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Development of Biodegradable Food Packaging Incorporated with Pigment of Rose and Red Cabbage

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Abstract: Food packaging is essential for maintaining the quality and safety of food. Excessive food packaging made of plastics could be harmful to the environment. Plastic food packaging takes a long period of time to biodegrade while most of them do not biodegrade and are harmful to the environment. To improve the properties of packaging and extend the shelf-life of packaged food, development of biodegradable food packaging is implemented by using natural and renewable resources for the main materials such as extracts from plants due to its ability to decompose and biodegrade in a short time. In this case, biodegradable polymers and films are needed to reduce the external influence of environment such as oxygen and moisture. In this paper, the usage of red cabbage and rose as pH indicator was introduced through extractions using solvents of ethanol and water. The production of film for packaging incorporates starch and chitosan solution and were compared with commercial packaging. Each of the samples or rose and red cabbage were used for the preparation of film by using hot press method. This paper will examine the results of chemical properties such as interaction in the mixture by using FTIR and biodegradability of the film, mechanical properties like tensile strength, and physical properties like pH, colour and the thickness of the film. Commercial packaging gave a better result in term of tensile strength and biodegradability. It also showed that rose is better than red cabbage in terms of preventing food spoilage. The FTIR results for all samples were quite similar as all the peaks fall into a single bond region.

Keywords: Food packaging, pH indicator, physical properties, chemical properties, mechanical properties

1. Introduction

Food packaging is essential in maintaining the quality and safety of packaged food without the occurrence of any spoilage. It can also be used to store food effectively. Food packaging is created for a purpose of containment like a food container or as a wrapper to prevent spoilage of food. Food packaging contributes to the advantages of minimizing environmental impact and secure the safety and health of consumers. It has a function of containment which food need to be contained before they were moved from one place to another place. It prevents any losses from the myriad of the food. It is also used as a protection which known as preservation process as it can extend the shelf-life of food. Food packaging protect food from outer effects such as water vapor, odors and microorganisms. Food packaging has a characteristic of oxygen permeability which contributes to the extending of shelf life of food. Food packaging has a function of making it easier for the users to simply use their food without removing any packaged if they want to reheat the food. Packaging makes the products can be used conveniently. Food packaging contributes to the process of marketing and create a communication between consumers and manufacturer [1].

Food packaging implied to avoid food losses especially among fresh fruit and vegetables which is considered as perishable food. Waste of foods can be reduced through implementation of food packaging [2]. Packaging has its own role in food industry to minimize negative impacts. To prevent any of it happens, food packaging is created based on

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many types of packaging materials such as plastic, paper and cardboard, metal, and glass. Plastic films in food packaging is used to maintain the nutritious of food and the sensory quality. Plastic films include laminated aluminium foil (LAF), polyethylene (PE), polypropylene (PP), low density polyethylene (LDPE) and high density polyethylene (HDPE). Meanwhile, paper and cardboard are made from cellulose fibres extracted from wood. To overcome a poor barrier property of paper, paper can be improved by coating method. Paperboard packaging usually will be used in horticultural industry that produce fruit and vegetables. Metal has a good physical protection. Two main metals used in food industry were aluminium for carbonated beverages and steel for processed foods. Glass is commonly used for packaging of processed foods that need moisture and oxygen barriers. Glass packaging has an advantage of withstanding carbon dioxide pressure [3].

Biodegradable means the ability of substances to break down after disposal. Biodegradable food packaging is made from renewable resources such as fruits and vegetables. Biodegradable and renewable resources are important aspect in producing food packaging. Non-biodegradable and non-renewable materials gave a solution to the researchers on the usage of biopolymers in development of intelligent food packaging [4]. Biodegradable polymers such as starch contributes to the development of biodegradable food packaging. Bioplastics have been used in food packaging such as bio-based polymers that will be extracted from plants, biodegradable plastics made from natural resources, oxo-biodegradable plastics that contains polyolefins (polyethylene and polypropylene), and bio-nanocomposites that use nanoparticles which has a good mechanical property. Trends in biodegradable packaging are extraction of corn kernels to be used for biodegradable plastic, and bamboo which is an alternative to paper and plastic. This was commonly used as plates and bowls, plant fibres from cellulose extracted from plants as biodegradable food packaging. Wood fibres creates a cellulose-based films and can be recycled, and mushroom which is a part of mushrooms has a usage of polystyrene or styrofoam type of packaging [5].

Bio-based polymers that have been used in food packaging application are considered safe compared to conventional food packaging. In producing bio-based polymer packaging, there is definitely has to face many obstacles. The durability of food packaging and shelf life of food are crucial in determining the quality of food packaging. Spoilage of food which caused by microorganisms or humidity affect the rate of degradation of packaging. Biodegradable food packaging implemented to replace conventional food packaging according to the safety and health aspect [6]. Excessive food packaging made of plastics could be harmful to the environment. The landfills that is full of waste clogged waterways due to excessive food packaging's waste. Plastic food packaging takes a longer period to biodegrade and most of them do not biodegrade. It is a part of the main concern globally as it generates a large amount of waste. Fruits contains high moisture contents, took longer time taken to dry. Regarding the issues of high moisture contents of fruits, they have a short shelf-life and easy to deteriorate due to environmental impact such as humidity and poor oxygen permeability. This study uses fruits as a pH indicator in food packaging due to its pigment that will change color in response to pH. Most of the pigments are anthocyanins which makes them a natural and edible pH indicator. Besides that, the quality and safety of packaged food plays an important role in minimizing environmental impact. Poor mechanical properties and barrier influence the quality of packaged food. Conventional food packaging which is made from non-renewable and non-biodegradable resources such as petroleum reduce the rate of degradation of food packaging.

Fruits and vegetables have high moisture, it will dry quickly as its loss rigidity and cell shrinkage which can cause it to wilt. Food spoilage resulted in affecting people such as food poisoning [7]. To maintain food quality, food packaging needs to have a specialty such as can retard the microbial growth in food. Biodegradable food packaging gives advantage to human and nature as they are eco-friendly materials. Their composition is also natural which make them safe to use. They are produced from plant and easily decompose in the landfills [8]. The development of biodegradable food packaging was conducted by extraction of pigment of rose and red cabbage by using a solvent of ethanol and water followed by the production of starch and chitosan solution. Strawberry will be use as a testing material for film packaging. The physical properties such as color, pH and thickness, chemical properties such as FTIR and biodegradability, and mechanical properties such as tensile strength can be measured based on the film packaging made

2. Methodology

2.1 Material

Red cabbage or known as Brassica Oleraceae can be purchased at Jaya Grocer, Bukit Jelutong. Ethanol, chitosan, and any other chemicals can be obtained from Merck or Sigma [9]. Meanwhile, rose flowers can be obtained at Mek Su Florist, PKNS in Shah Alam. Commercial packaging that will be used for testing comparison was purchased at Jaya Grocer, Bukit Jelutong.

2.2 Methods

150 g of red cabbage was crushed and diluted with 70ml of ethanol to water with a ratio of 7:3 in a beaker [10]. The red cabbage anthocyanin extracted was stored in oven at 70^{o}C for 2 hours for protection and filtered to get the extracted. The rose petals were washed with water to remove any impurities present. 10g of rose petals was torn into smallest pieces and soaked with 70ml of ethanol to water with a ratio of 7:3 in a beaker [11]. The material was stored in oven at 70^{o}C for 2 hours for protection and filtered to get the extract [12].

25g of starch, 15ml of glycerol, 2g of chitosan and 5ml to 10ml of sample of red cabbage and rose were mixed at 25ºC and 60rpm for 30 minutes. The sample was stored in a plastic bag for 24 hours. 6g of each sample was used for preparing a film by using a hot press with preheating of 120ºC for 8 minutes and pressed for 10 minutes with a cooling temperature of 60ºC. The pressure limit of the hot press was set to 700psi (Ibrahim, 2020). All the films will then compare with commercial film (bought at supermarket) by using different parameters such as red cabbage, rose petals, commercial packaging in accordance with thrice a week.

The thickness of the film was measured by using micrometer at three random spots on the film of red cabbage and rose to obtain an average value. Universal indicator has been used in testing of pH for strawberry and films at room and cold temperature. Color of the film was measured by using Konica Minolta chroma meter CR-400. The films used are commercial packaging, rose film and red cabbage film. The chroma meter determine L* which represents lightness, a* indicates redness-greenness and b* indicates yellowness-blueness of the film. Intermolecular interactions were observed by Fourier Transform Infrared (FTIR) analysis.

Biodegradability of the film is determined by using a method of calculation of percentage of weight loss which the samples will be buried in a soil and the weight is recorded once a week for a month and half. Tensile strength can be determined by using Tinius Olsen Horizon universal testing machine with ASTM D882-10 method. The mechanical properties were determined by using universal tensile machine supported with 2.5kN load cell and a crosshead speed of 10mm/min. The films were cut into a dimension of 20mm X 50mm. tensile strength is determined to measure the force for the specimen to break while stretching to the breaking point. ASTM D882-10 was used for a specimen with a thickness less than 1mm. It is used to measure the stress, strain, strength at break and young modulus.

3. Results and Discussion

3.1 Film Thickness

Film thickness affects chemical and mechanical properties of the film, and the preparation of the film affects the film thickness. It is essential to ensure that there were no precipitate present within the solution as it will affect film thickness [10]. The addition of glycerol was shown to increase the film thickness. Based on Table 1, it shows that Film 1 is for commercial plastic film, Film 2 is for red cabbage's films and Film 3 is for rose films. These results will be used in determining the tensile strength [11].

Table 1 - Thickness of the film

Properties	Thickness (mm)
Film 1	0.339
Film 2	0.323
Film 3	0.327

3.2 pH Measurement

The colour of the film will change according to the changes of the pH value. Data in Fig. 1 and Fig. 2 shown that the value of pH is increased with increasing of duration of strawberry's exposure to the temperature which means it turns from acid to neutral and alkaline condition. The films of red cabbage, rose and commercial packaging were used in determining their pH at room and cold temperature. Meanwhile, for the strawberry it is divided into four types for pH measurement at room and cold temperature which are uncoated strawberry and a coated strawberry of red cabbage film, rose film and commercial packaging. The change of pH is depending on temperature. When it is being exposed with increasing of duration in room temperature, the pH will likely increase rapidly due to moisture absorption compared to cold temperature condition.

The testing on pH buffer solutions have been carried out on pH 3, pH 4, pH 5, pH 6, pH 7 and pH 8 using both films which are rose and red cabbage. The results showed in Table 2 that for the rose film, it turns to pink in pH 3 which in acid solution and the color faded until it turns to light purple in pH 7. The color turns to red in pH 8 which is alkaline solution. Meanwhile, for the red cabbage film it turns to pink in pH 3 and pH 4 which in acid solution. The color turns to purple in a pH solution from pH 5 to pH 7 and blue in pH 8. The pigment undergoes structural and physical changes and exhibit color changes due to different pH level.

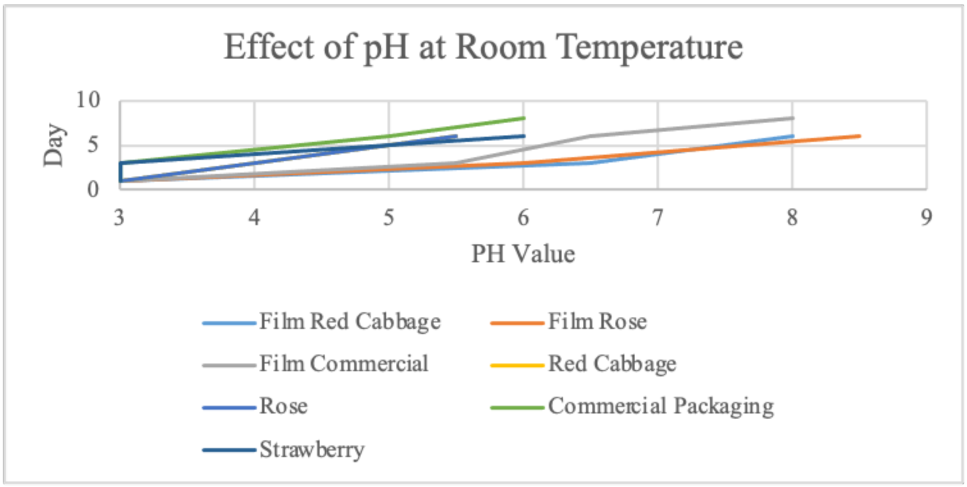


Fig. 1 - Effect of pH at room temperature.

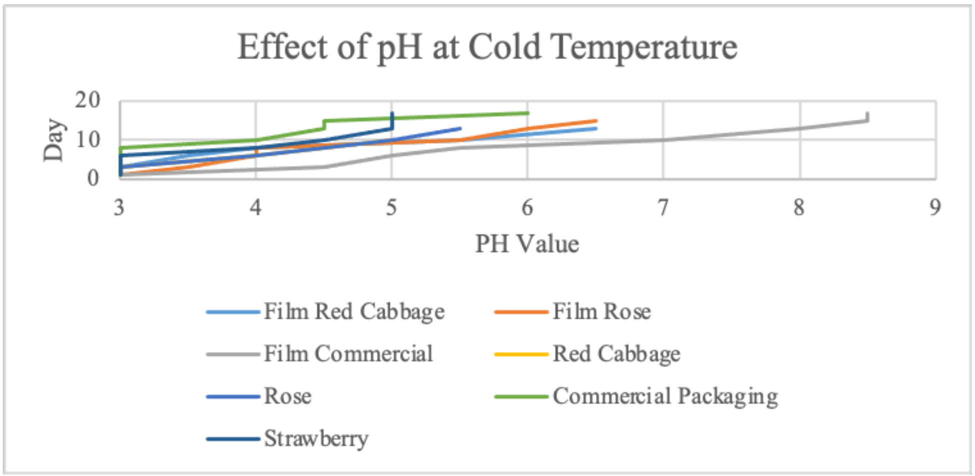
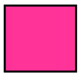
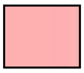
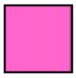
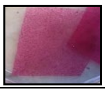
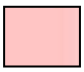
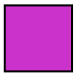
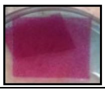
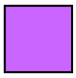
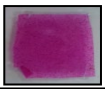
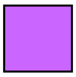
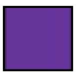


Fig. 2 - Effect of pH at cold temperature

Table 1 - pH indicator on different buffer solutions

	Rose	Color Code	Red Cabbage	Color Code
pH 3				
pH 4				
pH 5				
pH 6				
pH 7				
pH 8				

3.3 Color Measurement

The color of the film fades as the temperature increases due to alkaline condition. Based on Table 3, the strawberry at the room temperature has a short shelf life as it can only last a week for red cabbage and rose coating. Meanwhile, the coated strawberry with commercial packaging has the longest shelf life which can lasts for up to 10 days. The strawberry with a coating at cold temperature gave better results compared to the result at room temperature according to Table 4. The strawberry with a red cabbage coating lasts for 2 weeks while for rose coating it can lasts for 15 days until it becomes rotten. The longest shelf life for the strawberry is the one that was coated with commercial packaging which lasted for 3 weeks.

Table 2 - Coated strawberry at room temperature

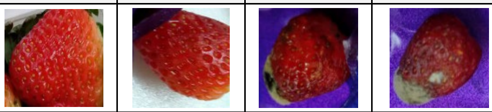
Week	Week 1			Week 2			Week 3	
Day	1	3	6	8	10	13	15	17
Red Cabbage					-	-	-	-
Rose					-	-	-	-
Commercial						-	-	-

Table 3 - Coated strawberry at cold temperature

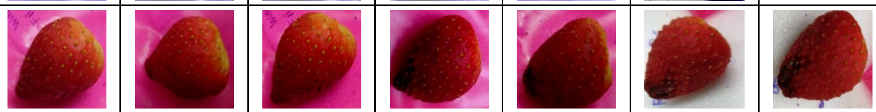
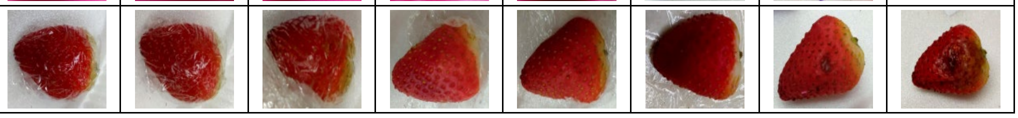
Week	Week 1			Week 2			Week 3	
Day	1	3	6	8	10	13	15	17
Red Cabbage							-	-
Rose								-
Commercial								

Table 5 - Uncoated strawberry at room and cold temperature

Week	Week 1		Week 2				Week 3	
Day	1	3	6	8	10	13	15	17
Room Temperature					-	-	-	-
Cold Temperature								

Based on Table 5, the strawberry without any coating at room temperature is the shortest shelf life that the strawberry ever had, in which it gets rotten within 8 days. Meanwhile, the best uncoated strawberry is at cold temperature can last longer for up to 3 weeks. From Table 3, although coated strawberry for both red cabbage and rose lasts as long as 8 days, but the appearance of the strawberries looks better (juicier, acceptable red colour, less black spots), compared to the uncoated strawberries at both room and cold temperatures. The color measurement using chroma meter for both room termperature and cold temperature were measured and shown in graphs in Fig. 3 for L*, b* and a* values which decrease slightly every week. Meanwhile, the figure in Table 6 shows pictures taken starting from the first day of observation and

Table 7 shows the color observations which lasted only up to 3 weeks (depends on when the strawberry started to rot). The color of the red cabbage film, rose film and commercial packaging showed no signifance difference in color changing.

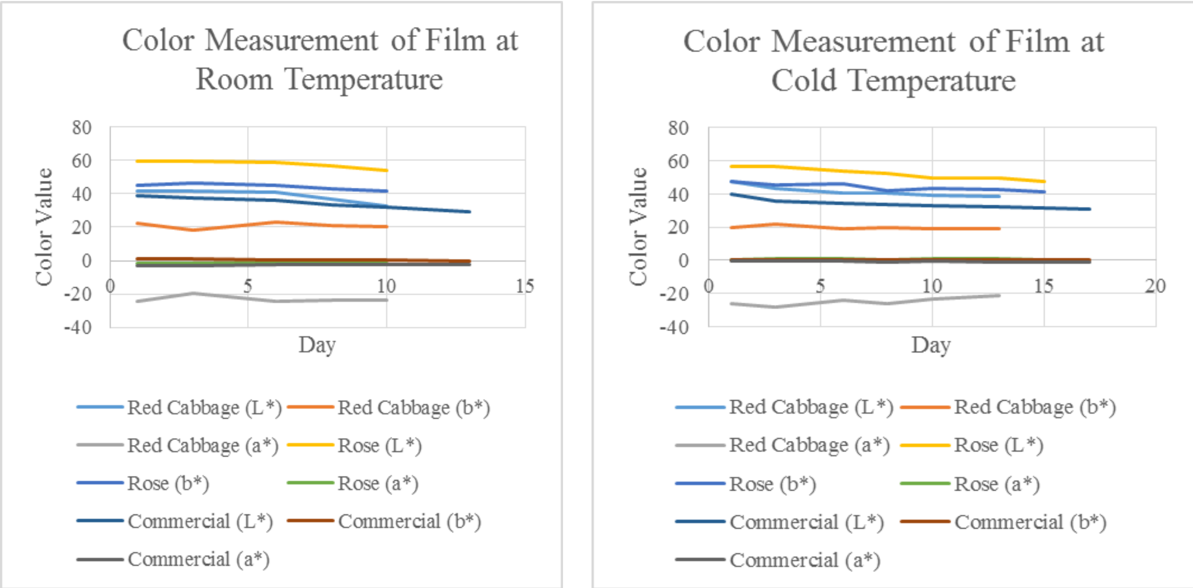
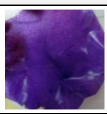
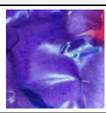
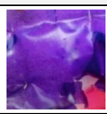
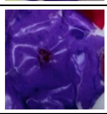
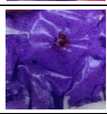
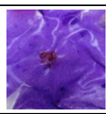
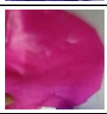
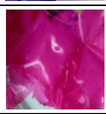
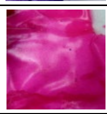
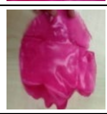
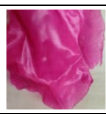
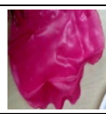


Fig. 3 - Color measurement of film at room temperature and cold temperature.

Table 6 - Films on day 1

Film	Red cabbage	Rose	Commercial
Day 1			

Table 7 - Observation on the films at room temperature and cold temperature

Week	Week 1		Week 2			Week 3	
Day	3	6	8	10	13	15	17
Red cabbage (Room Temperature)					-	-	-
Red cabbage (Cold Temperature)						-	-
Rose (Room Temperature)					-	-	-
Rose (Cold Temperature)							-
Commercial (Room Temperature)						-	-
Commercial (Cold Temperature)							

3.4 Fourier Transform Infrared (FTIR) Analysis

Weak intermolecular interactions can be identified when all specific peaks of active films were shifted to lower wavenumbers than the control films [14]. The presence of anthocyanin can weaken the intermolecular interactions in O-H bond at alcohol functional group [11]. FTIR spectra with imaging microscope used to determine chemical interactions and surface topography [13].

There are 4 regions in FTIR results where they were differentiated by the range of wavenumbers. The 4 regions are single bond stretch, double bonds, triple bonds, and fingerprint region which have a range of wavenumber of 2500cm^{-1}-4000cm^{-1}, 1500cm^{-1}-2000cm^{-1}, 2000cm^{-1}-2500cm^{-1} and 500cm^{-1} and 1000cm^{-1}. The peaks showed the intensity of the compound in these regions. The fingerprint region has its unique pattern produced by a certain compound. According to Fig. 4, the region started with fingerprint region followed by double bonds, triple bonds, and single bond stretch.

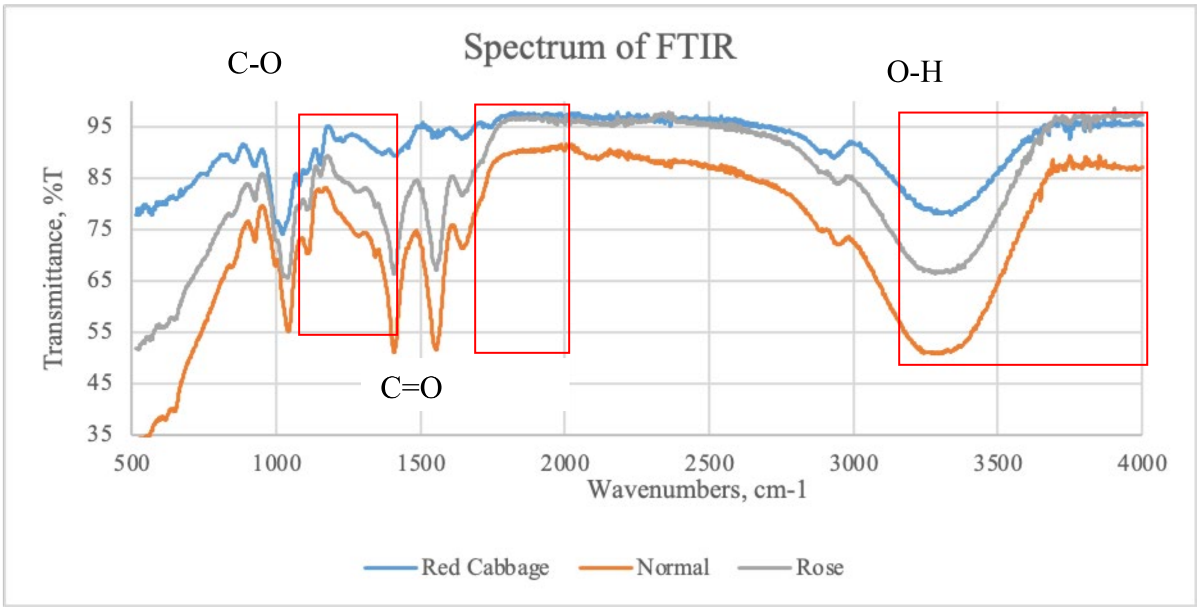


Fig. 4 - Spectra of FTIR for the films

Based on the results in Fig. 4, three of the films showed almost similar characteristics. The most intense peaks fall under the single bond stretch which has a stretching of C-0. In a single bond stretch, the O-H (acids) was shown in Fig. 4 which gave broad stretch range. The peaks that fall under double bond stretch showed to be the compound of C=O, and the most obvious peaks were for the normal and rose film. All of the films have a property of single bond and double bonds regions. The results showed different intensity peaks resulted from different properties of the films used for fruits packaging.

3.5 Biodegradability

Biodegradability is the ability for organic materials to break down to base substances. To determine the biodegradability of the sample, a sample with good mechanical properties was chosen. In some cases, percent of mineralization will be present in the film. The percent of mineralization denotes the percent of carbon molecules that will be converted to carbon dioxide during the test for biodegaradation [14]. The weight of the film was measured for 7 weeks and calculated for the percentage of weight loss of the film given by the formula:

$$\text{Weigh tLoss (\%)} = \frac{\text{Initial Weight} - \text{Current Weight}}{\text{Initial Weight}} \times 100\% \quad (1)$$

The weight for the films were measured by using measuring balance weight. The initial weight for rose film is 1.902g, red cabbage is 2.399g and commercial packaging is 0.449g. In Fig. 5, the graph showed that the value for measured weight in 7 weeks decreased with time. Therefore, the percentage of weight loss increases with time. Fig. 6 shows that the films did not fully biodegrade in 7 weeks but shows a good percentage for the weight loss. Based on the testing, commercial packaging has the least degradation by having the slowest weight loss compared to rose and red cabbage film.

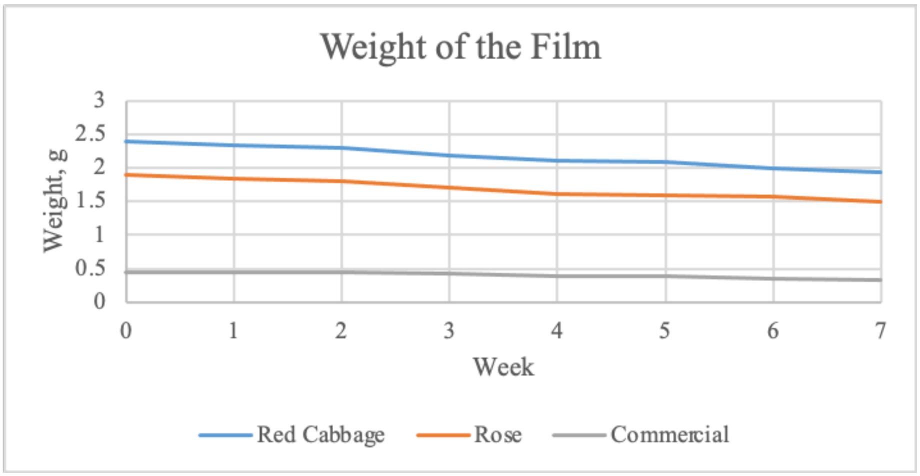


Fig. 5 - Weight of the films

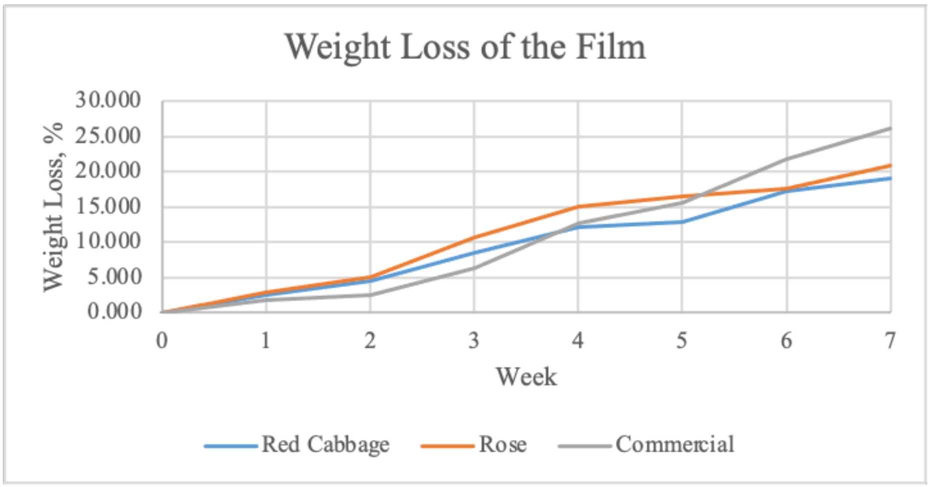


Fig. 6 - Percentage of weight loss of the films

3.6 Tensile Strength

Tensile strength and elongation at break test are needed to determine the mechanical properties of the film. High tensile strength shows that the film has low flexibility and high rigidity. Stress increase with strain as time increases, but it will decrease drastically when it reaches a certain point [10] The film with higher tensile strength will result in lower elongation and higher concentration of glycerol will result in lower tensile strength. The increased in tensile strength is due to excellent compatibility [13].

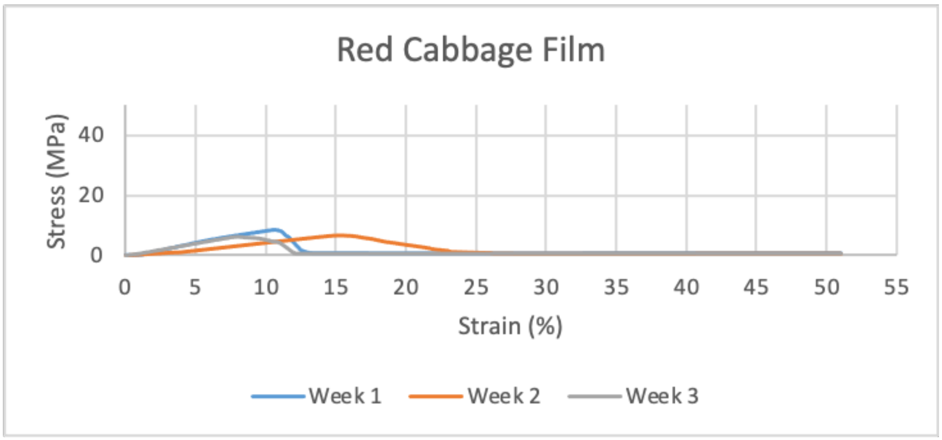


Fig. 7 - Tensile strength of red cabbage film

Based on Fig. 7, a film with a thickness of 0.263mm, width of 5mm and area of 1.32mm2 was used in week 1. The results showed that the ultimate stress is 8.37MPa at 10.6%. The breaks stress is at -0.127MPa and break strain is 0% with a modulus of 118MPa. In a second week, the film used is a film with a thickness of 0.188mm, width of 5mm and area of 0.940mm2. The graph showed the ultimate stress is 6.47MPa at 14.6%. The breaks stress is at 0 MPa and break strain is 53.5% with a modulus of 87.4MPa. The last week, a film with a thickness of 0.314mm, width of 5mm and area of 1.57mm2 was used. The data showed the ultimate stress is 5.93MPa at 7.67%. The breaks stress is at -0.106MPa and break strain is 0% with a modulus of 95.7MPa.

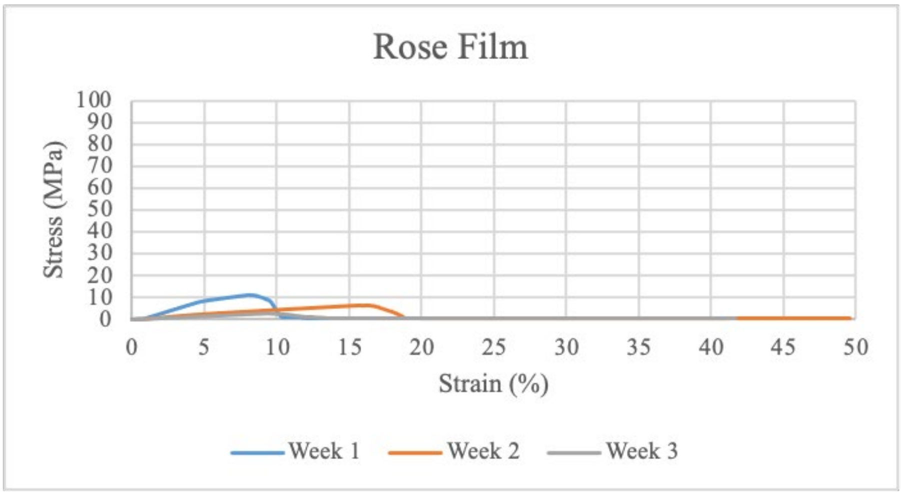


Fig. 8 - Tensile strength of rose film

Based on Fig. 8, a film with a thickness of 0.207mm, width of 5mm and area of 1.04mm2 was used in week 1. The results showed the ultimate stress is 11.2MPa at 8.19%. The breaks stress is at 0 MPa and break strain is 0% with a modulus of 218MPa. In a second week, the film used is a film with a thickness of 0.410mm, width of 5mm and area of 2.05mm2. The graph showed the ultimate stress is 6.46MPa at 15.3%. The breaks stress is at -0.122MPa and break strain is 0% with a modulus of 67.7MPa. The last week, a film with a thickness of 0.440mm, width of 5mm and area of 2.20mm2 was used. The data showed the ultimate stress is 2.80MPa at 9.42%. The breaks stress is at 2.69MPa and break strain is 10.2% with a modulus of 56.7MPa.

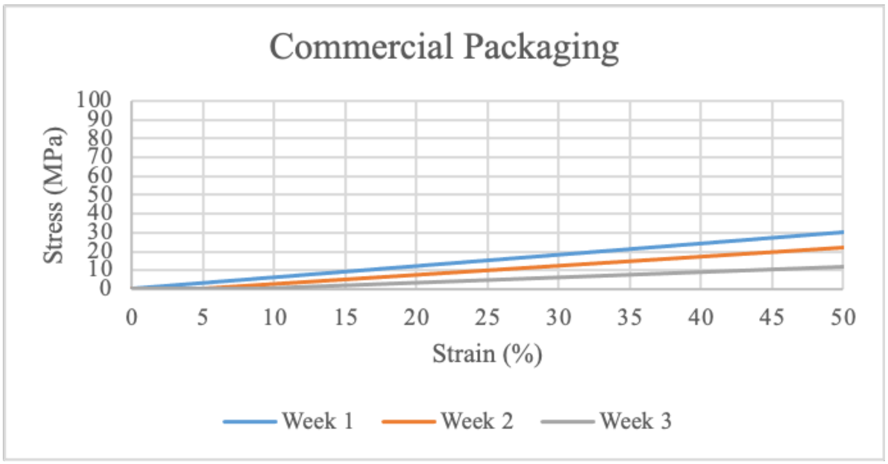


Fig. 9 - Tensile strength of commercial packaging

Based on Fig. 9, a film with a thickness of 0.0730mm, width of 5mm and area of 0.365mm2 was used in week 1. The results showed the ultimate stress is 65.5MPa at 322%. The breaks stress is at 65.5MPa and break strain is 324% with a modulus of 83.3MPa. In a second week, the film used is a film with a thickness of 0.0730mm, width of 5mm and area of 0.365mm2. The graph showed the ultimate stress is 33.8MPa at 109%. The breaks stress is at 0 MPa and break strain is 0% with a modulus of 54.5MPa. The last week, a film with a thickness of 0.0730mm, width of 5mm and area of 0.365mm2 was used. The data showed the ultimate stress is 19.4MPa at 190%. The breaks stress is at 0 MPa and break strain is 0% with a modulus of 32.2MPa. As a comparison, commercial packaging has a better mechanical property rather than both films of red cabbage and rose.

4. Conclusion

Red cabbage and rose are well known for their anthocyanin pigment that is able to change color in response to pH. It is widely used as a pH indicator in producing food packaging by using any suitable method. In this paper, the usage of red cabbage and rose were introduced in producing film for food packaging by using hot press method. Based on the results and discussion, both films showed similarity in their properties. The comparison between rose film and red cabbage film with commercial packaging have been made and it shows a lot of difference. Commercial packaging gave a better result in term of tensile strength and biodegradability. Red cabbage and rose film tend to turn purple and pink in color measurement by using chroma meter but red cabbage almost gives an accurate requirement for color measurement according to the different pH value. Meanwhile, rose is recommend instead of red cabbage for food packaging due to its good performance of pH measurement. It shows that rose is better than red cabbage in term of preventing food spoilage. The FTIR results for all samples were quite similar as all the peaks fall into a single bond region. Further studies may need to improve the physical, chemical, and mechanical properties of the biodegradable film.

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