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Absorption Ability and Degradable of Thin Film From Orange Peel Waste

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ABSTRACT

Bioplastics are plastic derived from natural resources and they are bio-degradable entirely or partially. Fruit waste is supposed to be an undesirable matter and will be used as compost. The present work aimed to produce a thin film from fruit material, in converting the fruit-derived waste into useful material. The thin film was developed by film casting method using waste fiber from orange peel, glycerol, and corn starch. The thin film was characterized by water, oil absorption, and biodegradable properties. The fact, natural fibers that originate from the surface of the fruit are hydrophilic rather than oleophilic, so the thin film tends to absorb more water than cooking oil over 28 days of observation. The biodegradation rate of orange peel film is quickest for films with 50 wt.% of orange peel powder and slowest for films with 0% of orange peel powder. We concluded that these materials can be used for membrane and packaging applications. Therefore, this work aims to provide a promising bioplastic that will help the environment and be an alternative material to modern society.

Keywords: *Bioplastic, Thin film, Absorption, Degradable, Orange peel waste*

1. INTRODUCTION

Traditional plastic waste has sparked worries about sustainability, environmental preservation, and a deep awareness of the environment. Plastic waste will build up in landfills and endanger the environment. The ban on conventional plastics has increased requests for biodegradable polymers and they have developed quickly recently from an environmental perspective.

Disposable catering supplies, packaging, and agricultural films or grow sacks are the primary applications for biodegradable plastics. The ease with which biodegradable polymers decompose and biodegrade when released into the environment will stimulate their development. Although there are many benefits and drawbacks to using plastic, including the fact that it cannot be disaggregated organically and that harmful compounds may move into food. The usage of edible films is particularly promising due to the requirement that the packaging be environmentally friendly. Edible films have advantages over commonly used plastic packaging in that they protect food products, keep the product's natural appearance, allow for direct consumption, and are environmentally friendly [1].

Today, sustainability and environmental issues remain priorities for research firms [2,3], which explains the recent growing interest in research in new areas of application based on non-oil structural materials such as starch [4] and cellulosic materials (crystalline cellulose and amorphous cellulose), which are naturally renewable, biodegradable, and environmentally friendly polymers [5].

This study evaluates the evolution of orange peel into bioplastic which is a thin film as well as its properties. Orange peel is chosen because of its high cellulose content and good availability. As an outcome of our research, orange peel has been given a new purpose, and biofilms have been produced without the need for chemical pre-treatment. Algae, potatoes, tapioca, maize starch, and sugar cane bagasse are just a few of the natural resources used to create these bioplastics. Depending on their properties, they are frequently totally or partially compostable or biodegradable.

The importance of producing a thin film is to ensure that it is either absorbed or resistant to water and oil and also easy to decompose/degrade. Water and oil absorbent behavior are important to certify the thin film is suitable for various applications in the future, such as food packaging, membranes, household, and utensils. The biodegradable properties also will prove that the thin film will not harm the environment.

Several tests were conducted, which are the absorption capacity of water and cooking oil and the degradation of thin film. The oil and water absorption test is to evaluate the potential of the thin film to absorb or resist oil and water. This is important for the main application of thin film as food packaging. The degradation test is to estimate the decomposition behavior of thin film in the soil by natural degradation process. This study aims to develop a promising bioplastic that can replace traditional and banned plastics while causing less or no harm to the environment during its production. This approach takes into account the evolving needs of modern society, which demands materials that are more sustainable and environmentally friendly.

2. MATERIALS AND METHODS

Orange peels were collected as waste after eating. The peels were cleaned and cut into small pieces. Then they were dried under the sun until completely dry, milled, and sieved to 125 mesh. Glycerol as the plasticizer was purchased from Merck. Starch and vinegar as additives were purchased from local shops only.

The films were prepared using the casting technique. Table 1 below displays all the materials and their composition that are used to produce a thin film.

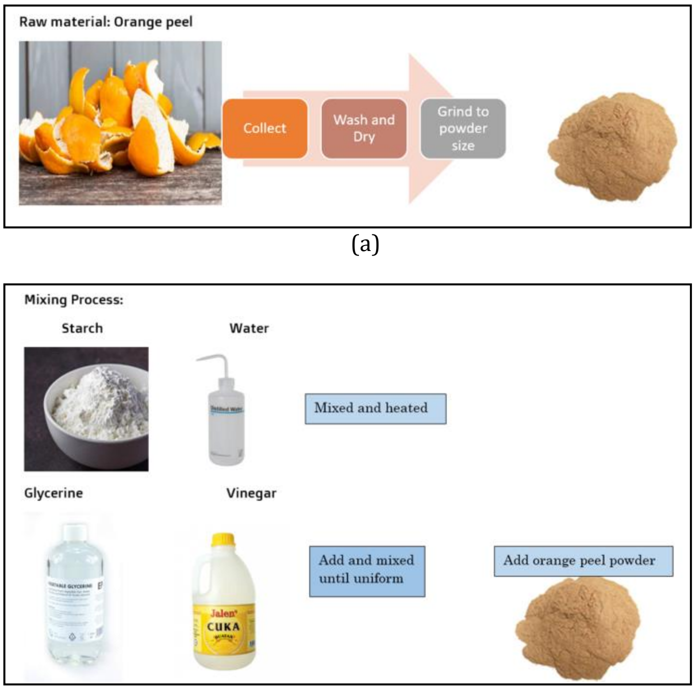
Table 1 The formulation of the orange peel thin film

Sample	1	2	3	4	5
Orange Peel Powder (g)	0	2	3	4	5
Glycerol (g)	5	5	5	5	5
Starch (g)	10	8	7	6	5
Water (ml)	200	200	200	200	200

Starch with various weights was dispersed in distilled water to form a mixture. Glycerol was then added to the mixture. After adding orange peel powder according to the weight of the mixture, it was heated to 95 °C with constant stirring at 200 rpm for 10 minutes. The solution was then cast on a 20 x 20 cm acrylic plate, dried at room temperature for 20 hours, and peeled. Before undergoing testing, the resulting thin films were kept at room temperature for 7 days in an environment with a relative humidity of 60 %. The process for thin filmmaking is illustrated in Figure 1.

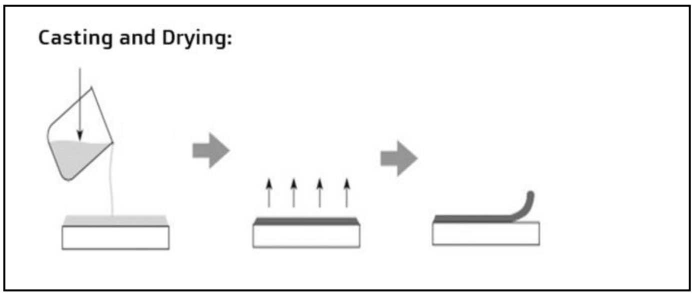
Water and oil absorption tests have been done to prove the ability of the thin film either in terms of hydrophilic, oleophilic, or both. The oil absorption test used cooking oil as the medium and followed ASTM Oil No. 3 [6]. The water absorption test used distilled water as a medium and referred to ASTM D570 [7]. The samples were weighted every day for 28 days, at room temperature, and calculated using Equation 1;

$$\text{Absorption percentage} = \frac{(Initial\ weight - final\ weight)}{final\ weight} \times 100 \quad (1)$$



(a)

(b)



(c)

(d)

Figure 1. The orange peel thin film making in graphic (a)Raw material of orange peel (b) Mixing process (c) Casting process (d) Final sample of thin film.

The thin film used for the degradation test, also known as the soil burial test, was buried in compost soil at a depth of 7.5 cm depth, exposed to natural conditions (outside) for 28 days. Sampling was conducted every two days during this time. After the burial period, the samples were cleaned to remove any soil residue. The decomposition of the thin film was assessed by examining its physical condition, with pictures taken weekly to document any changes. However, the percentage of weight loss was not evaluated in this study.

3. RESULTS AND DISCUSSIONS

3.1. Thin Film

For the physical observation, the thin films made from starch, glycerin, water, vinegar, and different percentages of orange peel powder were found to be soft and flexible. The surface was relatively smooth. Due to its flexible and stretchable nature, this thin film was useful in making wrapping film for food packaging. However, some improvements may be needed to enhance rigidity for commercial applications and sustainable packaging.

The opacity of the thin film was transparent when no orange peel powder was used as filler. However, it became opaque with the presence of fillers. The color also became darker with an increase in filler content, reflecting the color of dried peel fiber. The ground and dried orange peel had a brown color. The more orange-peel powder was used, the darker the film became. Figure 2 below shows the thin film without any filler up to 50% content of the orange peel powder.

0 wt%	
20 wt%	
30 wt%	
40 wt%	
50 wt%	

Figure 2. The thin film is filled with different percentages of orange peel.

3.2. Absorption Test

The absorption test was conducted to evaluate the ability of the produced thin film to absorb and resist water and oil. The absorption percentage after 28 days, with different orange peel powder loading, can be seen in Figure 3. As an increasing of filler loading increased, the thin film absorbed a higher percentage of water and oil. Clearly shown, the water and oil absorption percentages were directly proportional to the percentage of orange peel powder.

The absorption of water and oil is a swelling behavior. The rate can occur in three stages: a short and quick stage, a slow stable stage during up taking, and finally, an abrupt and very quick stage. Referring to the previous figure, it can be expected that the orange thin film exhibits a slow stable stage of water and oil absorption. Water and oil molecules enter the voids or interface between the fibers and polymer matrix, as well as the pores inside the fibers themselves. Swelling induces microcracks at the interface region, which further increases the absorption of water and oil. The fibers also swell when in contact with any liquid, as the gaps between the fiber and matrix are filled. These gaps are formed during the compounding process due to poor impregnation of the filler and thermal shrinkage [8].

By comparing the absorption percentages of water and oil, it is evident that this thin film has a higher affinity for water than oil. This can be attributed to thin film's hydrophilic nature, as opposed to their oleophilic properties. As previously mentioned, agricultural and fruit skin fibers, are known to be highly hydrophilic due to the presence of hydroxyl group in cellulose, which allows them to form hydrogen bonds with water and the fillers [9]. It is widely recognized that natural fillers absorb water by establishing hydrogen bonds with water molecules.

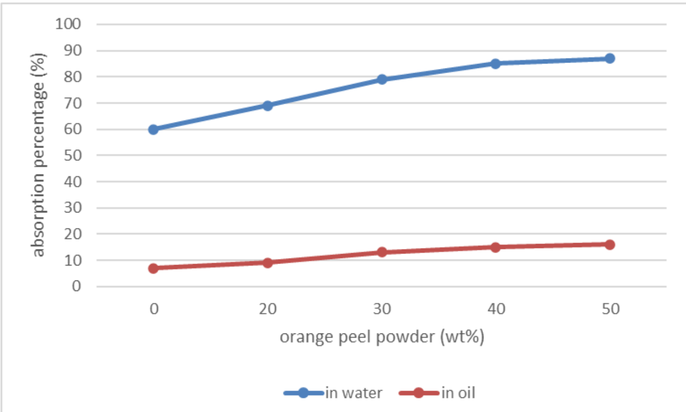


Figure 3. The absorption of thin film in water and cooking oil at a different weight percent of orange peel.

The water absorption, as reported by Mohammed et al. [10], causes the natural fiber to swell and can disrupt other properties, specifically mechanical properties. Certain researchers have proposed chemically treating the natural fiber before adding a filler to the polymer. This treatment can reduce hydrophilicity, clean the surface, increase toughness, and lower water absorption capability. Additionally, it decreases the number of OH functional groups, thereby enhancing the reinforcing of the filler-matrix interface.

The oil absorption capacity may vary depending on several factors, including area, density, viscosity, immersion time, and so forth, according to Ali et al. [11]. In this instance, the absorption of oil is proportional to the amount of orange peel powder increases. The capillary action allows the oil to flow into the thin film's porous structure, illuminating the oil absorption mechanism by trapping oil droplets within the open spaces of the orange peel powder.

Water and oil are theoretically different due to their density and viscosity values [9]. This difference is evident in the absorption percentage for 28 days. A great example that illustrates the contrast between viscosity and density is the comparison between oil and water. Oil, although less dense than water (it floats on top of water), is more viscous. It resists flowing, whereas water flows more easily. Additionally, other ingredients present in the film also impact its behavior. Starch, for example, contains hydroxyl groups, which means that even films without filler can absorb water. Water is also attracted to glycerol.

3.3. Degradation Test

Biodegradable plastics may be defined as those that follow a significant change in chemical structure under certain environmental conditions. The changes result in a loss of physical and mechanical properties. They degrade as per the effects of the microorganisms, like bacteria, algae, and fungi. According to Chuangan et al. [12], degradation mechanisms can be categorized as complete or incomplete. In this study, the mechanism can be classified as biodegradable since the thin film is buried in soil and naturally degraded under natural conditions. The findings from the soil burial test were used to determine the decomposition stages, over 28 days, which is a standard test for assessing biodegradability.

During the initial three days, the degradation rate was slow as the soil microbial biota adapted to the new environment. The presence of starch, pectin, and cellulose in the thin film provided essential carbon sources for the growth and proliferation of microbes. Based on these results, even though this experiment only for 28 days, it can be concluded that the thin film can degrade within approximately 40-50 days.

Polymer properties, including tacticity, crystallinity, molecular weight, functional group type, organism type, and pre-treatment type, are among the various parameters influencing biodegradation [13]. Priyanka et al. also concluded that the test is considered unacceptable if 70% of the cellulose is not degraded in 45 days. During biodegradation in compost, some factors such as temperature, water, and air, accelerate the biodegradation rate. It is an accelerated/simulated test under defined conditions.

The results of the biodegradability test for all the films are presented in Table 2, showcasing their physical outcomes. Following 7 days in organic soil, a noticeable, adhesive, and, transparent layer was observed on the soil surface of orange peel powder films with varying amounts of orange peel powder. Changes in the chemical structure of lignocellulosic complex of the orange peel upon biodegradation have led to changes in the color of the thin film due to the presence of lignocellulosic material [13].

This test is conducted in a natural environment to replicate the degradation process that takes place when materials are burial in soil. As a result of the flexibility of thin film to contract and expand, an annealing effect was observed after the 14-day biodegradability. When exposed to sunlight, the film made from orange peel powder undergoes contraction.

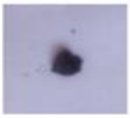
The hydrophilic polymer thin film may cause the orange peel powder to expand or swell upon contact with rain. This expansion and swelling resulted in surface cracking, as observed. The figure demonstrates that the film's physical appearance suggests a slower degradation rate compared to other films.

This thin film can be disposed of in a secure and environmentally responsible way, using techniques like applying soil, composting, and using biological wastewater therapy [14]. Based on its importance the research on the application of biodegradable natural fiber in thin film is going on day by day.

In this particular scenario, the inclusion of orange peel filler has been found to improve biodegradability. The thin film surface becomes adhesive, facilitating microbial attachment and subsequent biodegradation, as previous studies have confirmed. The presence of filler can enhance the decomposition process by increasing the surface contact area. As orange peel powder is derived from natural sources, it accelerates the biodegradation process similarly to other natural fillers. Films that incorporate orange peel powder degrade at a faster rate due to the filler's physical and chemical properties, which promote quicker breakdown.

During the experiment, the orange peel powder was immersed in water, aiding in the breakdown process. A portion of the film may likely detach and enter the soil, potentially resulting in the formation of microorganism colonies on the film. This could pose challenges in cleaning the film post-test. Furthermore, the distribution of orange peel powder within the film can influence its rate of biodegradability. A higher of orange peel powder within the film might accelerate degradation.

Table 2 Degradation stages for the thin film within 28 days

Composition of orange peel powder	Time				
	Day 1	Week 1	Week 2	Week 3	Week 4
0 wt%					
20 wt%					
30 wt%					
40 wt%					
50 wt%					

On the other hand, a dispersed film with a lower loading of orange peel powder may require additional time to initiate degradation. Therefore, it is crucial to achieve proper dispersion of the film in order to control the composition of the biofilm [15]. Based on the findings, it can be concluded that the utilization of waste can offer an alternative solution to address the issues related to agricultural residue. Additionally, the biodegradation of plastic is an inevitable environmental process for plastic to enter the environment.

4. CONCLUSION

In conclusion, fruit fiber, which is often considered waste in the agricultural industry, has the potential to be transformed into valuable and useful products. The main objective of this study was to investigate the potential of orange peel waste as a natural filler for thin film production. Additionally, the compatibility of orange peel powder with other natural materials such as starch, glycerol, and vinegar were examined. The primary qualities of orange peel powder as a filler in thin film can be summarized in terms of its absorption behaviors and degradation. Throughout the study, these thin films were exposed to water and oil, two distinct environments. Due to the hydrophilic nature of the natural fibers found on the fruit's surface, the thin film exhibited a higher water absorption rate compared to oil over a 28-day observation period. The water absorption reached its peak at 96%, while the absorption of oil was highest at 19 %. Furthermore, the degradation rate of the orange peel film was found to be fastest in films containing 50 wt.% of orange peel powder and slowest in films with 0% orange peel powder. This experiment successfully achieved the final goal of determining the degradation performance of biofilms made from different mixtures of orange peel powder.

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