Preparation and Characterization of Biodegradable Plastic Film from Starch Enriched Tubers

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***Abstract* - In this research work, potatoes and sweet potatoes were selected as vegetable tubers in the preparation of biodegradable plastic films. Firstly, the starch powders were prepared from potatoes and sweet potatoes by washing, cutting, grinding, drying and pulverizing. The physico-chemical properties of prepared starches such as pH, moisture content, ash content, bulk density, gelatinization temperature and protein were investigated. The elemental compositions of prepared starches were analyzed by Energy Dispersive X-Ray Fluorescence (EDXRF). Secondly, the biodegradable plastic film was prepared using starch powder, water and glycerol as plasticizer. In this experiment, the effects of amount of starch powder, amount of glycerol and volume of water on the tensile strength of prepared biodegradable plastic films were investigated. The organoleptic, chemical and mechanical properties of prepared plastic films were determined and the solubility test was also carried out. Moreover, the evaluation of biodegradability property was conducted by soil burial method. The functional groups of prepared plastic films were investigated by Fourier Transform Infrared Spectroscopy (FTIR).**

***Keywords* — biodegradable plastics, starch, glycerol as plasticizer, biodegradability property**

I. INTRODUCTION

Biodegradable plastics or bioplastics are produced from biopolymer obtained from natural sources, such as starch, cellulose and proteins. Biodegradation results in a change in the plastic chemical structure. The change is usually caused by the biological activity of microbes in the environment contributing to naturally occurring metabolic end products. Biodegradable polymer is the best alternative to petroleum-based polymers in many applications owing to their biodegradability, biocompatibility and the rising cost of petroleum-based plastics. Biopolymers can be classified as natural biodegradable polymers, polymers with hydrolysable backbones and polymers with carbon backbones. The natural biodegradable polymers are defined as the polymers that are formed naturally during the growth cycles of all organisms. They are divided into three main groups: polysaccharides, polypeptides of natural origin and bacterial polyesters. In the field of material science, cellulose and starch are the most abundant of the naturally occurring polymers as such have gained much attention [1]. Starch is a polymer material that occurs widely in plants like potatoes, corn and rice as water insoluble granules. Starch has been widely used as a raw material in film production because it is the most abundant; it is available in bulk in all parts of the world at low cost and it has polymeric properties and can be easily modified both physically and chemically. Starch based films makes them attractive materials for food packaging because of the low permeability characteristic. Besides, starch is composed of amylose and amylopectin elements and it has swelling, water solubility and water binding capacities. After reacting starch with water in a heat treatment, together with addition of some plasticizer and thickener producing a stronger film, the film formation can be improved [2]. There are a number of plasticizers such as glycerol, sorbitol, xylitol, urea, formamide that have been widely used for making bioplastic film. The most common plasticizers used in the preparation of bioplastic film are water and glycerol. Since it is food grade, edible, safe for consumption and comes from natural sources, glycerol is the most commonly used as a plasticizer to produce edible film. Hence, addition of glycerol helps to plasticize together the starchy solutions to a film with plasticity effect. There are various types of film formation methods for production of bioplastic like solution casting method, melt mix method, electro spinning method, thermo pressing and casting, extrusion blown film method. The casting method is the most widely used technique for the production of starch based film [3]. There are many advantages in the biodegradable plastic films whereas; they do have some disadvantages as well. The main benefits of bio based plastics are low carbon footprint, low energy costs in manufacturing and reduction in litter with improved compostability. Many studies have been applied to produce starch based polymer for conserving the petrochemical resources and reducing environmental impact. In contrast, starch based

biodegradable plastic film have some drawbacks such as poor mechanical properties and long term stability caused by water absorption and retrogradation. To overcome these limitations, plasticizer such as glycerol has been added to improve shelf-life and elasticity of the product [4]. In this research, starch is prepared from vegetable tubers and biodegradable plastic films are made from prepared starch. Biodegradable plastic film is easy to breakdown and not takes up large space in landfills. The aims of this research are to be applied in food packaging industry, to reduce the carbon footprint of traditional resins because it can replace petroleum based plastics with natural polymers, to reduce solid wastes and improve compostability from using biodegradable plastics.

II. MATERIALS AND METHOD

In this research work, potatoes and sweet potatoes were selected as valuable raw materials in the preparation of biodegradable plastic films. They were collected from Shan Lay Kyune Village, Amarapura Township, Mandalay Region, Myanmar.

A. Isolation of Starch from Vegetable Tubers

Potatoes were peeled, washed, sliced for easy blending and ground in a blender using 1:2 (w/v) ratio of water until thoroughly fine. The thoroughly fine mixture was filtered through cotton cloth and then the filtrate was allowed to settle for 15 minutes at room temperature. After that, the supernatant was decanted and the precipitate was collected as wet starch. It was dried in an oven at 50ºC for 5 hrs. The dry starch lump was gently crushed into powders using motor and pestle and screened with 100 mesh size sieve. The starch powders were stored in an airtight plastic bag to prevent moisture and contamination for further analysis. The above procedure was conducted to isolate the starch powder from sweet potatoes.

B. Preparation of Biodegradable Plastic from Starch

Biodegradable plastics were prepared with potato starch powder, glycerol as plasticizer and distilled water. 1g of potato starch powder, 0.5g of glycerol and 20 mL of distilled water were added into the beaker and heated with constantly stirring using magnetic stirrer until the mixture to gelatinize at approximately 70ºC. The resultant starch paste was poured and spread onto a large steel plate and then dried in hot air oven at 50ºC for 90 minutes to obtain the film. The dried film was manually peeled off and stored in airtight container at room temperature. The same procedure was carried out for preparation of biodegradable plastic film from sweet potato starch powder. In the preparation of biodegradable plastic film, the effect of amount of glycerol, amount of starch, volume of water on the tensile strength of prepared biodegradable plastics were determined. The same procedure was carried out for the preparation of biodegradable plastic film from sweet potato starch.

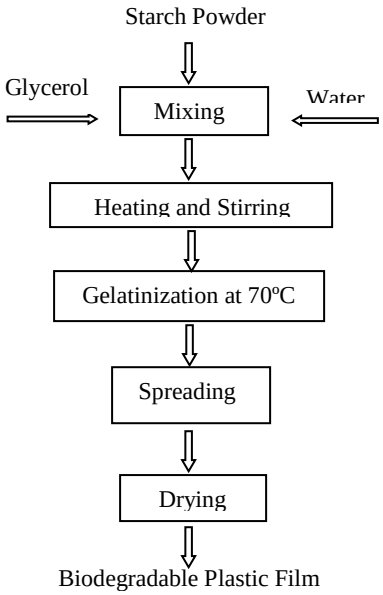


Fig. 1 Flow diagram for the preparation of biodegradable plastic films

III. RESULTS AND DISCUSSION

The physico-chemical characteristics of prepared potato and sweet potato starch powder are shown in Table I. According to the results, the moisture content, protein content and gelatinization temperature of potato starch were higher than that of sweet potato starch and other characteristics such as pH, ash content, bulk density and yield percent of potato starch were lower than the sweet potato starch.

Table I Physico-chemical Characteristics of Starch

Sr. No.	Characteristics	Potato Starch	Sweet Potato Starch
1	pH	7.02	7.14
2	Moisture content (%w/w)	16	10
3	Ash content (%w/w)	0.2	0.4
4	Bulk density (g /ml)	0.47	0.87
5	Gelatinization temperature (˚C)	61.2	59.5
6	Protein content (%)	7.50	3.47
7	Yield percent (% w/w)	50	64

The elemental compositions of prepared starches were analyzed by EDXRF method as shown in Fig.2 and Fig.3. From these results, harmful elements such as arsenic, cadmium, mercury and lead did not contain in prepared starch samples. It can be clearly seen that starches were actually natural organic polymers and

environmentally friendly materials. Therefore, it can be used in the preparation of bioplastic films.

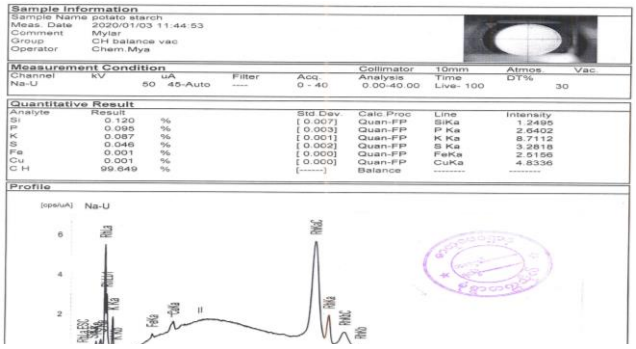


Fig. 2 The elemental compositions of potato starch were analyzed by EDXRF method

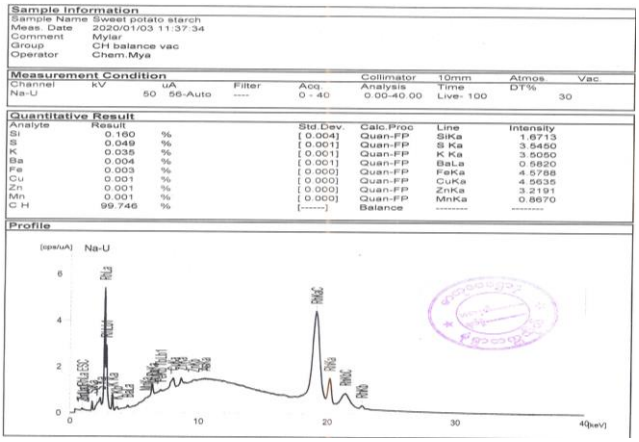


Fig. 3 The elemental compositions of sweet potato starch were analyzed by EDXRF method

The effects of amount of starch powder, the amount of glycerol and the volume of water on the tensile strength of prepared biodegradable plastic were investigated and shown in Table II and Table III.

Table II Variable Parameters for Potato

Sr. No.	Parameters	Levels of Variables		
1.	Amount of Starch (g)	0.5	1*	1.5
2.	Amount of Glycerol (g)	0.25	0.5*	0.75
3.	Volume of Water (ml)	10	20*	30

*the most suitable conditions

Table III Variable Parameters for Sweet Potato

Sr. No.	Parameters	Levels of Variables		
1.	Amount of Starch (g)	0.5	1*	1.5
2.	Amount of Glycerol (g)	0.5	0.75*	1
3.	Volume of Water (ml)	10	20*	30

*the most suitable conditions

The chemical properties of prepared biodegradable plastic film are shown Fig.4. From the results of analysis, prepared plastic film using potato starch was higher absorption resistant to water and moisture than prepared plastic film using sweet potato starch. In the acid medium, the absorption capacity of plastic film using sweet potato starch was faster than bioplastic film using potato starch. However, it was observed that both prepared biodegradable plastic films using potato and sweet potato starch were completely soluble in the base medium.

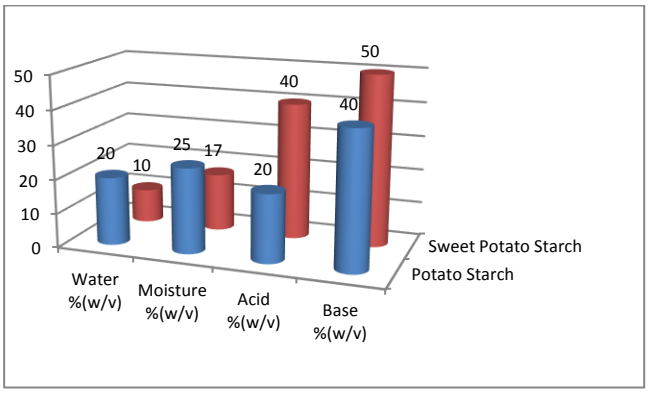


Fig. 4 Comparison of the chemical resistant of prepared biodegradable plastics films from potato and sweet potato

Table IV Solubility Test

Sr. No.	Solvents	Potato Starch		Sweet Potato Starch	
		Room Temp:	60˚C	Room Temp:	60˚C
1	Chloroform	I	B	I	B
2	Acetone	I	I	I	I
3	Ethanol	I	S	I	S
4	Methanol	I	I	I	I
5	Benzene	I	I	I	I

Where, S = Soluble, I = Insoluble, B = Brittle

The solubility test for prepared biodegradable plastic films in different solvents is described in Table (IV). When the solubility of prepared bioplastic films in different solvents like chloroform, acetone, ethanol and methanol and benzene were investigated both at room temperature (28ºC-30ºC) and at 60ºC, all the bioplastic films were found to be insoluble at room temperature but the films turned to be brittle in chloroform and be swollen in ethanol at 60ºC.

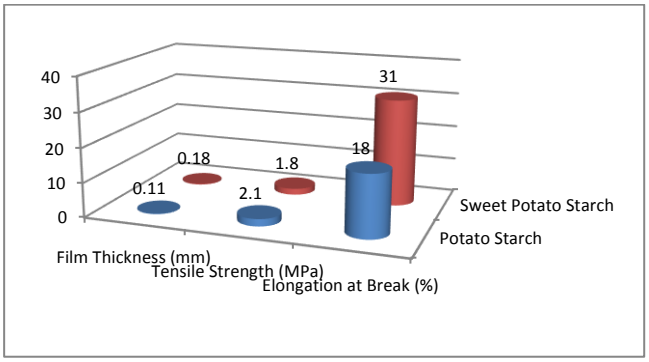


Fig. 5 Comparison of mechanical properties of prepared biodegradable plastics films from potato and sweet potato starches

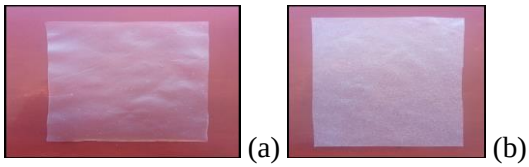
From the results of the mechanical properties of prepared biodegradable plastic film using potato and sweet potato starch, potato starch based plastic film had good tensile strength and low in elongation at break compared to sweet potato starch based plastic film as shown in Fig.5.

Table V Biodegradable Properties

Sr. No.	Time	Potato Starch			Sweet Potato Starch		
		W_1 (g)	W_2 (g)	W (%)	W_1 (g)	W_2 (g)	W (%)
1	One week	3.2	2.1	34	3.1	2.4	26
2	Two weeks	3.1	1.5	51	3.3	1.9	42
3	Three Weeks	3.1	0.6	80	3.1	0.9	70
4	Four weeks	3.2	0	0	3.2	0.2	97

Where, W_1 = Initial weight of biodegradable plastic
W_2 = Final weight of biodegradable plastic
W = Weight loss of biodegradable plastic

According to the results of the biodegradable property of prepared biodegradable plastic films are shown in Table V, it can be seen that prepared biodegradable plastic film was completely biodegrade after 30 days of exposure to soil. The organoleptic properties of prepared biodegradable plastic films are shown in Table VI and Fig.6. It can be clearly seen that plastic film using potato starch had white colour, no odour, and good smooth, translucent and stretchable. Similarly, plastic film using sweet potato starch possesses white colour, no odour and good smooth but it was opaque and slightly stretchable.



(a) (b)

Fig. 6 Biodegradable plastic films using (a) potato Starch (b) sweet potato starch

Table VI Organoleptic Properties

Sr. No	Characteristics	Potato Starch	Sweet Potato Starch
1	Colour	White	White
2	Odour	Nil	Nil
3	Texture	Smooth	Smooth
4	Transparency	Translucent	Opaque
5	Extensibility	Very Stretchable	Slightly Stretchable

The FTIR spectrum curve of prepared biodegradable plastic films was shown in Figure (7) and Figure (8) and the observed functional groups are tabulated in Table (VII). The frequencies at 3292.17cm-1 and 3292 cm-1 were respectively represented the presence of alcohol and phenol group which has –OH stretching vibration. The band at 2924.71 cm-1 and 2926.31 cm-1 were indicated the alkynes group which has C-H stretching vibration. The small peaks at 1645.27 cm-1 and 1645.48 cm-1 were corresponded to the presence of C=O stretching vibration of the aldehyde group. The band at 1000.21 cm-1 and 1018.39cm-1 were also represented the characteristics of C-O stretching vibration of alcohol and phenol group respectively. From the FTIR analysis, the presence of O-H, C-H, C=O and C-O absorption peaks, which indicated the formation of biodegradable plastic has already occurred. The result was also verified with the available results of other researchers.

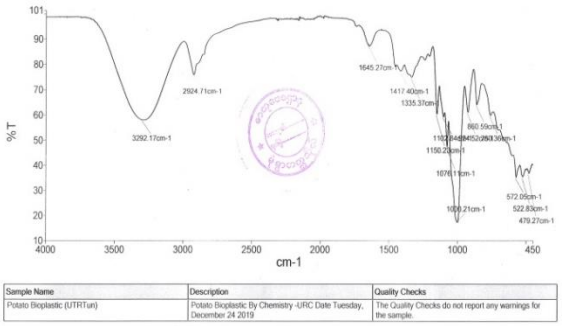


Fig.7 The functional groups of biodegradable plastic using potato starch were analyzed by FTIR method

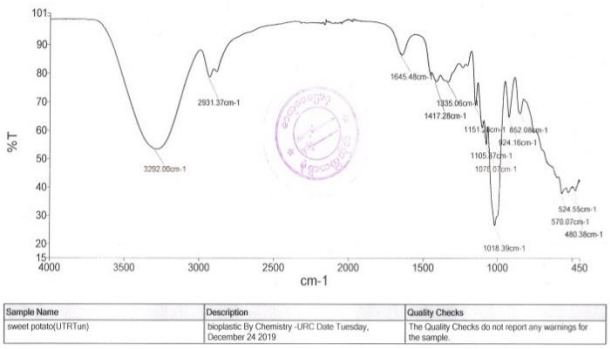


Fig.8 The functional groups of biodegradable plastic using sweet potato starch were analyzed by FTIR method

Table VII Characteristics of Functional Groups

Sr. No	Observed Frequency (cm^{-1})		Literature Frequency (cm^{-1})	Band Ascription
	Potato	Sweet Potato		
1	3292.17	3292.00	3277.76	O-H stretching vibration
2	2924.71	2931.37	2926.31	C-H stretching vibration
3	1645.27	1645.48	1643.22	C=O stretching vibration
4	1000.21	1018.39	1014.48	C-O stretching vibration

Literature Frequency = [5]

IV. CONCLUSIONS

Biodegradable plastic films have been successfully produced from potato and sweet potato with glycerol as plasticizer and water as solvent by the casting method. Both potato and sweet potato tubers are found to be highest starchy raw materials, cheap, abundant and readily availability. According to the EDXRF analysis, there were no toxic elements in the prepared starch. Therefore, it can be used in the preparation of starch based biodegradable plastic film as food packaging material. Based on the results of chemical, mechanical an biodegradable properties of prepared plastic films, it can be concluded that plastic film using potato starch was found to be better chemical resistant, better tensile strength and faster rate of soil biodegradation than sweet potato starch. The prepared bioplastic film using potato starch was found to be good smooth, transparency and flexibility while the prepared bioplastic film using sweet potato starch was observed to be good texture and slightly flexibility. In comparison with the convectional plastic materials, biodegradable plastic film based potato and sweet potato starch are eco-friendly class of materials which can be used for food packaging. The functional group O-H, C-H, C=O and C-O indicate the formation of starch based bioplastics which was confirmed by FTIR spectroscopy. Therefore, it can be concluded that this bioplastic film was used for food packaging industry and they can also reduce the environmental pollution.

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