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參展科別　環境工程

作品名稱　**Process of making a new eco-friendly membrane**

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關鍵詞　**Alginate、Plasticizer、Plastic wrap**

作者簡介

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李建樺，民雄農工汽車科三年級。何家柔及林書榆，協同中學二年級。三人因關心環境而有機會相識，也因都想減少塑膠污染，便一起合作實驗。研究過程中，學習到團隊合作的重要性，也感受到科學研究必須具備堅持的精神，並重視使用者需求，才能讓成果有益於人類福祉。研究期間非常感謝教授與老師以及實驗室學長學姐們的指導，協助解決各種問題。

摘要

本研究目的是為了更了解海藻膠製成的膠膜於食品包裝的應用。我們將此膠膜命名為新型環保非塑性保鮮膜。實驗顯示，環保非塑性保鮮膜的成功取決於甘油和醋酸的關鍵比例成份。我們以適當比例的甘油，醋酸和海藻膠糊液，能夠控制薄膜的流動性和柔軟性。藉由透明度、穿刺強度、拉伸強度和伸長率的物理性能測試，我們的研究證明，新型保鮮膜具有初步商品化之水準。環保非塑性保鮮膜之水活性值遠小於0.6。在實際應用上，「自製新型保鮮膜」包裝功能特性、包裝視覺效果甚佳，並具備優良的冷藏保鮮效果，而且不用擔心因保鮮膜接觸油脂、蒸煮或微波加熱處理所衍生的食安問題。「自製新型保鮮膜」之水活性值遠小於0.6，因此，常溫下具有相當好的貯藏性。最後，經3週掩埋測試，證明「自製新型保鮮膜」之腐敗性甚佳，是一種對環境十分友善的環保材質。

Abstract

This research aims to obtain a better understanding of use of algin making a film for food packaging. We named this film as a new style of eco-friendly non-plastic wrap. The experiment has shown that the success of eco-friendly non-plastic wrap depends on the key ingredients of glycerin and acetic acid. With appropriate proportions of glycerin, acetic acid, and algin, we would be able to control the fluidity and softness of films. Through physical property tests of opacity, puncture strength, tensile strength and elongation, our research proved that new style of eco-friendly non-plastic wrap can initially reach to commercial grade. The eco-friendly non-plastic wrap has superior storage property at room temperature with a water activity much less than 0.6. It has excellent performance of cold preservation in the refrigerator as well. Moreover, there is no need to worry about food safety issues caused by cooking in steamer, heating in microwave, or contacting with oil. Furthermore, applying burying test for three weeks, the eco-friendly non-plastic wrap was completely decayed. This shown that new style of eco-friendly non-plastic wrap has excellent property of corruption. Therefore, it is an environmental friendly material that will not cause environmental pollution.

1. Introduction

1.1 Research motivation

Plastic materials are widely used in our daily life. Most of grocery stores still use amount of plastic materials to pack their products. Over-packaged food has been causing environment pollution for years. The environmental protection administration (EPA) of Taiwan has been constantly promoting the plastic limit policy. In order to reduce the use of plastic packaging, supermarkets have responded by looking for alternatives to all that plastic. Some foreign supermarkets are ahead of the pack when it comes to reuse and refill schemes. Although customers take their own container to pack food, the container might not be clean to fill the food and the foods are not kept fresh. Also, food safety and hygiene may be affected due to contact with hands or dust. Hence, it is difficult to make a tradeoff between plastic restriction and food safety (Fig. 1).

PVC or PVDC plastic wrap not only satisfies the preservation of foods in refrigerators, but also can be used for microwaves. Moreover, heating has become one of the commonly used packaging materials in developed countries. The Food and Drug Administration of the Ministry of Health and Welfare announced " Food utensils, food containers or packaging with polyvinyl chloride (PVC) or polyvinylidene chloride (PVDC) on its food contact surface, shall be labelled with the note that the products shall not directly contact with high-fat and high-temperature food, or the words with equivalent meaning." Therefore, the PVC or PVDC plastic wrap for food packaging and heating would be increasing issues on food safety (Fig. 2).

Figure 1. Eco-friendly v.s food safety

Figure 2. Hesitation of contact with heat and fat

1.2 Purpose

1. To develop a new production process of non-plastic wrap.
2. To solve the food safety concerns of plasticizers or toxic substances in the plastic wrap due to

grease or heat treatment.

3. To develop a non-plastic film that can be "decomposed" and is eco-friendly.

2. Research process and method

2.1 Literature review

2.1.1 Glutinous rice [17][23]

Glutinous rice which is also called sticky rice is named from its characteristic. It is a traditional food in Asia. The main ingredient is starch. Mix starch in water and heat them, the original bond between the starches is broken, and water molecules will be inserted between the starches. After continuous heating, the water molecules will surround the starch molecules, which is the complete starch gelatinization.

2.1.2 Alginate [7][8][9]

Alginate is a naturally occurring polysaccharides commonly produced by brown algae (Phaeophyceae). The molecular structure of linear alginates is based on two monomeric units, β-D-mannuronic acid(M) and α-L-guluronic acid(G) residues linked by 1–4 glycosidic bonds, with homogeneous blocks of M and G, and alternating MG blocks. Alginate functions in seaweeds are of structural and ion exchange type. Only the G-blocks participate in intermolecular cross-linking with divalent ions(e.g. Ca^{2+}), affecting the hydrogel properties of alginate. Between two chains(GG) bound calcium ions and form divalent salt bridges, so the alignment of the G-blocks changes and the egg-box model formats, resulting in a gel structure. (As shown on figure 3)

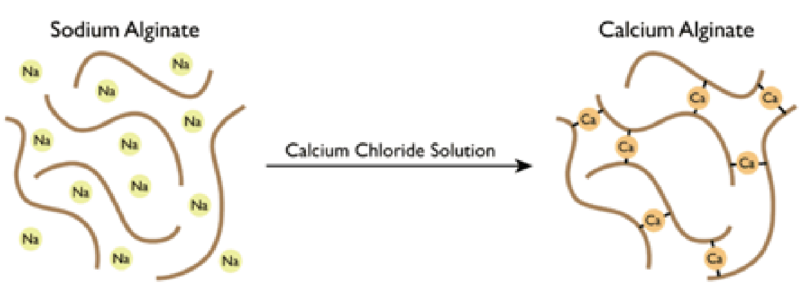


Figure 3. Gel principle of sodium alginate

2.1.3 Calcium chloride [4][6]

Calcium chloride solution dissociates Ca^{2+} and Cl^- , adding certain bivalent cation to alginate solution would cause solution form into gel through ion exchange. Also, calcium is one of bivalent cation that can be eaten by animals.

2.1.4 Glycerin [4]

Glycerin is one kind of plasticizer used in food processing. With three hydroxyl groups, glycerin is miscible with water and organic solvents. The hydrogen bonds between water and alginate would be weakened because of the higher water-glycerin affinity. Between glycerin and water would form hydrogen bonds showed significantly higher moisture content. The glycerin addition would decrease the tensile strength, but for tensile elongation would increase.

2.1.5 Acetic acid [26]

It is a weak acid that can dissociate CH_3COOH^+ and H^+ partially in solution. In acidic solution, the functional group of alginate is protonated, the sodium ions and acetate anions are connected to each other which often used in food.

2.1.6 Plasticizer [3][5][10]

Phthalates are a group of diesters of ortho-phthalic acid (dialkyl or alkyl aryl esters of 1,2-benzenedicarboxylic acid). High polymer phthalates, such as di-2-ethylhexyl phthalate (DEHP), are primarily used as plasticizers to soften polyvinyl chloride (PVC) products, while the lower polymer phthalates, such as diethyl phthalate (DEP), di-n-butyl phthalate (DBP), and butyl benzyl phthalate (BBzP), are widely used in various products. Phthalates have become common environmental contaminants due to volatilization and leaching from their widespread applications, and thus the environment contamination has become another important source for phthalates in foods in addition to migration from packaging materials. Human exposure to phthalates has been an increased concern due to the findings from toxicology studies in animals. DEHP, one of the important and widely used phthalates, is a rodent liver carcinogen. DEHP, DBP, BBzP, and several phthalate metabolites are teratogenic in animals. The objective of this review is to identify the knowledge gaps for future investigations by reviewing levels of a wide range of phthalates in a variety of foods.

2.1.7 Plastic wrap [11]

A related study by National Cheng Kung University has shown that the plasticizer in microwave-heated food in convenience stores may contaminate food through leakage of food packaging, plastic packaging materials or containers in plastic wrap. Moreover, even if it is not heated, the dissolved DEHP content is higher than the tolerable intake kilograms per person per day in the EU. The fat content of the food itself may be one of the factors that affect the migration of DEHP. Plastic packaging materials or containers are microwaved and cooked. The best way to avoid plasticizer pollution is not to use plastic materials. As polyvinyl chloride is a chlorine-containing substance, it will release toxic dioxin after being burned, which is harmful to human health and the biophysical environment. Therefore, hot food or microwave heating, do not use plastic wrap for microwave or steaming, and do not use packaged oily food. Many related reports in the media have gradually established consumers' correct concept that PE plastic wrap on markets has gradually replaced PVC plastic wrap. After keeping heating plastic materials, there will be food safety concerns about the dissolution of plasticizers.

2.2 Instruments and materials

2.2.1 Instruments


Electronic Balance
GR-120 (Japan)


Electronic Scale
Jin Yuan JYK-6000 (Taiwan)


Hot Plate/Magnetic stirrer
CORNING PC-420D (USA)


Water Activitymeter
AquaLab lite (USA)


Microwave
NN-ST342 (Japan)


Air Brush BRUSH
BD-134 (Taiwan)


Air Compressoe HORSE
JF-RU06 (Taiwan)


Steam Cooker
TATUNG (Taiwan)


Camera
NIKON D700 (Taiwan)


Force Gauge
Lutron FG-5005 (Taiwan)


Homogenizer
HM-0025 (Taiwan)


Viscometer
BROOKFIELD DV-E (USA)


Spectrophotometer
HITACHI U-1900 (Japan)


3-Axis CNC Milling Machine
Bonta Diffraction (Taiwan)

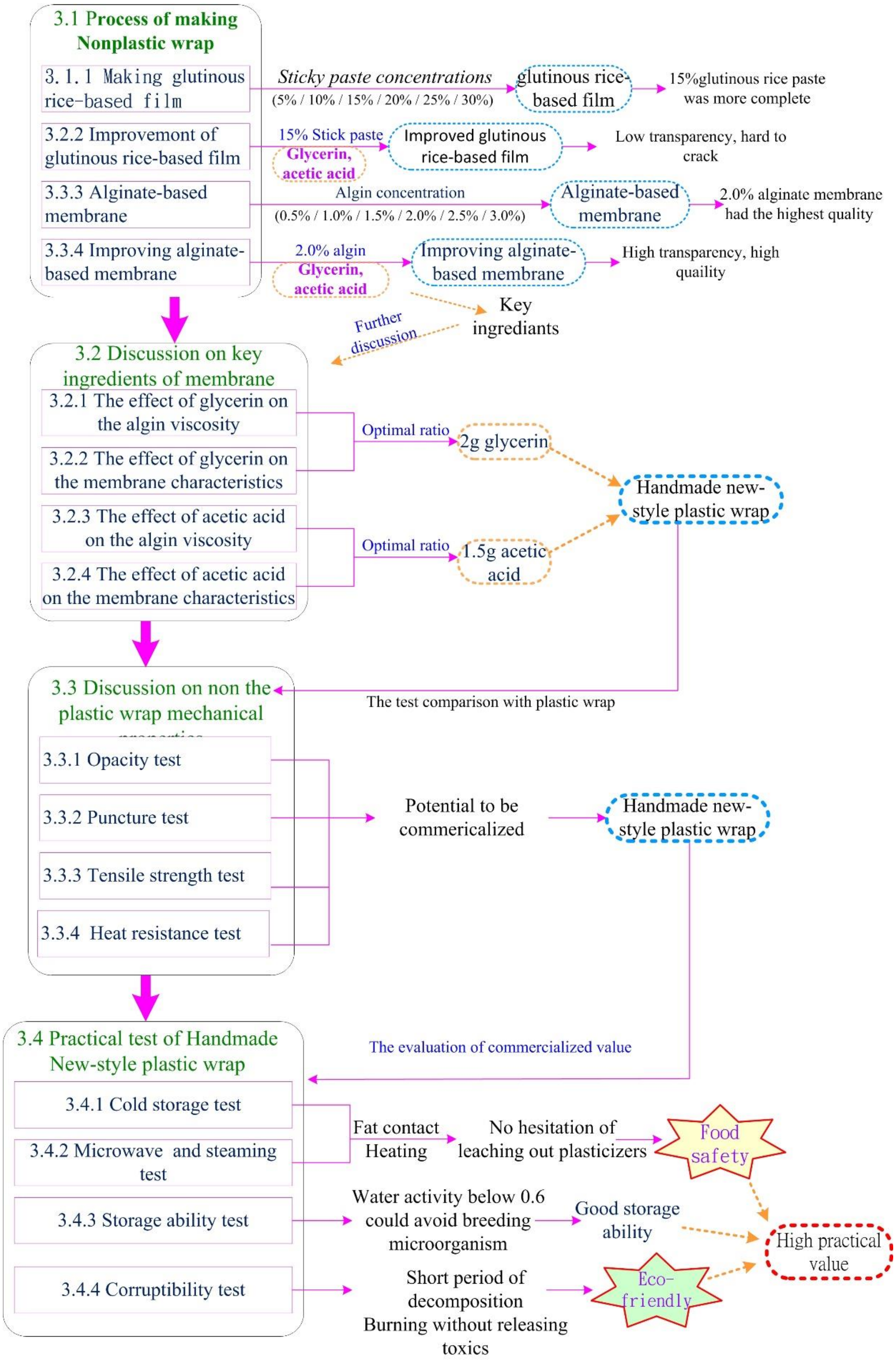

Vacuum Packaging Machine
FUSERJOY (Taiwan)


Hot-air Dryer
SUN CHION (Taiwan)

2.2.2 Materials

1. Glutinous rice (Ping Tung Foods Corp.)
2. Alginate (Sin Long Foods Additive INC.)
3. Calcium chloride (Choneye Pure Chemicals, Taiwan)
4. glycerin (Choneye Pure Chemicals, Taiwan)
5. Acetic acid (Miani Chem, Taiwan)

2.3 Architecture

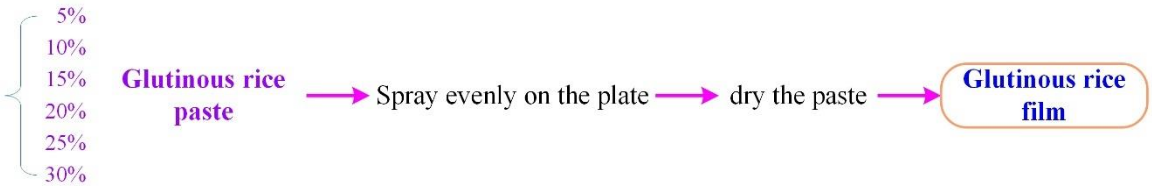


3. Analysis and results

3.1 Process of making non-plastic wrap

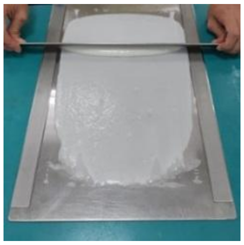
3.1.1 Making and testing of glutinous rice film

Glutinous rice film was the traditional packaging film that was both edible and eco-friendly. This experiment attempts to realize the characteristics of the glutinous rice film by production process. *(Fang Yi et al., 2020)*



Procedure

1. Independent variables: the concentration of glutinous rice paste followed as 5%, 10%, 15%, 20%, 25% and 30%(w/w).
2. Weigh 5g, 10g, 15g, 20g, 25g, and 30g glutinous rice flour and mix each with 100ml water, then stir evenly to make 5%, 10%, 15%, 20%, 25%, and 30% glutinous rice paste, respectively. *(Fang Yi et al., 2020)*
3. Apply hot plate magnetic stirrer to heat and stir glutinous rice paste until boiling.
4. Smear the glutinous rice paste on the stainless-steel plate, fixed the thickness of paste to 1mm. (as shown on the right figure).



5. Dry for 4 hours at 50°C in a hot-air dryer.
6. After drying, cool down to room temperature. Observe and record the “glutinous rice film.”

Results

Regardless of the concentration of paste, various textures of glutinous rice paste were hard and easy to break. The film with 15% glutinous rice was less broken, and the appearance of film was relatively complete (Fig. 4).

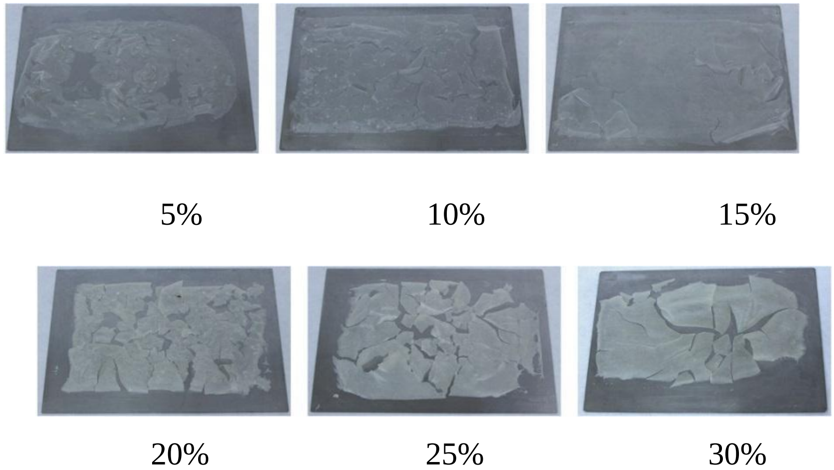


Figure 4. Different concentrations of glutinous rice films (before demolding and cutting)

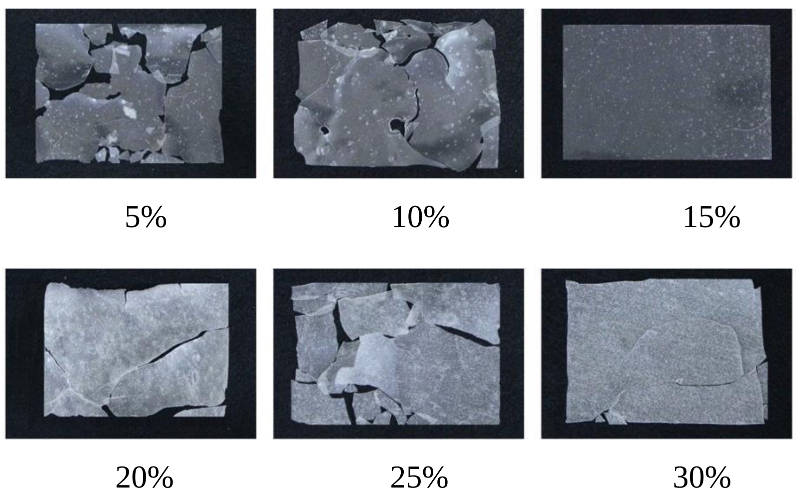


Figure 5. Different concentrations of glutinous rice films (after demolding and cutting)

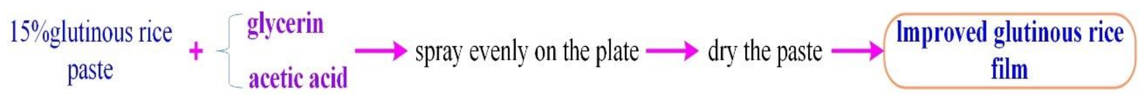
The films crisped easily during the cutting process, only 15% glutinous rice film had a relatively complete appearance after demolding and cutting (Fig. 5). The more concentration of the paste was, the higher thickness and opacity of the glutinous rice film would be.

Discussion

Considering the hardness, thickness, opacity, and cutability of the glutinous rice films, we proposed to use 15% glutinous rice paste for the following experiments. Our research showed the films made only with glutinous rice flour were crispy, hard to cut, and had low value in practical use. Fang Yi et al. (2020) found that glutinous rice film usually used food additives to improve the films properties, so that the glutinous rice films had commercial value.

3.1.2 Improvement of glutinous rice film

We used food additives, glycerin and acetic acid, which had been used in the experiment *(Aonomus, 2011)* to improve the strength of glutinous rice film. Further, we attempt to reduce shattering during cutting operation and enhance practical value of glutinous rice film.

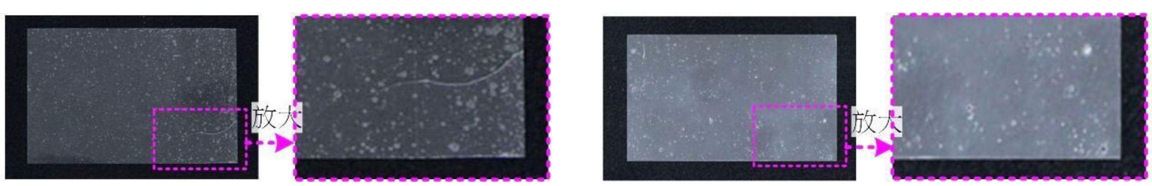


Procedure

1. Mix 15g glutinous rice flour with 100ml water (w/w) and stir evenly. *(Aonomus, 2011)*
2. Apply hot plate magnetic stirrer to heat and stir glutinous rice paste until boiling, then add 5g glycerin and 0.275g acetic acid, and stir evenly for 3 minutes. *(Aonomus, 2011)*
3. Smear the glutinous rice paste on the stainless-steel plate, fixed the thickness of paste to 1mm.
4. Dry for 4 hours at 50°C in a hot-air dryer.
5. After drying, cool down to room temperature. Observe and record the "improved glutinous rice film."

Results

As shown on figure 6(A), the film made with 15% glutinous rice paste had a hard and fragile texture. We could see a little shatter on the surface of film after cutting. As shown on figure 6(B), the improved film was soft and flexible. Its appearance could maintain intact after cutting, and it was less likely to break.



A. Glutinous rice film **B.** Improved glutinous rice film

Figure 6. The comparison of appearance between glutinous rice film and improved glutinous rice film (both demolding and cutting)

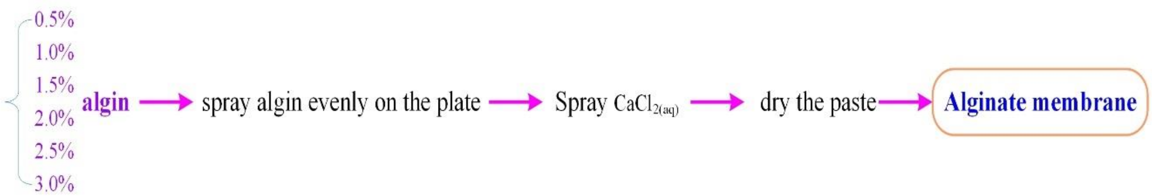
Discussion

Instead of *Aonomus (2011)* used corn flour as the main material and add glycerin and acetic acid to make bio plastic film, we used glutinous rice flour. The “Improved glutinous rice film”, which added glycerin and acetic acid, had softer texture and flexibility. Also, it had complete appearance after cutting and was hard to break, which effectively increased the value of film.

Whether it was “glutinous rice film” or “improved glutinous rice film”, there were obvious bubbles on film surface, which influenced their appearance. To solve this disadvantage, we found *Lin Yizhen et al.*, which used vacuum packaging machine to eliminate bubbles.

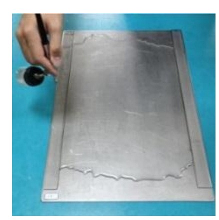
3.1.3 Making and testing of alginate membrane

We found that *Lin Yizhen et al. (2019)* used algin making their products, so we imitated them to use algin instead of glutinous rice flour to explore its feasibility.



Procedure

1. Independent variables: the concentration of algin followed as 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% (w/w).
2. Weigh 0.5g, 1.0g, 1.5g, 2.0g, 2.5g, and 3.0g sodium alginate, respectively, dissolve in 100ml water, and stir with the homogenizer for 10 minutes at 8000rpm.
3. Smear the glutinous rice paste on the stainless-steel plate, fixed the thickness of paste to 1mm.
4. Spray 10% calcium chloride solution evenly on the surface of paste. (as shown on the right picture)



5. Dry for 4 hours at 50°C in a hot-air dryer.
6. After drying, cool down film to room temperature, observe and record the “Alginate membrane.”

Results

Before demolding and cutting, the alginate membrane made in different concentrations texture was slightly stronger than that of glutinous rice film. Also, the surface of glutinous rice film was more complete. Despite external force, it might still shatter (Fig. 7).

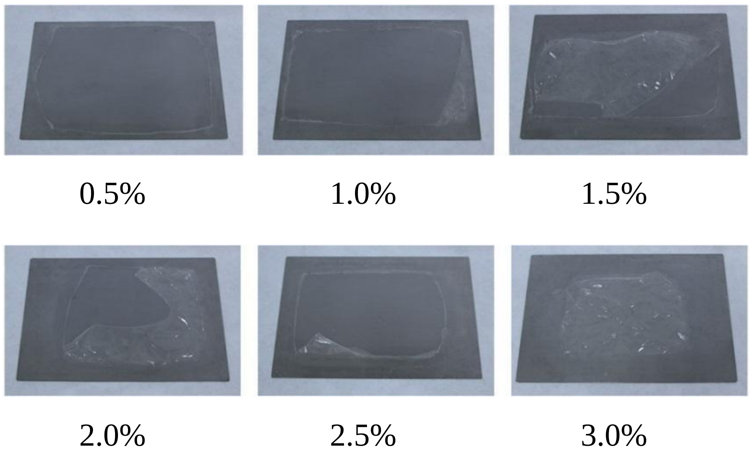


Figure 7. The different concentration of alginate membranes (before demolding and cutting)

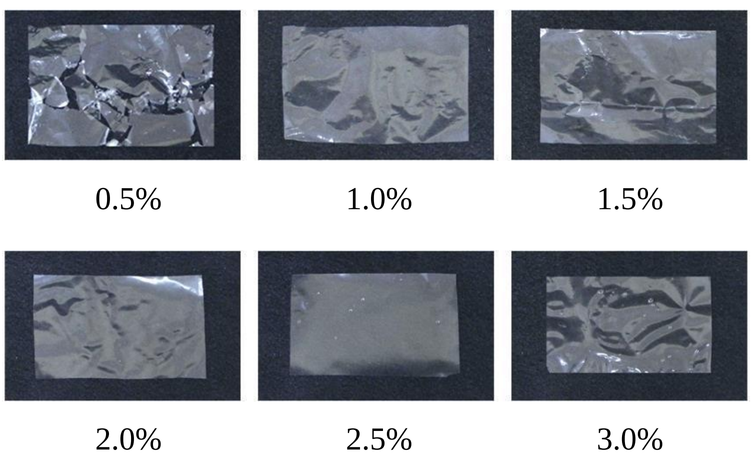


Figure 8. The different concentration of alginate membranes (after demolding and cutting)

Comparing with glutinous rice films, all kinds of alginate membranes have better transparency and much harder texture and its appearance could be kept intact(Fig. 8). The higher algin concentration was, the thicker and the stronger strength membrane would be.

Discussion

According to the results, we considered algin membranes hardness and thickness, so we planned to use 2% algin to continue the following experiment. With pure algin, the membrane was fragile. Therefore, there is space for improvement. In the process of making alginate membrane, sodium alginate would bonded to calcium ions, the membrane shrinked immediately. We tried many ways to overcome this problem, and finally found it to use a stainless-steel plate and micro-spraying technique which provided adhesion to the membranes and an appropriate amount of calcium ions.

In this experiment, we established a new procedure for producing membranes.

1. Smear the paste of sodium alginate on the stainless-steel plate, fixed the thickness of paste to 1mm with a regulated pad. [Fig. 9(A)]
2. Spray 10% calcium chloride solution evenly on the surface of paste. [Fig. 9(B)]
3. Calcium ions exchange with sodium in the paste of alginate, forming into calcium alginate. [Fig. 9(C)]
4. Dry the calcium alginate with hot air. Then, it would form membrane of calcium alginate. [Fig. 9(D)]
5. Cool down to room temperature and demold to get the finished membranes. [Fig. 9(E)].

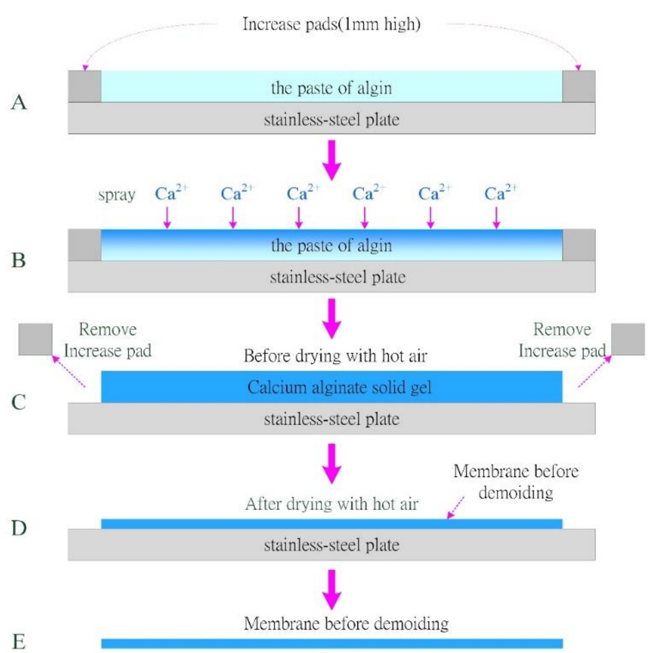
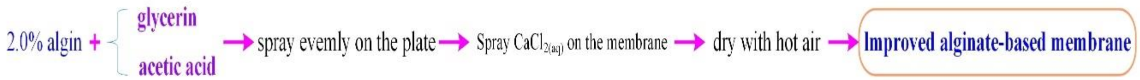


Figure 9. Process of making alginate membranes

3.1.4 Improvement of algin membrane

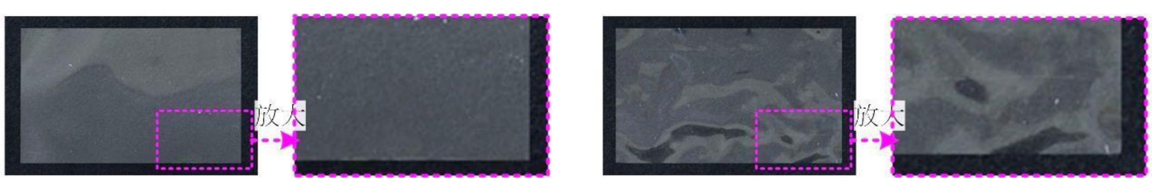
We added glycerin and acetic acid into the algin to improve the properties of the alginate membrane, trying to increase the transparency, tensile strength, and flexibility of the membrane, so that alginate membrane could be more useful.



Procedure

1. Mix 2.0g sodium alginate with 100ml water. Use the homogenizer to stir for 10 minutes at 8000rpm.
2. We followed the ratio of glycerin and acetic acid by *Aonomus (2011)*, adding 5g glycerin and 0.275g acetic acid to the algin. Then, stir with the homogenizer for 3 minutes at 8000rpm.
3. Smear the paste of algin on the stainless-steel plate, fixed the thickness of paste to 1mm.
4. Spray 10% calcium chloride solution evenly on the surface of algin.
5. Dry for 4 hours at 50˚C in a hot-air dryer.
6. After drying, cool down to room temperature. Then, observe and record the “Improved alginate membrane.”

Results



A. Alginate membrane B. Improved alginate membrane

Figure 10. The difference in alginate membrane before and after improvement (after demolding and cutting)

Compared to the “Improved alginate membrane”, “Alginate membrane” had poorer transparency, harder texture and slightly better flexibility, besides, its appearance could be kept intact after cutting [Fig. 10(A)]. The “Improved alginate membrane” had better flexibility, better transparency, softer texture, and the membrane was quite complete.

Discussion

The results showed that the “Improved alginate membranes” transparency and viscosity were similar to common plastic wrap. For it had good flexibility and stretchability, it could be use in commercial product.

The key ingredients, glycerin and acetic acid, changed alginate membrane characteristics which could be seen in this experiment. Therefore, we tried to find the best ratio.

3.2 Discussion on key components of membrane

3.2.1 The effect of glycerin on the paste viscosity

We dissolved only glycerin in the algin to realize the influence on the paste viscosity so that we could find appropriate ratio of algin and glycerin to make better membrane.

Procedure

1. Independent variables: different amount of glycerin (0g, 1g, 2g, 3g, 4g, and 5g).
2. Mix 2.0g sodium alginate with 100ml water. Then, stir them with the homogenizer for 10 minutes at 8000rpm.
3. Separate algin into six samples which added glycerin (0g, 1g, 2g, 3g, 4g, and 5g), respectively.
4. Stir samples with the homogenizer for 3 minutes at 8000rpm.
5. Measure and record the viscosity of each paste with the viscometer. (As shown in the right figure)

6. Use Excel and xlstat software to analyze statistical data and determine whether there are significant differences in the viscosity of the six samples (95% confidence level) and use SigmaPlot software for graphing data (Lu Xiuying, 2011).

Results

The glycerin viscosity in different concentrations changed a little and all viscosities were in the range of 2000cP~3000cP. All samples had differences from each other (95% confidence level). (Table 1 and Fig.11)

Table 1. The different concentration of glycerin effecting paste viscosity

Glycerin	Viscosity (cP)				
	Test 1	Test 2	Test 3	Average	Standard deviation
0 g	2010	2014	2022	2015 f	16
1 g	2612	2600	2605	2639 a	6
2 g	2180	2165	2172	2172 d	8
3 g	2220	2214	2208	2214 c	6
4 g	2060	2076	2058	2065 e	10
5 g	2244	2238	2274	2252 b	19

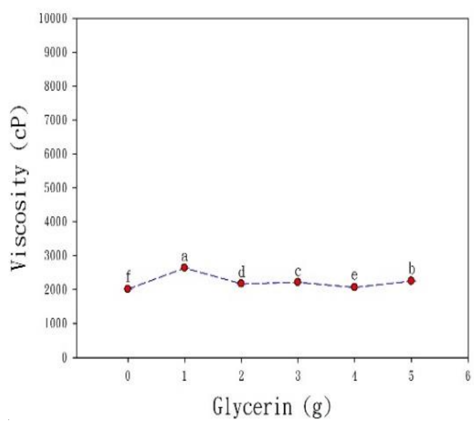


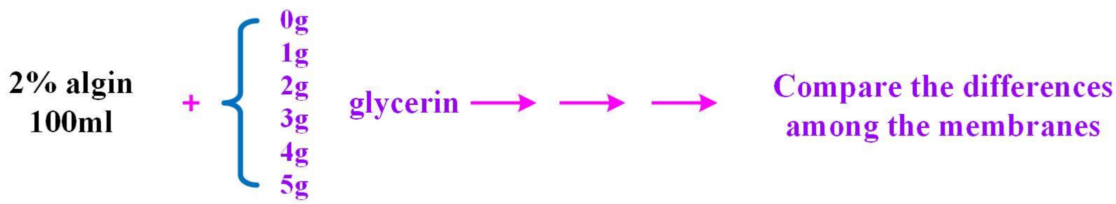
Figure 11. The different concentration of glycerin effecting paste viscosity

Discussion

There were slight effects among different concentrations of glycerin on paste viscosity.

3.2.2 The effect of glycerin on the alginate membrane

In this experiment, we wanted to know that the characteristic of alginate membrane with the different ratios of glycerin. Then, we mixed glycerin with the algin to observe the influence on the membranes.



Procedure

1. Independent variables: different amount of glycerin (0g, 1g, 2g, 3g, 4g, and 5g).
2. Follow the previous **experiment 3.2.1** step 2.
3. Follow the previous **experiment 3.2.1** step 3.
4. Follow the previous **experiment 3.2.1** step 4.
5. Use the vacuum packaging machine to eliminate bubbles for samples.
6. Smear each sample on stainless-steel plate, fixed the thickness of each sample to 1mm.
7. Spray evenly 10% calcium chloride solution on the surface of each sample.
8. Dry for 4 hours at 50˚C in the hot-air dryer.
9. After drying, cool down to room temperature. Observe and record the result of each sample.

Results

All membranes smoothly attached to the stainless-steel plate. As the glycerin concentration increased, its thickness became more uneven, but 1g glycerin in algin seemed changed rare.

The membranes in 4g or 5g glycerin surfaces were little greasy. If glycerin was not added, the transparency, flexibility, and stretchability of the membrane were obviously poor. With 2g,3g,4g,5g glycerin, we could see that the membranes characteristic told above improved, but the membranes strength showed a decreasing trend which means it is easy to slit. (Fig. 12 and Fig. 13)

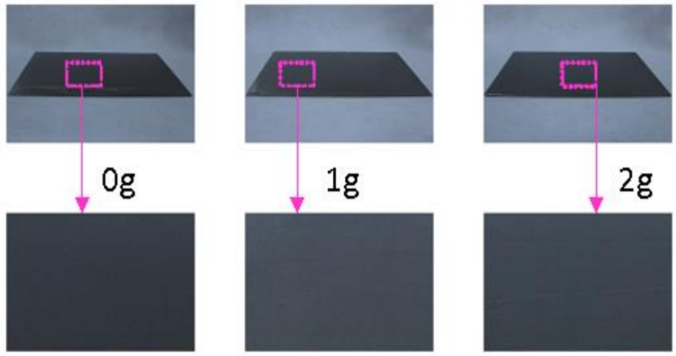


Figure 12. Glycerin in 0g, 1g, 2g concentrations (before demolding and cutting)

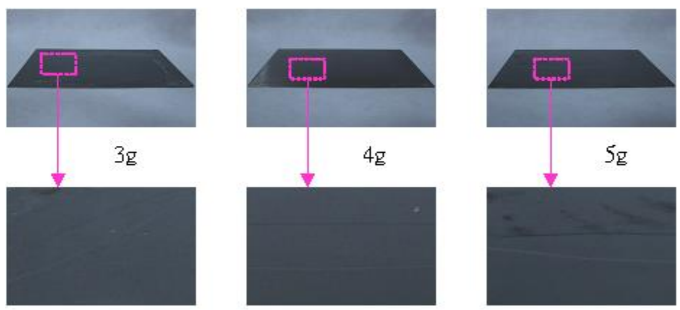


Figure 13. Glycerin in 3g, 4g, 5g concentrations (before demolding and cutting)

Discussion

We could find that the mechanical properties and the appearance had changed due to the glycerin. Compared with the membrane without glycerin, the characteristics of membranes with glycerin were completely different. Therefore, it was proved that glycerin was an important key. We discovered that the membrane have better commercial value.

The glycerin brought a great advantage to the membrane. However, as we considered to the application of membrane in the market, it was a flaw that the membranes strength would decrease with more glycerin. The uneven thickness of the membranes not only influenced the membranes appearance but also reduced the force on the membranes. The conclusion was that 2g glycerin was a better ratio to make an ideal film in practical applications. Therefore, in the following experiments, the amount of glycerin was fixed at 2g.

3.2.3 The effect of acetic acid on the paste viscosity

We dissolved only acetic acid in the algin to realize the influence on the paste viscosity so that we could find appropriate ratio between them to make better membrane.

Procedure

1. Independent variables: different amount of acetic acid (0g, 0.5g, 1g, 1.5g, 2g, and 2.5g). Fixed parameter: 0.275g acetic acid.
2. Following steps refer to **experiment 3.2.1**.

Results

There was difference among each (95% confidence level). With more acetic acid, the algin got stickier. (Table 2 and Fig. 14)

Table 2. The different concentration of acetic acid effecting the paste viscosity

Acetic acid	Vicosity (cP)				
	Test 1	Test 2	Test 3	Average	Standard deviation
0.0 g	2010	2014	2022	2015 f	6
0.5 g	2213	2220	2224	2219 e	6
1.0 g	2334	2304	2328	2322 d	16
1.5 g	2475	2464	2458	2466 c	9
2.0g	2634	2647	2644	2642 b	7
2.5 g	2775	2784	2768	2776 a	8

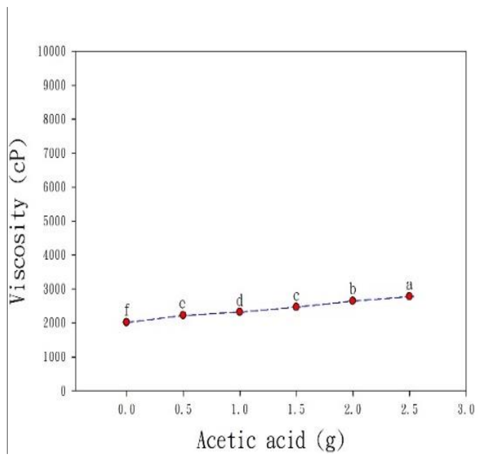


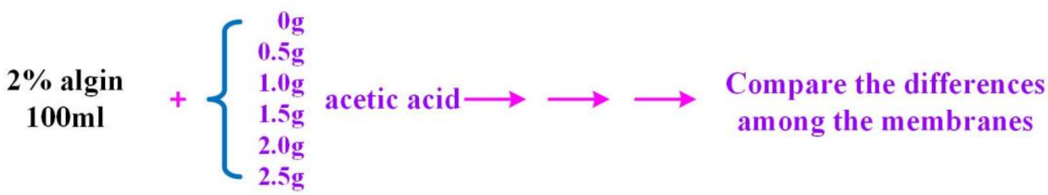
Figure 14. The different concentration of acetic acid effecting the paste viscosity

Discussion

With more acetic acid, the viscosity grows approximately linearly. There were slight effects among different concentrations of acetic acid on the paste viscosity. We speculated that acetic acid dissociates into hydrogen ions and acetate ions in algin. Acetate ions and water form hydrogen bonds. Also, there is a partial hydrogen bond between algin and acetate ions. Thus, it increases the intermolecular force and the viscosity.

3.2.4 The effect of acetic acid on the alginate membrane

We dissolved only acetic acid in the algin to realize what the alginate membrane characteristic had been changed.



Procedure

1. Independent variables: different amount of acetic acid (0g, 0.5g, 1g, 1.5g, 2g, and 2.5g).
2. Following steps refer to **experiment 3.2.2**.

Results

Under the observation of naked eye, it was hard to see any difference of the membranes. However, the more acetic acid we added in, the stronger strength the membrane would be(Fig. 15).

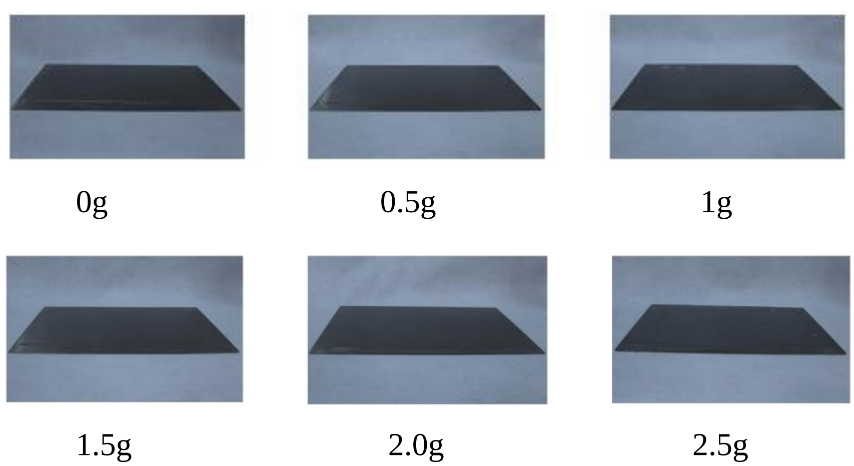


Figure 15. 0g to 2.5g acetic acid dissolved in algin. (before demolding and cutting)

Discussion

We considered that the one with 1.5g acetic acid was the best one because its strength wasn't too weak and it had better stretchability than 2g and 2.5g acetic acid in membranes.

3.2.5 Optimal ratio

In this experiment, we set 2g glycerin as a fixed parameter and regulated the concentrations of acetic acid to see if there was any chemical change that changed the original properties of paste and made the best membrane.

Procedure

1. Independent variables: different amount of acetic acid (0g, 0.5g, 1g, 1.5g, 2g, and 2.5g).
2. Fixed parameter: 2g glycerin.
3. Mix 2.0g sodium alginate with 100ml water, and stir them with the homogenizer for 10 minutes at 8000rpm.
4. Heat the stir different ratio of acetic acid and glycerin that put in different beakers with hot plate/magnetic stirrer for 3 minutes.
5. Separate algin into six samples which added acetic acid (0g, 0.5g, 1g, 1.5g, 2g, and 2.5g) with 2g glycerin, respectively.
6. Stir samples with the homogenizer for 3 minutes at 8000rpm.
7. Measure and record the viscosity of each paste with the viscometer. (As shown in the right figure).

8. Use Excel and xlstat software to analyze statistical data and determine whether there are significant differences in the viscosity of the six samples (95% confidence level) and use SigmaPlot software for graphing data *(Lu Xiuying, 2011).*

Results

Under observation of naked eye, there was no obvious difference in appearance among the samples of acetic acid (0g, 0.5g, and 1g). However, the samples of acetic acid (1.5g, 2g and 2.5g) had more and more bubbles through the increasing concentration (Fig. 16). Also, we could see that the algin become stickier and tend to form gelation.

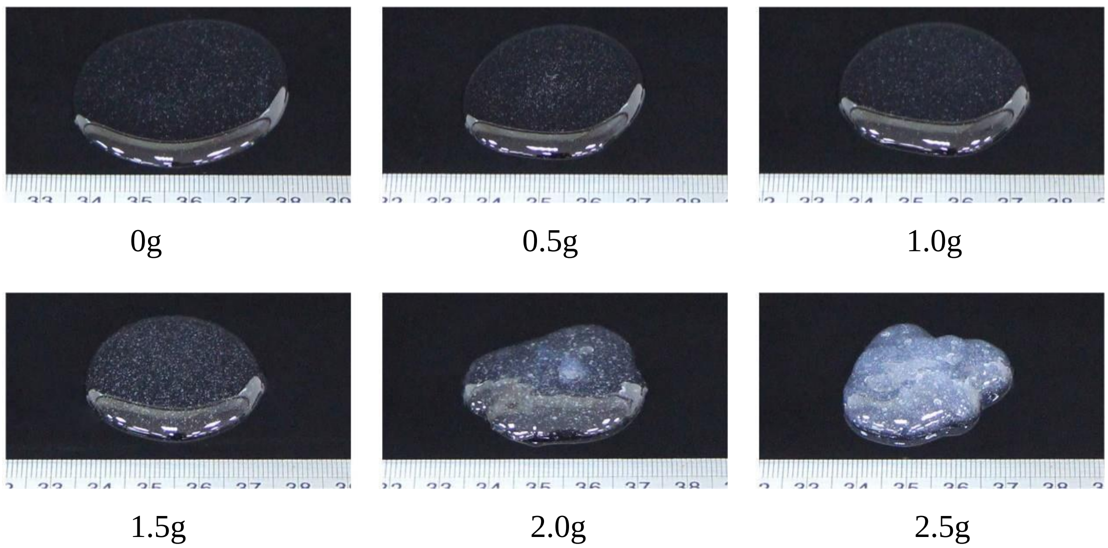


Figure 16. The effect of 0g to 2.5g acetic acid(with 2g glycerin) on the paste appearance.

The more acetic acid we added, the slightly higher the paste viscosity was, but when the amount of acetic acid added to 2g, there was an obvious increasing in paste viscosity (Table 4, Fig. 17). We could even see that the line of viscosity rose substantially and reached to the high peak in 2.5g acetic acid sample (Fig. 17).

Table 4. The paste viscosity values of 0g to 2.5g acetic acid with 2g glycerin.

Acetic acid	Vicosity (cP)				
	Test 1	Test 2	Test 3	Average	Standard deviation
0.0g	2874	2901	2897	2891d	12
0.5 g	2911	2952	2946	2936d	18
1.0 g	3114	3066	3108	3096c	21
1.5 g	3137	3107	3119	3121c	12
2.0 g	4498	4374	4446	4439b	51
2.5 g	9037	8720	9037	8931a	149

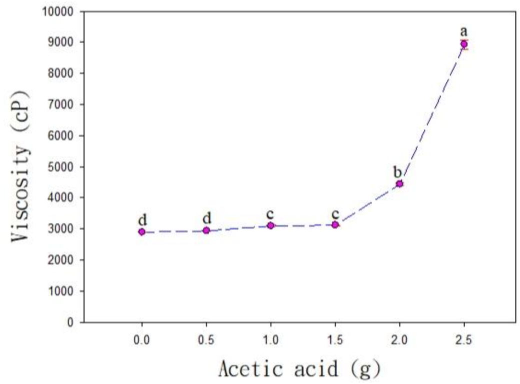


Figure 17. The paste viscosity values of 0g to 2.5g acetic acid with 2g glycerin.

Through statistical analysis, we knew that there was no significant difference between the viscosity of 0g acetic acid sample and 0.5g acetic acid sample (95% confidence level), and so was that between 1.0g acetic acid sample and 1.5g acetic acid sample, while the rest of them were significantly different from each other (95% confidence level).

Discussion

According to the experiment, it showed a significant increase in viscosity when acetic acid reached 2g or more which meant the amount of acetic acid reached the critical value would influence viscosity of algin a lot. Because of the obvious increase in viscosity, the number of bubbles which covered in algin increased. In addition, when we added 2.5g acetic acid, the paste was more likely to appear gel phenomenon and seemed to be more difficult to eliminate bubbles by vacuum.

3.2.6 The effect of optimal ratio on alginate membrane

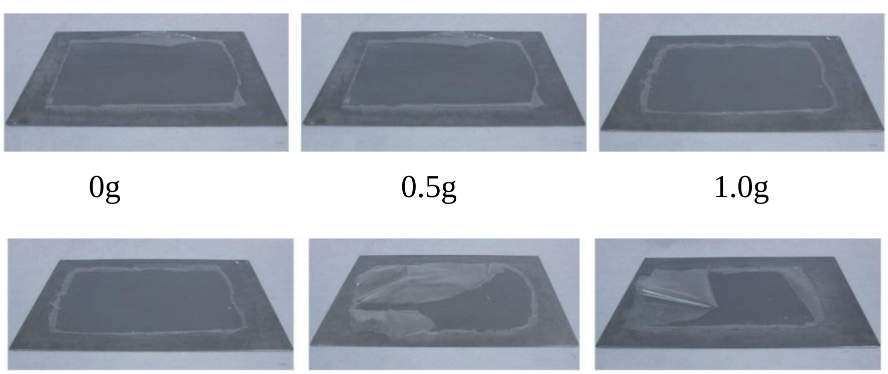
In this experiment, we tried to see if there was chemical reaction between glycerin and acetic acid which might influence the physical mechanical properties of the membrane.

Procedure

1. Independent variables: different amount of acetic acid (0g, 0.5g, 1g, 1.5g, 2g, and 2.5g). Fixed parameter: 2g glycerin.
2. Follow the previous **experiment 3.2.5** step 3.
3. Follow the previous **experiment 3.2.5** step 4.
4. Follow the previous **experiment 3.2.5** step 5.
5. Follow the previous **experiment 3.2.5** step 6.
6. Apply the vacuum packaging machine to eliminate bubbles of six samples.
7. Smear each sample on each stainless-steel plate, fixed the thickness to 1mm with a regulated pad.
8. Spray evenly 10% calcium chloride solution on the surface of six samples.
9. Dry for 4 hours at 50°C in a hot-air dryer.
10. After drying, cool them down to room temperature. Observe and record each result.

Results

The membranes with 0g, 0.5g, 1.0g and 1.5g acetic acid smoothly attached to the stainless-steel plate. On the contrast, the membranes with 2.0g or 2.5g acetic acid would shrink obviously after drying. Therefore, it could not completely attach on the plate (Fig. 18).



0g 0.5g 1.0g

1.5g 2.0g 2.5g

Figure 18. Acetic acid in different concentrations with 2g glycerin dissolved in algin. (before demolding and cutting)

When we added acetic acid from 0.5g to 2.5g, the flexibility and stretchability would gradually decrease. On the other hand, the strength of the membrane would gradually increase (Fig. 19).

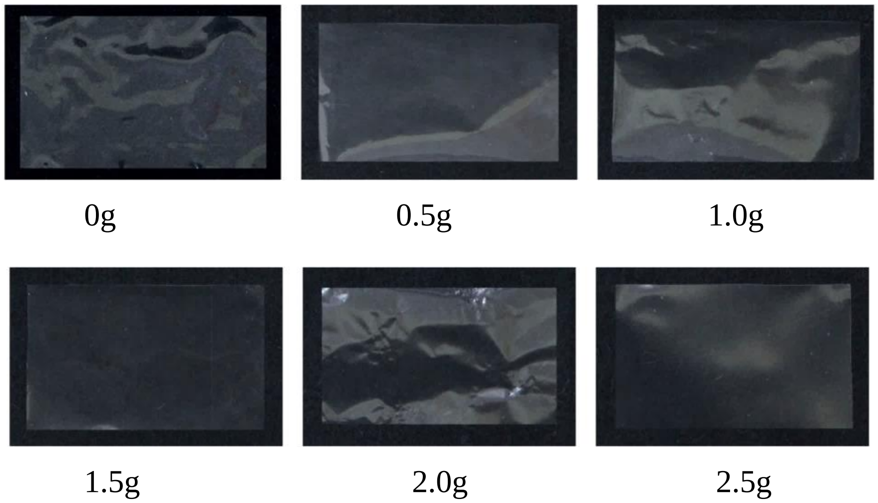


Figure 19. Acetic acid in different concentrations with 2g glycerin dissolved in algin. (after demolding and cutting)

Discussion

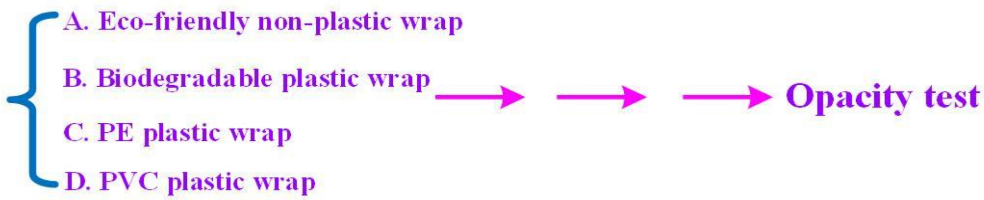
In this experiment, the membrane with only glycerin would have better transparency, stretchability, and flexibility compared with other membranes which added acetic acid (0.5g, 1.0g, 1.5g, 2.0g, and 2.5g).

According to the experiment 3.2, we attempted to use 2% algin, 2g glycerin and 1.5g acetic acid to make the membrane in following experiment. In this way, the characteristics of membrane were much similar to commercial plastic wraps which had the practical use. We defined the membrane as "eco-friendly non-plastic wrap."

3.3 Discussion on the physical properties of non-plastic wrap

3.3.1 Opacity test

We tested the opacity of the membrane and other kinds of market plastic wrap to compare the difference, so that we could explore whether the membrane had practical value.



Procedure

1. Independent variables: Eco-friendly non-plastic wrap, biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap. Fixed parameter: alginate membrane

2. Refer to the method by *Fang Boxiang(2015)*, we cut five samples which are A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap, and alginate membrane into a 10 mm × 30 mm rectangle, and put them in the sample tank to measure the absorbance values by spectrophotometer (U-1900, Hitachi Instruments Inc., Tokyo, Japan).

3. Calculate the integrated area of the scanning wavelength range, representing the result in AU·nm, the average of each group of samples is measured for three times. (The initial set of wavelength was 400-800 nm)

4. Opacity (AU·nm)=Σ(absorbance value × scanning wavelength)

5. Use Excel and xlstat software to analyze statistical data and determine whether there is significant difference in the opacity of each sample (95% confidence level) and use SigmaPlot software for graphing data.

Results

Biodegradable plastic wrap, PE wrap, and PVC wrap, their opacity was 29.81, 33.15, 28.56 (AU * nm) in order, and their wavelength was not short, which represents good transparency. We knew that there was no significant difference among three commercial plastic wraps (biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap) (95% confidence level). The opacity of three kinds of plastic wrap (eco-friendly non-plastic wrap, commercial plastic wraps, and alginate membrane) had noticeable significance (95% confidence level). (As shown in Table 5 and Fig. 20)

Table 5. Opacity of various plastic wrap.

Plastic wrap	Opacity (AU*nm)				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. Eco friendly non-plastic wrap	59.65	59.08	59.20	59.31 b	0.30
B.Biodegradable plastic wrap	26.40	26.40	36.62	29.81 c	5.90
C.PE plastic wrap	36.46	34.80	28.20	33.15 c	4.37
D.PVC plastic wrap	32.87	26.40	26.40	28.56 c	3.73
E.Alginate membrane (Fixed paramter)	109.49	108.93	108.75	109.06 a	0.39

(A. Eco friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap, E. Alginate membrane)

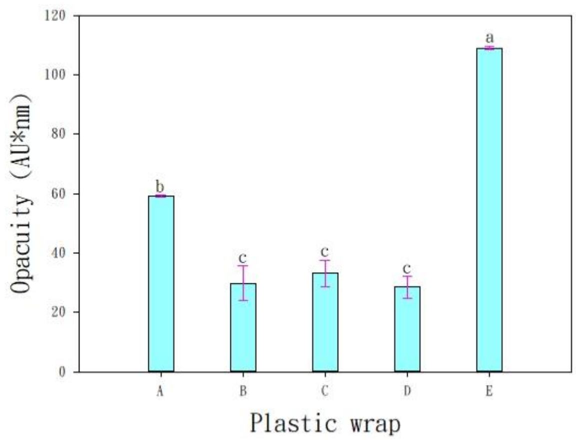
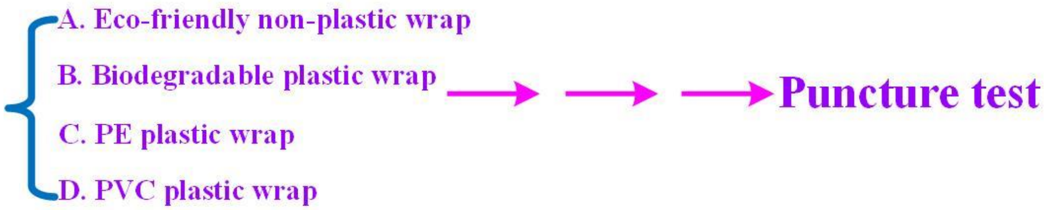


Figure 20. Opacity of various plastic wraps.

Discussion

The lower the value of opacity was, the better transparency of the plastic wrap would be. Because the glycerin didn't add in the algin (the fixed parameter), the opacity of it was obviously the highest, that was, the transparency was the worst. Although opacity of eco-friendly non-plastic wrap was higher than that of the other three plastic wraps (sample B, sample C, and sample D), its transparency was good enough with the observation of naked eye. Hence, the transparency of "eco-friendly non-plastic wrap" had initially reached commercial levels.

3.3.2 Puncture test

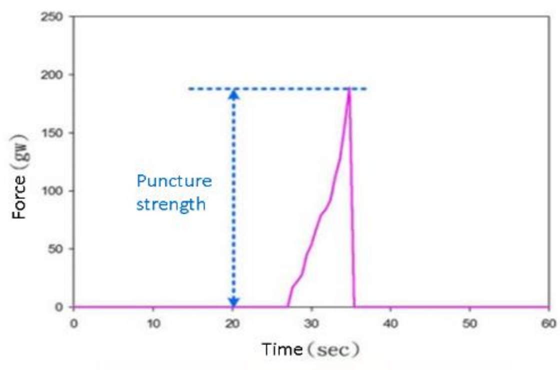


The test of puncture strength was regulated by CNS, we planned to test various plastic wrap to evaluate whether eco-friendly non-plastic wrap had practical value.

Procedure

1. Independent variables: eco-friendly non-plastic wrap, biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap.
2. According to *Bureau of Standards, Metrology and Inspection(2011)*, we did the puncture test of plastic wrap based on **CNS 10481, Z5131**.
3. Homemade physical property meter: install the force gauge which could control up and down accurately, precision ±0.01mm, in the direction of the Z-axis movement of the CNC engraving machine. With the coding to control the movement of the Z axis, we could operate the force gauge. The data is transferred to the computer by connecting the force gauge to the computer [Fig. 21 (A)].
4. Cut the sample to a suitable size and put on the stainless-steel base, and then use clips to fix it. Install a measuring needle (a spherical probe with a diameter of 1mm) at the speed of 0.8mm/ min and execute the program to puncture the sample vertically. [Fig. 21 (B,C)]

Figure 21. Puncture test with homemade physical property meter



5. During the test, puncture the membrane made the force change. We got the data and graph of "time-force" with the computer. After data analysis, the maximum stress value (peak value) is obtained as the "puncture strength", as shown in the right figure.

6. Follow the previous **experiment 3.3.2** step 5.

Results

Using the homemade physical property meter, we are able to apply puncture test on various plastic wraps for evaluation. The continuous images of the puncture test were shown in Figure 22.

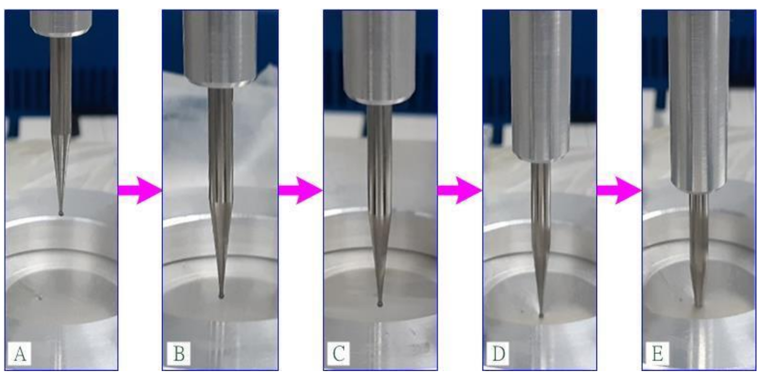


Figure 22. Continuous images of the puncture test

We initially learned that the wave peaks (maximum stress value) of the Eco-friendly non-plastic wrap and PVC plastic wrap were higher; while the maximum stress values of the biodegradable plastic wrap and PE plastic wrap were lower, as shown in Figure 23.

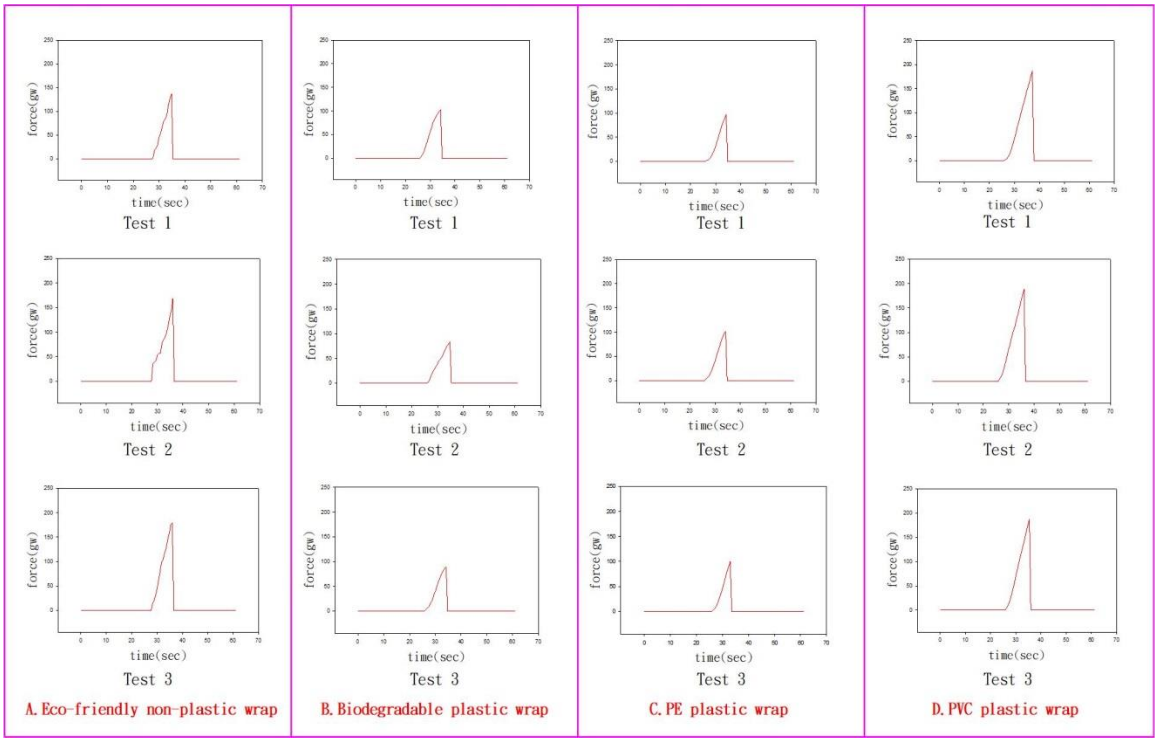


Figure 23. Puncture test on different plastic wraps (time-force graph).

The puncture strength of eco-friendly non-plastic wrap and PVC plastic wrap was stronger than that of biodegradable plastic wrap and PE plastic wrap. (Table 6 and Fig. 24)

Table 6. Puncture test on different plastic wraps

Plastic wrap	Force (gw)				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. Eco-friendly non-plastic film	137	169	179	161[a]	21.94
B. Biodegradable plastic wrap	103	83	89	91[b]	10.26
C. PE plastic wrap	97	101	100	99[b]	2.08
D. PVC plastic wrap	187	188	187	187[a]	0.58

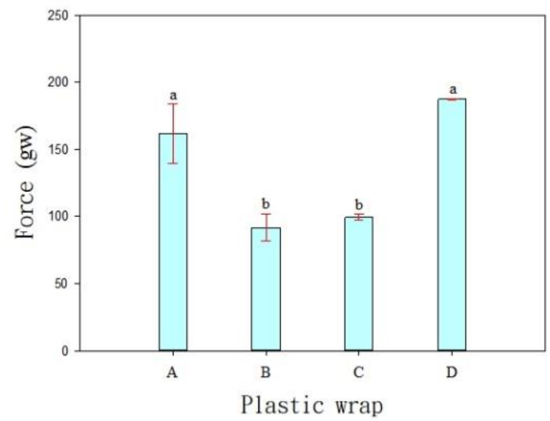


Figure 24. Puncture test on different plastic wraps

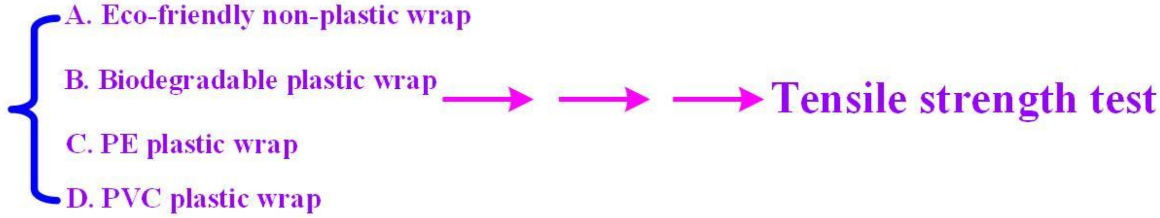
(A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap, E. Alginate membrane)

Discussion

Polyvinyl chloride (PVC) was the only plastic containing chlorides among five common plastics (PE, PVC, PP, PS, and ABS) and its texture would not be softer if it didn't add the plasticizer. Plasticizer made PVC plastic wrap have better viscosity, which lead to dissolving plasticizer when microwave or packaging food. Furthermore, it would produce dioxin when burning PVC plastic wrap. Environmental Protection Administration, Executive Yuan had planned to announce the draft prohibiting the manufacture, the import, and retail sales of PVC and PVDC plastic wrap. *(Toxic and Chemical Substances Bureau, EPA, Executive Yuan, 2000)*

The puncture strength of eco-friendly non-plastic wrap is significantly stronger than that of PE plastic wrap which is common in the market recently. We learned the puncture strength of both had significantly difference (95% confidence level), which indicated the "eco-friendly non-plastic wrap" had initially reached commercial level.

3.3.3 Tensile strength test



The test of tensile strength was regulated by CNS, we planned to test different plastic wraps to evaluate whether eco-friendly non-plastic wrap had potential for practical application.

Procedure

1. Independent variables: Eco-friendly non-plastic wrap, Biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap.

2. According to *Bureau of Standards, Metrology and Inspection(2011)*, we did the tensile test of plastic wrap based on **CNS 10481, Z5131**.

3. Cut the sample to a suitable size and put on the stainless-steel base, and then use clips to fix it. [Fig. 25(A)]

4. Connect the force gauge to the computer and execute the program to start the test (Setting the initial distance: 50mm and the stretching speed: 200 mm per minute). The force gauge would exert tensile stress until the sample broken.[Fig. 25(E)] Start tensile test, the clipper would exert tensile stress until sample broken.

5. During the test, stretching the membrane made the force change. We got the "time-force" data and graph with the computer. After data analysis, the maximum tensile stress (peak value) is obtained as the " tensile strength". In addition, we calculated the stretch length of the samples = stretch speed x stretch time.

6. Follow the previous **experiment 3.3.2** step 5.

Results

Using the homemade physical property meter, we were able to apply tensile test on different plastic wraps for evaluation. The continuous images of the tensile test were shown in Figure 25.

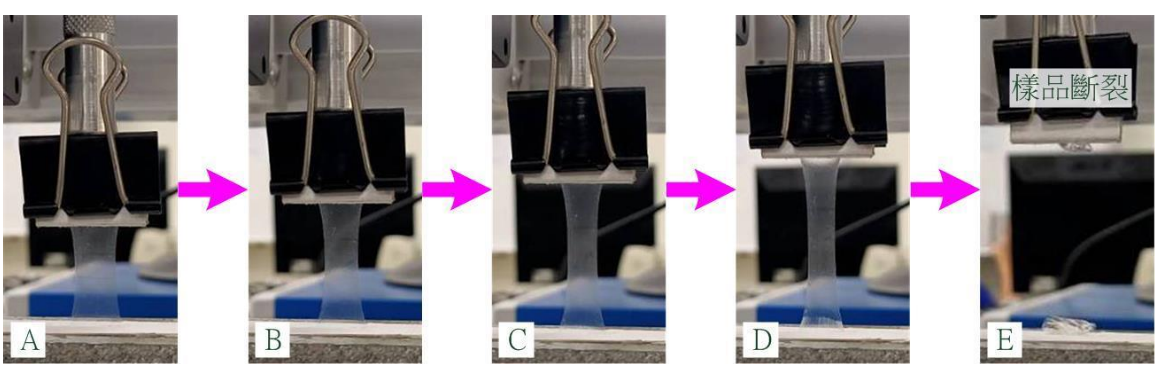


Figure 25. Continuous images of the tensile test

We could initially arrange the peak (maximum tensile stress) from high to low: PVC plastic wrap, biodegradable plastic wrap, PE plastic wrap, and eco-friendly non-plastic wrap (Fig. 26).

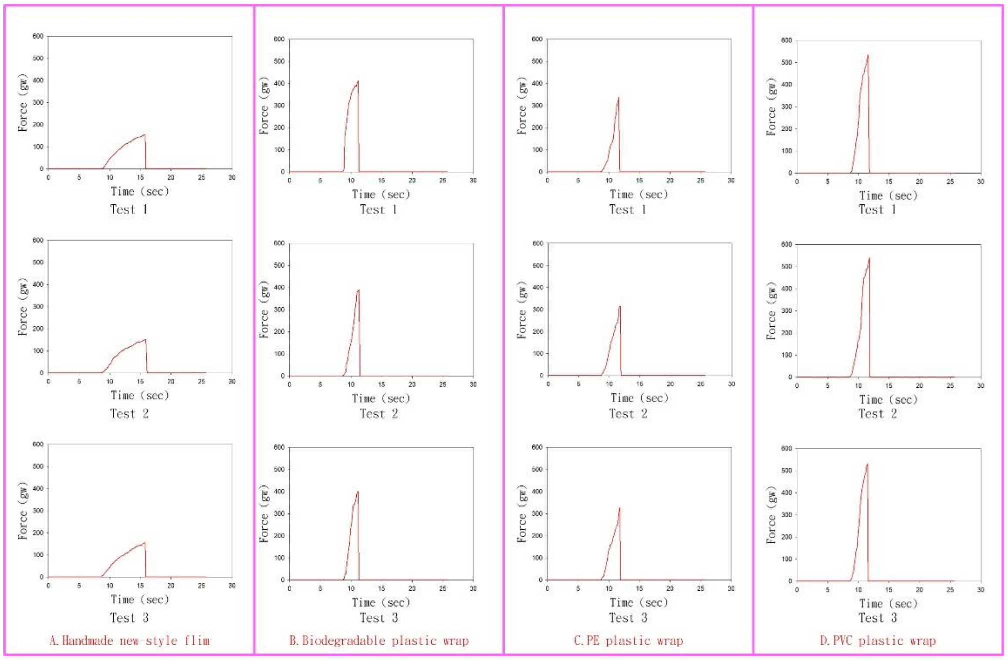


Figure 26. Tensile strength of different plastic wraps

The tensile strength of PVC plastic wrap was the strongest; while the eco-friendly non-plastic wrap was the weakest (Table 7 and Fig. 27). We could know that the tensile strength of all samples had significantly differences (95% confidence level) and that the stretch length of all samples had few differences (95% confidence level).

Table 7. Tensile strength test of various plastic wraps

Plastic wrap	Force (gw)				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. Eco-friendly non-plastic film	156	151	155	154 d	3
B. Biodegradable plastic wrap	412	390	401	401 b	11
C. PE plastic wrap	337	314	328	326 c	12
D. PVC plastic wrap	535	540	532	536 a	4

Table 8. Stretch length test of various plastic wraps

Plastic wrap	Length (mm)				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. Eco-friendly non-plastic film	29.67	33.67	31.16	31.50 a	2.02
B. Biodegradable plastic wrap	29.67	23.67	25.67	26.33 a	3.06
C. PE plastic wrap	19.67	19.67	24.00	21.11 a	2.50
D. PVC plastic wrap	21.67	26.33	45.33	31.11 a	12.54

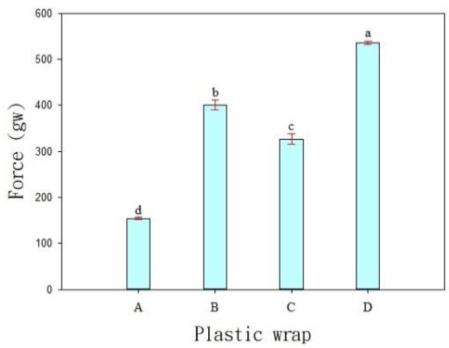


Figure 27. Tensile strength of plastic wraps

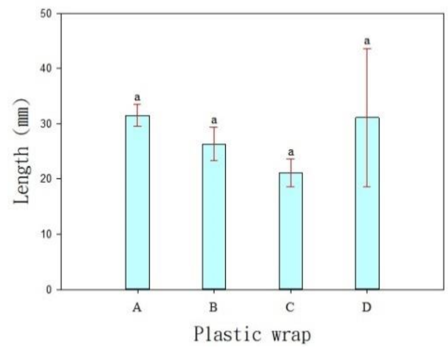


Figure 28. Stretch length of plastic wraps

(A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap, E. Alginate membrane)

Discussion

This experiment proved PVC plastic wrap tensile strength was the best, according to the information released by Toxic and Chemical Substances Bureau, Executive Yuan, PVC plastic wrap had less breakage, better viscosity, and better transparency. Therefore, fresh fruits, vegetables and meat sold in the supermarkets usually used it. Despite its advantages, considering food safety and environmental issues, it is still a future trend to ban it.

Through the results, we learned that the stretch length of the "Eco-friendly non-plastic wrap" was similar to that of three plastic wraps. We knew that the stretch length of those samples wasn’t significantly different (confidence level 95%), which indicated the "Eco-friendly non-plastic wrap" had initially reached the level of commercialization.

3.3.4 Heat resistant test

The test of tensile strength was regulated by CNS, we planned to test different plastic wraps to evaluate whether eco-friendly non-plastic wrap had potential for practical application.

Procedure

1. Control group: A. Unheated eco-friendly non-plastic wrap. Independent variables: eco-friendly non-plastic wrap in different temperatures (B. 90℃, C. 100℃, D.110℃, E. 120℃, F. 130℃).
2. Cut the eco-friendly non-plastic wrap into 3 test pieces of 3cm x 14cm.
3. Fixed the upper ends of the sample on the double-sided tape of the long cardboard, keeping apart from each in 5cm width. Clamp the lower ends of it between 2 short cardboards, and attach the upper part with the another long cardboard.
4. Use the clamp to fix the upper ends of the combination on the appropriate iron frame and place it in the constant temperature cabinet with pre-adjusted heat resistant temperature.
5. After 1 hour, take out the combination and cool down for 30 minutes.
6. Measure the L, a, b values of the samples after heating with the color difference meter, and then use a standard white board as the benchmark (L=100, a=0, b=0) to calculate the difference.

Results

When the temperature reached to 130°C, the eco-friendly non-plastic wrap still didn't break, which presented that the eco-friendly non-plastic wrap had enough heat resistance. (Fig. 29)

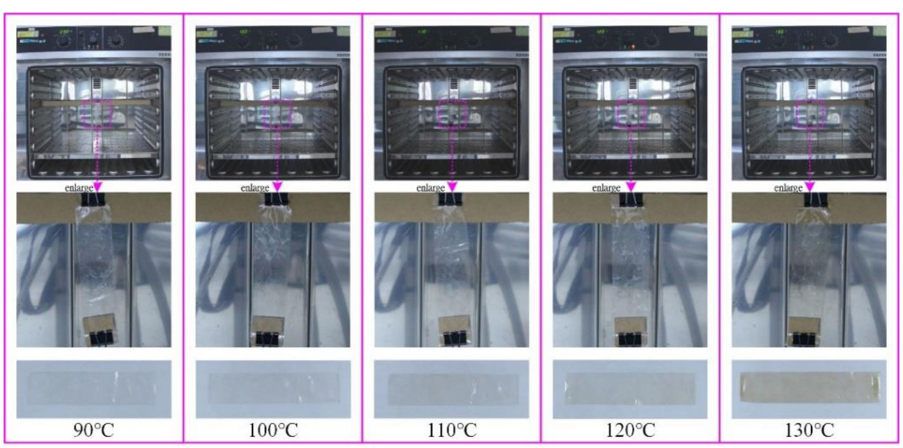


Figure 29. The change of temperature on the color of the eco-friendly non-plastic wrap

The appearance of eco-friendly non-plastic wrap was complete at different temperatures, but as the temperature increased, the color of it increased, especially at 130°C (Control group: The unheated eco-friendly non-plastic wrap).

When it reached to 100°C, there were significant difference between the tested eco-friendly non-plastic wrap and control group.(As shown on Fig. 30 and Fig.31)

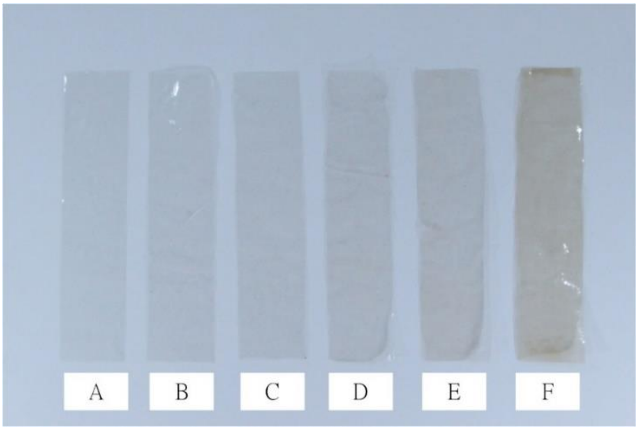


Figure 30. The change of temperature on the color of the eco-friendly non-plastic wrap

(A. Unheated eco-friendly non-plastic wrap, B. 90℃, C. 100℃, D.110℃, E. 120℃, F. 130℃)

Table 9. The different temperatures on the color difference of the eco-friendly non-plastic wrap

Sample	Color difference(△Eab)				
	Test 1	Test 2	Test 3	Average	Standard
A:Control group	0.59	0.67	0.81	0.69 e	0.11
B:90℃	0.75	0.96	0.69	0.80 e	0.14
C:100℃	1.86	1.94	2.07	1.96 d	0.11
D:110℃	3.90	3.96	4.26	4.04 c	0.19
E:120℃	5.79	5.98	6.54	6.10 b	0.39
F:130℃	10.03	10.96	11.11	10.70 a	0.59

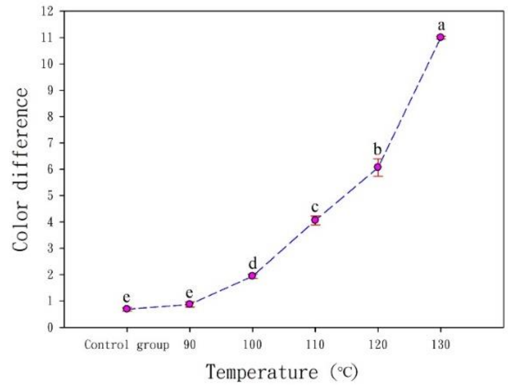
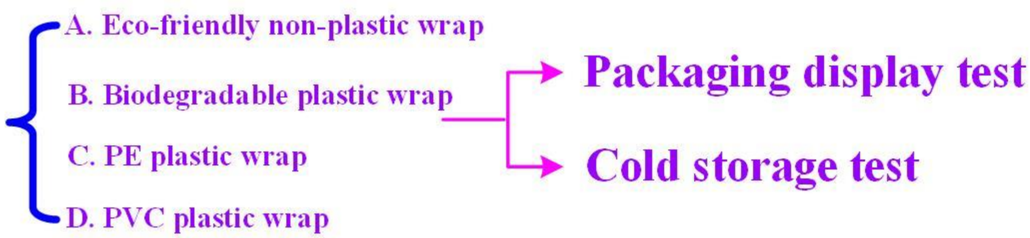


Figure 31. The different temperatures on the color difference of the eco-friendly non-plastic wrap

3.4 Practical test of eco-friendly non-plastic wrap

3.4.1 Cold storage test



We tried to package fruits and vegetables with different kinds of plastic wraps to conduct visual difference test and cold storage test. The main purpose of packaging fruits and vegetables with plastic wrap was to prevent water loss and ensure that fruits and vegetables remain fresh, or it would cause food sanitation and safety concerns.

Procedure

1. Independent variables: A.Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap.
2. Packaging display test: distribute the fresh fruits and vegetables into the containers, cover each container with eco-friendly non-plastic wrap, biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap. Observe and record the packaging display to see if there is any different.
3. Cold storage test: choose fresh vegetables to distribute into the containers, wrap them with eco-friendly non-plastic wrap, biodegradable plastic wrap, PE plastic wrap, and

PVC plastic wrap. Place the samples in the refrigerator for 24 hours. Observe and record the changes before and after the test. Fixed parameter: uncoated container.

Results

There is no difference among these samples. With the observation of naked eye, the difference was indistinguishable (Fig. 32).

A. Eco-friendly non-plastic wrap

B. Biodegradable plastic wrap

C. PE plastic wrap

D. PVC plastic wrap

Figure 32. Packaging display test of different plastic wraps

After the samples were refrigerated for 24 hours, the leaves that were not covered with plastic wrap were significantly shrunk, but those covered with plastic wraps didn't shrink. The effects of cold preservation was satisfying (Fig. 33).

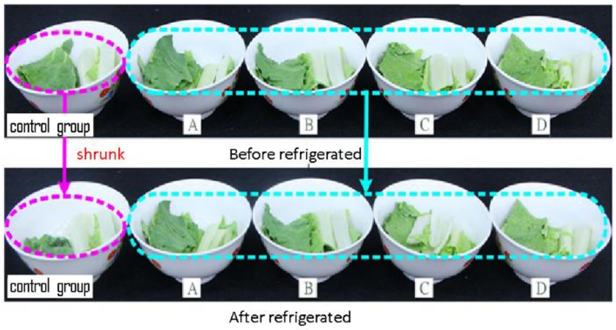


Figure 33. Cold storage test of different plastic wraps

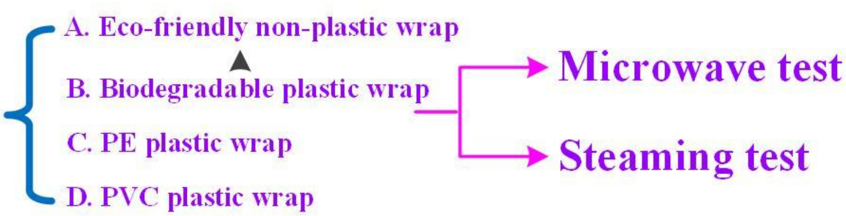
(A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap)

Discussion

In the packaging applications, the “eco-friendly non-plastic wrap” was very similar to other kinds of plastic wraps, which also had the packaging function. The effect of visual packaging was good.

We conducted cold storage test with "eco-friendly non-plastic wrap" and other kinds of plastic wraps. With low temperature testing in refrigeration for 24 hours, it has proved that the effect of eco-friendly non-plastic wrap was as satisfactory as that of various plastic wraps.

3.4.2 Microwave and steaming test



Plasticizers contained with food might leach out from food packaging, plastic wraps or containers. Moreover, microwaving or steaming with packaging food at high fat or high temperature, the plasticizers are much easier to release from the packaging. This experiment applied microwave and steaming test to the "eco-friendly non-plastic wrap", which verified whether it had the practical value.

Procedure

1. Steaming test: put the meat into the container and wrap it with "Eco-friendly non-plastic wrap". Before using the steam cooker, add a cup of water to the outer pot and press the switch. After steaming, take out sample and observe the changes.

2. Microwave test: prepare a boxed meal, wrap it with "eco-friendly non-plastic wrap" and heat it in a microwave. After heating for 3 minutes, take out the sample and observe the changes of the "eco-friendly non-plastic wrap."

Results

After steaming, eco-friendly non-plastic wrap was quite complete (Fig. 34).

A. Before steaming B. Steam with the electric pot C. After steaming

Figure 34. Steaming test: cover the container with eco-friendly non-plastic wrap

After microwave, eco-friendly non-plastic wrap was quite complete (Fig. 35).

A. Before microwaving B. Microwaving C. After microwaving

Figure 35. Microwave test: cover the boxed meal with eco-friendly non-plastic wrap

Discussion

Whether microwaving and steaming, the "eco-friendly non-plastic wrap" could withstand the high temperature and pressure, and the film remained complete after heating.

Plastic wraps were all made of plastic ingredients. The biggest disadvantage was the public worried about food safety due to lipid exposure and heating process. Unlike plastic wrap, "eco-friendly non-plastic wrap" had no plastic ingredients at all and could be used to pack food. Therefore, eco-friendly non-plastic wrap has no food safety problems.

3.4.3 Storage ability test

We tried to test the water content and water activity of the "eco-friendly non-plastic wrap", assessing whether the "eco-friendly non-plastic wrap" had good storage property.

Procedure

1. Independent variables: drying time (an hour, a day, a week)
2. According to *Bureau of Standards, Metrology and Inspection(2011)*, we did the determination of moisture(air-oven method)based on **CNS 5033, Z6114**.
3. Wash the weighing bottle and dry it to make sure the weight was fixed. Accurately weigh 2 g sample and place it in the weighing bottle. After drying for 2 hours in an oven at 110°C, take it out of the desiccator. Cool down the sample and weigh it.

$$water\ content(\%) = \frac{(b-c)}{(b-a)} \times 100\%$$

a：weight of weighing bottle(g), b：weight of weighing bottle and sample(g), c：fixed weight of weighing bottle and dry sample(g)

Results

After we dried eco-friendly non-plastic wrap, the more time we put samples in normal temperature, the less water content they would be (Table 10 and Fig. 36).

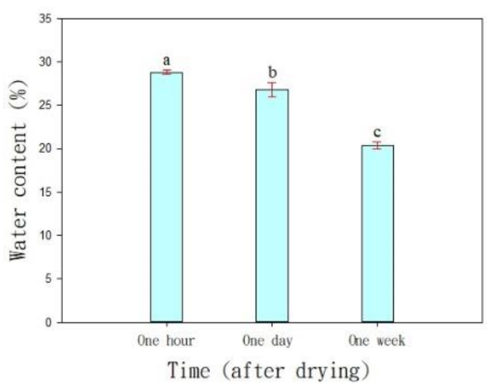
Table 10. Different time effecting the water content of plastic wrap

Plastic wrap	Water Content (％)				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. An hour after dry	28.73	28.56	29.12	28.80 a	0.23
B.A day after dry	27.81	26.81	25.83	26.82 b	0.81
C.A week after dry	19.97	20.22	20.95	20.38 c	0.41

The more time we put samples in normal temperature, the fewer water activity they would be (Table 11 and Fig. 37). The water content of drying eco-friendly non-plastic wrap for one hour in normal temperature was 28.80% and the water activity of that was 0.532. After one week, the water content was 20.38% and the water activity of that was 0.461.

Table 11. Different time effecting the water activity of plastic wrap

Plastic wrap	Water Activity				
	Test 1	Test 2	Test 3	Average	Standard deviation
A. An hour after dry	0.532	0.534	0.529	0.532 a	0.002
B. A day after dry	0.508	0.506	0.502	0.505 b	0.002
C. A week after dry	0.459	0.463	0.462	0.461 c	0.002



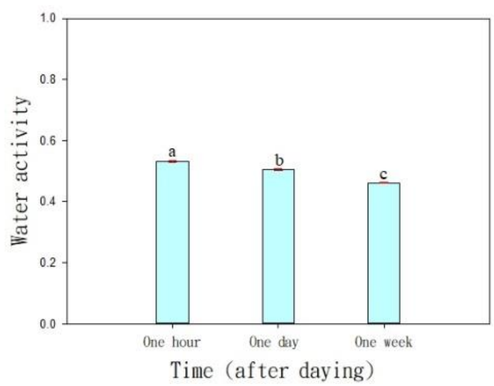


Figure 36. Different time effecting the water content **Figure 37.** Different time effecting the water activity

Discussion

As stated above, we learned that water activity were all much less than 0.6. The more time we put samples in normal temperature, the fewer water activity and the less water content they would be. This phenomenon would benefit to promote its storage time.

3.4.4 Corruptibility test

We compared eco-friendly non-plastic wrap with biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap in the test to prove it was eco-friendly and easy to decompose.

Procedure

1. Independent variables: A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap.
2. Split eco-friendly non-plastic wrap, biodegradable plastic wrap, PE plastic wrap, and PVC plastic wrap into two groups (Buried / Not buried) to test their corruptibility.
3. Buried test: the four kinds of plastic wraps were buried in soil. We observed and recorded the changes of them after three weeks. Not buried test: the four kinds of plastic wrap were put flat on the soil, we observed and recorded the changes of them exposing to nature environment every day.

Results

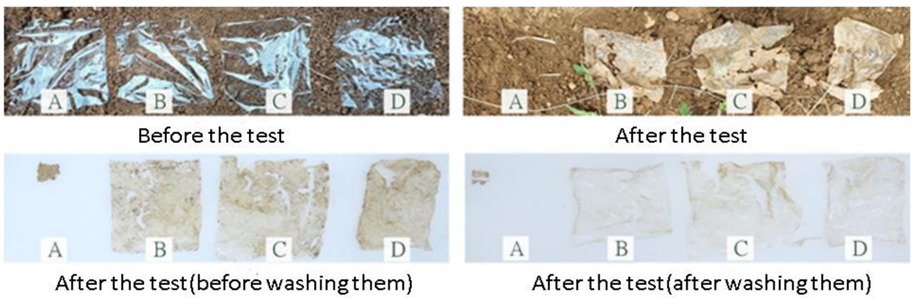


Figure 38. The corrupting changes of the plastic wraps (Buried test).

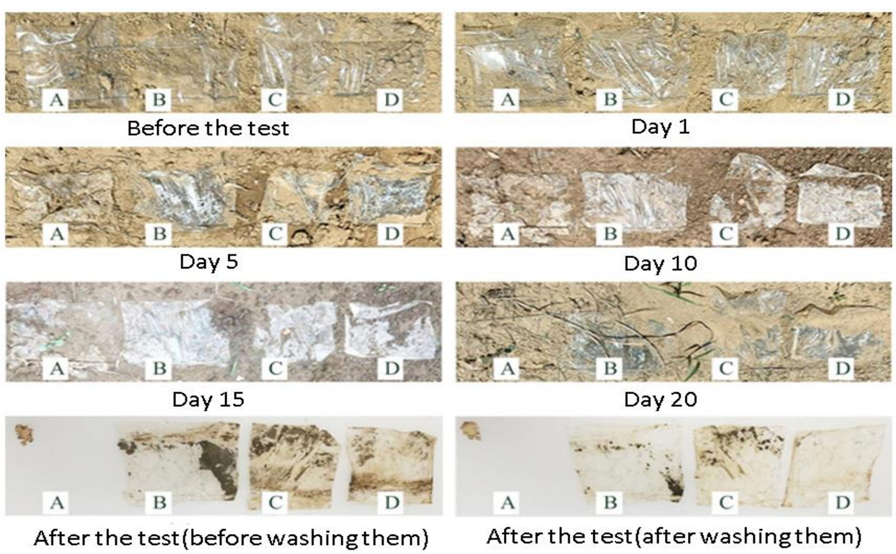


Figure 39. The corrupting changes of the plastic wraps (Unburied test).

(A. Eco-friendly non-plastic wrap, B. Biodegradable plastic wrap, C. PE plastic wrap, D. PVC plastic wrap)

Samples of B, C, and D were all slightly damaged, but the appearance was almost complete, and the corruption was not obvious; while eco-friendly non-plastic could not be identified with the observation of naked eye (Fig. 38). Samples of B, C, and D were all slightly damaged, but the appearance was almost complete, and the corruption was not obvious. By contrast, there were only some putrescible fragments of eco-friendly non-plastic wrap remained (Fig. 39).

Discussion

Burying test proved that the characteristic of "eco-friendly non-plastic wrap" was far superior to the three plastic wraps. It was an eco-friendly material.

The biodegradable plastic wrap used in this research was mainly made of low-density PE and added with decomposing particles. However, in the buried test, the corruptibility was not ideal. In fact, many products that advertised decomposable plastic certification needed to be decomposed in 90 days under high temperature and humidity.

Many plastic wraps on the market advertised "biodegradable" which didn’t really mean "decomposed" at all. The main material was usually PE that would cracked into plastic particles and caused environmental hazard. Furthermore, plastic particles might be ingested by small organisms and went through the food chain to large organisms. As a result, human beings would eat up what they produced. Thus, it was already the global trend of environmental protection in the future to carry out the ban on plastics.

4. Conclusion

4.1 Processing of making non-plastic films

【Experiment 3.1.1】

Whether the concentration of paste was high or low, various glutinous rice films were breakable during the cutting process. Only 15% glutinous rice film had a relatively complete appearance after demolding and cutting.

【Experiment 3.1.2】

The improved glutinous rice film had a soft texture, flexibility, hard to break. It had a complete appearance after cutting. These properties could increase the product value.

【Experiment 3.1.3】

2% sodium alginate had better transparency and slightly harder texture than glutinous rice film. It maintained a complete appearance after cutting, but with external force, it might crack, there had room to improve. Furthermore, we established a new procedure.

【Experiment 3.1.4】

"Eco-friendly non-plastic wrap" used sodium alginate as the main raw material and added glycerin and acetic acid improved its properties. Glycerin and acetic acid were the key point. "Eco-friendly non-plastic wrap" had good characteristic which were similar to plastic wraps, that was, it had market value.

4.2 Discussion on key components of membrane

【Experiment 3.2.1】

The glycerin viscosity in different concentrations changed a little and the values were all in the range of 2000cP~3000cP. There were slight effects among different concentrations of glycerin on paste viscosity.

【Experiment 3.2.2】

The transparency, strechability, and flexibility of the membrane would increase due to the increasing amount of the glycerin. But it was a flaw that the strength of membranes would decrease with more glycerin. Considering to the strength of membranes, 2g glycerin was the better ratio to make an ideal film in practical applications.

【Experiment 3.2.3】

Increasing amount of acetic acid showed a linear growth in viscosity of the membrane, but the differences are not easy to pick an optimal parameter for the research. So, we couldn't determine how much acetic acid in algin in this experiment.

【Experiment 3.2.4】

It was hard to determine any difference among them with the observation of naked eye. With external force, we learned that the strength of 1.5g acetic acid in membrnae wasn't too weak, and it had better stretchability than 2g or 2.5g acetic acid in membranes.

【Experiment 3.2.5】

It showed a significant increase in viscosity when acetic acid reached 2g or more, and bubbles increased. 1.5g acetic acid was the best ratio because its viscosity hadn't change a lot and the bubbles in it could eliminate easily.

【Experiment 3.2.6】

We found out that 2% algin, 2g glycerin, and 1.5g acetic acid were an appropriate proportional for making eco-friendly non-plastic wrap. The characteristics of membrane were much similar to commercial plastic wraps which had the practical use. Hence, we defined it as the ingredients of "eco-friendly non-plastic wrap."

4.3 Discussion on the physical properties of non-plastic wrap

【Experiment 3.3.1】

"Eco-friendly non-plastic wrap" had higher opacity than other wraps, but its transparency retained in clear condition under the observation of naked eye. Hence, the eco-friendly non-plastic wrap can reach commercial level.

【Experiment 3.3.2】

"Eco-friendly non-plastic wrap" puncture strength was better than the common-used PE plastic wrap on the market.

【Experiment 3.3.3】

"Eco-friendly non-plastic wrap" had the lowest tensile strength, but its elongation was similar to other plastic wraps. "Eco-friendly non-plastic wrap" has reached commercial performance.

【Experiment 3.3.4】

"Eco-friendly non-plastic wrap" could resistant high temperature, "Eco-friendly non-plastic wrap" has reached commercial performance.

4.4 Practical test of eco-friendly non-plastic wrap

【Experiment 3.4.1】

"Eco-friendly non-plastic wrap" had good packaging visual effect, and it was indistinguishable with the observation of naked eye. In the cold storage experiment, coated vegetables proved that the "eco-friendly non-plastic wrap" had potential to practical use.

【Experiment 3.4.2】

Because of non-plastic ingredients, the non-plastic wrap is able to heat or microwave food without release of plasticizers. Thus, there is no need to concerns of the food safety problem caused by the contact with oil and heat.

【Experiment 3.4.3】

The water activity decreased after placed it for a period of time. The water activity is less than 0.6, so it can prevent the growth of microorganisms.

【Experiment 3.4.4】

"Eco-friendly non-plastic wrap" corrupted after burying tests. It proved that "eco-friendly non-plastic wrap" was an environment friendly product.

4.5 Contributions

1. This research successfully developed an innovative producing process to make eco-friendly non-plastic wrap.
2. This research developed "eco-friendly non-plastic wrap" that can solve the food safety concerns of plasticizers or toxic substances caused by contact with grease or heat treatment.
3. This research developed a new type of eco-friendly non-plastic wrap that can be "decomposed" and is extremely friendly to the ecological environment.

References

1. Aonomus (2011). Chemistry Corner – Bioplastics. Youtube 網站(https://reurl.cc/e8p7pK)
2. Arshad Mehmood Abbasi, Munir Hussain Shah, Mir Ajab KhanWild (2014). Edible Vegetables of Lesser Himalayas: Ethnobotanical and nutraceutical, volume 1 (https://reurl.cc/Y6DR4a)
3. Axelsson J, Rylander L, Rignell-Hydbom A, Jönsson BA, Lindh CH, Giwercman A (2015). Phthalate exposure and reproductive parameters in young men from the general Swedish population. (https://reurl.cc/1487XD)
4. Chengcheng Gao, Eric Pollet, Luc Avérous (2016). Properties of glycerol-plasticized alginate films obtained by thermo-mechanical mixing https://www.sciencedirect.com/science/article/abs/pii/S0268005X16304337
5. Jong-WhanRhim (2004). Physical and mechanical properties of water resistant sodium alginate films (https://reurl.cc/Ld2LQ4)
6. Kanishka Bhunia, Shyam S. Sablani, Juming Tang ,Barbara Rasco (2013). Migration of Chemical Compounds from Packaging Polymers during Microwave, Conventional Heat Treatment, and Storage (https://reurl.cc/VX2QYY)
7. Kawan Soetanto, Man Chan and Motoyoshi Okujima (1996). Effect of Calcium Chloride on Sodium Alginate Microbubbles as Ultrasound Contrast Agent (https://reurl.cc/n0p4Yd)
8. Kuen Yong Lee, David J. Mooney (2012). Alginate: properties and biomedical applications (https://reurl.cc/odv4VD)
9. Leonel Pereira and João Cotas (2019). Introductory Chapter: Alginates - A General Overview (https://reurl.cc/8neLX7)
10. Lin Yizhen, Lin Yingshi, Lin Yixiu (2020). Process of making a new environmental friendly straw. 2020 Taiwan International Science Fair second place project (https://www.shs.edu.tw/works/essay/2015/03/2015032816334126.pdf)
11. Mei-Lien Chen, Jing-Shieng Chen, Chia-Ling Tang, I-Fang Mao (2008). The internal exposure of Taiwanese to phthalate--an evidence of intensive use of plastic materials (https://reurl.cc/pyp4aQ)
12. Otto G. Piringer, A. L. Baner (2008). Plastic Packaging Materials for Food: Barrier Function, Mass Transport, Quality Assurance, and Legislation (https://reurl.cc/0OmlWx)

13. Tugce Senturk Parreidt, Kajetan Müller, Markus Schmid (2018). Alginate-Based Edible Films and Coatings for Food Packaging Applications (https://reurl.cc/n0p4ql)

14. Water structure and science (2003). (http://www1.lsbu.ac.uk/water/water_activity.html)

15. Xu-Liang Cao (2009). Phthalate Esters in Foods: Sources, Occurrence, and Analytical Methods (https://reurl.cc/VX2QYZ)

16. 吳冠良（2019）。市售加工食品中鄰苯二甲酸酯濃度調查與國人暴露風險評估研究。國立成功大學環境醫學研究所碩士學位論文。

17. Greenpeace 綠色和平（2019）。超市要減塑，具體該做的 5 件事。(https://reurl.cc/m9p4z9)

18. 方柏翔（2015）。不同界面活性劑對糖質克弗爾多醣／小麥澱粉 可食膜物理性質的影響。國立中興大學 食品暨應用生物科技學系碩士學位論文。

19. 呂秀英（2011）。正確使用統計圖表呈現處理間比較台灣農業研究。台灣農業研究 60 (1)：p61–71。

20. 經濟部標準檢驗局（1984）。食品中水分之檢驗方法。中華民國國家標準(CNS 5033 N6114)。

21. 經濟部標準檢驗局（2011）。食品包裝用塑膠薄膜通則。中華民國國家標準(CNS 10481, Z5131)。

22. 衛生福利部（2016）。食品器具、食品容器或包裝標示相關規定。衛生福利部公告，部授食字第 1041304938 號。

23. 環境保護署毒物及化學物質局 綜合規劃組（2000）。PE 保鮮膜可取代 PVC 業者：努力改良。持久性有機污染物(POPs)資訊網站。(https://reurl.cc/EzmLY0)

24. 方奕、邱翔澤、林俊維、李奕德、陳信叡（2012）。神奇的糯米紙。中華民國第 52 屆中小學科學展覽會優勝作品。

25. 環境保護署毒物及化學物質局 綜合規劃組（2000）。戴奧辛之源 環署擬禁用 PVC 保鮮膜。持久性有機污染物(POPs)資訊網站。取自(https://reurl.cc/Md2L9k)

26. 陳靜、張柏豪、張曉婷（2015）。海藻酸鈉的奧秘。取自 https://www.shs.edu.tw/works/essay/2015/03/2015032816334126.pdf

Appendix

Thickness test

In this test, we measured the membranes thickness to ensure it wouldn't influence the properties of membrane.

Procedure

1. Draw a regular circle on each membrane.Divide the prepared circular membrane into eight sectors with the center of circle. Take one point on each sector and the center of circle, totally nine points.
2. Measure each point thickness with micrometer caliper.
3. Calculate the average of nine points. Repeat it in three samples.
4. Use Excel and xlstat software to analyze statistical data and determine whether the opacity of each sample was significantly different (confidence level95%) and use SigmaPlot software to make the graphic.

Results

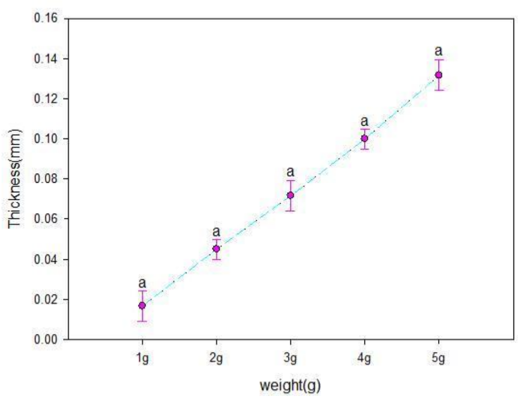


Figure 1 The membranes thickness in different glycerin concentrations.

We could know that when there was more glycerin added in the algin, the membranes would be thicker. Also, it showed a regular linear growth. Through statistical analysis, we knew that there was no significant difference among all kinds of membranes(Fig. 1).

Discussion

Glycerin had water binding capacity which meant after drying in 4hr at 50°C, the algin might hold water in and lead to thickness increase. Considering to other mechanical properties of the membranes, we would choose 2g glycerin which had better properties(experiment 2.2.1 and 2.2.2) was also not too thick or thin that influenced the appearance.

【評語】200013

本作品以海藻膠製成可應用於食品包裝的非塑性保鮮膜替代品，探討最佳的甘油、醋酸之添加成分，以獲得較理想薄膜柔軟度、透明度、拉伸強度及伸長率等。對與環境工程之關連性說明，除腐化實驗外，建議可再加強之。