World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:7, No:9, 2013

Some Characteristics of Biodegradable Film Substituted by Yam (*Dioscorea alata*) Starch from Thailand

Orose Rugchati, Khumthong Mahawongwiriya, and Kanita Thanacharoenchanaphas

Abstract**—**Yam starch obtained from the water yam (munlued) by the wet milling process was studied for some physicochemical properties. Yam starch film was prepared by casting using glycerol as a plasticizer. The effect of different glycerol (1.30, 1.65 and 2.00g/100g of filmogenic solution) and starch concentrations (3.30, 3.65 and 4.00g/100g of filmogenic solution) were evaluated on some characteristics of the film. The temperature for obtaining the gelatinized starch solution was 70-80°C and then dried at 45°C for 4 hours. The resulting starch from munlued granular morphology was triangular and the average size of the granule was 26.68µm. The amylose content by colorimetric method was 26% and the gelatinize temperature was 70-80°C. The appearance of the film was smooth, transparent, and glossy with average moisture content of 25.96% and thickness of 0.01mm. Puncture deformation and flexibility increased with glycerol content. The starch and glycerol concentration were a significant factor of the yam starch film characteristics. Yam starch film can be described as a biofilm providing many applications and developments with the advantage of biodegradability.

Keywords**—**Characteristics of Biodegradable film, yam starch, *Dioscorea alata*, substitute, Thailand.

I. Introduction

EDIBLE and/or biodegradable films are made from renewable and natural polymers. Among the natural polymers biodegradable films are not meant to totally replace synthetic packaging films; however, they do have potential to replace the conventional packaging in some applications. The use of edible films and coatings has been constantly increasing in the food industry. Coatings help meet many challenges related to the storage and marketing of food products. The functionality and performance of edible films and coatings depend on their barrier and mechanical properties, which in turn depend on film composition, its formation process, and the method of application onto the product. Edible films include lipids, proteins, and carbohydrates, such as cellulose, starch, and their derivates in their formulation [6], [8]. The use of a biopolymer, such as starch can be an interesting solution as one of the most promising candidates for future materials because this polymer is quite cheap, abundant, biodegradable, and edible with thermoplastic behavior.

Starch is one of the most commonly used agricultural raw materials since it is a renewable source, inexpensive (even cheaper than polyethylene), widely available, and relatively of the most promising candidates for future materials because this polymer is quite cheap, abundant, biodegradable, and edible with thermoplastic behavior. Starch is a polymeric carbohydrate composed of hydroglucose units. This is not a uniform material and most starches contain two types of glucose polymers: a linear chain molecule termed amylose and a branched polymer of glucose termed amylopectin [7]. The ratio of amylase to amylopectin content is critical for technological applications. The potential of starch as a material for edible films and for biomaterials has been widely recognized. It is an appropriate matrix-forming material and it provides a good barrier to oxygen and carbon dioxide transmission but a poor barrier to water vapor [9]. One of the most important limitations of the use of starch for films and coatings is the hydrophilicity of this material. Preponderance of amylose in starches gives stronger films. The branched structure of amylopectin generally leads to films with different mechanical properties, such as decreased tensile stress.

Water yam or greater yam (*Dioscorea alata*) is the edible yam being most frequently cultivated in tropical areas. They come from Southeast Asia. Yam tubers are distributed in all regions of Thailand. Yams are also favored for extraction of starch on a commercial scale when compare with other starch sources (cassava, potato, maize, wheat, and sweet potato). Yam starch can be extracted from tubers by wet milling using water as the extracting solvent; the starches are very pure. One starch content was 97-98.53% (dry basis) when estimated by enzymatic method. The granular size of yam starch averages 26.68 (µm). Yam starch (*Dioscorea alata*) contains about 24-26% amylose; the ratio of amylose to amylopectin content is 0.32, and this is important for film production because amylose is responsible for the film-forming capacity of starches [1], [13], [14].

Plasticizers, such as glycerol, are often used to modify the mechanical properties of the film. Plasticizers decrease intermolecular attractions between adjacent polymeric chains increasing film flexibility, but they may also cause significant changes in the barrier properties of the film [3]-[5].

The purpose of the present work was to evaluate the influence of the presence of plasticizers (glycerol), the amount of yam starch on some characteristics, and the mechanical

Orose Rugchati is with the Department of Agro-Industry, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok Thailand, 65000, (e-mail: oroser@nu.ac.th):

Khumthong Mahawongwiriya is with the Faculty of Agricultural Technology Valaya Alongkorn Rajabath University Thailand (e-mail: khumthong@vru.ac.th).

Kanita Thanacharoenchanaphas is with the Department of Natural Resources and Environment, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok Thailand, 65000, (Corresponding author; e-mail: kanitat@nu.ac.th).

properties of starch films. These properties were quantified by water vapor permeability measurements and by a tensile test, respectively for suitable formulation of yam starch film products.

II. Material and Method

A. Raw Material

Fresh tubers of water yam, munlued (*Dioscorea alata*), with uniform size and shape, without any mechanical and pathological injuries, were obtained from a local farm in Phitsanulok, Thailand.

B. Sample Preparation

Yam starchwas extracted in the wet milling process [1], [13]. Amylose and amylopectin content of the yam starch was determined simultaneously by the Knutson method [16].

C. Film Preparation

Yam starch film was prepared by thermal gelatinization technique [10] with different glycerol and yam starch concentrations. The nine filmogenic solution formulations selected were gram of yam starch/100 g of solution and gram of glycerol/100g of solution (Table I).

TABLE I
Filmogenic Solution Formulations (100 g of Solution)

Formulations	Starch (g)	Glycerol (g)
a		1.30
b	3.30	1.65
c		2.00
d		1.30
e	3.65	1.65
f		2.00
g		1.30
h	4.00	1.65
i		2.00

The films were prepared by casting; yam starch (dry basis) and glycerol were directly mixed with distilled water to make batches with a total weight of 500g. The filmogenic solutions were transferred quantitatively to the cup of a Brabender Viscograph, and they were heated from 30 to 80°C at a constant heating rate (2°C/min) and maintained at 80°C for 10 min, with regular shaking (75rpm). Gelatinized suspensions were immediately poured on rectangular acrylic plates (20 x20 cm). For each experiment, the quantity of starch suspension poured onto the plate was calculated to obtain a constant weight of dried matter of approximately 12.25mg/cm^2. The starch suspensions were dried (45°C) in a ventilated oven (about 4h). The result was translucent films, which can be easily removed from the plate. The films were equilibrated at room temperature and a relative humidity (RH) of 70% for 48 h before being tested [11], [12].

D. Characterization of Starch Films

Yam starch films were characterized by scanning electron microscopy (SEM), JEOL JSPM 100 electron microscope (Japan). Water vapor permeability (WVP) ASTM E96-80 (ASTM, 1980) with water vapor permeation tester: Lyssy L80-4000, Oxygen gas transmission (OGT) ASTM D3985-81 ASTM, 1981) with Oxygen permeation tester Illinois 8000 (TISI Standard .1136-2536) [2].

E. Physical and Mechanical Properties

1. Thickness Measurements

The thickness of the films was determined using a manual micrometer at 10 random positions on the films. The mean standard deviation within the film was about 5% of the average thickness by micrometer EDP63191 The L.S. Starrett Co., Athol, MA Micrometer,

Moisture content of film by infrared automatic moisture meter MA 40 SARTORIUS, and color measurement by Hunter Lab model DP 9500 [15].

2. Mechanical Properties

The tensile properties and puncture tests were studied. Puncture tests were made to determine force using an Instron 4411 (Instron Ltd., Canton, USA).

3. Statistical Analysis

Statistical analyses were conducted by one-way analysis of variance. Means were compared using the Duncan's new multiple range test. Data analyses were performed using the SPSS 11.5 for Windows.

III. Results and Discussion

A. Raw Material

Some morphological characteristics of the water yam tuber, leaf, starch sample, and starch granule shape (SEM 1000X) can be seen in Fig. 1.

Fig. 1 Some morphologilcal characteristics of the water yam tuber (A) leaf, (B) whole tuber and pulp, (C) starch sample, and (D) starch granule

The fresh root of the water yam consisted mainly of starch (65%), and the purple tuber pulp is high in moisture content (82%). Starch was extracted and purified from the fresh root. The color of the starch was slightly white and a fine powder. The starch granular shape was triangular and the average size was 26.68 (μm) [1].

B. Characterization of Yam Starch Films

The appearance of yam starch film for most of the formulations was transparent, smooth, and glossy (Fig. 2).

SEM observations (Fig. 3) showed differences among the samples containing different concentrations of plasticizer. Films presented smooth surfaces. In some formulations, there were some pores or cracks and a compact structure when compared with other treatments. The homogeneous matrix of the films is a good indicator of their structural integrity and consequently good mechanical properties. The differences observed of the films occurred because the formulation amount of starch and plasticizer was not suitable.

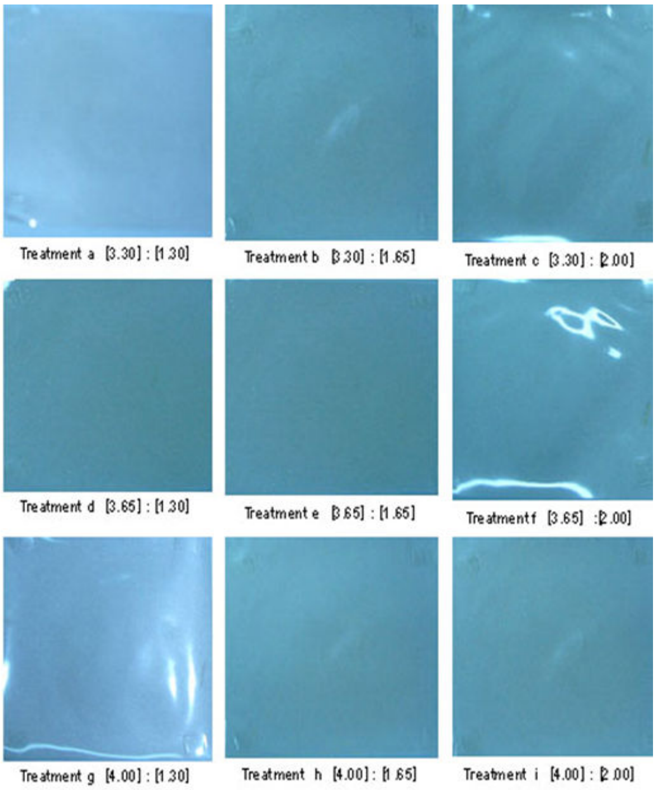

Fig. 2 Appearance of yam starch films

The water vapor permeability (WVP) contents and the oxygen gas transmission (OGT) content were significantly different ($p\leq 0.05$) as shown in the Table II. Yam starch films exhibited decreased WVP values at increased starch and glycerol concentration, which could be related to a higher number of free hydroxyl groups, that might enhance interactions with water, favoring water vapor transmission through the films; starch concentration was a significant factor for WVP and O_2 permeability (Table II) [4], [10], [12].

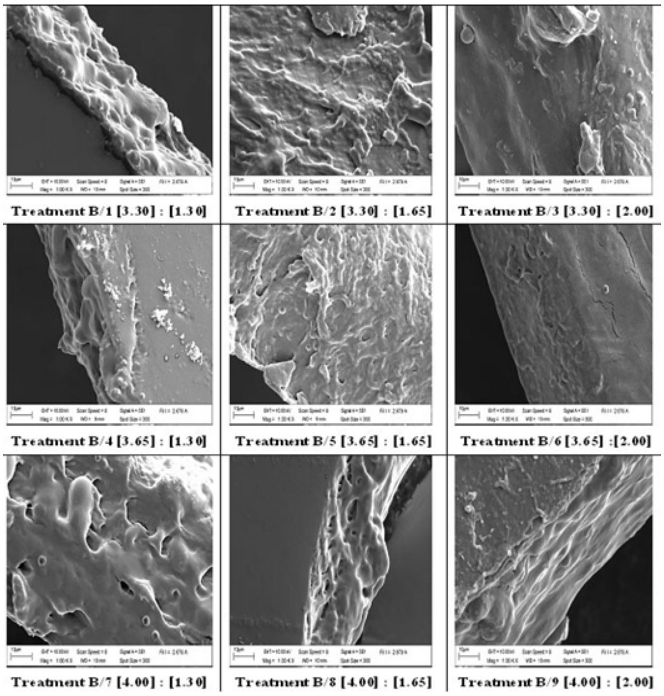

Fig. 3 SEM micrographs(1000x) of yam starch films

TABLE II
WATER VAPOR PERMEABILITY AND OXYGEN GAS TRANSMISSION OF FILMOGENIC FORMULATIONS OF YAM STARCH FILM

	WVP (g/m^2/day)	OGT (cm^3/m^2/day)
a	2097 ± 12.0^{a}	9.79 ± 0.91^{cd}
b	2095 ± 78.0^{a}	12.10 ± 0.5^{b}
c	2027 ± 3.0^{ab}	9.42 ± 0.68^{cd}
d	1759 ± 7.5^{c}	10.95 ± 0.35^{bc}
e	1923 ± 41.3^{bc}	11.0 ± 0.80^{bc}
f	2006 ± 17.5^{b}	11.8 ± 0.60^{b}
g	2069 ± 61.0^{ab}	19.45 ± 0.65^{a}
h	1553 ± 17.0^{d}	10.65 ± 0.35^{cd}
i	2009 ± 23.0^{b}	9.26 ± 1.04^{d}

Note: All values are mean ± standard deviation of three replicates (n=9).a–d Means within a column with different letters are significantly different ($p\leq 0.05$)

TABLE III
COLOR MOISTURE CONTENTS AND THICKNESS OF FORMULATIONS OF YAM STARCH FILM

Treatment	Moisture (%)	Thickness (µm)	L*
a	23.26 ± 0.86^{de}	0.08 ± 0.05^{a}	25.29 ± 0.54^{a}
b	25.84 ± 0.74^{bc}	0.09 ± 0.06^{a}	22.95 ± 0.41^{b}
c	27.80 ± 0.84^{ab}	0.06 ± 0.02^{a}	23.00 ± 0.56^{b}
d	22.77 ± 1.56^{e}	0.06 ± 0.02^{a}	22.52 ± 0.27^{b}
e	25.58 ± 1.69^{c}	0.07 ± 0.02^{a}	26.00 ± 1.40^{a}
f	29.03 ± 0.42^{a}	0.06 ± 0.01^{a}	23.81 ± 1.09^{b}
g	21.71 ± 0.77^{e}	0.06 ± 0.02^{a}	25.32 ± 0.01^{a}
h	25.05 ± 1.24^{cd}	0.06 ± 0.01^{a}	22.70 ± 0.16^{b}
i	23.75 ± 1.68^{cde}	0.06 ± 0.01^{a}	22.70 ± 0.19^{b}

Note: All values are mean ± standard deviation of three replicates (n=9).
a–f Means within a column with different letters are significantly different ($p\leq 0.05$)

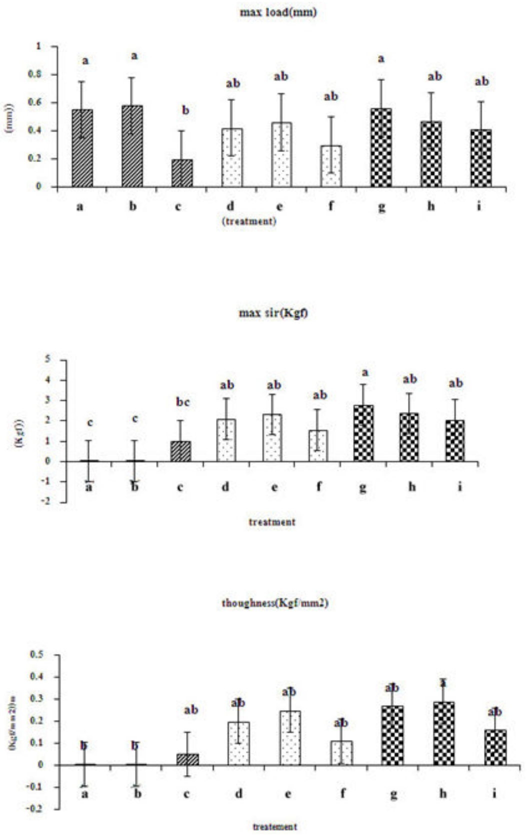

Fig. 4 Mechanical properties (a) max load (mm), (b) max SIR (Kgf) and (c) toughness (Kgf/mm^2)

The thickness of all formulation of film is not significant ($p \geq 0.05$). The color of yam starch film is quite significantly different ($p \leq 0.05$). Trend of the brightness (L*) of yam film starch is increased as starch content decreased and glyceral concentration increased. The effect could be related with binding of free hydroxyl group and molecule of glycerol enhanced to interaction with water so the appearance of yam film is brighter [2], [9]. Moisture content of yam starch film, glycerol concentration was a significant factor for moisture content (Table III).

4. Mechanical Properties

The tensile properties and puncture tests of yam starch film starch concentration was a significant factor for puncture tests and toughness of yam film (Fig. 4).

IV. Conclusion

This research has shown the characterization of yam starch film. Starch from water yam in Thailand and glycerol were used as plasticizers. The appearance of yam film is clearly smooth and glossy. In other characteristics, the concentration of starch and glycerol were a significant factor. In mechanical properties, higher starch concentration enhanced toughness more than lower starch, and a higher concentration of glycerol decreased puncture and tensile properties. Starch concentration was a significant factor for WVP and O_2.

Acknowledgment

This research was supported by Naresuan University, Thailand and The Higher Education Commission for Research Funding. The authors are also grateful to the Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand and the Faculty of Agricultural Technology Valaya Alongkorn Rajabath University, Phatumtanee for laboratory equipment.

References

[1] OroseRugchati and Kanita Thanacharoenchanaphas. “Comparison in Some Characteristic of Yam Tubers Starch (Dioscoreaceae spp.) from Thailand,” International Journal of Environmental and Rural Development volume 1(2) , 2010, pp.102-106.

[2] Al-Hassan, A.A. and M.H. Norziah, “Starch–gelatin edible films: Water vapor permeability and mechanical properties as affected by plasticizers,” Food Hydrocolloids, 2012. 26(1): p. 108-117

[3] Alves, V.D., et al., “Effect of glycerol and amylose enrichment on cassava starch film properties,” Journal of Food Engineering, 2007. 78(3): p. 941-946.

[4] Bertuzzi, M.A., et al., “Water vapor permeability of edible starch based films,” Journal of Food Engineering, 2007. 80(3): p. 972-978..

[5] Brandelero, R.P.H., F. Yamashita, and M.V.E. Grossmann, “The effect of surfactant Tween 80 on the hydrophilicity, water vapor permeation, and the mechanical properties of cassava starch and poly (butylene adipate-co-terephthalate) (PBAT) blend films,” Carbohydrate Polymers, 2010. 82(4): p.1102-1109.

[6] Carvalho, A.J.F., Chapter 15 " Starch: Major Sources, Properties and Applications as Thermoplastic Materials, in Monomers, Polymers and Composites from Renewable Resources,” B. Mohamed Naceur and G. Alessandro, Editors. 2008, Elsevier: Amsterdam. p. 321-342.

[7] Carvalho, A.J.F., 7”Starch: Major Sources, Properties and Applications as Thermoplastic Materials, in Handbook of Biopolymers and Biodegradable Plastics,” 2013. William Andrew Publishing: Boston. p. 129-152.

[8] Falguera, V., et al., “Edible films and coatings: Structures, active functions and trends in their use,” Trends in Food Science & Technology, 2011. 22(6): p. 292-303.

[9] Liu, H., et al., “Thermal processing of starch-based polymers,” Progress in Polymer Science, 2009. 34(12): p. 1348-1368.

[10] Mali, S., et al., “Microstructural characterization of yam starch films,” Carbohydrate Polymers, 2002. 50(4): p. 379-386.

[11] Mali, S., et al., “Effects of controlled storage on thermal, mechanical and barrier properties of plasticized films from different starch sources,” Journal of Food Engineering, 2006. 75(4): p. 453-460.

[12] Mali, S., et al., “Mechanical and thermal properties of yam starch films.” Food Hydrocolloids, 2005. 19(1): p. 157-164.

[13] Gebre-Mariam T. et al., “Some Physico-Chemical Properties of Dioscorea Starch from Ethiopia,” Starch/starke, 1998. 50 (6) :p241-246.

[14] Hoover, R.,” Composition, Molecular Structure, and Physiochemical Properties of Tuber and Starches : Review,” Carbohydrate Polymers, 2001.45: p 253-267.

[15] Association of Official Analytical Chemists (AOAC). Official Method of Analysis .The Association of Official Agricultural Chemists, Virginia, 1990. Vol.2. 15th ed., 163 p.

[16] Knutson, C.A., “A simplified colorimetric procedure for determination of amylose in maize starches,” Cereal. Chem, 1986. 63(2) : p 89-92