*Journal of Applied Horticulture, 21(1): 13-19, 2019*

# Characteristics of bio-plastic composites from the modified cassava starch and konjac glucomannan

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## Abstract

The production of bio-plastics from modified cassava starch and konjac glucomannan had been widely and dependently developed but still demonstrated characteristics that do not meet international quality standards. Therefore the key question for further exploration was to improve the protocol so as to develop a composite bio-plastic using the aforementioned materials. This study aimed to determine the ratio of modified cassava starch and konjac glucomannan and the concentration of acetic acid solution required to produce bio-plastic composites with the best characteristics. This study followed a Factorial Randomized Block Design with two factors. Factor I was the ratio of the modified cassava starch and konjac glucomannan, and consisted of 5 levels namely 100:0, 75:25, 50:50, 25:75 and 0: 100. The factor II was the concentration of acetic acid which consisted of 5 levels, *viz.,* 0, 0.5, 1.0, 1.5 and 2.0 %. Each treatment combination was grouped into 4 blocks based on the processing time of making bio-plastic composites, resulting in an altogether 100 experimental units. The data obtained were subjected to analysis of variance followed by Duncan's multiple comparison tests. The results showed that the ratio of the modified cassava starch and konjac glucomannan, the concentration of acetic acid and its interaction had a very significant effect on the tensile strength, elongation at break, Young's modulus, swelling and the degradation time of bio-plastic composites. The ratio of the modified cassava starch:konjac glucomannan :: 75:25 with supplemented with 1 % acetic acid produced the best bio-plastic composites with the desired characteristics *viz.,* tensile strength of 1997.40 MPa, elongation at break of 8.90 %, Young's modulus of 22442.70 MPa, swelling of 10.40 % and the degradation time of 6.33 days. The surface profile of bio-plastic composites in longitudinal appearance displayed presence of regular waveforms along with air cavities or regular pores. Bio-plastic composite profile in transverse appearance revealed arrangement of fibers in the form of regular nets and smooth cross links. These bio-plastic composites contained -OH, -CH, -C-C, -C=C, -NH and -C=O functional groups.

**Key words:** Bio-plastic composites, modified cassava starch, konjac glucomannan, acetic acid concentration

## Introduction

The starch from cassava and glucomannan from konjac tuber have great potential to be used as bio-plastics. The production of starch and glucomannan based bio-plastics independently has been widely developed, but still demonstrated poor characteristics. Darni and Utami (2010) for instance, found that bio-plastics made of starch have poor water resistance and mechanical strength. Romadloniyah (2012) showed that adding of 1.5 mL sorbitol in the manufacture of bio-plastic from cassava starch produced a tensile strength of 126.87 MPa and a percentage of elongation at break of 23.33 %. Meanwhile Kumoro and Purbasari (2014) stated that producing bio-plastic composite using glycerol 2 % (w/w) has characteristics: Young's modulus value of 40.5 MPa, tensile strength of 17 MPa and elongation at break of 38 %. Harsojuwono and Arnata (2016) used modified cassava starch (6 %) combined with 1 % glycerol resulting in a moisture content of 3.98 %, elongation at a break of 18.75 %, tensile strength of 930 MPa and Young's modulus of 50 MPa. Harsojuwono *et al. (*2017) made bio-plastic using modified cassava starch by drying at 50°C for 5 hours using automatic cabinet dryer with a debit air flow of 5±0.1 $m^3$ / minute, resulting in tensile strength of 1057.40 MPa, elongation at break of 15.95 %, Young's modulus of 6629.47 MPa, swelling of 9.91 % and degradation time of 7 days. Harsojuwono *et al.* (2018) developed the research by optimizing the gelatinization temperature at 75 ±1°C and pH 5, to produce modified cassava starch bio-plastics with characteristics as follows: tensile strength of 1657.43 MPa, elongation at break of 10.32 %, Young's modulus of 16060.37 MPa, swelling of 9 % and the degradation time of 7.33 days. Meanwhile Pradipta and Mawarani (2012) made bio-plastic from glucomannan at a stirring temperature of 80°C and addition of 10 mL plasticizer, resulting in tensile strength of 0.035 MPa, swelling of 61.6 % with a degradation time of 9 days. Those studies show that the characteristics of synthesized bio-plastics still do not meet the International Plastic Standards (ASTM 5336). Therefore, it is necessary to optimize the influential factors such as mixtures of polymer materials and use of acetic acid to produce good quality bio-plastic composites that meet the International Plastic Standards (Ban, 2006)

The formation of bio-plastic composites is basically influenced by many factors including a ratio of the mixtures polymer material and the concentration of acetic acid solution used as a regulator of acidity in gel formation (Henrique *et al.*, 2007). Both of these are critical for the composite characteristics (Harsojuwono, 2011). Dinda, *et al. (*2014) showed that carrageenan bio-plastic composites and cassava starch in a ratio of 3:2 using 0.5 %

sorbitol had a tensile strength of 49.2 MPa, elongation at break of 8.9 %, Young's modulus of 1095 MPa and swelling of 35, 49 %. Ariska and Suyatno (2015) showed that bio-plastic composites from banana hump starch and carrageenan in a 1:2 ratio with glycerol as plasticizers had a tensile strength of 5.15 MPa, elongation at break of 14.25 % and Young's modulus of 0.36 MPa. Meanwhile, Siswanti *et al. (*2009) showed that glucomannan and cornstarch composites in a ratio of 15:85 had a thickness value of 0.18 mm, solubility of 50.58 %, tensile strength of 1.49 MPa and elongation at a break of 30.56 %. According to Maulana *et al.* (2016) decrease in ratio of glucomannan and tapioca reduces the tensile strength and Young's modulus, but increased the elongation at break. However Abdurrozag (2016) showed that the mixture ratio of 30 % konjac glucomannan, 70 % starch with 25 % glycerol had characteristics with a tensile strength of 9.3 MPa, elongation at break of 44.68 %, swelling of 136.73 % and the degradation time of 20.5 days. Primaningrum and Sari, (2014) produced glucomannan and chitosan composites in a 1:3 ratio using 0.5 % acetic acid solution and 3 % glycerol had a tensile strength of 2.14 MPa, Young's modulus value of 9.52 MPa, and elongation at break 22.5 %, swelling of 41.67 % with a degradation time of 6 days. Dewi (2015) produced a bio-plastic composite of cassava skin starch and chitosan in a 4: 1 ratio using 1 % acetic acid solution and 1.5 % glycerol produced a tensile strength of 0.39 MPa, elongation at a break of 44.06 %, Young's modulus of 0.08 MPa and the degradation time of 7 days. Al Hasan and Norziah (2012) explained that the formation of composite films from a mixture of starch and gelatin improved its mechanical properties compared to the formation of films from individual material alone.

The above finding shows that a ratio of the mixture of polymer materials and the concentration of acetic acids influenced the characteristics of bio-plastic composites. The optimum value of modified cassava starch-konjac glucomannan ratio and acetic acid concentration in the manufacture of bio-plastic composites has not been identified. Thus, it is necessary to explore the mixing ratio of the modified cassava starch-konjac glucomannan and the concentration of acetic acid solution that can improve and enahnce the bio-plastics composites characteristics in accordance with the International Plastic Standards. The purpose of this study was to investigate the effect of the modified cassava starch-konjac glucomannan ratio and acetic acid concentration on the characteristics of bio-plastic composites.

## Materials and methods

**Material**: The materials used in this study were the modified cassava starch from Indo Food Chem., pure konjac glucomannan from CV Nura Jaya, acetic acid, glycerol and aquadest from Bratha Chem.

**Research design**: Using factorial randomized block design. The first factor was ratio of the modified cassava starch - konjac glucomannan, consisting of 5 levels, namely 100:0, 75:25, 50:50, 25:75, and 0:100. The second factor was concentration of acetic acid which consisted of 5 levels, namely 0; 0.5; 1.0; 1.5; 2.0 %. Each treatment combination was grouped into 4 based on the time of the bio-plastic manufacturing process, with total of 100 experimental units.

**Making of bio-plastic composites:** Took 6 g of a mixture of modified cassava starch and konjac glucomannan with a ratio according to treatment, then added 93 g of acetic acid solution with a concentration according to treatment and stirred for 10 minutes with a spatula in glass beaker , then added plasticizer glycerol 1 g, followed by a 10-minutes stirring process for homogenization. Next, the mixture was heated and stirred on the waterbath at 75 ± 1°C until it formed a gel. The formed gel was then printed on Teflon with a diameter of 20 cm. After that, it was dried in an oven at 50°C for 5 hours. The bio-plastic composite formed was cooled for 24 hours at room temperature (27±1°C).

**Observation variables**: Tensile strength, elongation at break, Young's modulus (ASTM D638), swelling (Harsojuwono, 2016), degradation time / biodegradation (ISO 17556), surface profile with Scanning Electron Microscopy (SEM) (Harsojuwono *et al*, 2017) and functional groups with FTIR spectrometer (Gable, 2014).

**Data analysis:** The data obtained were analysed for variance and followed by Duncan's multiple comparison tests. The program used for data analysis was SPSS 25.

## Results

**Tensile strength, elongation at break and Young's modulus**: Analysis of variance showed that a ratio of the modified cassava starch - konjac glucomannan and acetic acid concentration and their interactions have a very significant effect on tensile strength, elongation at break and Young's Modulus of bio-plastic composites. The mean values of tensile strength, elongation at break and Young's Modulus of bio-plastic composites ranged from 959.69 - 1990.47 MPa, 8.90 - 18.90 % and 5421.98 - 22442.70 MPa, respectively, as shown in Table 1. The Table 1 shows that the highest mean of tensile strength with value of 1997.40 MPa owned by the composite with a ratio of the modified cassava starch - konjac glucomannan = 75:25 with addition of 1 % acetic acid. The low mean tensile strength values were from bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 0:100 added with 0, 0.5, 1.5, and 2.0 % acetic acid concentration. This is not significantly different from the mean of tensile strength possessed by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 100:0; 50:50; 25:75 at 0 % acetic acid concentration and a 25:75 ratio at 0.5 % acetic acid concentration. Table 1 also shows that the lowest mean of elongation at break (8.90 %) shown by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 75:25 at 1 % acetic acid concentration, followed by 1.5 % acetic acid concentration with value of 8.99 %. This value was not significantly different with elongation at break of bio-plastic composite in a ratio of the modified cassava starch - konjac glucomannan = 100: 0 at 1 % acetic acid concentration, and a ratio of 75:25 at acetic acid concentration of 0, 0.5, 2.0 % . It was also not significantly different with elongation at break of bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 50:50 at acetic acid concentration of 0 - 2.0 %, as well as a ratio of 25:75 at acetic acid concentration of 1 %. Table 1 also shows the highest mean Young's Modulus owned by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 75:25 at 1 % acetic acid concentration with a value of 22442.70 MPa. The high mean of Young's Modulus is also owned by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 0:100 at acetic acid concentration of 0, 0.5, 1.0, 1.5, 2.0 %, and a ratio of 100:0 at concentration of 0, 1.5 and 2.0 %. This is not significantly different with elongation at break of bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 50:50 at 0 % acetic acid concentration and a ratio of 25:75 at 0, 1.5 and 2.0 % acetic acid concentration.

Table 1. Tensile strength, elongation at break and Young's modulus of bio-plastic composites on ratio variations of the modified cassava starch - konjac glucomannan and acetic acid concentration

| Ratio* | Mean of tensile strength (MPa) | Mean of elongation at break ( %) | Mean of Young's modulus (MPa) |
|---|---|---|---|
| 100 : 0 ; 0 % | 1027.40$^{cd}$ | 18.90$^{a}$ | 5435.98$^{d}$ |
| 100 : 0 ; 0.5 % | 1336.70$^{bc}$ | 18.70$^{a}$ | 7148.13$^{cd}$ |
| 100 : 0 ; 1 % | 1657.43$^{b}$ | 10.32$^{bc}$ | 16060.37$^{b}$ |
| 100 : 0 ; 1.5 % | 1295.90$^{bc}$ | 18.63$^{a}$ | 6955.99$^{d}$ |
| 100 : 0 ; 2 % | 1102.45$^{c}$ | 18.88$^{a}$ | 5839.25$^{d}$ |
| 75 : 25 ; 0 % | 1257.43$^{bc}$ | 11.32b$^{c}$ | 11108.04$^{c}$ |
| 75 : 25 ; 0.5 % | 1332.70$^{bc}$ | 10.70b$^{c}$ | 12455.14$^{c}$ |
| 75 : 25 ; 1 % | 1997.40$^{a}$ | 8.90$^{c}$ | 22442.70$^{a}$ |
| 75 : 25 ; 1.5 % | 1463.60$^{bc}$ | 9.99$^{c}$ | 14650.65$^{bc}$ |
| 75 : 25 ; 2 % | 1385.40$^{bc}$ | 10.80$^{bc}$ | 12827,78$^{c}$ |
| 50 : 50 ; 0 % | 1081.60$^{cd}$ | 11.70$^{bc}$ | 9244.44$^{cd}$ |
| 50 : 50 ; 0.5 % | 1112.21$^{c}$ | 10.32$^{bc}$ | 10777.23$^{c}$ |
| 50 : 50 ; 1 % | 1221.32$^{bc}$ | 10.93$^{bc}$ | 12299.30$^{c}$ |
| 50 : 50 ; 1.5 % | 1178.36$^{c}$ | 10.56$^{bc}$ | 11158.71$^{c}$ |
| 50 : 50 ; 2 % | 1154.38$^{c}$ | 11.54$^{bc}$ | 10003.29$^{c}$ |
| 25 : 75 ; 0 % | 1011.60$^{cd}$ | 13.70$^{b}$ | 7383.94$^{cd}$ |
| 25 : 75 ; 0.5 % | 1093.21$^{cd}$ | 12.32$^{b}$ | 8873.46$^{cd}$ |
| 25 : 75 ; 1 % | 1181.32$^{c}$ | 10.93$^{bc}$ | 10808.05$^{c}$ |
| 25 : 75 ; 1.5 % | 1148.36$^{c}$ | 12.56$^{b}$ | 9142.99$^{cd}$ |
| 25 : 75 ; 2 % | 1104.38$^{c}$ | 13.54$^{b}$ | 8156.43$^{cd}$ |
| 0 : 100 ; 0 % | 959.69$^{d}$ | 17.70$^{a}$ | 5421.98$^{d}$ |
| 0 : 100 ; 0.5 % | 990.21$^{d}$ | 16.96$^{a}$ | 5838.50$^{d}$ |
| 0 : 100 ; 1 % | 1011.32$^{cd}$ | 14.03$^{ab}$ | 7208.26$^{cd}$ |
| 0 : 100 ; 1.5 % | 998.36$^{d}$ | 16.56$^{a}$ | 6028.74$^{d}$ |
| 0 : 100 ; 2 % | 979.38$^{d}$ | 17.54$^{a}$ | 5583.69$^{d}$ |

*Ratio of the modified cassava starch - konjac glucomannan and acetic acid concentration
The same notation shows no significant difference at the 5 % significance level

**Swelling and biodegradability**: Analysis of variance showed that a ratio of the modified cassava starch - konjac glucomannan and acetic acid concentration and their interactions significantly affect the mean of swelling and degradation times. The mean of swelling ranged from 9.00 - 179.45 %, while the degradation time ranged from 2.33 to 7.67 days. Table 2 shows that high swelling is owned by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 0: 100 at 0, 0.5, 1.0, 1.5 and 2 % acetic acid concentration. Meanwhile, the bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 100: 0 at 0, 0.5, 1.0, 1.5 and 2 % acetic acid concentration has a mean of low swelling. Table 2 also shows that the mean of bio-plastic composite degradation time with a ratio of the modified cassava starch - konjac glucomannan = 100:0 and 75:25 at 0, 0.5, 1.0, 1.5 and 2 % acetic acid concentration, took the longest time to degrade. This is not significantly different with the degradation time of bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 50:50 at 0, 0.5, 1.0, 1.5 %, 2.0 % acetic acid concentration and a ratio of 25:75 at concentration of 1.5 and 2.0 %. Meanwhile the mean of bio-plastic composites degradation time with a ratio of the modified cassava starch - konjac glucomannan = 0:100 at 0, 0.5, 1.0, 1.5 %, 2.0 % acetic acid concentration, took the shortest time, which is not significantly different from the time of bio-plastic composites degradation with a ratio the modified cassava starch - konjac glucomannan = 25:75 at 0, 0.5 and 1.0 % acetic acid concentration.

Table 2. Swelling and the degradation time of bio-plastic composites in variations in a ratio of the modified cassava starch - konjac glucomannan and acetic acid concentration

| Ratio* | Mean of swelling (%) | Mean of degradation time (day) |
|---|---|---|
| 100 : 0 ; 0 % | 9.42$^{d}$ | 7,33$^{a}$ |
| 100 : 0 ; 0.5 % | 9.12$^{d}$ | 7,33$^{a}$ |
| 100 : 0 ; 1 % | 9.00$^{d}$ | 7,33$^{a}$ |
| 100 : 0 ; 1.5 % | 9.62$^{d}$ | 7,67$^{a}$ |
| 100 : 0 ; 2 % | 9.72$^{d}$ | 7,67$^{a}$ |
| 75 : 25 ; 0 % | 12.70$^{c}$ | 6,33$^{a}$ |
| 75 : 25 ; 0.5 % | 11.12$^{c}$ | 6,33$^{a}$ |
| 75 : 25 ; 1 % | 10.40$^{c}$ | 6,33$^{a}$ |
| 75 : 25 ; 1.5 % | 10.59$^{c}$ | 6,33$^{a}$ |
| 75 : 25 ; 2 % | 11.77$^{c}$ | 6,33$^{a}$ |
| 50 : 50 ; 0 % | 36.97$^{c}$ | 5,33$^{ab}$ |
| 50 : 50 ; 0.5 % | 33.33$^{c}$ | 5,33$^{ab}$ |
| 50 : 50 ; 1 % | 31.67$^{c}$ | 5,33$^{ab}$ |
| 50 : 50 ; 1.5 % | 32.79$^{c}$ | 5,33$^{ab}$ |
| 50 : 50 ; 2 % | 37.89$^{c}$ | 5.67$^{ab}$ |
| 25 : 75 ; 0 % | 73.12$^{b}$ | 4.67$^{bc}$ |
| 25 : 75 ; 0.5 % | 67.25$^{b}$ | 4.00$^{bc}$ |
| 25 : 75 ; 1 % | 59.37$^{b}$ | 4.33$^{bc}$ |
| 25 : 75 ; 1.5 % | 62.47$^{b}$ | 5.67$^{ab}$ |
| 25 : 75 ; 2 % | 67.17$^{b}$ | 5.67$^{ab}$ |
| 0 : 100 ; 0 % | 179.45$^{a}$ | 2.33$^{c}$ |
| 0 : 100 ; 0.5 % | 162.35$^{a}$ | 2.33$^{c}$ |
| 0 : 100 ; 1 % | 159.65$^{a}$ | 3.33$^{c}$ |
| 0 : 100 ; 1.5 % | 151.57$^{a}$ | 3.33$^{c}$ |
| 0 : 100 ; 2 % | 149.98$^{a}$ | 3.67$^{c}$ |

*Ratio of the modified cassava starch - konjac glucomannan and acetic acid concentration
The same notation shows no significant difference at the 5 % significance level

**Surface profile of bio-plastic composites**: The longitudinal surface profile of bio-plastic composites depending upon the ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration, is shown in Fig. 1a, depicting the presence of regular waveforms along with air cavities or regular pores. In comparison, the modified cassava starch bio-plastic, as reported by Harsojuwono *et al.* (2018), the existence of irregular waveforms along with air cavities or random pores (Fig. 1b). The transverse surface profile of bio-plastic composites

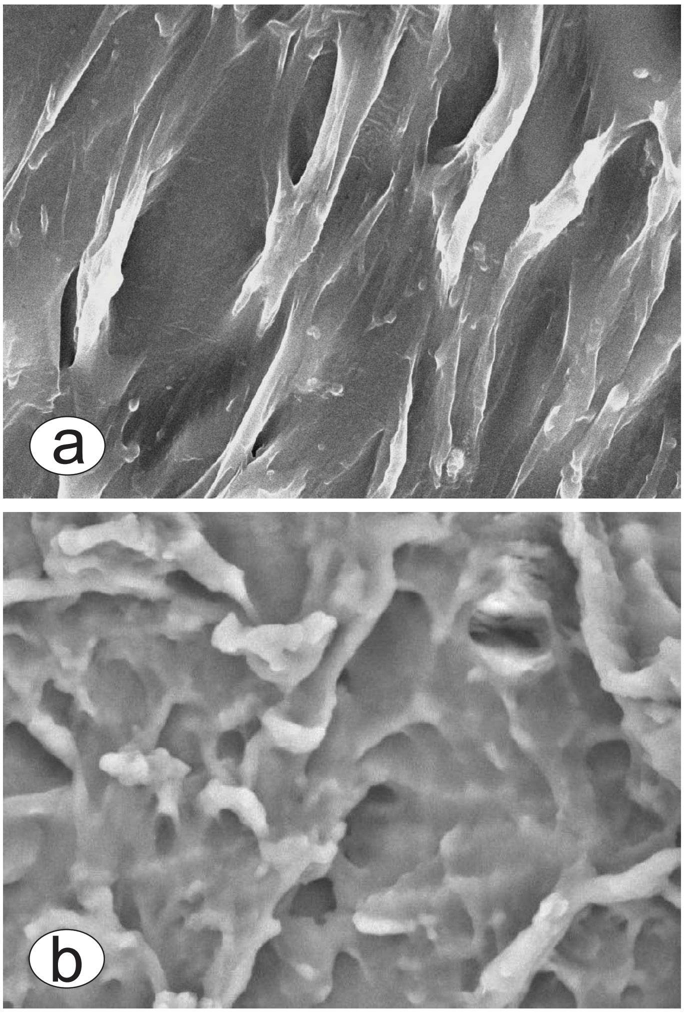


Fig. 1. The longitudinal surface profile (a) bio-plastic composites at a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration at 3000X magnification, (b) the modified cassava starch bio-plastics at 3000X magnification (Harsojuwono, *et al.*, 2018 )

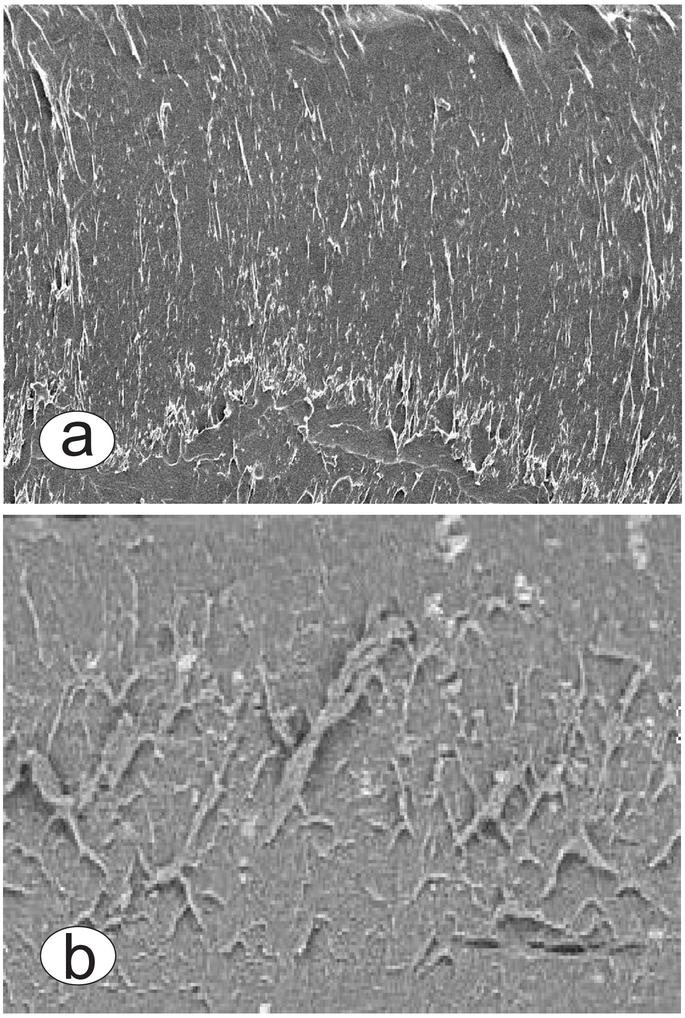


Fig. 2. The transverse surface profile (a) bio-plastic composites in a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration at 180X magnification, (b) the modified cassava starch bio-plastics at 180X magnification (Harsojuwono *et al*, 2018)

on a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration, is shown in Fig. 2a, while the comparison of Harsojuwono's (2018), showed research results is the modified cassava starch bio-plastic, shown in Fig. 2b. In Fig. 2a, the arrangement of fibers in the form of regular nets and smooth cross links of bio-plastic composites formed by the modified cassava starch polymers and glucomannan is seen. Meanwhile, Fig. 2b shows the arrangement of fibers in the form of nets or cross links with larger and taller fiber protrusions.

**The functional group of bio-plastic composite**: The spectrogram in Fig. 3 shows the wave number range 453.27 to 3984.93 $cm^{-1}$ which is owned by bio-plastic composites on a ratio the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration, while in Fig. 4 shows the wave number range 435.91 up to 3460.30 $cm^{-1}$ that owned by bio-plastic of the modified cassava starch of the research Harsojuwono, *et al.*, 2018. Comparison between Fig. 3 and Fig. 4, show that the number of wave numbers detected is more in Fig. 3 and the known functional groups are also more than in Fig. 4.

## Discussion

**The tensile strength, elongation at break and Young's modulus:** Starting with lower ratio of the modified cassava starch-konjac glucomannan, initially increased tensile strength was observed but after achieving the optimum ratio, the decrease in the ratio of modified cassava starch - konjac glucomannan caused a decrease in tensile strength of bio-plastic composite. This is in accordance with Jian *et al.* (2016) who explained that the greater increase in glucomannan in the Tilapia myofibrillar protein caused a decrease in the strength of the gel from the bio-plastic composite. Meanwhile, an increase in the concentration of acetic acid also decreases the tensile strength value after optimum conditions. This is in accordance with result of the research by Yang *et al. (*2013) who stated that the use of acidic pH or high acidity will cause degradation during the gelatinization process which has an impact on tensile strength. In this study, the highest average tensile strength was owned by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 75:25 at 1 % acetic acid concentration of 1997.40 MPa. This value is higher than the results of research by Harsojuwono, *et al. (*2018) who made bio-plastic from the modified cassava starch with tensile strength values of 1657.43 MPa. This is much higher than the bio-plastic composite of carrageenan and cassava starch in a 3:2 ratio using 0.5 % sorbitol which has a 49.2 MPa tensile strength (Dinda, *et al.*, 2014), also higher than a composite of the sago starch and natural rubber latex which has a tensile strength value of 20.73 MPa (Cheong *et al*, 2010),

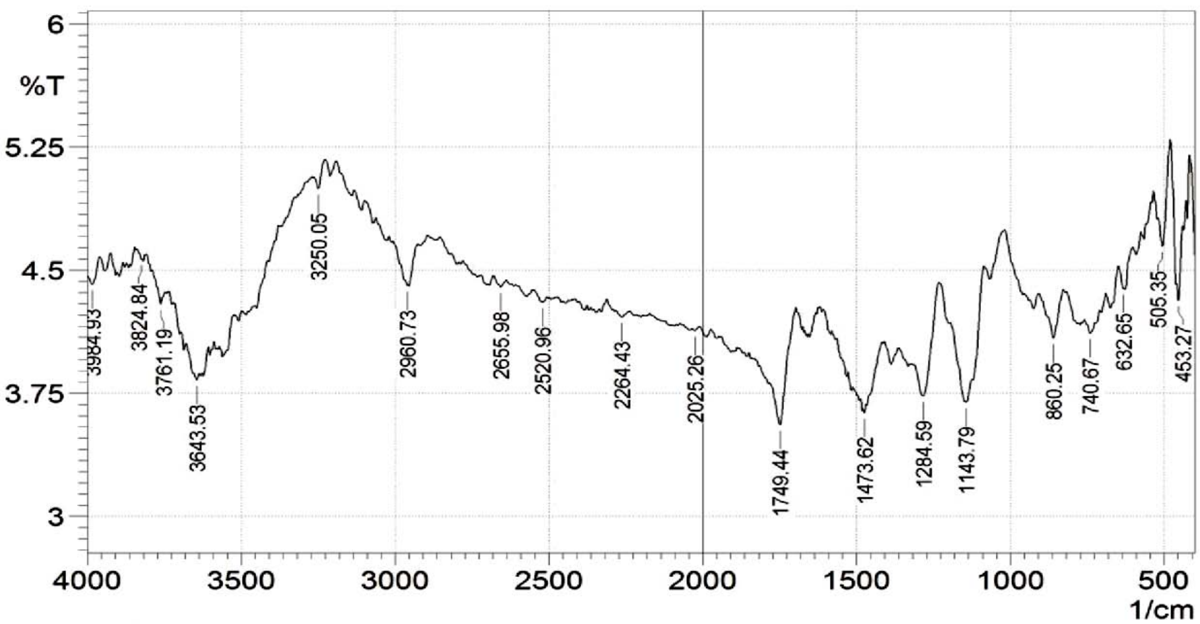


Fig. 3. The wave number spectra of bio-plastic composites in a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration

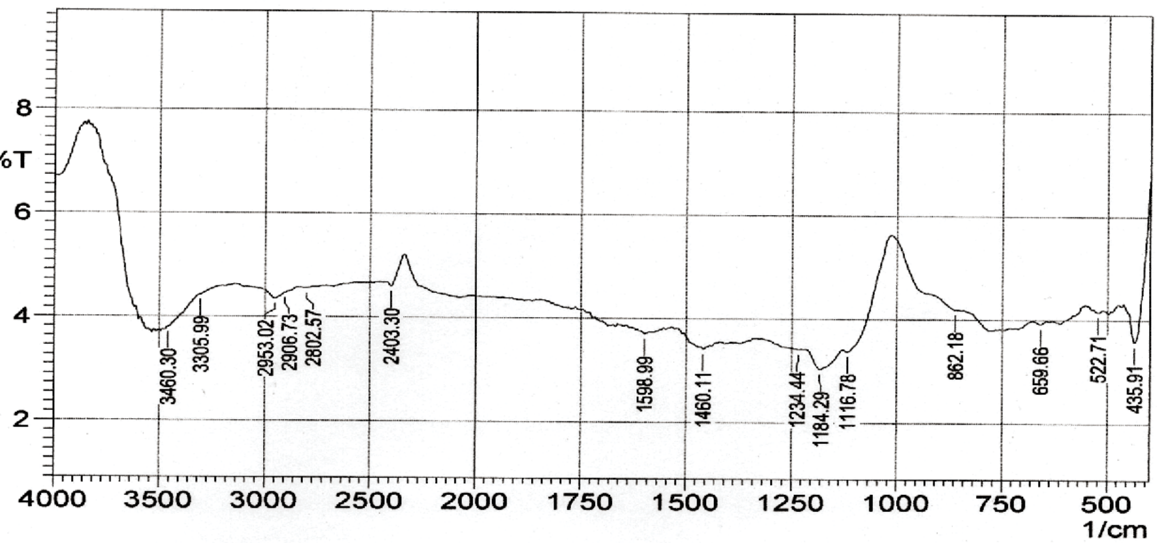


Fig. 4. The wave number spectra of the modified cassava starch bio-plastics (Harsojuwono, *et al*, 2018)

and also bio-plastic composites of glucomannan and corn starch with tensile strength values of 1.49MPa (Siswanti, *et al.*, 2013), bio-plastic composites from konjac tuber and CMC starch with value of 18.68 MPa (Sari, 2016) as well as a glucomannan-based bio-plastic composites from research of Maulana *et al. (*2016) which has a tensile strength value of 0.67 MPa. However, a bio-plastic composite of the modified cassava starch - konjac glucomannan only meets the PCL plastic standard from the UK which stipulates a minimum tensile strength value of 190 MPa but does not meet international plastic standards (ASTM 5336) for PLA plastics from Japan that establish a tensile strength value of 2050 MPa (Averous , 2009). Meanwhile, the low mean of elongation at break is shown by bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 75:25 at 1 % acetic acid concentration with value of 8.90 % and 1.5 % acetic acid concentration with value of 8.99 %. This shows that the mean of elongation at break is lower than elongation at break of the modified cassava starch bio-plastic which has the value is 10.32 % (Harsojuwono *et al*, 2018) but still higher than elongation at break of the breadfruit and chitosan starch composite which has the value of 6.00 % (Setiani *et al.*, 2016). The value of elongation at break from a bio-plastic composite of the modified cassava starch - konjac glucomannan has met international plastic standards (ASTM5336) which stipulate that elongation at break is less than 500 % for PCL plastics from England, as well as PLA plastic standards from Japan that set maximum of the elongation at break of 9 %. In addition it was shown that bio-plastic composites with a ratio of the modified cassava starch - konjac glucomannan = 75: 25 at 1 % acetic acid concentration had the highest average Young's Modulus with a value is 22442.70 MPa. This Young's Modulus value is higher than the modified cassava starch bio-plastics obtained by Harsojuwono *et al. (*2018) whose value is 16060.37 MPa. This is much higher than the composites of glucomannan and chitosan in a ratio of 1: 3 at 0.5 % acetic acid concentration with Young's Modulus values 9.52 MPa (Primaningrum *et al.*, 2014), as well as the composites of cassava skin starch and chitosan in a 4: 1 ratio at 1 % acetic acid concentration with Young's modulus value of

0.08 MPa (Dewi, 2015). According to Leuangsukrerk *et al.* (2014) an increase in the ratio of glucomannan and whey protein isolates causes an increase in Young's modulus, and tensile strength but decreases the transparency of the film composites.

**Swelling and biodegradability**: There was a tendency that the lower the ratio of the modified cassava starches to the glucomannan, the higher the swelling of bio-plastic composites. This seems to be related to the ability of glucomannan to absorb and retain water in the gel which reaches more than 300 % of the weight of the dry matter. This was in accordance with the study by Leuangsukrerk *et al.* (2014) which showed that the higher glucomannan ratio to whey protein isolates caused a decrease in integrity but increased swelling of bio-plastic composites. According to Maulana *et al.* (2016), the lower ratio of the tapioca and glucomannan caused an increase in swelling of biopolymer composites. They explained that the ratio of tapioca and glucomannan = 5:5 causes an increase in swelling reaching 33.12 %. Meanwhile, according to Cheng *et al.* (2006), this is related to the extensive interaction between plasticizers and glucomannan which affected the active (OH) side, thus affecting the ability to absorb water or swelling. In addition, there was a tendency that the smaller the ratio of the modified cassava starch to the glucomannan, shorter was the degradation time. According to Torres *et al.* (2011), all starch-based films decompose in three stages of the process, which are weight loss of up to 30 % due to glycerol washing, loss of up to 90 % due to biological activity, loss of up to 95 % due to further biodegradation which causes reduced the mechanics properties. It was further explained that rate of the weight loss of starch-based films is higher than rate of the weight loss of cellulose-based films. The bio-plastic composites of modified cassava starch and glucomannan have a mean degradation time of 2.33 - 7.67 days; this is shorter than the degradation time of a mixture of 30 % glucomannan and 70 % starch which has a degradation time of 20.5 days (Abdurrozag, 2016). The degradation time of other composites that entered the degradation time span of bio-plastic composites from modified cassava starch - konjac glucomannan (2.33-7.67 days) was a bio-composite of research results by Primaningrum and Sari, (2014). Primaningrum and Sari (2014) showed that bio-plastic composites of the glucomannan and chitosan with a 1: 3 ratio using 0.5 % acetic acid solution had a 6-day degradation time. Likewise, the results of Dewi's research (2015) showed that the degradation time of composites bio-plastic the cassava skin starch and chitosan in a 4: 1 ratio with 1 % acetic acid solution was 7 days. This degradation time is still shorter than the standard PLA plastic from Japan and the PCL from England which sets 60 days.

**The surface profile of bio-plastic composites**: bio-plastic composites with a ratio the modified cassava starch - konjac glucomannan = 75: 25 with 1 % acetic acid concentration, have a better and more regular longitudinal and transverse surface profile than bio-plastics of the modified cassava starch which is the result of research by Harsojuwono *et al.* (2018). In a longitudinal position it appears that a regular wave shape is followed by the arrangement of air cavities or regular pores. In the transverse position, it appears that the fibers are tight and smooth. This is due to the regular and smooth cross links of composites formed by the modified cassava starch polymers and glucomannan. The existence of this cross link tends to increase mechanical properties because the polymer bonds are getting stronger. According to Gunorubon and Dagde (2012) the level of acidity influences the formation of bio-plastic cross linking. It was further explained that optimum acidity produces bio-plastics which are acid resistant, tolerant to high temperatures, stirring, but not easily swelling and having a high viscosity.

**The functional group of bio-plastic composite:** based on information on wave numbers and functional groups from Gable (2014), the functional groups contained in the bio-plastic composites on a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration, are functional groups of (O-H), (C-H), (C-N), (C-O), (C-C), (N-H), -$(CH_2)_n$, (C=C) and (C=O). The functional group detected in this composite bio-plastic is slightly different than the results of a study by Harsojuwono *et al.* (2018) which found a functional group of (O-H), (C-H), (C-N), (C-O), (C-C), (N-H), -$(CH_2)_n$, (C=C) and (C-OH) in bio-plastic modified starch. According to Cheong *et al.* (2010), the FTIR spectrum of films exhibited a wide O-H stretching absorbance centered around 3400 $cm^{-1}$, a slight C-H stretching band at 2921 $cm^{-1}$, and a characteristic set of strong C-O stretching bands between 960-1190 $cm^{-1}$.

The conclusion of this study are that the ratio of the modified cassava starch - konjac glucomannan, the concentration of acetic acid and their interaction had a very significant effect on tensile strength, elongation at break, Young's modulus, swelling and the degradation time of bio-plastic composites. The best bio-plastic composites was obtained at a ratio of the modified cassava starch - konjac glucomannan = 75:25 with 1 % acetic acid concentration that had characteristics: tensile strength of 1997.40 MPa, elongation at break of 8.90 %, Young's modulus of 22442.70 MPa, swelling of 10.40 % and the degradation time of 6.33 days. Meanwhile, the surface profile of bio-plastic composites in longitudinal appearance shows the presence of regular wave forms along with air cavities or regular pores. Bio-plastic composite profile in transverse appearance shows the arrangement of fibers in the form of regular nets and smooth cross links. These bio-plastic composites contain functional groups: (O-H), (C-H), (C-N), (C-O), (C-C), (C=C), (N-H), -$(CH_2)_n$ and (C=O).

## Acknowledgement

We would like to thank Udayana University for providing research funding and facilitating the publication of this scientific article.

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Received: October, 2018; Revised: November, 2018; Accepted: November, 2018