Biodegradable film from wild taro *Colocasia esculenta* (L.) Schott starch

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Abstract: The challenge today is to develop a biodegradable packaging material to partially substitute the conventional plastic. Biodegradable plastics made from starch-based are more environmentally friendly, and they degrade faster than the traditional plastics. This study was aimed to produce and characterize a biodegradable film from Colocasia esculenta (L.) Schott starch and glycerol plasticizer. Two levels of taro starch (5 g and 10 g) and three percentage of glycerol (2%, 3%, and 4%) were used in the production film. Results showed that taro and glycerol based biodegradable film obtained a lowest density, water absorption and thickness swelling of 0.98 g cm-3, 51.53% and 9.29%. The highest tensile strength and elongation obtained are 9.51 MPa and 21.60%. After one week of biodegradability test, the taro starch and glycerol based biodegradable film was degraded by 64.45%.

Keywords: taro starch, glycerol, biodegradable film, tensile strength, biodegradability

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1 Introduction

Taro Colocasia esculenta (L.) Schott is a tropical tuber crop that cultivated in many countries, including the Philippines. It is also used in baby food, taro chips, taro bread and taro sorbet (Hong and Nip, 1990). It has 73%-76% starch (dsb) (Jane et al., 1992).

Starch is a polysaccharide which has thermoplastic properties and is widely produced in the domestic market, whereas glycerol is a residue that can come from oil or biodiesel industry. The major components, amylose and amylopectin in starch are biopolymers. These biopolymers are attractive to raw materials as barrier in packaging materials. The starch is used in industrial foods and used to produce biodegradable films to partially or entirely replace plastic polymers because of its low cost and renewability, and it has good mechanical properties (Babu et al., 2013).

Starch is totally biodegradable in a wide variety of environments and can be used in the development of totally degradable products for specific market needs. Degradation or incineration of starch products recycles the atmospheric CO2 trapped by starch-producing plants during their growth, thus closing the biological carbon cycle (Bastioli, 1998).

On the other hand, glycerol is the simplest trihydric alcohol and is called glycerin. It is a colorless, odorless and viscous liquid with a sweet taste. It is completely soluble in

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water and alcohol, but is only slightly soluble in many common solvents, such as ether, ethyl acetate and dioxane. The addition of plasticizers makes the brittle films more flexible, but also less strong and results in higher moisture permeability (Tongdeesoontorn et al., 2011). Glycerol can influence significantly the tensile and barrier properties of the films ($P < 0.05$). The lower glycerol content of the films, the tensile strength and barrier properties will be better than films with higher content (Souza et al., 2012).

The challenge today is to develop a biodegradable packaging material to partially substitute the conventional plastic. Biodegradable plastics made from starch-based are more environmentally friendly and degrade faster than that of the traditional plastics. Tongdeesoontorn et al. (2011), Sriroth et al. (2001), Basilla (2011), Cheong et al., (2010) and Tuates et al. (2016) developed cassava starch based biodegradable film, disposable foamed food containers using starch and nanoclay and bio-based polymer made from sago derived from starch, respectively.

The goal of this study is to develop a biodegradable film that can be used as a substitute for food packaging.

2 Materials and methods

Wild taro starch and glycerol (92.09% Ajax Finechem Univar ® Analytical Reagent) were used as film forming and plasticizer to provide biodegradable film

2.1 Film preparation

A mixture of taro starch (5 and 10 g) and glycerol (2%, 3%, and 4%) was prepared. The resulting mixture was added to 100 mL distilled water. The whole mixture was stirred and heated at 80^{o}C for 15 minutes until it gelatinized. The heated mixture was spread on the glass and petri plates and allowed at air-conditioned room (17^{o}C) for 3 to 4 days.

2.2 Characterization of the biodegradable film

Tests were performed to characterize the biodegradable film in terms of density, water absorption, thickness/swelling, tensile strength and biodegradability.

2.2.1 Density

The density of the biodegradable film was determined based on ISO 1183 (ASTM D792) method of test.

2.2.2 Water absorption

The water absorption of biodegradable film was determined based on ISO 62 (ASTM-D570) method of test.

2.2.3 Thickness swelling

The thickness swelling of biodegradable film was determined during the water absorption test by measuring and recording the thickness of the specimen before and after soaking the samples for 24 hours at room temperature.

2.2.4 Tensile strength and elongation

The tensile strength and elongation of biodegradable film was tested using universal testing machine (INSTRON model). The samples were formed into dumb bell shapes with gage length of 150 mm (50 mm longer than the initial grip separation as per standard), width of 12.7 mm along the test area, width of 25.4 mm near the grips, and thickness of 0.15-0.20 mm as per specimen. The thickness of the specimens was noted before each trial was conducted. The initial grip separation used was 100 mm and the rate of grip separation was 50 mm min^{-1}. Standard operating procedure was employed at normal room condition (73°F, 50% RH).

2.2.5 Test for biodegradability

The specimens were weighed and placed separately in a bottle with a soil added with *Trichoderma harzianum* obtained from Ramon Magsaysay - Center for Agricultural Resources and Environment Studies (RM-CARES. Every week weight was determined by digging the specimens, washing it with distilled water to remove dirt particles and oven-dried for 24 hours. The weight of the specimens was recorded in one week. The purpose of this is to determine if the treatment can degrade in the soil with *T. harzianum*.

2.3 Experimental design

The data gathered was consolidated and analyzed using 2 × 3 factorial in complete randomized design. Analysis of Variance (ANOVA) table was utilized to determine the level of significant among treatments. The difference among means was analyzed using Duncan's Multiple Range Test (DMRT).

3 Results and discussion

3.1 Description of biodegradable film

The biodegradable film is made of taro starch and glycerol (Figure 1). The biodegradable film was developed thru heating at 80°C at 15 minutes until it become gelatinized. The heated mixture was spread on the glass and petri plates, and allowed at air-conditioned room at 17°C for 3-4 days.

Figure 1 Taro starch and glycerol based biodegradable fruit bag

3.2 Density

Table 1 shows that the mean density of the film increased as the amount of starch and percent glycerol decreased. This is in agreement with the density values found by Moore et al. (2006) ranging from 0.92 to 1.10 g cm^{-3} for keratin films using different glycerol concentrations.

Table 1 Density of biodegradable film

Starch (g)	Glycerol (%)			Mean
	2.0	3.0	4.0	
5.0	1.05	0.99	0.99	**1.01**
10.0	0.99	0.98	0.99	**0.99**
Mean	**1.02**	**0.99**	**0.99**	

Note: Means not sharing letter in common differ significantly at 0.05 level of significance by DMRT

3.3 Water absorption

Table 2 shows that 5 g of starch with different percentage of glycerol had lower water absorption while 10 g of starch with different levels of glycerol obtained higher water absorption. This can be attributed to the low moisture content of starch which absorbed more amount of water.

Table 2 Percent water absorption of biodegradable film

Starch (g)	Glycerol (%)			Mean
	2.0	3.0	4.0	
5.0	53.67^{a}	75.18^{bc}	51.53^{a}	60.13
10.0	85.51^{c}	69.25^{b}	74.62^{c}	76.46
Mean	69.3	66.7	58.3	

Note: Means not sharing letter in common differ significantly at 0.05 level of significance by DMRT

3.4 Thickness swelling

Thickness swelling (TS) is an important property that represents the stability performance of the composite. Generally, the swelling rates for polymer matrix composites are low during initial stages of moisture absorption due to the visco-elasticity of the polymer matrix (Adhikary et al., 2008).

Table 3 shows that the higher level of glycerol decreased the percent of thickness swelling. The 10 g starch with 2% glycerol had higher swelling thickness while the lowest swelling thickness was the 10 g starch with 4% glycerol.

Table 3 Thickness swelling of biodegradable film

Starch (g)	Glycerol (%)			Mean
	2.0	3.0	4.0	
5.0	32.29^{b}	35.45^{b}	13.06^{a}	26.92
10.0	51.56^{c}	35.68^{b}	9.29^{c}	32.18
Mean	41.93	35.55	11.17	

Note: Means not sharing letter in common differ significantly at 0.05 level of significance by DMRT

3.5 Tensile strength and elongation

Table 4 shows the results of tensile strength (Mpa) and the elongation (%) of biodegradable film. The highest tensile strength (Mpa) of the biodegradable film was obtained at 10 g starch and 4% glycerol with a value of 9.51. This can be attributed to the crosslinking reaction density in starch films between hydroxyl groups and crosslinking agent (Detduangchan et al., 2014).

On the other hand, the higher percent elongation was obtained at 5 g. According to Thakore et al. (1999), the decrease of tensile strength was occurred due to the weakness of interfacial adhesion between starch-polymer.

Table 4 Tensile strength and percent elongation at break of biodegradable film

Level of starch	Level of glycerol	Max. stress, Mpa	% Elongation
5 g Starch	2%	2.71	16.45
	3%	1.96	20.08
	4%	1.45	21.60
10 g Starch	2%	1.84	19.78
	3%	4.82	15.36
	4%	9.51	12.76

3.6 Test of biodegradability

After one week of biodegradability test, the taro starch and glycerol based biodegradable film was degraded by 64.45%.

4 Conclusion

(1) Wild taro starch is a feasible component in the production of biodegradable films.

(2) Taro starch and glycerol based biodegradable film obtained a lowest density, water absorption and thickness swelling of 0.98 g cm^{-3}, 51.53% and 9.29%. The highest tensile strength and elongation obtained are 9.51 MPa and 21.60%.

(3) The flexibility of the film is affected by the amount of the glycerol. Higher level of glycerol increases the tensile strength and decreases the elongation.

(4) After one week of biodegradability test, the taro starch and glycerol based biodegradable film was degraded by 64.45%.

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