2020 年臺灣國際科學展覽會
優勝作品專輯

作品編號　200013

參展科別　環境工程

作品名稱　Synthesis of Biodegradable Plastic From Food Waste

得獎獎項　大會獎：四等獎

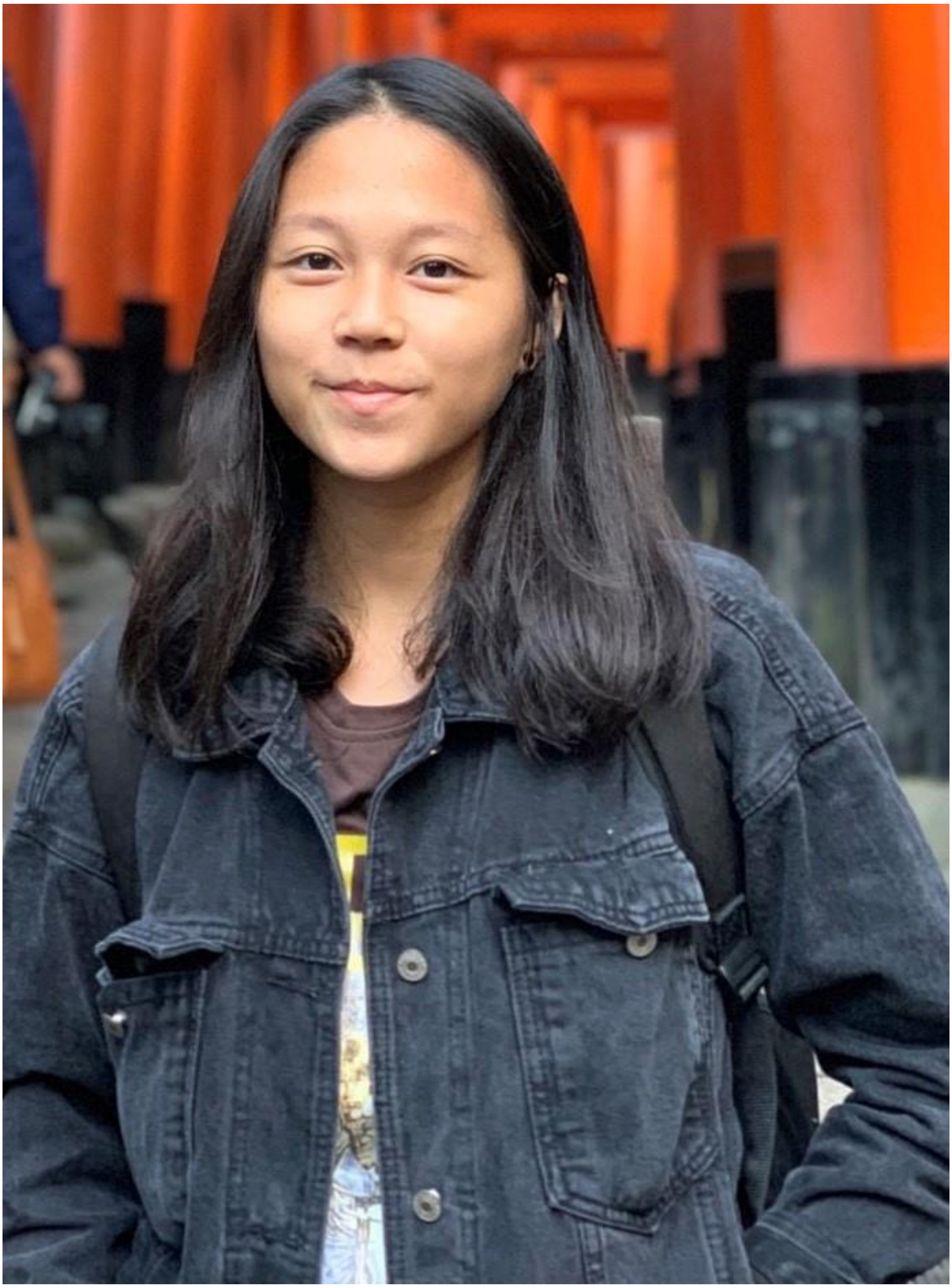
國　　家　Singapore

就讀學校　Anglican High School 圣公会中学

作者姓名　Gan Shu Ying

關鍵詞　Biodegradable plastic, recycling food waste

作者照片



Abstract

(a) Background and Purpose of the research area

Based on NEA Waste Statistics and Overall Recycling Rate for 2017, 809,800 tonnes of food waste and 815,200 tonnes of plastic waste was generated. Both food waste and plastic waste account for more than 10% of the total waste generated in Singapore in 2017 respectively. However only 16% of the food waste and 6% of plastic waste was recycled, the rest of it was disposed at the incineration plants and then the landfill. Such action will eventually lead to 2 major environmental issues that Singapore will face in near future:

1) Semakau landfill is our only landfill left and it is expected to run out of space in near future
2) The burning of food waste results in the release of methane (CH_4), a greenhouse gas that has over 25 times the impact in trapping excess heat in the atmosphere as compared to Carbon Dioxide (CO_2). This will increase carbon footprint and contribute to greenhouse effect and global warming in due course.

According to the Sustainable Singapore Blueprint 2015, Singapore is working towards becoming a Zero Waste Nation by reducing our consumption, reusing and recycling all materials. A national recycling rate target of 70% has been set for 2030 with an aim to increase domestic recycling rate from 20% in 2013 to 30% by 2030 and non-domestic recycling rate from 77% in 2013 to 81% by 2030.

As part of our total commitment towards waste management and sustainability effort, the purpose of doing this research project is to investigate whether food waste can be recycled and made into biodegradable plastics. First of all, chitosan will be derived from shrimp shells and be dissolved in acetic acid and lactic acid produced by probiotic fermentation of fruit and/ or vegetable waste for synthesis of biodegradable plastics.

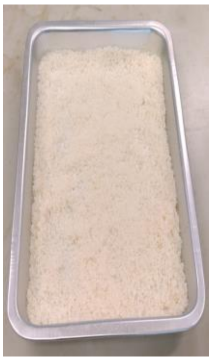
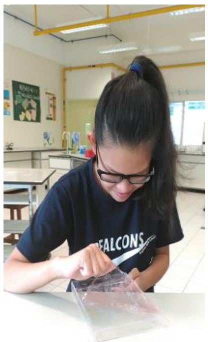
(b) Hypothesis of the research

Food waste is commonly found everywhere in Singapore. By implementing Probiotic Fermentation, a new food waste recycling process that is used to recycle biodegradable food waste by homemade probiotic (lactobacillus) solution. Food waste such as fruit and vegetable

waste can be converted into acetic acid and lactic acid which can be used to dissolve chitosan derived by shrimp shells to make biodegradable plastics.

(c) Experimental Methods and Results

Planning Schedule

Phase I: Making of probiotic solution (Lactobacillus)	**Phase II:** Carry out probiotic fermentation of fruit and vegetable waste	**Phase III:** Collection of solvent from the barrel	**Phase IV:** Extraction of chitosan from shrimp shells	**Phase V:** Making of biodegradable plastics and carry out quality control tests
				

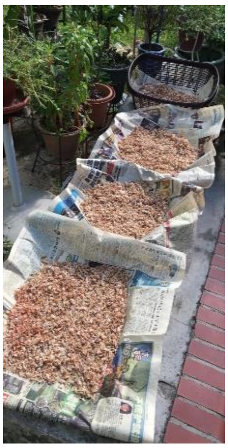
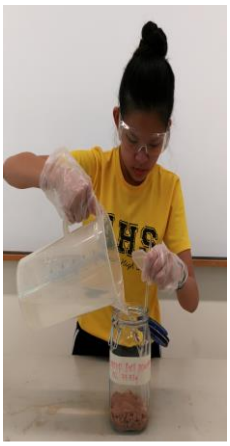
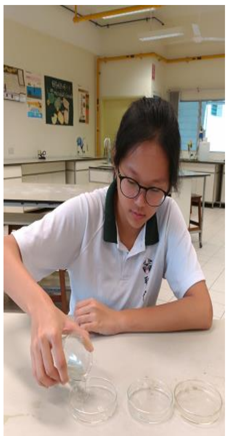
Phase I: Making of probiotic solution (Lactobacillus)

Step I: Place 100ml of rice water in a dark, cool environment for 1 week.	**Step II:** After 1 week, Strain the liquid in the jar and add milk in a ratio of 1 part rice water to 10 parts milk.	**Step III:** After another 1 week, separate the curd settlement from the mixture leaving behind the probiotic solution (whey).	**Step IV:** Add molasses or sugar to the probiotic solution left behind to keep the lactobacillus alive and refrigerate.
			

Phase II to III: Probiotic Fermentation of fruit and vegetable waste

Step I: Place a layer of shredded newspaper into the barrel	**Step II:** Pour in Probiotic (Lactobacillus) solution	**Step III:** Tear the food waste into smaller pieces and place them into the barrel over the shredded newspaper.	**Step IV:** Pour in the probiotic solution onto the layer of food waste and repeat Step I to IV till the barrel is full to ferment for 31 weeks
			

Phase IV to V: Extraction of shrimp shells and making of biodegradable plastic

Step I: Collect and dry shrimp shells	**Step II:** Deproteination – add 1M sodium hydroxide to shrimp shells powder in 1:10 for 72h	**Step III:** Demineralisation – add 1M hydrochloric acid to deproteinised shrimp shell powder in 1: 10 for 24h	**Step IV:** Deacetylation – add 40% sodium hydroxide for 2h at 100°C to convert chitin to chitosan	**Step V:** Dissolution & molding – add 100ml of acids from probiotic fermentation to dissolve chitosan and pour the mixture in mold
				

Phase V: Quality Tests for biodegradable plastic (Methods & Results)

Test 1: Glass transition temperature test of bio-plastic: Obtain a sample of the plastic. See if it is flexible at room temperature (25^oC). Put the plastic sample in the refrigerator for 15 mins (3^oC) and check its flexibility. If the plastic sample is still flexible, place it in the freezer for 15 mins (-20^oC) and check its flexibility. If the plastic sample is brittle, then the glass transition temperature is between refrigerator and freezer temperature. If the plastic sample is flexible, then the glass transition temperature is lower than freezer temperature

Glass transition temperature	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
> 25^{o}C	Flexible	Flexible	Flexible
< 25^{o}C	Flexible	Flexible	Flexible
3^{o}C	Flexible	Flexible	Flexible
< -20^{o}C	Flexible	Flexible	Flexible
Conclusion	Lower than freezer temperature	Lower than freezer temperature	Lower than freezer temperature

Test 2: Ultimate tensile strength test of bio-plastic: Cut plastic sample into 3.81cm by 3.81cm. Add mass to the plastic sample until it tear. Calculate the force that the plastic sample can handle until it tear and calculate the ultimate tensile strength by dividing force by area

	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
Cross-sectional area (m^2)	0.001452	0.001452	0.001452
Force in Newton = mass x acceleration due to gravity	1.50	3.90	1.60
UTS in MPa = Force / Area	1.03×10^{-3} MPa	2.69×10^{-3} MPa	1.10×10^{-3} MPa
Conclusion	Least tear-resistant	Most tear-resistant	More tear-resistant than bio-plastic with glycerin but less tear-resistant than without glycerin

Test 3: Stress (elasticity) test of bio-plastic: Cut plastic sample into 3.81cm by 3.81cm. Add mass to the plastic sample until it stretches. Calculate the force that the plastic sample can handle until it stretches and calculate the stress (elasticity) by dividing force by area.

	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
Cross-sectional area (m^2)	0.001452	0.001452	0.001452
Force in Newton = mass x acceleration due to gravity	0.60	0.60	0.50
UTS = Force / Area	4.13×10^{-4}	4.13×10^{-4} MPa	3.44×10^{-4} MPa
Conclusion	More stretchable		Less stretchable

Test 4: Relative clarity of bio-plastic: Hold the plastic sample firmly against a text to be read. Slowly move the sample away from the test. When you can no longer read the text clearly, record the distance in cm. Repeat, this time record the distance at which the text cannot be determined at all

	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
Distance at which text cannot be read clearly	15 cm	15 cm	15 cm
Distance at which text cannot be read at all	40 cm	40 cm	40 cm
Relative Clarity	Transparent	Transparent	Transparent

Test 5: Water resistance test of bio-plastic: Measure the mass of 2cm by 2cm plastic sample**.** Place the plastic sample in a container of room temperature water for 5 mins**.** Remove the plastic sample and measure its mass. If the plastic sample weighs less, then some of it dissolved in the water. If the plastic sample weighs more, then it absorbed the water. If the weight did not change, it is water resistant

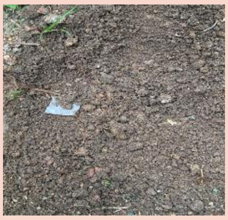
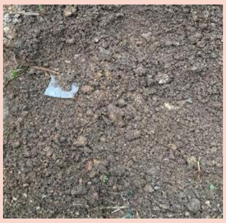
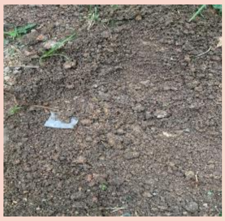
	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
Initial mass in gram	0.15	0.15	0.15
Final mass in gram	0.15	0.15	0.15
% of difference in mass = [(Final mass – Initial mass) / Initial mass] x 100%	0	0	0
Water Resistance	Water resistant	Water resistant	Water resistant

Test 6: Elongation, strain & stiffness test of bio-plastic: Cut plastic sample into 3.81cm by 3.81cm**.** Stretch the plastic sample to the maximum length**.** Calculate the elongation by the

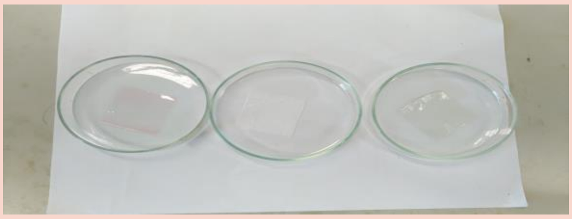
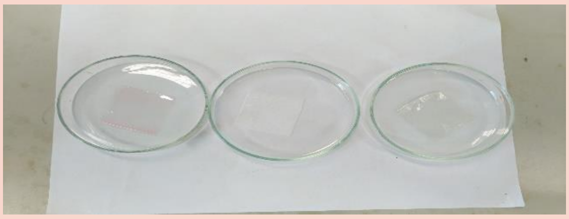
difference of the original and final length after stretching. Calculate the strain by using elongation divided by original length multiply by 100%. Calculate stiffness by using stress (elasticity) divided by strain

	Bio-plastic with glycerin	Bio-plastic without glycerin	Commercial plastic
Elongation measured in m = final length – initial length	0.00254	0.0001	0.0381
Strain (%) = Elongation/ initial length x 100%	6.67	0.26	100
Stiffness in MPa = stress (elasticity)/ strain	0.0154MPa	1.03MPa	0.00110MPa
Conclusion	More stiff than commercial plastic but less stiff than bio-plastic without glycerin	Most Stiff	Least Stiff

Test 7: Soil burial degradation test of bio-plastic: Cut the plastic sample into 3.81cm by 3.81cm. Bury the plastic sample into the ground at 8cm depth; burial duration varied (10, 30, 60, 90 & 120 days). Take photo of the plastic sample on the 10th, 30th, 90th and 120th Day and observe whether there is any physical change

Day 10	Day 30	Day 60	Day 90	Day 120
				

Test 8: Shelf life test of bio-plastic: Cut the plastic sample into 3.81cm by 3.81cm. Leave each plastic sample in the petri dish. Place the petri dish at room temperature for 90 days. This test will determine the durability level of the bio-plastic as plastic packaging

Before 90 Days	After 90 Days
	

(d) Conclusion

It is possible to convert food waste such as shrimp shell, rice water, fruit and vegetable waste into biodegradable plastic with the potential to be marketable and has qualities that are equal to or better than the commercial plastic that it is compared to.

(e) Discussion of the Results and Implications

Overall the plastic made from food waste has glass transition temperature that is above freezer temperature as it is still flexible after placing it in the freezer for 15 mins. It has the same relative clarity as the commercial plastic. It is water-resistant, more tear-resistant and stretchable as compared to commercial plastic. It is biodegradable in soil after 30 days but has long shelf life up to 90 days when left in room temperature and dry environment. With the addition of glycerin, the biodegradable plastic will be less stiff and can be bent into different shape.

(f) Bibliography of References

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This research project investigated whether food waste can be recycled and made into biodegradable plastics. Fruit and vegetable waste and shrimp shell were used as the raw materials. After a series of test, the plastic made from food waste shows high potential tto be margetable. It is water resistant, moire tear-resistant and stretchable as compared to commercial plastic. It is biodegradable in soil afer 30 days. Thus, all wastes can be back to environment.