both to see if they are two forms of cellulose acetate the test is easy. And just need to see if they dissolve in acetone. So, add a small amount of each to two test tubes followed by an equal amount of acetone. ended up adding more acetone to speed things up and all the diacetates eventually dissolved however most of the triacetate remained This is exactly what's expected to happen, and it confirms that we did make two different products.

The products of two crunchy samples

The triacetate powders

moved on to trying the same things with the triacetate except for this time. I can't use acetone because the triacetate isn't soluble in it so instead I use a mixture of nine to one DCM to methanol I started with a bit more solvent than I needed here, so I just kept adding the triacetate until I got to a saturated solution I Poured it all into a glass dish and this time I decided to do a time-lapse I also want to see what would happen if I lightly blew on it with a fan and the answer is that it's not good The solvent evaporated way too quickly and the triacetate contracted in on itself by the time all the solvent disappeared and as I expected it was brittle There was little to no flexibility and it snapped and shattered with only a bit of bending so, the triacetate powder didn't achieve the design requirements and failed in its mission to form the plastic films

The diacetate powder with and without plasticizers:

threw a random amount that was enough into a beaker, and then shot in some acetone the Quantities here aren't super important, and I'm just trying to make a concentrated solution it took quite a bit of stirring and something like five minutes, but eventually, everything disappeared and let it evaporate on something thought it would just stick to the sides and be a complete mess, but it was extremely easy to remove It's not the most beautiful piece of plastic. it seemed to be a little bit more flexible, then I wanted to try next to see if I can make the plastic less brittle by adding a plasticizer The thali beast plasticizers are the most used ones. I decided to go with 20% I Went with 20 because it seemed to offer a good combination of strength as well as flexibility Anyway, just like before. It was all dissolved in a minimal amount of acetone and then pour it into a glass dish I Wait for all the solvent to evaporate and I remove it from the dish Parts of it were still pretty brittle, but in general, It was a lot more flexible the quality of my film is still not very good But you can see that the addition of the plasticizer did get it closer to being a usable product I think the reason why it's still kind of brittle is because of the low-quality cellulose acetate amusing Even after everything was dissolved in the acetone. I did snap off a small portion of it this small section was extremely flexible but it was also pretty strong I was able to completely bend it in half and it was very elastic

IV. FEEDBACK CONTROL SYSTEM

The feedback is an electric signal transmitted from the output to the controller, allowing the controller to calculate how the output differs from the desired value. With the help of this feedback signal, the controller would be able to determine the previous state of the system output. To obtain the appropriate output, the controller would calculate the error and modify the system input. The closed-loop system is also known as a feedback system because it feeds back the output into the input to clear mistakes and maintain the required output quality. The feedback control's purpose is to eliminate the measured disturbances. The feedback controls are automated, and they should do the detecting, calculating, and manipulating that the equipment should do, and each element in the control system must interact with the others.

The products generated throughout the test plans had various flaws that damaged the product itself. These flaws can be increased by the product's pH. As is customary, the product has a high acidity due to the addition of acids during the processes, and it was discovered that the acidic medium affects the product's flexibility and tensile strength.

The feedback control system was used to solve this problem. It will include a pH sensor, an Arduino board, a water pump, and a DC motor. It will be placed in the last step of the product before it dries. The goal is to transmit positive or negative feedback to the microcontroller, which will then act based on its nature. If the feedback is positive, it means that the pH of the product is approaching 7, and the project's program will stop at this point and go on to the next step. However, negative feedback indicates that the pH of the solution is still acidic. In this case, the water pump and DC motor will be opened and immersed in water until the pH of the product becomes neutral.

As Most of the time, the solution will be acidic and it will affect the final product, this problem will be solved by making a feedback system on the solution. This is by using the pH sensor which will measure the pH of the solution, water pump, and DC motor to stir the solution. The program was made to continue inserting water until the pH approaches 7 then the pump will stop and at this time a buzzer will make a sound means the program is ended and the product is ready the results of changing the pH will be shown on LCD.

The connection of the feedback control system

a cubic stand was designed to place the components above it which are: Arduino, H bridge, breadboard, LCD, resistance, and the buzzer for the feedback system. In addition, make a hole on the top of it for the DC motor to be connected to a stick that will stir the solution and a water pump in a container behind the cubic stand to add water to the solution.

Next, the LCD was connected to the breadboard and the pins of the breadboard were connected to the Arduino. Moreover, the variable resistance was connected to an LCD to control the intensity of the light.

Moreover, the PH sensor was connected to the Arduino and got its voltage from the breadboard, and the buzzer was connected to the constant resistance and the resistance to the breadboard. In addition to the second pin from the buzzer was connected directly to the Arduino. Then, the water pump and the Dc motor were connected to the H bridge, and the pins of the H bridge were connected to the Arduino. in addition, we have connected the project to a power supply by using a regulator as shown in the figures (1&2).



Fig (1)



Fig (2)

Following that, the Arduino was connected to the laptop by using an Arduino wire “USB2.0 printer cable” to upload the codes.

The Nernst equation will be utilized to compute the PH value of a solution. The Nernst Equation governs the glass electrode response and can be written as

$$E_{\text{cell}} = E_{\text{cell}}^{\ominus} - \frac{RT}{zF} \ln Q_r$$

Where:

Q= Reaction coefficient / E = mV output from the electrode / E0 = Zero offset for the electrode / N = Ionic Charge / R = Ideal gas constant= 8.314 J/mol-K / T = Temperature in °K / F = Faraday constant = 95,484.56 C/mol

The most common form of the motor is a DC motor (Direct Current motor). There are only two leads in most DC motors: one positive and one negative. The motor will rotate if these two leads are connected directly to a battery. The motor will rotate oppositely if the leads are switched, so we will utilize it to stir the solution.

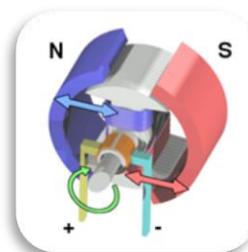


Fig (3)

Fig (4) shows a simulation of the connection of the feedback control system.

This is the finished project code link <https://bit.ly/3FGNT12>

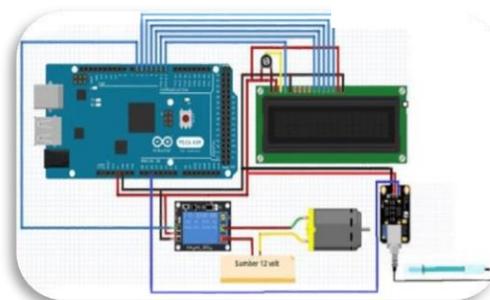


Fig (4)

V. REFLUX REACTION:

Reflux involves heating the chemical reaction for a set length of time while employing a condenser to continuously cool the vapor produced back into liquid form. The vapors created above the reaction are constantly condensed and return to the flask as a condensate. It ensures that the temperature of the reaction remains constant in this manner.

The acetic anhydride is required to complete the reaction during the project, but it is not available to gain, therefore we will make it use the reflux reaction. The goods will be of the same high quality as the original.

Acetic acid and sulphuric acid will be the only ingredients used in the reaction. They will install an air conditioner for two hours. Acetic acid to sulphuric acid concentration is a 2:1 ratio of concentrated acids.

The reaction will take 2 hours to complete before the product is created.

Figure (5) shows the air condenser device



Fig (5)

VI. PROTOTYPE DESIGN

The prototype was supposed to convert paper into plastic in three stages:

1-The first stage consists of the clamp stand being put to hold the flask which is in a beaker containing the water heater. And a beaker contains cut wastepaper that will be mixed with acetic acid and sulfuric acid before passing through another container that is the water pass with a water heater, all of which are held together by a clamp stand as in figure (6)



Fig (6)

2-The second stage will take the solution after the chemical treatment to neutralize it using a feedback control system, which consists of the cubic stand. comprised of a water pump that is responsible for adding water to the solution and a PH sensor that will determine the acidity of the solution and send signals to the water pump to stop adding water until the PH reaches 7. Furthermore, the DC motor is linked to a stick that is used to stir the solution. As shown in figure (7)

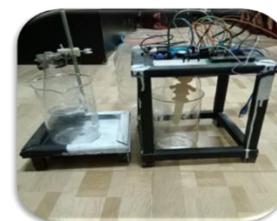


Fig (7)

3-The third stage consists of the vacuum filter prepared to separate the diacetate from the water as shown in figure (8)



Fig (8)

figure (9) shows the final prototype

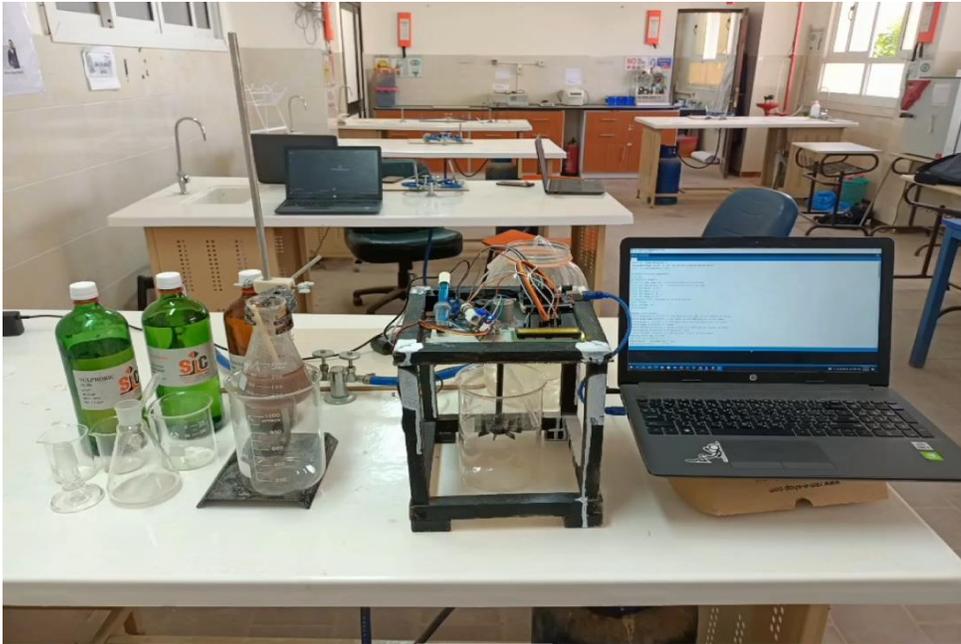


Fig (9)

VII. TEST PLANS

The test plan is completed to check that the solution met the design specifications. the efficiency of our prototype was increased, as evidenced by the tests that we conducted. Three trials were used in the test plan:

The first trial is as follows:

It was done manually without measuring the PH or using a feedback control mechanism, however, the powder of the combination after drying was not as expected. The product was cellulose triacetate. It was yellow because it was acidic, and its texture was like fine sand that might be broken; therefore, its flexibility was poor.

The second trial:

Here the process was modified to produce cellulose diacetate instead of cellulose triacetate Utilizing After drying the mixture, we obtain the diacetate. Its qualities were superior to the first. The yellowish color faded, and the flexibility improved. It had a plastic-like texture, but it also has some problems with flexibility and strength, however, the results were better than in the first trial.

The third trial:

we attempt to correct the problem by utilizing the feedback control method. Arduino did it automatically since it regulates the neutralizing reaction of the mixture. Utilizing After drying the mixture, we obtain the diacetate. Its qualities were superior to the first. The yellowish color faded, and the flexibility improved. It had a plastic-like texture and was more difficult to break than the first and second ones.

it involves adding Plasticizers to the mixture in addition to using the feedback control mechanism. This greatly increased its elasticity, making it difficult to break. The powder was white in color and had a texture like that of plastic.

VIII. RESULTS

The product was cellulose triacetate, and it failed due to insufficient flexibility and strength. Because plastic shrinks after drying, it did not take the shape of the template, and this product does not match our criteria. In this case, we modify the results (second test plan) by adding some acetic acid and water to the solution. By adding acetic acid, the solution is converted from cellulose triacetate to cellulose diacetate. Although cellulose diacetate is not easily soluble in acetone, it overcomes the problem of creating a plastic shape and does not shrink. However, it has several issues, such as the product's color being dark yellow when the desired outcome was light beige, which affects the color of the plastic liquid. The texture was grainy rather than smooth, as expected, and it has a lot of problems with solubility because it requires more work to dissolve. So, while the second test results did not match the requirements, they were very close. Flexibility and strength improve, but they are far from ideal. We determined that the problem was in the pH of the solution because it was acidic, and the ideal pH for cellulose acetates is 7. So, we add another component, the feedback control mechanism. The feedback control method eliminates the majority of the previous issues, and our third test plan is successful.

So, fig (10) shows the final plastic sheets from our project.

The diacetate product is seen in fig (11).

The triacetate product is seen in fig (12).



Fig (12)



Fig (11)

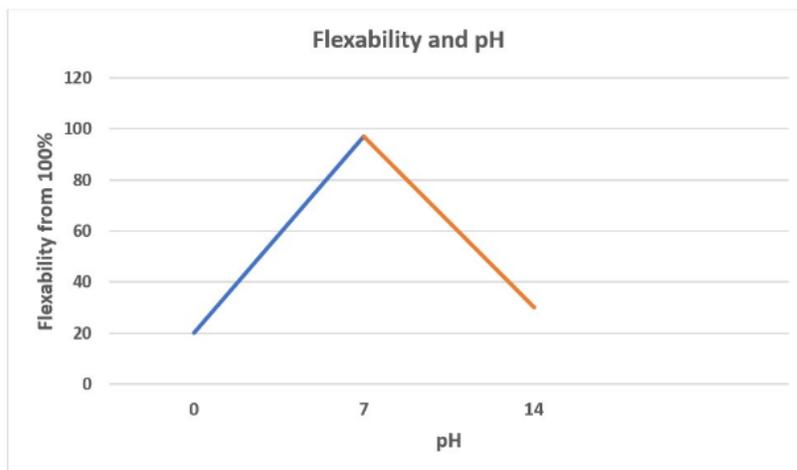


Fig (10)

The following graphs show our results:

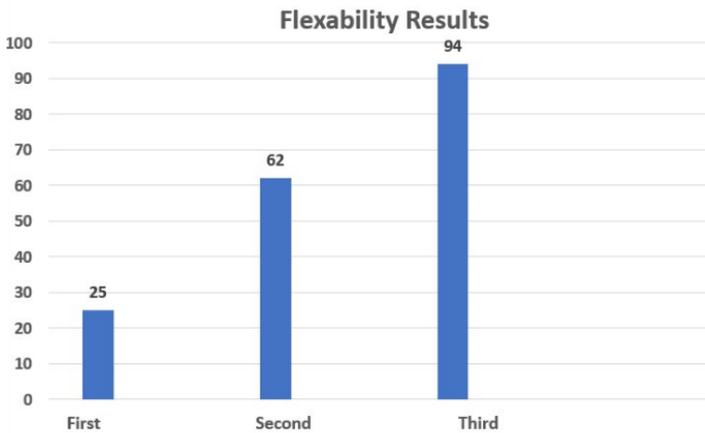
Three tests were performed, the first of which created triacetate, the second of which involved adding acids to produce diacetate, and the third of which included the feedback control system.

Graph (2) displays the relationship between flexibility and the pH of the mixture and demonstrates that adding acids to convert it to diacetate lowers the pH level, which increases flexibility, and when the solution is neutralized, it reaches its maximum flexibility, which meets the project's requirements.

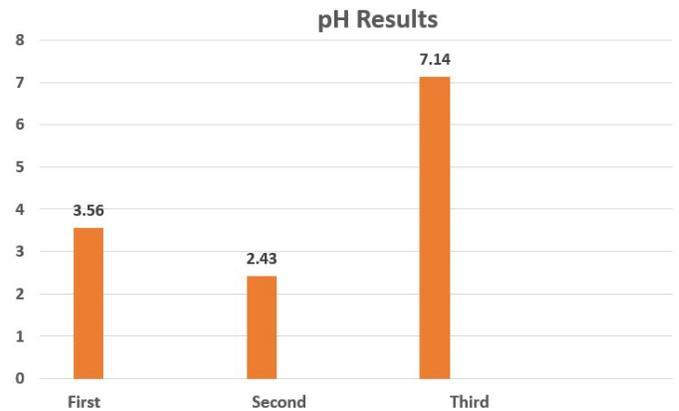


Graph (1)

Graphs (2&3 and) depict the relationship between pH value and flexibility. According to research and observations, increasing the pH from 0 to 7 enhances flexibility, but when the pH hits 7, it is regarded as a breakdown point where flexibility diminishes as the solution becomes more basic.



Graph (2)



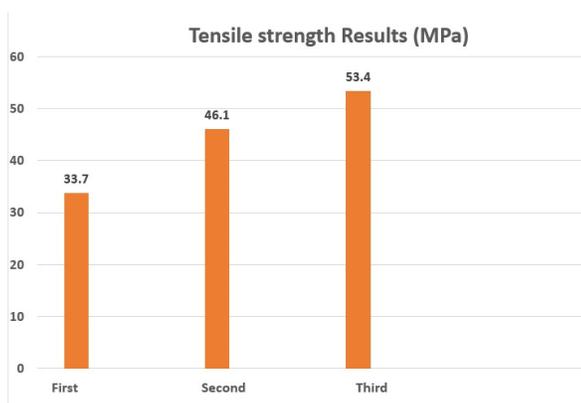
Graph (3)

	First	Second	Third
Flexibility	25%	62%	94%
pH value	3.56	2.43	7.14

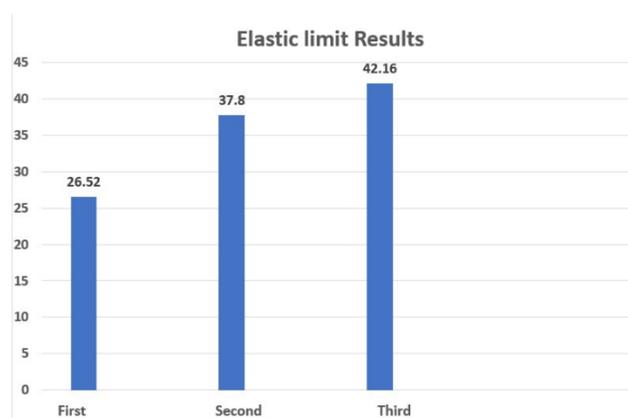
Table (1)

The tensile strength and elastic limits data are shown in graphs (4&5 and) to determine the product's durability. In this case, increasing the pH increases both the tensile strength and the elastic limits.

A tensile tester was used to determine the tensile strength, which can also be calculated using the formula $\sigma_{max} = P_{max} / A_0$. where P_{max} = maximum load, A_0 = original cross-sectional area.



Graph (4)

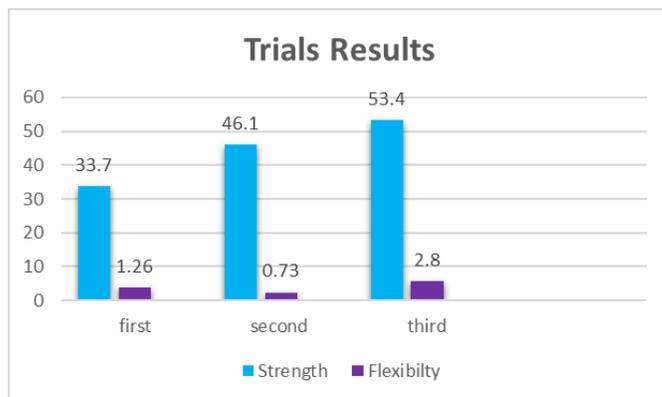


Graph (5)

	First	Second	Third
Elastic limit	26.32	37.8	42.16
Tensile strength	33.7	46.1	53.4

Table (2)

Graph (6) represents the final data that was collected during the project. it shows the tensile strength and the flexibility of the 3 trials. The third trial was the perfect one in which her results were approached to the real plastic as the flexibility and the tensile strength of the real plastic are 3 and 56.9 respectively. So, the project succeeds and achieves its design requirements.



Graph (6)

	First	Second	Third
Strength	33.7	46.1	53.4
Flexibility	1.26	0.73	2.8

Table (3)

IX. Discussion

The world generates 2.01 billion tons of municipal solid waste annually, with at least 33 percent of that—extremely conservatively—not managed in an environmentally safe manner.

When looking forward, global waste is expected to grow to 3.40 billion tons by 2050. Paper is the second-largest amount of waste globally as it presents 28.5% of the total wasted and is the 3rd largest industrial polluter of the environment. As shown in figure (13).

Fossil fuel plastics derived from petroleum are very common in our lives and we cannot think of our day without their use. At the same time, they are non-biodegradable and produce greenhouse gases, thus causing an environmental problem.

The solution to this problem is biodegradable bioplastic. Bioplastics are plastics derived from renewable biomass sources, such as vegetable fats, oils, or corn starch.

Fig (14) shows the structure of the bioplastic. There is a variety of materials in that bioplastics can be composed of cellulose or other biopolymers. The raw material used here is wasted paper, paper is short cellulose fibers, and thread-like structures can easily convert into bioplastic by a chemical treatment.

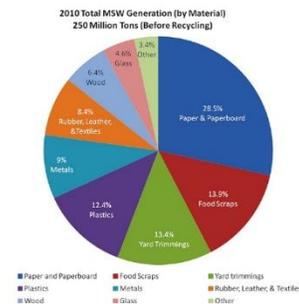


Fig (13)

the main idea of the solution is to convert the wasted paper into bioplastic. And this will be done a converting the cellulose fibers to acetate easier by the esterification reaction according to the organic chemistry and then to cellulose triacetate, and from cellulose triacetate to cellulose diacetate to meet the design requirement.

Fig (15) shows a summary of all the project reactions.

The prototype is designed to meet the project's procedures as it consists of 3 main parts. The first part represents half of the project, as most of the steps and chemical reactions will take place in it. The first part consists of a clamp stand, a movable flask on it, a glass container with water, and a glass heater. The second part is the feedback control system, which consists of a beaker, pH sensor, DC motor, and water pump to form the final product. The third part consists of a vacuum filter to remove excess water from the diacetate. The final product is left to dry, and a powder is formed. In this case, we dissolve the powder in acetone until

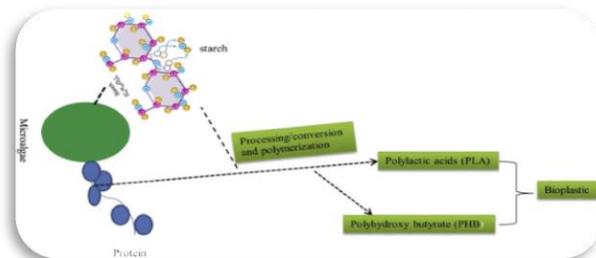


Fig (14)

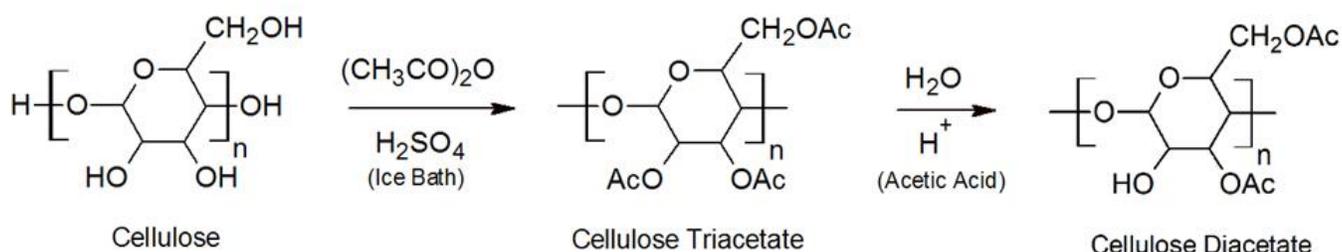


Fig (15)

the plastic is formed and put in the temple to take its shape.

Testing the prototype was done 3 times. the first-time product of the project was cellulose triacetate which is produced from cellulose as a source of acetate esters (triacetate). To form a plastic liquid, the resulting powder will dissolve in acetone, but the cellulose triacetate doesn't dissolve easily and needs some extra effort to dissolve. After dissolving it we pour it into a glass pot and let it dry.

Fig (16) shows the plastic resulting from cellulose triacetate and how it has a lot of problems. the product does not meet the design requirements. So, a chemical modification was done on cellulose triacetate to prepare cellulose diacetate. Cellulose diacetate is prepared consecutively from the cellulose triacetate solution by diluting acetic acid with water and heating. When the diacetate is dissolved in acetone and let it dry. The results were perfect but there were some problems firstly in the shape and the characteristics of the diacetate powder as the color of the powder was dark yellow, and the expected color was light beige. Secondly, the texture of the triacetate powder was rough. Thirdly, the solubility of diacetate was not easy. after searching we find that the cellulose diacetate will be soluble in acetone when its pH becomes 7. And in our solution, the product was an acidic mixture. not suitable pH can change its properties as shown. So, the feedback control system will be put to solve this error and achieve the design requirements which are the efficiency of the plastic and its applicability during preparation as shown in figure (17) the product of diacetate after inserting the feedback control system



Fig (16)



Fig (17)

X. CONCLUSION

After extensive study, it was discovered that the rate of wasted paper is the third cause of pollution in the environment, and the plastic industry consumes a lot of energy, therefore it was critical to find a solution to enhance the plastics industry while also lowering this type of pollution. As a result, our proposal, which is based on converting wastepaper into bioplastic, was chosen to be implemented because the plastic sector consumes a lot of energy, which can be reduced. We determined that the plastic met the design requirements in the third trial, where it has a higher proportion of hardness and flexibility, at the end of our prototype and after evaluating our solution. It has also been discovered to be more effective than other alternatives since it addresses three additional major challenges: pollution, waste recycling, and industry development.

Advantages of cellulose bioplastic over petroleum-based bioplastic

- What distinguishes bioplastic from petroleum-based plastic is that the manufacturing process can be reversed when the plastic ends up in a compost heap. Fungi and bacteria in the soil begin to degrade the cellulose bioplastic into its constituent pieces. The bioplastic will compost like any other organic material under aerobic (oxygen-rich) conditions, with heat and moisture. Compost bioplastic is broken down by microorganisms into humus, a nutrient-rich, soil-like substance that works as natural plant food. Carbon dioxide and water are the waste products.
- Cellulose bioplastic aids in the reduction of greenhouse gas emissions. Proponents also praise the use of cellulose, which is technically carbon neutral because it is derived from renewable, carbon-absorbing plants, as yet another approach to cutting greenhouse gas emissions on a rapidly warming planet. When burnt, cellulose bioplastic will not release any toxic fumes.

XI. ACKNOWLEDGMENT

It is an excellent opportunity for us to write on a topic such as BIO-PLASTICS. We read many books and websites while preparing this paper, which helped us become acquainted with new themes. We are concentrating on the things that are essential for us to learn this subject quickly.

We are grateful to prof. Saif Soliman, our respective teacher, has always been supportive.

been serious and helpful in helping us comprehend the many research systems and conceptual challenges in our article.

Apart from us, this report will undoubtedly be of great interest to anyone who wishes to learn more about this subject. We hope they will find it understandable.

We worked hard and sacrificed our souls to collect all essential documents on this issue. We don't know how far we'll be able to go.

Furthermore, we do not claim that all the information in this document is completely accurate. There may be shortcomings, factual errors, and incorrect opinions that are all our fault, and we are all liable for them, but we will attempt to provide a better volume in the future.

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