# Preparation and Characterization of Starch Based Bioplastic Film from Dent Corn

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## Abstract

In this research work, dent corn (*Zea mays* L.) was selected as a raw material in the preparation of bioplastic films. Firstly, the starch powders were prepared from dent corn 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 content were investigated. The elemental compositions of prepared starch were analyzed by Energy Dispersive X-Ray Fluorescence (EDXRF). Secondly, the bioplastic 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 (FT-IR).

**Keywords:** dent corn, starch, plasticizer, bioplastic film, biodegradable property

## 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, the most abundant of the naturally occurring polymers, have gained much attention (https://www.ijert.org/starch-basedbiodegrable-blends-a-review).

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; it has polymeric properties; and can be easily modified both physically and chemically. Starch based films make 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. The film formation can be improved after reacting starch with water in a heat treatment, together with addition of some plasticizer and thickener producing a stronger film (Mohd Marsin et al., 2008).

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 glycerol is food grade, edible, safe for consumption and comes from natural sources, it is the most commonly used as a plasticizer to produce edible film. Hence, addition of glycerol helps to plasticize together the

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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 most widely used technique for the laboratorial production of starch based film is casting method (Mali et.al., 2002).

There are many advantages in the bioplastic films, whereas they do have some disadvantages as well. The major advantages 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. However, starch based bioplastic film have some drawbacks including 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 (Nurul Aina, et al., 2016).

In this research, starch is prepared from dent corn and edible film is made from prepared starch. Bioplastic film is easy to breakdown and does not take 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 bioplastics.

## Materials and Methods

### Materials

In this research, dent corn was selected as valuable raw material in the preparation of bioplastic film. They were collected from Shan Lay Kyune Village, Amarapura Township, Mandalay Region. The required chemicals such as glycerol (Analar grade) and distilled water were purchased from Able Hospital Equipment & General Trading, at the Corner of 76$^{th}$ street and 29th street, Chanayetharzan Township, Mandalay Region.

### Methods

### Preliminary Preparation

Dent corn husks were firstly removed and washed with water to remove some trash. After that, dent corn grains were gathered from the cob by hand.

### Extraction of Starch from Dent Corn

Dent corn grain 100 g was thoroughly washed to remove foreign materials. Then, the grains were steeped in 500 ml of water for 24 hours and washed with water for three times. The grains were ground using a blender and the 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.

**Physico-chemical Characteristics of Dent Corn Starch**

The physico-chemical characteristics of prepared starch such as pH, moisture content, ash content, bulk density, gelatinization temperature and protein content were determined. The elemental compositions of prepared starch were also analyzed by Energy Dispersive X-Ray Fluorescence (EDXRF).

**Preparation of Bioplastic Film from Dent Corn Starch**

Bioplastic film was prepared with starch powder, glycerol as plasticizer and distilled water. 1g of 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.

**Effect of Ingredients on the Tensile Strength of Prepared Bioplastic Film**

Effect of Amount of Glycerol

To determine the most suitable amount of glycerol used as plasticizer, the amount were varied in the range of (0.25g to 0.75g), while the other variables were fixed using the same method mentioned above. The effect of amount of glycerol on the tensile strength of prepared plastic film was determined.

**Effect of Amount of Starch Powder**

The effect of amount of starch powder on the tensile strength of prepared plastic film was investigated as the same procedure mentioned above except variable of amount of starch in the range of (1g to 2.5g).

**Effect of Volume of Water**

The effect of volume of water on the tensile strength of prepared plastic film was carried out as the same procedure mentioned above except variable of volume of water in the range of (10mL to 30mL).

**Properties and Characteristics of Prepared Bioplastic Film**

**Chemical Properties of Bioplastic Film**

**Water Absorption Resistant**

The prepared bioplastic film were soaked in water at room temperature for 60min and dried with cotton pieces and weighed. The percentage of water absorption can be calculated as follow and the results are shown in Table (5).

$$\text{Water Absorption (\%)} = \frac{\text{Wet weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100$$

**Acid Absorption Resistant**

Acid resistant properties of bioplastic film were carried out by soaking a definite amount of prepared bioplastic film in 1N hydrochloric acid solution. Weights of the bioplastic film were determined at regular time interval of 1 hour. The percentage of acid absorption can be calculated as follows and the results are shown in Table (5).

$$\text{Acid Absorption (\%)} = \frac{\text{Wet weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100$$

**Base Absorption Resistant**

Base resistant properties of bioplastic film were carried out by soaking a definite amount of prepared bioplastic film in 1N sodium hydroxide solution. Weights of the sample were determined at regular time interval of 1 hour. The percentage of acid absorption can be calculated as follow and the results are shown in Table (5).

$$\text{Base Absorption (\%)} = \frac{\text{Wet weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100$$

**Moisture Absorption Resistant**

The prepared bioplastic film were dried in a desiccator until their weight became constant ($W_1$). These films were then placed in normal atmosphere for 24 hr. After that, the films were weighed ($W_2$) again. The percentage of moisture absorption can be calculated as follows and the results are indicated in Table (5).

$$\text{Moisture Absorption (\%)} = \frac{(W2 - W1)}{W1} \times 100$$

**Solubility Test for Bioplastic Film**

In this study, the solvents used were acetone, chloroform, diethyl ether, ethanol and methanol. The prepared bioplastic film was cut into small pieces and 0.3g of them was put into test tubes containing 3ml of each solvent. After an hour, the solubility of the films both at (28-30°C) and at (60°C) was observed. The respective results are shown in Table (6).

**Mechanical Properties of Bioplastic Film**

The film thickness**,** tensile strength and elongation at break of the prepared bioplastic films were determined with Tensile Testing Machine at Rubber Research and Development Centre, Ministry of Agriculture, Livestock and Irrigation, Yangon. The results are shown in Table (7).

**Biodegradability Property of Bioplastic Film**

Biodegradability test was done by using the soil burial method (R.Naryan, *et.al*., 1999) with a little modification. The prepared bioplastic film was cut into pieces of 3 inches length and 3 inches width and weighed ($W_1$). The weighed film was then buried inside the soil at a depth of 3 inches for one week under the room temperature. After that, the film was then again weighed ($W_2$). The starch content consumed by soil microorganisms will fracture the polymer chain thus cause the biodegradation. The percent weight loss of film can be calculated as follows and the results are recorded in Table (8).

$$\text{Percent Weight Loss, \%W} = \frac{(W1 - W2)}{W1} \times 100$$

**Organoleptic Properties of Bioplastic Film**

A nine-point hedonic scale with ratings ranging from 1-9 was used in the study. In the hedonic scale, 9 = the highest score (like extremely), 8= (like very much), 7= (like moderately), 6 = (like slightly), 5 = (neither like nor dislike), 4 = (dislike slightly), 3 = (dislike moderately), 2 = (dislike very much) and 1 = the lowest score (dislike extremely).

The organoleptic properties namely colour, odour, texture, transparency and extensibility were determined on the basis of 9 point Hedonic scale by a panel of 10 semi-trained judges. The overall acceptability of the product was taken as the average score of all these organoleptic properties. Sample of each of prepared bioplastic film was picked and

the sample was coded with symbols. Then the samples were presented in random manner and the tasted test was carried out and the results are presented in Table (9).

**Characterization of Functional Groups of Bioplastic Film**

The prepared films were analyzed by using a Fourier Transform Infrared Spectroscopy (FT-IR). The FT-IR spectra of prepared films are shown in Figure (5). The respective functional groups are shown in Table (10).

## Results and Discussion

The physico-chemical characteristics of dent corn starch are shown in Table (1). According to the results, although the pH value, moisture content and gelatinization temperature of dent corn starch were lower than that of the literature values, other characteristics such as ash content, protein content and yield percent were in the range of literature values. All these compositions could be depended on cultivar, region and climatic conditions. The elemental compositions of prepared starch were analyzed by EDXRF method as shown in Figure (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 starch was actually a natural organic polymer and environmentally friendly material. Therefore, it can be used in the preparation of edible film.

The effects of amount of glycerol, amount of starch powder and volume of water on the tensile strength of prepared bioplastic film are shown in Table (2), Table (3) and Table (4). In these results, it was found that 0.5g of glycerol, 1g of starch powder and 20 mL of water were the most suitable conditions because they gave more tensile strength than other amounts and volume.

The chemical properties of prepared bioplastic film are shown in Table (5). From the results of analysis, prepared bioplastic film using dent corn starch was observed to be reasonable absorption resistant to water and moisture. In the acid medium, the absorption capacity of prepared bioplastic film was also acceptable but it was completely soluble in the base medium. The solubility test for prepared bioplastic films in different solvents are described in Table (6). 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 (28ºC-30ºC) but the films turned to be brittle in chloroform and be swollen in ethanol at 60ºC.

From the results of the mechanical properties of prepared bioplastic film, it had good tensile strength and elongation at break that is suitable for food packaging as shown in Table (7). According to the results of the biodegradable property of prepared bioplastic film shown in Table (8), it can be seen that prepared bioplastic film was completely biodegrade after 30 days of exposure to soil. The organoleptic properties of prepared bioplastic film are shown in Table (9). It can be clearly seen that bioplastic film using potato starch had pale yellow colour, no odour, good smooth and translucent but it was opaque and slightly stretchable.

The FT-IR spectrum curve of prepared bioplastic film was shown in Figure (5) and the observed functional groups are tabulated in Table (10). The frequency at 3287.62 cm-1 was represented the presence of alcohol and phenol group which has –OH stretching vibration. The band at 2969.80 cm-1 was indicated the alkynes group which has C-H stretching vibration. The existence of C=O stretching vibration of carbonyl groups showed up the peak at 1738.15 cm-1. The frequency at 1365.17 cm-1 was corresponded to the presence of C-O-C stretching vibration of the aldehyde group. The band at 1021.27 cm-1 was also represented

the characteristics of C-O stretching vibration of alcohol and phenol group because FT-IR spectra exhibited that the intermolecular interaction in bioplastic occurred through C-O-H, O-H, C-H, C=O, C-O groups, it can be proved that this bioplastic was completely biodegradable.

Table (1) Physico-chemical Characteristics of Dent Corn Starch

| Sr.No | Characteristics | Dent Corn Starch | Literature Value* |
|---|---|---|---|
| 1 | pH | 7.02 | 7.14 |
| 2 | Moisture content (%w/w) | 6.5 | 8.5 |
| 3 | Ash content (%w/w) | 0.2 | 0.1-0.3 |
| 4 | Bulk density (g /ml) | 0.47 | - |
| 5 | Gelatinization temperature (˚C) | 61.2 | 66.3 |
| 6 | Protein content (%) | 2.0 | 1.1-2.0 |
| 7 | Yield percent (% w/w) | 64 | 50-70 |

*(Juan Carlos. et.al, 2019)

Figure (1) Dent Corn

Figure (2) Dent Corn Starch

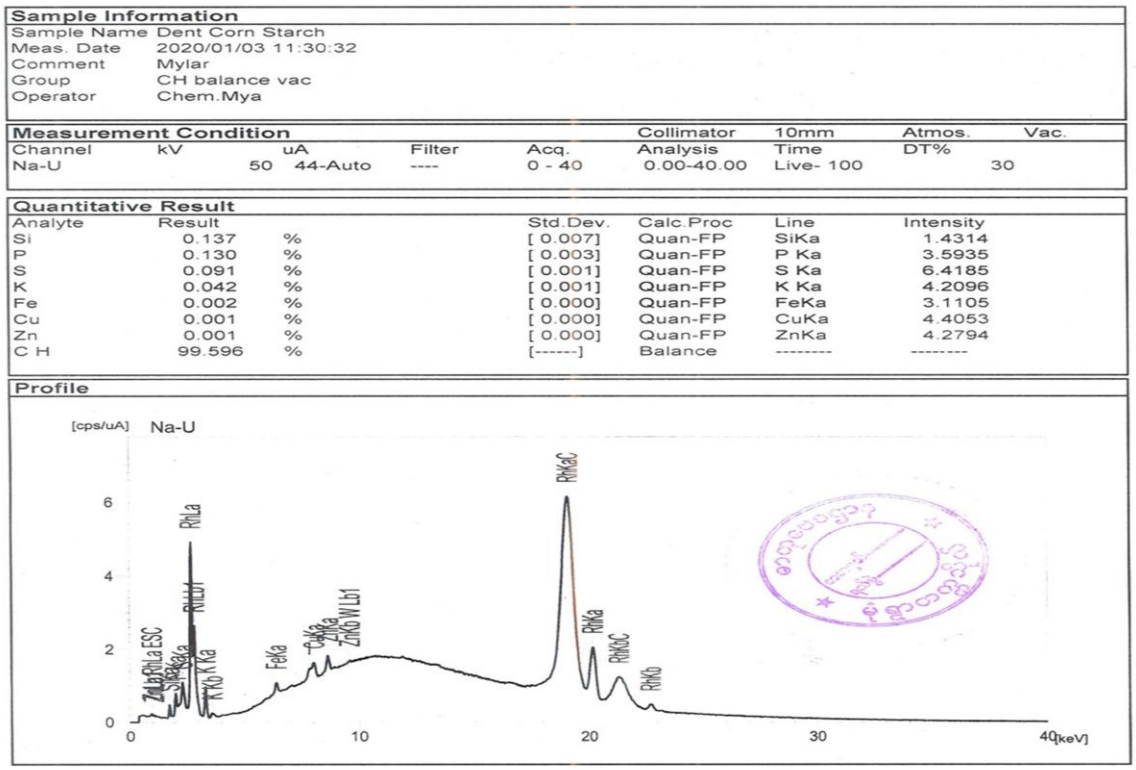


Figure (3) EDXRF Spectrum of Prepared Dent Corn Starch

Table (2) Effect of Amount of Glycerol on the Tensile Strength of Bioplastic Film

Amount of Starch = 1 g Volume of Water = 20 mL

| Sample No. | Amount of Glycerol (g) | Tensile Strength (MPa) |
|---|---|---|
| 1 | 0.25 | 1.9 |
| 2 | 0.5* | 2.2 |
| 3 | 0.75 | 1.7 |

*****the most suitable condition

Table (3) Effect of Amount of Starch Powder on the Tensile Strength of Bioplastic Film

Amount of Glycerol = 0.5 g Volume of Water = 20 mL

| Sample No. | Amount of Starch (g) | Tensile Strength (MPa) |
|---|---|---|
| 1 | 1 | 2.2 |
| 2 | 1.5 | 2.4 |
| 3 | 2* | 2.6 |
| 4 | 2.5 | 2.3 |

*the most suitable condition

Table (4) Effect of Volume of Water on the Tensile Strength of Bioplastic Film

Amount of Starch = 2 g Amount of Glycerol = 0.5 g

| Sample No. | Amount of Glycerol (g) | Tensile Strength (MPa) |
|---|---|---|
| 1 | 10 | 1.8 |
| 2 | 20* | 2.6 |
| 3 | 30 | 2.0 |

*****the most suitable condition

Table (5) Chemical Properties of Prepared Bioplastic Film

| Sr.No | Properties | Compositions |
|---|---|---|
| 1 | Water absorption resistant (% w/v) | 25 |
| 2 | Moisture absorption resistant (% w/v) | 30 |
| 3 | Acid absorption resistant (% w/v) | 20 |
| 4 | Base absorption resistant (% w/v) | soluble |

Table (6) Solubility Test for Prepared Bioplastic Film

| Sr.No. | Solvents | (28-30˚C) | (60˚C) |
|---|---|---|---|
| 1 | Chloroform | Insoluble | Brittle |
| 2 | Acetone | Insoluble | Insoluble |
| 3 | Ethanol | Insoluble | Swell |
| 4 | Methanol | Insoluble | Insoluble |
| 5 | Benzene | Insoluble | Insoluble |

Table (7) Mechanical Properties of Prepared Bioplastic Film

| Sr.No | Properties | Compositions |
|---|---|---|
| 1 | Film Thickness (mm) | 1.3 |
| 2 | Tensile Strength (MPa) | 2.6 |
| 3 | Elongation at Break (%) | 24 |

Table (8) Biodegradability Property of Prepared Bioplastic Film

| Sr.No | Time | Initial (g) | Final (g) | Weight Loss (%) |
|---|---|---|---|---|
| 1 | One week | 3.2 | 2.1 | 34 |
| 2 | Two weeks | 3.1 | 1.5 | 51 |
| 3 | Three weeks | 3.1 | 0.6 | 80 |
| 4 | Four weeks | 3.2 | 0 | 0 |

Table (9) Organoleptic Properties of Prepared Bioplastic Film

| Sr.No. | Properties | Characteristics |
|---|---|---|
| 1 | Colour | Pale Yellow |
| 2 | Odour | Nil |
| 3 | Texture | Smooth |
| 4 | Transparency | Opaque |
| 5 | Extensibility | Slightly Stretchable |

Figure (4) Bioplastic Film Using Dent Corn Starch

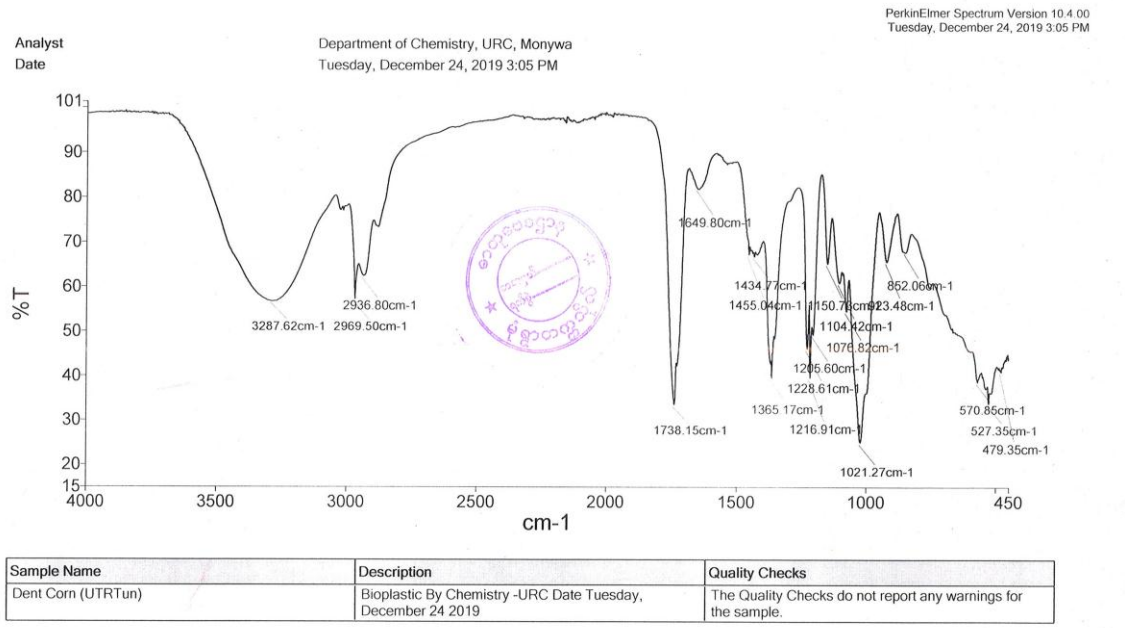


Figure (5) FT-IR Spectrum of Prepared Bioplastic Film

Table (10) Characteristics of Various Functional Groups of Prepared Bioplastic Films by Fourier Transforms Infrared Spectroscopy (FT-IR)

| Sr. No | Observed Frequency ($cm^{-1}$) | Literature Frequency* ($cm^{-1}$) | Band Assignment | Remark |
|---|---|---|---|---|
| 1 | 3287.62 | 3266.20 | O-H stretching vibration | Alcohol and Phenol groups |
| 2 | 2969.80 | 2925.27 | C-H stretching vibration | Alkynes group |
| 3 | 1738.15 | 1736.44 | C=O stretching vibration | Carbonyl groups |
| 4 | 1365.17 | 1367.04 | C-O-H stretching vibration | Aldehyde group |
| 5 | 1021.27 | 1035.75 | C-O stretching vibration | Alcohol and Phenol groups |

The data were determined at the Department of Chemistry, Monywa University, Myanmar

*M.I.J. Ibrahim.,et al. 2019.

## Conclusion

Bioplastics have been successfully produced from dent corn starch with glycerol as plasticizer and water as solvent by the casting method. Dent Corn is 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 bioplastic film as food packaging material. The prepared bioplastic film using dent corn starch was observed to be good texture and very flexibility. Based on the results of chemical, mechanical and biodegradable properties of prepared bioplastic film, it can claimed that bioplastic film based dent corn starch was found to be acceptable chemical resistant, tensile strength, elongation at break and faster rate of soil biodegradation compared to conventional plastics. The functional group O-H, C-H, C=O, C-O-H and C-O indicate the formation of starch based bioplastics which was confirmed by FTIR spectroscopy. The result was also verified with the available results of other researchers. 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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## References

A.Mohd Marsin, et.al.,(2017), "Preparation and Characterization of Purple Sweet Potato Starch- Based Edible Film with optimized Mixing Temperature," *Journal of Advanced Research in Materials Science*, Vol.16.No.1, Pages 1-10

AOAC Official Methods of Analysis of AOAC, (2000), International 7th Edition, 934.01.

Mali et al., (2005a), "Influence of Thickness on Properties of Plasticized Oat Starch Film", *Journal of Brazilian Archives of Biology and Technology*, Vol. 56, No.4, Pages-218-232.

Nural Aina Ismail, et.al., (2016). *"Synthesis and Characterization of Biodegradable Starch-Based Bioplastics",* Trans tech Publication, Vol.846, Pages 673-678.

Pearson, D., (1976). Chemical Analysis of Foods, Churchill Livingstone, Edinburgh London and New York, 7th edition.

**Website**

https://www.ijert.org/starch-basedbiodegrable-blends-a-review

http://www.wikipedia.org.com/glycerol