Regeneron International Science and Engineering Fair (ISEF) 2021
Project Topic: A New Concept of Packaging-Solving the Problem of Excessive Plastic

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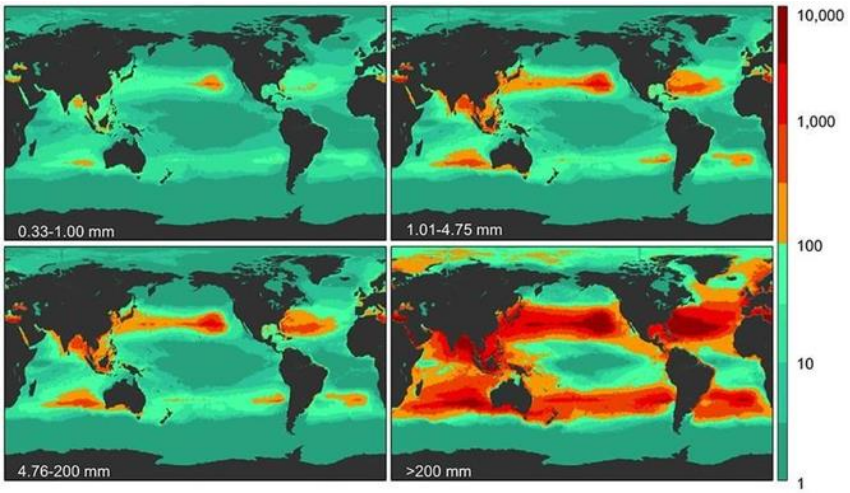
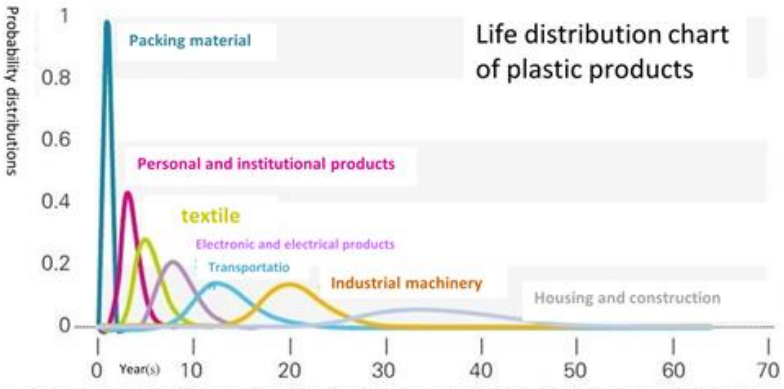
I. Introduction

With the change of the times, people's use of plastics has increased, coupled with the increase in the amount of plastic packaging bags under the influence of the epidemic, and the amount of solid waste in Macau has increased from 522,548 tons to 550,249 tons in just one year from 2018 to 2019. , An increase of 5.3%, the situation is not optimistic.

Since plastics are not degradable, and waste plastics will be treated in the form of incineration, the burning of plastics will release highly toxic gases, which will be transformed into humans and the earth's ecosystem, which will cause extremely serious environmental pollution problems. In order to solve this global problem, we thought of using sweet potato and tapioca starch to make natural flakes to develop different uses, such as natural toilet paper, toothpaste paper and granule packaging bags.





Source Roland Geyer et al. Production, use, and fate of all plastics ever made. *Science Advances*, July 2017 DOI: 10.1126/sciadv.1700782

II. Objective(s)

We found a natural soluble edible material (NSE material) --sweet potato starch. We decided to improve this NSE material into an environmentally friendly packaging that can replace plastic packaging. The uses include food packaging, tea bags, and coffee bags, Takeaway packaging bags, etc.

III. Methodology

combination/ element	Sweet potato starch	Potato starch	corn starch	water
B1	1	/	/	1
B2	/	1	/	1
B3	/	/	1	1
B4	/	1	1	2

For the experiment device, why we choose to use sweet potatoes? First, we tested different methods and raw materials, like the corn starch, purple sweet potato starch, and potato starch, in order to find the most suitable scale for making our NSE material. And finally, we found that the ratio of 1:1 of sweet potato starch and water is the best formula. In addition, we also used to steam and bake to make it, and finally found that steaming is the most suitable method because the NSE piece are both soluble in water and flexible.

IV. Solution and production method

1. Cut the recovered germinated sweet potatoes into small pieces, and grind them into powder in a flour mixer

2. Steam the sweet potato starch and water at a ratio of 1:1 to make a natural edible soluble material (sheet, paper)

3. Cut it into a suitable size to make natural toilet paper, toothpaste paper, and packaging bags

✧ Natural soluble toilet paper

1. Spread olive oil on it first, then spread the hand sanitizer evenly on it with a brush, and then let it air dry.

✧ Natural soluble toothpaste paper

1. Apply toothpaste on it and let it air dry.

✧ Natural edible dissolving packaging bag

1. Steam a small amount of sweet potato starch and a small amount of water at a ratio of 1:1 to half-cooked and a sticky shape

2. Spread the natural adhesive around the two pieces of materials and attach them up and down to make a packaging bag.

V. Summary of the questionnaire survey

In our online survey, we found that the majority of respondents thought plastic overuse was a serious problem, while others thought plastic takeaway cutlery bags were wasteful, but a small minority thought it was a storm in a teacup. As for the view of soluble and edible materials, although 93% people think that it is harmless and natural to the ecological environment, the remaining 7% people put forward different opinions respectively. There are also interviewees that in 3 seconds can be dissolved under the premise of the question of bearing capacity. It can be seen that our interpretation of this material in the questionnaire is still missing. It should be indicated that toxicity tests, bacterial tests, and dissolution temperature tests have been carried out. We will pay more attention to the publicity in the future.

According to the data, our natural materials are well received and accepted by the public, and it is easier to promote. Moreover, the problem of plastic intimidation exists in all regions of the world, so if it is promoted, it will completely replace plastic packaging bags on the market.

VI. The experiments

1. Test the practical feasibility of natural soluble toilet paper and toothpaste paper

✧ **Experiment A : Use the natural soluble toilet paper made of sweet potato starch and water at a ratio of 1:1 for skin test**

Experimental results:

1. The skin has the highest level of moisture and will not cause dry skin.
2. The pH value of the unfiltered solution is slightly acidic, and the pH value is closest to 6, which meets the national emission standards (pH6-9).
3. After two filtrations, the pH value of the solution is close to 7, which is similar to the pH value of deionized water, and will not pollute the tap water.
4. Its pH value is closest to 5.5, which is the closest to the pH value of human skin.

✧ **Experiment B: The cleanliness test of natural soluble toilet paper and toothpaste paper made with sweet potato starch and water at a ratio of 1:1**

Experimental results:

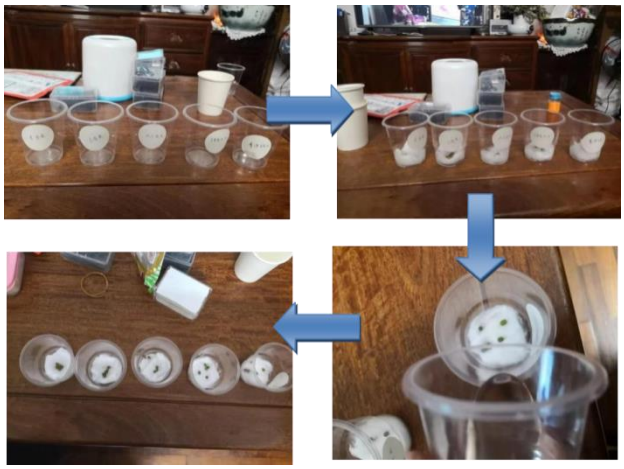
1. The number of colonies before and after cleaning with natural soluble toilet paper and toothpaste paper is significantly reduced
2. Compared with natural soluble toilet paper, the number of colonies before and after cleaning with no-wash disinfectant and wet paper towels does not change much.

Conclusion:

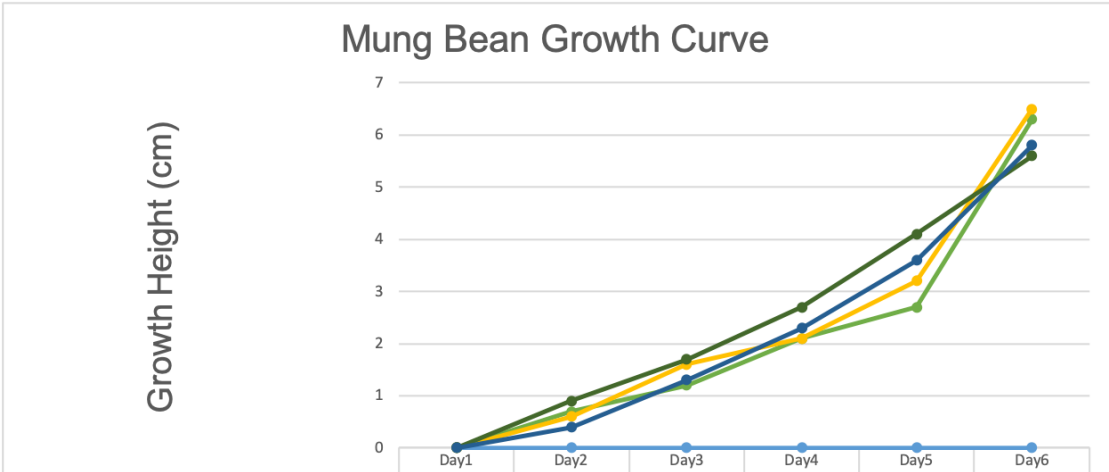
It can be concluded that the cleaning ability of natural soluble toilet paper and toothpaste paper is stronger than that of ordinary disposable disinfectant and wet wipes

2. Test the effect of natural edible soluble material solution on plant growth

✧ **Experiment: We used tap water and hand sanitizer water for comparison, and poured them into planting cups (as shown below)**



• Record the growth of mung beans



	Day1	Day2	Day3	Day4	Day5	Day6
Tap Water	0	0.7	1.2	2.1	2.7	6.3
Hand Soap	0	0	0	0	0	0
Natural Soluble Paper Solution	0	0.6	1.6	2.1	3.2	6.5
Unfilered Natural Soluble Hand Paper Solution	0	0.9	1.7	2.7	4.1	5.6
Filtered Natural Soluble Hand Paper Solution	0	0.4	1.3	2.3	3.6	5.8

Experimental results:

• The growth rate of mung beans under the unfiltered natural soluble paper towel solution is the same as that under running water

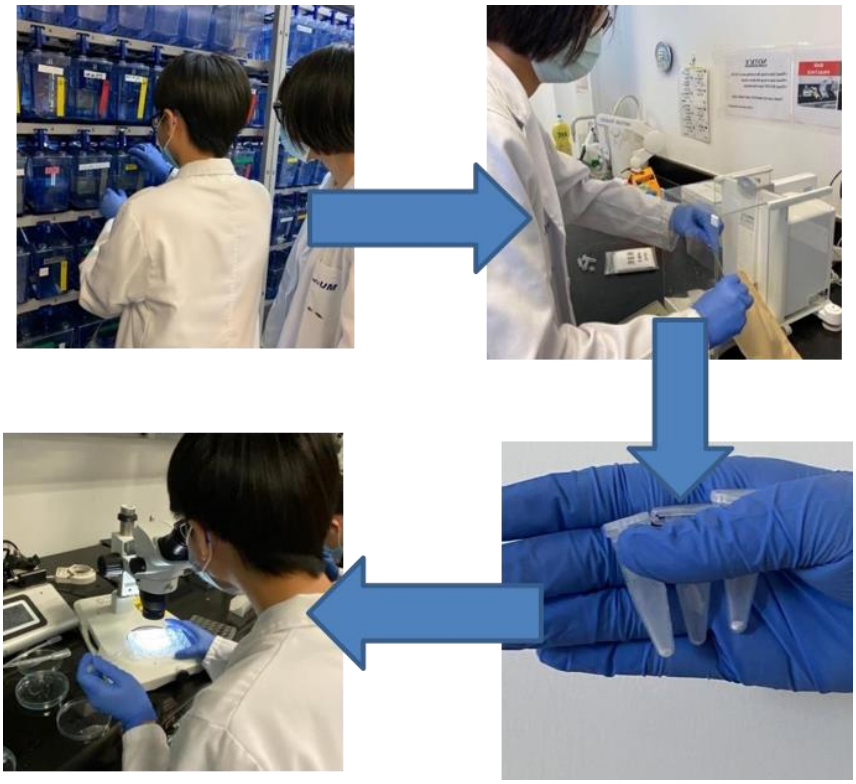
Conclusion:

It can conclude that the natural soluble material solution will not negatively affect the growth of plants base on the experimental results.

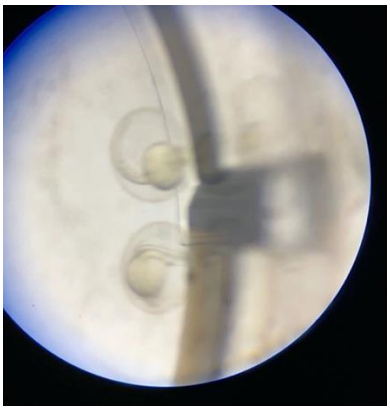
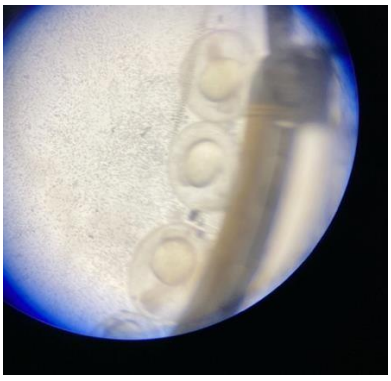
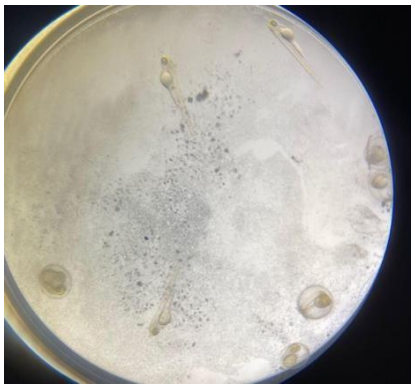
3. Test the effect of natural edible soluble material solution on animal growth

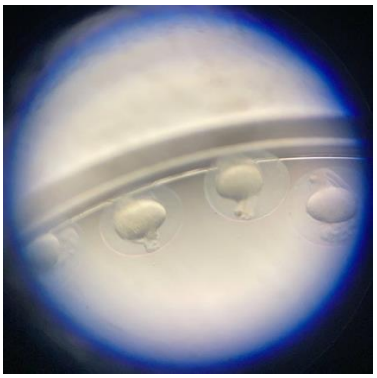
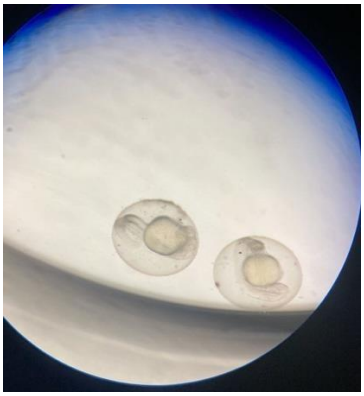
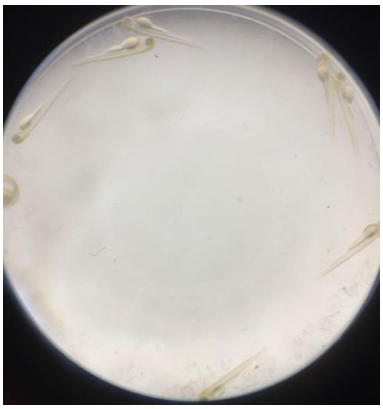
✧ **Experiment: We used three different concentrations of natural edible soluble material solutions to compare with ddH_2O, sweet potato powder solution, and tapioca powder solution.**

• Go to the fish house to collect zebrafish eggs, put every ten eggs in a well, and then add 900μL of medicine to each vertical row (3 wells)



• Dispensing: Combine ddH_2O, sweet potato powder solution, tapioca powder solution, natural edible soluble material solution 1 [concentration of $5x10^5$ mg/L], natural edible soluble material solution 2 [concentration of $2.5x10^5$ mg/L], natural edible soluble material solution Dissolved material solution 3 [concentration of $1.25x10^5$ mg/L] every 300μL is added to the dispensing vessel with a pipette and stirred.

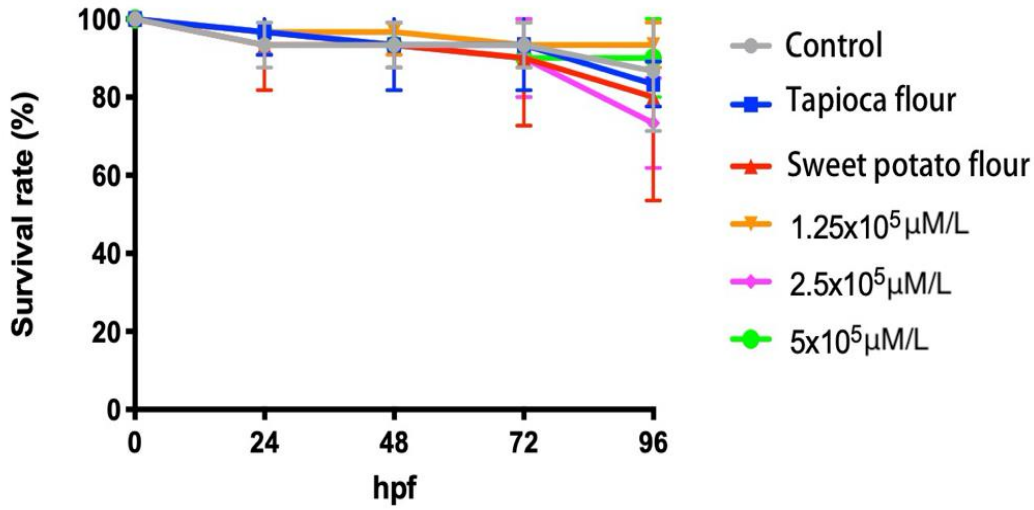
Drug name	Photos after 24 hours	Photos after 72 hours
Contrast		
Tapioca powder solution		
Sweet potato powder solution		

Solution 1		
Solution 2		
Solution 3		

Experimental results:

• The survival rate of zebrafish in natural edible soluble material solutions with concentrations of $5x10^5$ mg/L and $1.25x10^5$ mg/L is as high as 90%, which is even higher than that in water.

Drug name	Average 24-hour survival rate	Average 48-hour survival rate	Average 72-hour survival rate	Average 96-hour survival rate
Contrast	93.3%	93.3%	93.3%	83.3%
Tapioca powder solution	96.7%	93.3%	93.3%	83.3%
Sweet potato powder solution	93.3%	93.3%	90%	80%
$5x10^5$μM/L	96.7%	96.7%	93.3%	93.3%
$2.5x10^5$μM/L	96.7%	93.3%	90%	73.3%
$1.25x10^5$μM/L	96.7%	93.3%	90%	90%



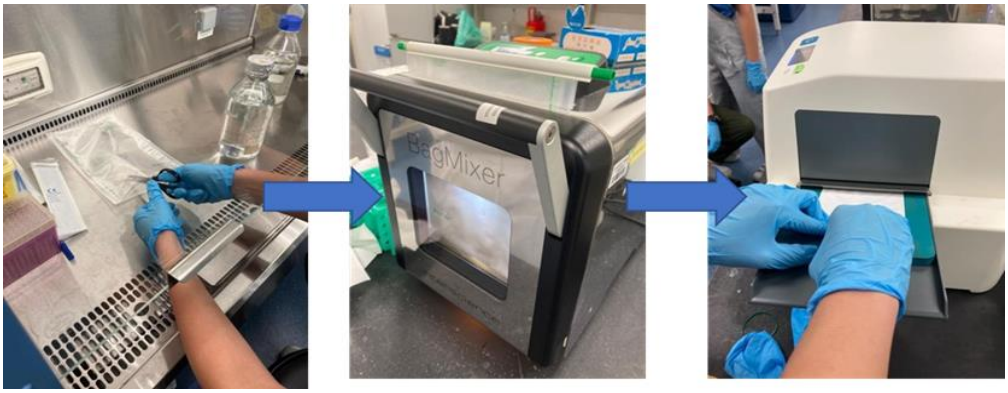
Conclusion:

Based on the above experimental results, It can be seen that our natural edible soluble materials are not toxic, also we can assume that if natural edible soluble materials flow into the sea through a pipe in the home, it will not pollute the water quality and organisms of the sea.

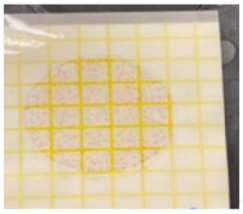
4. Detect the bacterial content in natural decomposable samples

- ✧ **Experiment A: Use a quantitative plate (5 grams of natural edible soluble material sample-100 mL of solution + 120 ml of protein syrup).**
- ✧ **Experiment B. Drop samples of natural edible soluble materials into 3M Petrifilm Coliform Count Plate**
- ✧ **Experiment C. Drop a sample of natural edible soluble material into the rapid bacterial test piece**

Steps:



Experimental results:

Type	Photo	Result
Container		24MPN/100g
E.coli Petrifilm Detection		It does not contain E. coli (Contain E.coli: purple [color changes])
Petrifilm Coliform Count Plate		1.6×10^4CFU/mL

Conclusion:

According to the classification defined by AOAC and FDA, the Escherichia coli group is classified, Lang's negative and will produce acid and gas under the action of lactose. Under the influence of acid, the pH indicator in Petrifilm EC will make the culture, and the medium will appear dark red. Therefore, a red colony surrounded by bubbles is identified as an E. coli colony. It can be seen from the picture that our quick-check film has not changed color, so it can be confirmed that it does not contain E. coli.

5. Experimental procedures for verifying natural adhesives and natural edible soluble packaging bags

✧ **Experiment: Two pieces of natural soluble material flakes were glued together with a natural adhesive and left to stand for 2 hours.**

Experimental results:

• The medicine bag is also not separated, which proves that the adhesive is stable and practical.

Conclusion:

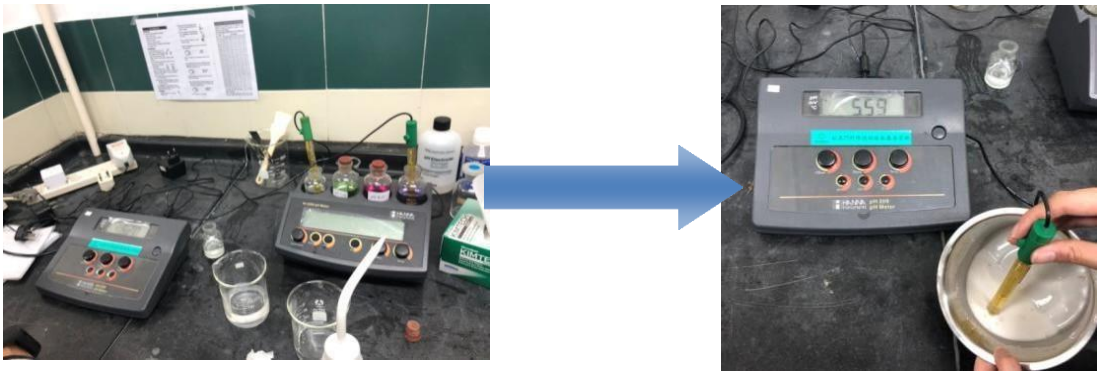
The medicine bag has not been worn or broken due to the number of pills, and it is still intact.

6. Test the pH value of natural soluble edible materials

In order to avoid the possibility of changing the pH of the water after the natural soluble edible materials are dissolved in the water, so that if excessive natural soluble edible materials are poured into the ocean, they will affect the habitat, so their pH should be tested

✧ **Experiment: testing the pH value of washing paper**

1. Calibrate the pH meter first
2. Put the probe of the pH meter in the mixed solution before steaming and wait for the pH value to stabilize before recording.



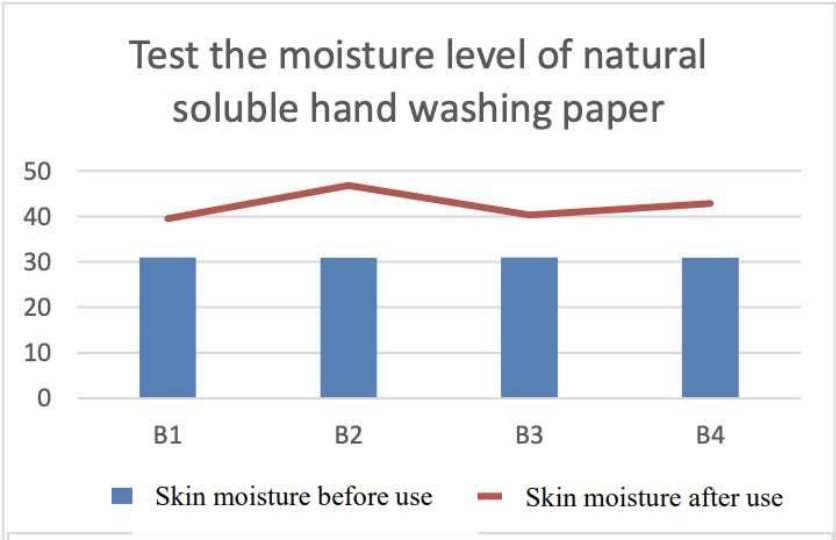
Experimental results:

1. Since the natural edible soluble materials made by the baking method are not soluble in water, we will not use the measured pH value of the solution used in the baking method.
2. After testing the measured pH value of the solution used in the steaming method, we found that the pH value of the solution was slightly alkaline, and it was made by

using sweet potato starch and water at a ratio of 1:1 The pH value of the solution is closest to 6, which meets the national emission standards (pH6-9).

Conclusion:

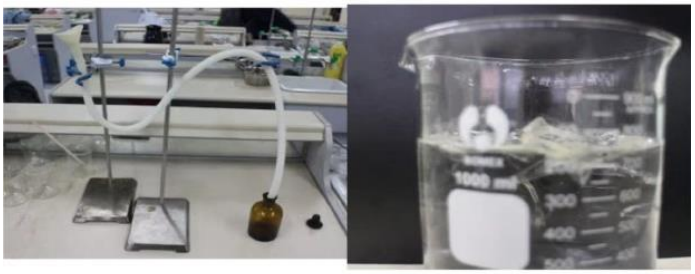
Based on the experimental results, the pH value of natural edible soluble materials match the national emission standards on human skins and disposed, so natural edible soluble handwashing paper and toothpaste paper are able to be used, also natural edible soluble products are able to be disposed.



B1: Cassava powder: water =1:1
B2: Sweet potato powder: water =1:1
B3: Corn starch: water =1:1
B4: Cassava powder :Corn starch: water =1:1:2

7. Simulate the actual situation of disposal of natural soluble materials after use

✧ **Experiment: Simulate the actual situation of the natural edible soluble products after they are thrown into the channel (the diameter of the pipe used in this experiment is 1 cm, which is thinner than the standard pipe diameter)**



Experimental results:

1. Natural edible soluble materials can successfully flow down to the other end of the water pipe completely and smoothly with the push of pipes and water
2. In addition, our natural materials become elastic and soft due to contact with water, which is more conducive to the flow in the pipeline

Conclusion:

Based on the experimental results, the natural edible soluble materials disposed by the water pipe successfully and smoothly with the room temperature water, which means that natural edible soluble products are able to dispose by the water pipe.

8. Comparative test of dissolving natural edible soluble materials at different water temperatures

✧ **Experiment A: Dissolve naturally in tap water at 20°C**

Experimental results:

• We found that it was completely soluble in water after 144 hours. Because water at 20°C is normal temperature water, it means that natural soluble edible materials are very easy to dissolve.

✧ **Experiment B: Continuous heating in 100°C tap water**

Experimental results:

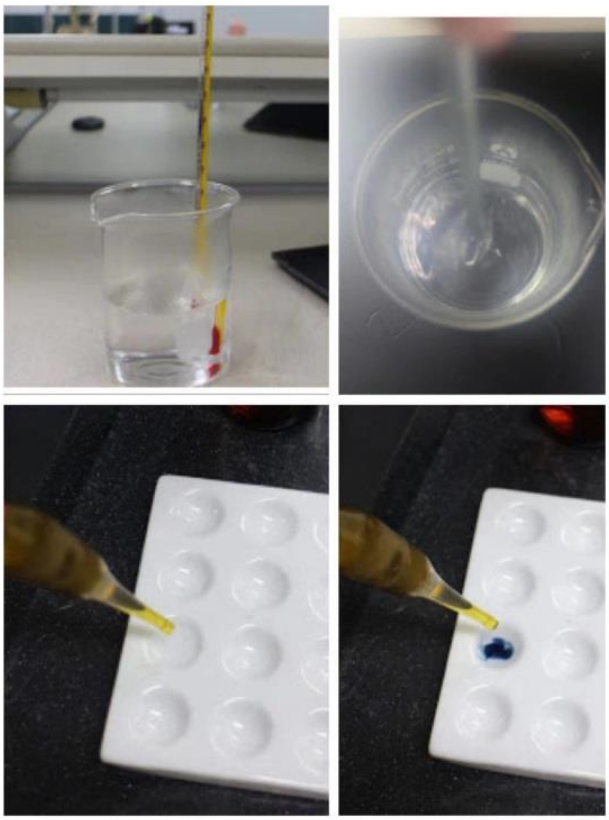
- The different amounts are completely dissolved after 8 minutes and 13 minutes respectively, which is more ideal than we expected.

Conclusion:

Based on the experimental results, the natural edible soluble materials can dissolve in room temperature water in 144 hours, and 5g of natural edible soluble materials can dissolve 750mL and 900mL water in 13 minutes and 8 minutes.

9. Measure the starch content of natural soluble edible materials

✧ **Experiment: Drop iodine solution into a sample of natural edible soluble materials and observe**



Experimental results and conclusion:

- The iodine solution changes from brown to blue-black, so we can be sure that the solution contains starch.

VII. Conclusion and application

- Because zebrafish can successfully survive in the natural edible soluble material solution, even if the natural edible soluble material solution is thrown into the sea, it will not pose a threat to the ocean
- Since natural edible soluble materials are not toxic, they will not cause adverse effects on the human body even if they are eaten
- Experiments have proved that the natural edible soluble material solution will not threaten the growth of plants, so even if it is thrown into the ground, it will not affect the plants
- Summarizing the above content, we have verified and tested that our natural

edible soluble materials are non-toxic through rigorous and safe experiments. It can be seen that our materials can be quickly dissolved and can be derived for many different purposes. In addition to benefiting In addition to bringing convenience to human society, it is believed that if it is widely used, it can also effectively solve the current global environmental pollution problem of "plastic flooding".

VIII. Compare with similar works

✧ Grace Biochemical Technology:

Research and development of biodegradable and compostable plastic pellets made of corn starch, and biodegradable packaging bags made of corn starch, which disappear after two or three months of being buried in the soil and are decomposed into carbon dioxide and water by microorganisms.

✧ Huazhilu Biomaterials Co., Ltd.:

Starch-based biodegradable plastic is an environmentally friendly plastic product made by blending starch (corn starch + tapioca starch), a natural polymer material from renewable resources, as the base material with other polymer materials.

The materials or finished products have passed the three-month composting test. During the biological reaction process, the plastic can be degraded within 120 days.

Disintegrate and disintegrate, and finally completely decompose into carbon dioxide, water and other small organic particles.

✧ The "new packaging concept" we made:

It is also made of sweet potato starch in starch, but it can be directly dissolved in boiling water, and it can disappear in water in only 3 seconds. Comparing the above two projects, the time we need to disassemble the packaging bag is much shorter and the cost is very cheap.

IX. Acknowledgements

For the acknowledgement, first, we want to thank our school principal—MS. LAN-FLENG LOU, MONICA and MR. WAI KEI TAM to give the opportunity to participate in ISEF and win the glory for our school and Macau. Second, we are very grateful for getting help from Professor SIMON, MING-YUEN LEE from State Key Laboratory of

Quality Research in Chinese Medicine of University of Macau and Professor SENG FAT WONG from The Macau lnstitution of Engineers. Also, we want to thank our supervisors—MS. KA MAN WONG and MR. YAN LONG LIN for giving us such many suggestions and recommendations to solve our problem which we met during the whole research. Finally, we want to thank our parents for giving us a lot of support and encouragement during the invention.

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