Hong Kong Student Science Project Competition 2022

Extended Abstract (Investigation)

Team Number: SBBC092
Project Title: Water on Wax
Project Type: Investigation
To our best knowledge and after thorough literature research, as at 30/09/2021 , there are similar works.

https://www.researchgate.net/publication/263811437_Developing_Hydrophobic_Paper_as_a_Packaging_Material_Using_Epicuticular_Wax_A_Sustainable_Approach

The enhancement our project has made for the existing related products or research is summarized as below:

Instead of investigating the feasibility of extracted wax from plant leaves and coat on paper, the enhanced focus of this project is

1. to extract wax from **agricultural plants** rather than non-agricultural ones to better utilize agricultural wastes;
2. to evaluate use of **various less hazardous solvents** rather than using toxic methanol and benzene
3. to find out the **optimal conditions** to extract wax;
4. to coat the wax on **existing daily-life materials** *(e.g. kraft paper, cloths)* instead of laboratory filter papers;
5. to evaluate the **limitations** of the coated papers; and
6. to offer an **effective method to purify the wax** extracted

I. Background

- Leaves of many agricultural plants are usually discarded after harvesting and they often become agricultural waste. For example, one hectare of banana trees produces about 220 tons of waste, including the leaves, per year. However, these leaves often exhibit good hydrophobicity, for example lotus leaves.
- It has been shown by the above research that epicuticular wax of non-agricultural plants *Calotropis procera* and *Alstonia scholaris* can be extracted by using ethanol and benzene
- With the basis of the mentioned research, this project further evaluated different aspects of leaf wax extraction, for examples different types of agricultural leaves, different solvents of distinctively different polarities, optimal extraction conditions, properties and limitations of papers coated with leaf wax, and simple method to purify the wax extracted

II. Objectives

- To compare the **effectiveness of extraction of epicuticular wax** from leaves of **agricultural plants** *(e.g. lotus leaves, taro leaves and banana leaves)* by using hexane, chloroform and ethanol.
- To find out the **optimal conditions** *(e.g. types of solvents, immersion time, temperature)* for wax extraction
- To **coat the wax on different daily-life materials** *(e.g. kraft papers, cloths)*
- To evaluate the **hydrophobicity, heat-sensitivity, pH-sensitivity, biodegradability** of coated papers
- To understand the limitations of the coated paper
- To evaluate the **use of activated charcoal to purify the extracted leaf wax**

III. Hypothesis

- Phenomenon: Water retains as spherical droplets on both upper and lower surfaces of lotus leaves, taro leaves and banana leaves. However, it is known that the micro-structures mainly present on the upper surface of the leaves only. Therefore, it is expected that the **epicuticular wax on both surfaces plays a significant role** in providing hydrophobicity to the leaves but **not just the micro-structures.**
  Experiment to test the hypothesis: Epicuticular wax were extracted from the leaves and the retention of hydrophobicity of the leaf surface was studied. The wax extracted was also coated on kraft papers to further test for its hydrophobicity.

- Phenomenon: Steamed lotus and banana leaves used for cooking retain their hydrophobicity as water is often seen to form droplets on the surface. It is expected that the **epicuticular wax can withstand high temperature**, at least up to 100°C.
  Experiment to test the hypothesis: Epicuticular wax were extracted from the leaves and the retention of hydrophobicity of the leaf surface was studied

- Phenomenon: **Activated charcoal** can be used to adsorb odour, filter water, and remove acid-alkali indicator from salt solution after titration. It is expected to be able to **purify crude wax extract** by **removing** the green pigment **chlorophyll**.
  Experiment to test the hypothesis: Mix activated charcoal with the wax extract solution and then note any changes in light absorbance by using a colorimeter.

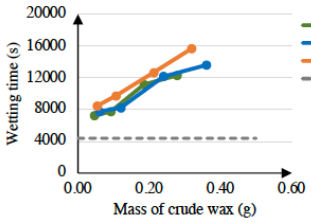
IV. Methodology

- Materials used: Lotus, taro and banana leaves, ethanol (95%), hexane, chloroform, kraft papers, commercial plastic-coated papers, activated charcoal, soil from potted plants
- Study of hydrophobicity: Measure the contact angles and wetting time after adding a water droplet on both coated and uncoated paper. The larger the contact angles and wetting time, the higher the hydrophobicity of a surface
- Study of thermal sensitivity: Treat both coated and uncoated papers to different temperatures and compare their wetting time
- Study of biodegradability of coated paper: Bury coated paper, uncoated paper and commercial plastic-coated paper of the same type into soil bed. The daily changes in areas of the papers were recorded. This is to simulate the decomposition of papers in landfill.
- Study of efficiency of chlorophyll removal by activated charcoal: Compare the light absorbance of wax extract with and without treating with activated charcoal by using colorimeter. The higher the green chlorophyll content, the higher the absorbance of light. By Beer-Lambert law, the concentration of chlorophyll is directly proportional to its absorbance of light
- Each experiment was repeated at least twice

V. Results

- Study of hydrophobicity

(a)



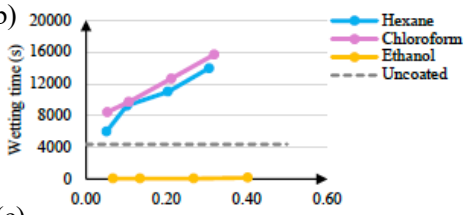
(a) Wetting time against mass of different leaf wax using chloroform

(b) Wetting time against mass of lotus leaf wax with different solvents

Lotus leaf wax extracted by chloroform gave the longest wetting time of the coated paper.

- Study of biodegradability of coated paper:

(b)

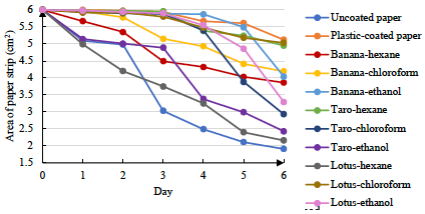


(c) Daily changes of area of paper strips in soil

Paper coated with leaf wax decomposed at a faster rate than commercial plastic-coated paper

- Study of thermal sensitivity:

(c)

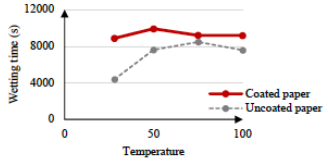


(d) Wetting time of papers coated with lotus leaf extract using chloroform

The coated papers are heat-resistant without decreasing in wetting time.

- Study of efficiency of chlorophyll removal by activated charcoal:

(d)



(e) Activated charcoal effectively reduced the chlorophyll concentration (from 43% to 59%) with a recovery rate of wax ranging from 45.5% to 85.7%

- Limitations: The coating of leaf wax on the papers were not sufficiently uniform.
- Potential applications: Chloroform and hexane are effective solvents to extract leaf wax (especially lotus leaf) and can be used to prepare bio-degradable hydrophobic papers to replace plastic-coated papers. This offers a renewable and sustainable alternative which can reduce the use of plastic on paper packaging and the consequent environmental pollution. Activated charcoal can be used to enhance the percentage purity of wax.

(e)

Types of leaf wax	Percentage decrease in chlorophyll content (%)
Banana	59
Taro	53
Lotus	43

VI. Conclusion

- Agricultural plant leaves, which are usually thrown away, can be utilized to prepare hydrophobic papers
- Optimal time for solvent extraction of 40mL solvent through soaking is between 20 to 30 minutes.
- The papers coated with leaf wax decomposed at a faster rate than plastic-coated ones, and they can withstand a high temperature (up to 100°C).
- For the kraft paper coated with about 0.1 g/cm^2 of lotus leaf wax extracted by chloroform, the wetting time increased by 256% comparing with an uncoated kraft paper. Thus, chloroform and lotus leaf are the most preferrable combination for wax extraction in this project.
- With a 2:1 mass ratio of activated charcoal to wax and 2-minute mixing time, up to 59% decrease in chlorophyll content was resulted while maintaining the ability to enhance hydrophobicity of kraft papers by 93%. Thus, activated charcoal is an effective way to purify the wax.
- Future work includes finding a better coating method and the optimal mass ratio of activated charcoal to wax for purification