



Application of Biodegradable Film from Yam (*Dioscorea alata*) Starch in Thailand for Agriculture Activity

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Abstract Starch sample obtained from water yam (mun lued) by wet milling process. Yam starch films were prepared by thermal gelatinization technique casting using glycerol as plasticizer. The effect of different glycerol (1.65 and 2.00 g/100 g of filmogenic solution) starch concentration (3.30 g/100 g of filmogenic solution) was evaluated for some characteristic of these films. The effect of different surfactant Span80 (1 ml/100 g of filmogenic solution) and Tween 20 (1.5 ml/100 g of filmogenic solution) was studied. Suitable characteristic of biodegradable film from yam starch are glycerol 1.65 and span 80 (1 ml/100 g) as filmogenic formulation. The temperature for obtaining gelatinized starch solution was 70-80 °C and then dried at 45 °C for 4 hours. Film sample was molding in plastic bag form by simple sealing machine in average size 6x9 square inch. The samples expected to be applied as agriculture bag for agriculture activity. As a result, the appearance of film sample was smooth, transparence and glossy, with average moisture content of 25.96% and thickness of 0.01 mm. Puncture deformation and flexible increased with glycerol content. The starch and glycerol concentration were significant factors for yam starch film characteristic. Surfactant Span80 increased smoother and reduce sticky properties of film than Tween 20. Yam starch film as biofilms could be applied and developed in qualities, and with the advantage of biodegradability.

Keywords biodegradable film, yam starch in Thailand, *Dioscorea alata*, agricultural activity

INTRODUCTION

Water yam (mun lued) or greater yam (*Dioscorea alata*) belonged to Family Dioscoreaceae is a food crop of economic value in Africa and Asia. The yam produces tubers, bulbils or rhizomes as a starch staple food. Edible yams being most frequently cultivated in tropical area. Originally from Southeast Asia, yam tubers were distributed in all regions of Thailand. However, the main utilization of yams tubers in Thailand only for home consumption and local economic food, not in industrial scale. Yam also used for extraction starch in commercial scale when compare with other starch source such as cassava, potato, maize, wheat and sweet potato. Yam starch can be extracted from tubers by wet milling using water as the extracting solvent. The starch extracted by this method are very pure. One starch content was 97-98.53% (dry basis) when estimated by enzymatic method. The granular size of yam starch averages is 26.68 µm. Some physico-chemical characteristics of yam starch are difference from cassava starch so it could be applied not only for food industry but also non-food industry (Rugchati et al., 2013).

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 derivatives in their formulation (Falguera et al., 2011; Carvalho, 2013). 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 cheap, abundant, biodegradable, and edible with thermoplastic behavior and this is important for film production because amylose is responsible for the film-forming capacity of starches (Rugchati and Thanacharoenchanaphas, 2010; Hoover, 2001; AOAC, 1990). 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 (Bertuzzi et al., 2007; Brandelero et al., 2010; Carvalho, 2008 and 2013). 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 one of the most promising candidates for future materials because this polymer is biodegradable and edible with thermoplastic behavior that is easy to handle.

Yam starch is one alteration for polymeric carbohydrate composed of anhydroglucose units. It is not a uniform material and most starch contains two types of glucose polymers: a linear chain molecule termed amylose and a branched polymer of glucose termed amylopectin (Falguera et al., 2011). The ratio of amylose to amylopectin content is critical for technological applications. Yam starch (*D. 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 (Al-Hassan and Norziah, 2012; Alves et al., 2007). 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 vaporation (Maliet et al., 2002; Bertuzzi et al., 2007). 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 film. The branched structure of amylopectin generally leads to films with different mechanical properties, such as decreased tensile stress. Surfactants could be incorporated into the film formulation to reduce surface tension of the solution, improving the wettability and adhesion of the film. These chemical components are characterized for being amphiphilic. The lipophilic part of the molecule tends to be in a nonpolar environment and the hydrophilic part prefers to be in a polar (aqueous) environment. The balance between two governs the functionality of the surfactant at interfaces and also its influence on the properties of the resulting films. With surfactant addition to film formulation, it is expected a decrease in water vapor permeability values, because some hydrophobic characteristic were incorporated with components. Sorbitan fatty acid esters (Spans) and the corresponding polyoxyethylene (POE) adducts (Tweens) applied in a wide range of food, pharmaceutical and other industries. In some formulations, mixtures of Span surfactants and Tween surfactants are required, but some of the physical properties of these mixtures are not well defined (Alves et al., 2007; Brandelero et al., 2010).

OBJECTIVE

The objectives of this study were to evaluate the influence of the presence of plasticizers (glycerol), and the influence of different surfactant (Span80 and tween 20) on *Dioscorea alata* film characteristics, and the mechanical properties of starch films for suitable formulation of yam starch film products that could be applied and developed in qualities, and with the advantage of biodegradability in agricultural activities.

METHODOLOGY

Raw Material

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

Sample Preparation

Yam starch was extracted in the wet milling process (Rugchati and Thanacharoenchanaphas., 2010). Amylose and amylopectin contents of yam starch were determined simultaneously by the Knutson method (Knutson, 1986).

Film Preparation

Yam starch film was prepared by thermal gelatinization technique (Mali et al., 2002) with different glycerol, Span80 (Arlacel 80: Sorbitan monooleate (oily liquid) HLB 4.3) and Tween 20 (Polysorbate 60: Polyoxyethylene (20) Sorbitan monolaurate (yellow liquid) HLB 16.7) yam starch concentration (3.30 g /100 g of filmogenic solution) (Brandelero et al., 2010; Rugchati et al., 2013). The four filmogenic solution formulations selected were milligram of surfactant/100 g of filmogenic solution and gram of glycerol/100 g of solution (Table 1).

Table 1 Filmogenic solution formulations (100 g of solution)

Formulation	Glycerol (g)	Surfactant (ml)
a	1.65	Span80 (1 ml)
b	1.65	Tween 20 (1.5 ml)
c	2.00	Span80 (1 ml)
d	2.00	Tween 20 (1.5 ml)

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 500 g. The filmogenic solutions were transferred quantitatively to the cup of a Brabender Viscograph, and its 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 (75 rpm). Gelatinized suspensions were immediately poured on rectangular acrylic plates (20x20 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 12.25 mg/cm². The starch suspensions were dried (45 °C) in a ventilated oven (about 4 h). 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 (Mali et al., 2005 and 2006).

Characterization of Starch Films

Yam starch films were characterized by using electron microscopy scanner (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) (Rugchati et al., 2013).

Physical and Mechanical Properties

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 was measured by infrared automatic moisture meter (MA 40 SARTORIUS), and color measurement by Hunter Lab (model DP9500) (Rugchati et al., 2013).

Mechanical properties: The tensile properties and puncture tests were studied to determine force using an Instron 4411 (Instron Ltd., Canton, USA) (Rugchati et al., 2013).

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.

RESULTS AND DISCUSSION

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 morphological characteristics of the water yam tuber A. leaf, B. whole tuber and pulp, C. starch sample and D. starch granule

Table 2 Some physic-chemical characteristic of yam starch film

Treatment	Moisture (%)	Thickness (μm)	L*	WVP($\text{g}/\text{m}^2/\text{day}$)	OGT($\text{cm}^3/\text{m}^2/\text{day}$)
a	26.00 \pm 0.04ns	0.01	25.09 \pm 0.54a	2105 \pm 0.5a	13.10 \pm 0.5a
b	25.99 \pm 0.70ns	0.01	24.99 \pm 0.54a	2099 \pm 0.8a	12.95 \pm 0.5a
c	25.97 \pm 0.10ns	0.01	24.29 \pm 0.54b	2087 \pm 0.3b	11.42 \pm 0.5b
d	25.89 \pm 0.74ns	0.01	24.19 \pm 0.54b	2079 \pm 0.8b	12.00 \pm 0.5b

Note: All values are mean \pm standard deviation

a–b Means within a column with different letters are significantly different ($p \leq 0.05$)

Table 3 Mechanical characteristic of yam starch film

Formulation	Max load (mm)	Max SIR (Kgf)	Toughness (Kgf/mm^2)
a	0.54 \pm 0.09a	1.08 \pm 0.00a	0.025 \pm 0.00ns
b	0.41 \pm 0.12b	0.99 \pm 0.58a	0.023 \pm 0.05ns
c	0.37 \pm 0.10c	0.29 \pm 0.54b	0.025 \pm 0.5ns
d	0.40 \pm 0.74b	0.25 \pm 0.54b	0.024 \pm 0.5ns

Note: All values are mean \pm standard deviation

a–c Means within a column with different letters are significantly different ($p \leq 0.05$)

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 fine powder. The starch granular shape was triangular and the average size was 26.68 μm (Rugchati et al., 2013).

Characterization of Yam Starch Films

The appearance of yam starch film for most of the formulations was transparent, smooth, and glossy and some physic-chemical characteristic has shown on tables 2 and 3.

CONCLUSION

This research showed the characterization of yam starch film. Starch from water yam mixed with and glycerol 1.65 and span80 (1 ml/100 g) were used as filmogenic formulation. The appearance of yam film is clearly smooth and glossy. In other characteristics, the concentration of glycerol and surfactant were a significant factor. In mechanical properties, type and concentration of surfactant enhanced the puncture properties and a higher concentration of glycerol and surfactant decreased puncture and tensile properties. Glycerol concentration was a significant factor for WVP and O2.

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