CELLUPOLYSIDE

A biodegradable fabric designed to be used in clothing

.⋆˚.🔬★⋆⚛️ **STEAM ISA Presentation (2025) CELLUPOLYSIDE**˚⋆⋆🧪🥽⋆˚⚛️

Designed by Armance Young, Jocelyn Fong, Mila Martinez, Gemma bruce and Francesca Polley.

THE TEAM

Jocelyn Fong

Researcher and statistics

Armance Young

Team Leader and Researcher

Francesca Polley

Researcher

Gemma Bruce

Finance and Analyst

NON VERBA SED FACTA

ST CATHERINE'S SCHOOL
TWICKENHAM

Mila Martinez

Mathematics

Introduction

Textile production is one of the largest contributors to environmental pollution, with conventional materials such as cotton requiring vast amounts of water and chemicals. In contrast, biodegradable textiles made from agricultural waste provide a sustainable solution. Our idea investigates the potential of corn waste, such as husks and stalks, as a raw material for cellulose fibre production. These fibres will be coated with PLA, a biodegradable polymer derived from renewable resources, to enhance their water-resistant properties. The goal is to create a sustainable, functional textile suitable for various applications.

In response to these concerns surrounding textiles waste and synthetic fibres such as polyethylene terephthalate and polyester, we aim to develop a sustainable, biodegradable fabric using agricultural waste. Specifically, we will extract cellulose from discarded corn plants (husks and stalks) to produce eco-friendly fibres. These fibres will then be coated with poly (lactic acid) (PLA), a biodegradable polymer which can also be derived from corn, to create a waterproof layer.

The motivation behind this project is to reduce the reliance on conventional textiles like cotton, which require significant water and pesticide inputs, and instead we aim to utilise agricultural byproducts that would normally contribute to waste. By repurposing corn waste, we can create an innovative fabric which minimises environmental impact. Furthermore, this material would align with the principles of the circular economy.

Statistics

92M Tonnes

POLYESTER CLOTHES THROWN AWAY ANNUALLY

270 Kg Co_2

CARBON PRODUCED PER ANNUM BY THE FASHION INDUSTRY

93 Billion m^3

WATER IS CONSUMED EACH YEAR BY FASHION INDUSTRY

Fast fashion describes low-priced but stylish clothing that moves quickly from design to retail stores to meet and capitalise on trends. However, it is more often so than not, one of the most harmful industries to both workers and the environment. 92 million tonnes of polyester clothing is thrown away each year. 270 kg of carbon dioxide is produced, and 93 billion meters cubed of water is consumed by the fashion industry.

These figures not only show how damaging this industry is, but how much waste there is, and how much more we can do to protect our environment. This is why we came up with a solution called Cellupolyside.

OUR JOURNEY 01

CHITOSAN

Firstly, our design journey started off with the initial idea of using chitosan, a biodegradable polymer derived from chitin, as the base for our fabric. Chitosan seemed like a promising option due to its natural origin. However, upon further research we realised that it was not durable and water resistant which were both crucial elements to our design. This led to us to explore alternative biodegradable polymers, we then chose PLA and realised if we formed a solution with it we could use it to form a waterproof layer on top of a fabric.

OUR JOURNEY 02

COTTON COATED IN PLA

We then decided that we would create a film of PLA on some cotton fabric. We initially designed an experiment for this however we were unable to perform the experiment as the temperatures needed presented health and safety hazards. Overall, we were tasked to create a biodegradable and sustainable material for clothes. Therefore, our aim was to try and find a substance/source that would meet the requirements of this. We wanted to aim to find an alternative to polyethylene terephthalate polyester, which is a non-biodegradable polymer, that accounts for 53 million metric tonnes of waste worldwide.

Corn is the largest crop in the United States with 96,700,000 acres of land for its production, and also generates a significant amount of agricultural waste. To address this, we aimed to extract cellulose from corn waste and process it into eco-friendly fibers. We chose corn as our source of cellulose and PLA as once the fruit of the corn plant is harvested millions of tons of husks and stalks are cleared and thrown away. However these are abundant in cellulose with 50-60 percent being cellulose. Furthermore we can also extract PLA from the corn, ensuring every bit of it is used.

OUR MISSION

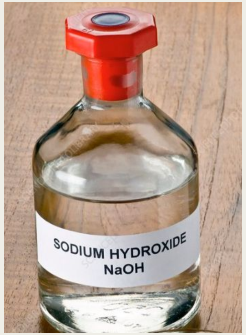
Alternative to **Polyethylene Terephthalate Polyester**
53 million metric tonnes of waste world wide
Extract **Cellulose** from **Corn Waste** and Processing it into Eco-Friendly Fibres



Our 4 Main Goals

- ➔ Extract **CELLULOSE** from **CORN WASTE**
- ➔ Process cellulose into **FIBRES** (desirable mechanical properties)
- ➔ Apply **PLA** coating to achieve **WATERPROOFING** - maintain **BIODEGRADABILITY**
- ➔ Assess **performance**, **durability**, and **cost-effectiveness** of developed fabric

CELLULOSE EXTRACTION



1. **Prepare the material:** clean dy and shred the corn waste
2. **Chemical treatment:** NaOH solution to remove lignin.
3. **Purification:** Bleach with H_2O_2 and wash to obtain pure cellulose
4. **Refining:** dry and refine the cellulose into fine fibres

Sodium Hydroxide 5% solution - NaOH is used as an alkaline treatment, this helps break down and remove the lignin and hemicellulose from the plant, leaving behind relatively pure cellulose. NaOH disrupts the ester and ether linkages in lignin, breaking them into smaller, soluble fabric. NaOH also hydrolyzes the glycosidic bonds in hemicellulose (heteropolymer) which is more amorphous and soluble compared to cellulose, aiding its removal. Cellulose preservation - NaOH only removes non-cellulose components.
5% solution used because it acts as a compromise between effective lignin/hemicellulose removal and minimising cellulose degradation.
80°C, 2 hours = To enhance the breakdown process while avoiding excessive degradation.

CELLULOSE EXTRACTION

Why we need to remove lignin: This is to remove the lignin and hemicellulose. These need to be removed as they are complex polymers which encase the cellulose in plant cell walls and structures, making it difficult to extract pure cellulose. Removing them will improve the fibre quality. Secondly, lignin is a rigid, hydrophobic polymer that can make the fibres brittle. Removing it helps achieve softer and more flexible fibres suitable for textiles. Lignin's hydrophobic nature can hinder the adhesion of PLA to the fibres. Removing it enhances surface hydrophilicity (attraction to water), ensuring better interaction between the cellulose and the PLA coating.

Hemicellulose makes up part of the plants cell wall, it is amorphous and water-soluble so it can impact the structural integrity and uniformity of the fibres therefore it needs to be removed alongside Lignin.

Hydrogen Peroxide 5% solution - We will be using H202 as an oxidising agent to bleach the cellulose by breaking down the remaining lignin residues and non-cellulosic impurities. Oxidative bleaching, H202 decomposes into water and oxygen radicals which oxidise chromophores in lignin, making the fibres appear white. The 5% solution is used as it provides effective bleaching without causing fibre weakening.

FIBRE FORMATION

1. **Open end spinning:** The now purified cellulose is subjected to open-end spinning to produce continuous fibres.
2. **Dried and stretched:** The fibres should then be stretched and dried to enhance their mechanical properties.

Mechanical refining is the process in which we will produce the cellulose fibres from the corn waste. Mechanical refining helps to improve the properties of the cellulose fibres. The extracted fibres can become coarse and irregular in size. Mechanical refining helps break them down into finer and more consistent fibres. Enhances quality of fibre. This also increases the surface area of the cellulose fibres, which improves their ability to bond with PLA. Improves their tensile strength and flexibility.
Mechanical refining also does not use any additional chemicals, making it more sustainable than other chemical refining methods.
Fibres are fed into a spinning rotor to form yarn without twisting them in the traditional sense.

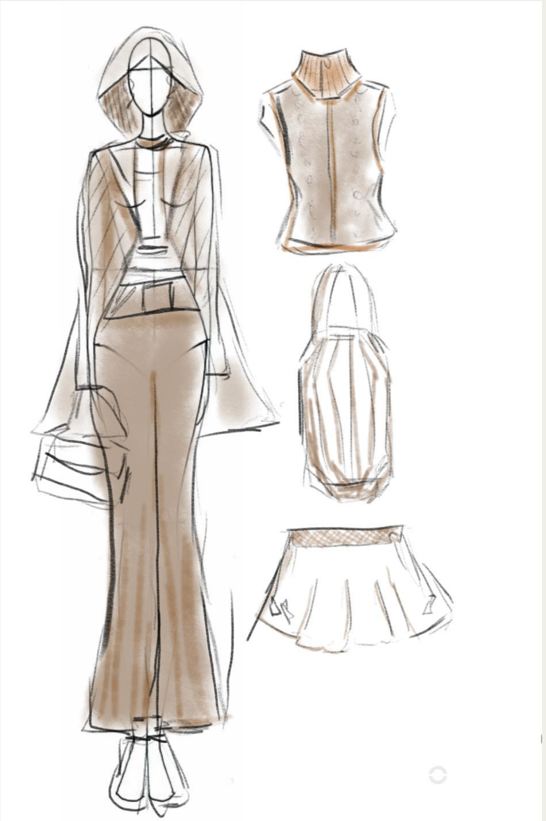
Chloroform is used as PLA does not dissolve in water but dissolves readily in organic solvents such as chloroform. It is also used as it provides a stable, uniform solution of PLA without degradation. The solution concentration is typically 5-10%(w/v) to ensure even coating without excessive thickness. 5-10%is used as too high of a conc can lead to thin castings with poor waterproofing performance, whether a high concentration can lead to thick brittle layers that may crack and reduce fabric flexibility.

PLA COATING

1. **Solution:** The poly(lactic)acid firstly needs to be dissolved in Chloroform to form a solution.
2. **Coating:** The Fibres should then be coated in the PLA solution and removed slowly to ensure uniform coating.
3. **Curing:** Then cure the fibres at 60°C for 4 hours to allow the solvent to evaporate and the polymer to solidify.

Poly(lactic) acid is a biodegradable polymer which we will coat the fabrics with as it will form a biodegradable, hydrophobic layer on the fibres. PLA is derived from corn starch. It is hydrophobic and provides an effective barrier against moisture without using synthetic, non-biodegradable coatings. It also adheres well to cellulose when properly coated. Poly (lactic) acid from a waterproof coating due to its hydrophobic properties and its ability to create an impermeable barrier when applied to fibres. PLA forms a waterproof coat because PLA molecules structure contains ester functional groups, which are generally hydrophobic.

Coated using dip-coating. Solution adheres to fabric through capillary action. To ensure that the coat is even we will time the speed of immersion, (if it is too fast it can trap air bubbles.) Dwell time (soaking phase), fabric is held in a solution for a set period allowing PLA molecules to interact with fibre surface.



ILLUSTRATION

Here is an illustration of our fabric in use. In this image, we can showcase the fabric being utilised as dyed material, showcasing its ability to absorb and retain colours. The corn-based textiles demonstrated excellent ability to retain dyes, making it suitable for application in fashion and design.

PERFORMANCE TESTING

Waterproof Properties + Biodegradability

Over the next few slides, we’ll be talking about our product's qualities such as biodegradability as well as its waterproof limit. It is extremely important for our product to be biodegradable as it ensures that it’s an efficient product that aligns with our 4 main goals. The waterproof trait is important due to the same reasons.

HOW TO TEST ITS WATER PROOF PROPERTIES

Mass of water coming off: To test that our product is water repellent we could measure the volume of mass coming from it.

HYPOTHETICAL RESULTS

10% PLA concentration this much mass of water came off the cotton sample.

HOW TO TEST ITS BIODEGRADABILITY

1. **Soaking In Water:** Leave fabric sample in separate trays of water (should be at room temperature). Record initial mass of the fabric sample.

2. **Recording Mass Difference:** In 5 day intervals, record how much of the cotton has degraded by measuring the difference in mass.

HYPOTHETICAL RESULTS

After 5 days the mass of the fabric had gone down by 2 grams - shows its degrading in the water.

EVALUATION

Our project successfully demonstrates a biodegradable, waterproof fabric from corn waste and poly(lactic)acid. The developed material presents a sustainable alternative to traditional fabrics, with potential applications in fashion. In the future we will aim to focus on optimising the fibre production process and exploring alternative biodegradable coatings to further improve flexibility and cost-effectiveness.

Limitations:

Although one of the key limitations in this project is the inability to conduct the experiment within school grounds we strongly believe that if we had the correct equipment we would be able to create this fabric. Certain stages of the process, such as the mechanical refinement and open-end spinning are not achievable in a school setting. Furthermore, some of the high temperatures needed are not feasible in a school environment and could provide potential health and safety limitations.These limitations mean that some aspects of the project, such as large-scale production and long-term environmental testing, cannot be fully explored at this stage and would require further investigation in a more equipped setting.

Expected Outcome:

Overall, this material is a biodegradable, sustainable, and eco-friendly fabric that reduces waste by using all aspects of the corn, and has an innovative and new approach to fashion textiles. By solving UN Sustainable Development goals 12 (Responsible Consumption and Production), and 13 (Climate Action), this material aims to create a greener future too.

CONCLUSION

Therefore, our project aims to create a biodegradable, environmentally friendly and sustainable fabric which aligns with the UN sustainability goals and the belief of a circular economy. This is because the use of agricultural waste lowers raw material costs and reduces landfill contributions.

Thank you!