ISSN: 3064-9846
Research Article
Journal of Agricultural, Earth and Environmental Sciences

Study on the Concentration of Polyvinyl Alcohol in Bioplastic Composites of Taro Starch and Polysaccharides Other

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Submitted: 29 December 2025 **Accepted:** 03 January 2026 **Published:** 10 January 2026

Citation: *Hartiati, A., Harsojuwono, B. A., Arnata, I. W., & Tuningrat, I. A. M. (2026). Study on the Concentration of Polyvinyl Alcohol in Bioplastic Composites of Taro Starch and Polysaccharides Other. J of Agri Earth & Environmental Sciences,5(1), 01-08.*

Abstract

Taro starch has been utilized to make liquid sugar [1-3]. Taro starch can also be used to make bioplastics. Bioplastic or degradable plastic is packaging that can decompose in the soil and is made from renewable materials so that its use does not pollute the environment [4]. This research aims to determine the effect of the concentration of polyvinyl alcohol (PVA) reinforcing material on the characteristics of the composite of taro starch and other polysaccharides produced and to determine the bioplastic composite of taro starch-other polysaccharides which produces the best characteristics as a packaging material. This research used an experimental design that used a randomized block design with 9 variations in the ratio of taro starch composite with 2 other polysaccharides (glucomannan and carrageenan) with a ratio of 25:75; 50:50 and 75:25 with 3 levels of PVA concentration, namely 0, 5 and 10% (calculated from the composite material). The treatment combination table can be seen in Table 1. All treatments were divided into 2 groups based on the processing time for making the composite so that 36 treatment units were obtained. The data was analyzed for diversity and if it had a real effect, it was continued with the Duncan test. The variables observed were tensile strength, elongation of bioplastics, elasticity, biodegradation of bioplastics, swelling, and functional group testing for the best treatment. The results of the research show that variations in bioplastic and polyvinyl alcohol composite materials have a significant effect on tensile strength, elongation at break and elasticity on the characteristics of the taro starch-other polysaccharide composites produced. In the treatment variations of taro starch: carragegenan ratio of 25:75 with a PVA concentration of 10% produced the best bioplastic composite characteristics.

Keywords: Glucomannan, Carrageenan, Bioplastic Composite, Taro Starch and Polyvinyl Alcohol.

Introduction

Efforts to utilize minor or potential tubers such as suweg, gadung, gembili, and taro have been widely implemented due to their starch content of around 30%. These tubers are not only easy to cultivate but also due to their high starch content. Taro tubers have a high starch content, ranging from 17 to 30% [5], Saputra et al., 2016; Permana et al., 2017). Taro starch has been utilized to produce liquid sugar [1-3]. Taro starch can also be used in the manufacture of bioplastics. Bioplastics, or degradable plastics, are packaging that can decompose in the soil and are made from renewable materials, so their use does not pollute the environment [4]. Bioplastic research using starch as a raw material has been widely conducted, including those derived from cassava peel starch [6], banana stem starch, corn, water hyacinth [7], tapioca flour and cornstarch [8], and kepok banana peel starch (). The high starch content allows it to be used as a bioplastic. These studies have not yet be [9] able to meet the Indonesian National Standard (SNI), let alone international standards. The tensile strength variable used as a basic reference for bioplastic quality, in these studies produced a maximum of 10 MPa. The SNI requirement for the tensile strength variable is a minimum of 24.7 MPa if it is to be used as packaging (SNI, 2016).

Other studies have been conducted to increase the tensile strength of bioplastics by making bioplastic composites. Composites are

a type of engineered bioplastic consisting of two or more materials with different properties of each material, both chemically and physically, or composite materials (Nayiroh, 2013). Several composite studies have been conducted, namely [10] composited cassava starch with other polysaccharides (glucomannan, carrageenan, chitosan, alginate) and the best was starch:carrageenan at a ratio of 25:75, 10% ZnO filler, 1% glycerol plasticizer which produced a bioplastic composite with a tensile strength of 27.35 MPa. [11] reported that a composite of gadung starch and carrageenan in a 50:50 ratio using 5% nanocellulose filler (of the total composite material) produced the highest tensile strength of 19.33 MPa. [12] reported that a bioplastic composite made from taro starch and chitosan in a 60:40 ratio with 0.5% stearic acid plasticizer produced the highest tensile strength of 23 MPa. Research on a cassava starch composite with glucomannan in a 3:1 ratio produced the highest tensile strength of 1099 MPa [13].

The materials used in composite manufacturing must be compatible with each other, so trials must be conducted to obtain a composite that is ready and meets the requirements for packaging according to the Indonesian National Standard (BSN, 2016) for bioplastics as shopping bags. Factors to consider include the type of polymer, the type and concentration of plasticizer, the type and concentration of filler, and the reinforcing material. These studies have partially met the requirements in terms of tensile strength, but have not met the requirements for other variables such as elongation at break and elasticity. To meet these requirements, this study will try the use of reinforcing materials such as polyvinyl alcohol (PVA) in several composites resulting from previous studies made from taro starch and other polysaccharides such as carrageenan, glucomannan, and chitosan. Another thing is also to ensure whether by using PVA as a reinforcing material, the resulting bioplastic composite sheets can be shaped and cut as needed for packaging called biothermoplastics. PVA is a hydrophilic biodegradable polymer that has the properties of being able to form good films, is soluble in water, is easy to process, is non-toxic, and is biocompatible (Vega et al., 2016). Biothermoplastic composites are plastics made from materials that readily decompose in the soil, unlike synthetic plastics, which have the disadvantage of not being able to decompose for hundreds of years. This research aligns with Udayana University's Research Master Plan (RIP) for the 2022–2026 period, focusing on food security, energy, and the environment. These areas are among four other leading areas that serve as guidelines and formats for decentralized management of higher education research used by the Ministry of Research, Technology, and Higher Education.

Methods

Making taro starch

Fresh taro tubers are peeled, cleaned, and washed. The cleaned tubers are thinly sliced and blended in a 1:6 ratio of peeled tubers to water. The blended mixture is filtered through a cheesecloth. The extract is allowed to stand for 12 hours, the water is discarded, leaving the sediment to settle. The mixture is then dried at 80°C ± 2°C, or to a maximum moisture content of 11%.

Bioplastic Composite Manufacturing

The biodegradable plastic manufacturing process begins with taro starch, carrageenan, glucomannan, and chitosan, weighed according to the treatment in ratios of 25:75, 50:50, and 75:25, with a total composite material of 6 grams (Simarmata et al., 2020) as per Table 2, 1 gram of glycerol plasticizer, 0.5%, and 10% PVA (Sipayung et al., 2021) according to the treatment, and 5% nanocellulose filler [11]. Finally, 1% glacial acetic acid is added to the mixture to a total of 100 grams (Mirah et al., 2015), [3]. First, taro starch and carrageenan, glucomannan, chitosan, plasticizer, filler, PVA, and solvent (glacial acetic acid) were mixed until all 100 grams were obtained. All were mixed until evenly distributed, stirred using a hot plate stirrer heated to a temperature of 75oC ± 2°C and a stirring time of 10 minutes (Sinaga et al., 2014). The molding of the mixture which is a biodegradable plastic/composite was carried out on a 20 cm diameter Teflon. The composite solution was poured onto the Teflon until it had the same thickness. Then it was oven-baked at a temperature of 50oC for 3 hours. After that, it was cooled at room temperature for 24 hours and the bioplastic composite was released from the mold (Epriyanti et al., 2016). The variables observed were tensile strength, bioplastic elongation, elasticity (Young's modulus), bioplastic biodegradation, swelling, WVTR, heat adhesion test and functional group test (FT-IR) for the best treatment.

1. Tensile strength (Gibson, 1994)

Tensile strength testing was performed using ASTM D 695-90. The test procedure was as follows: The sample was cut to a width of 3 cm and a length of 8 cm. The sample was mounted in a tensile test vise, with a length of 4 cm being tested. The dial gauge was then set to 0 (zero). The dial gauge was then turned on, and the handle on the instrument was slowly turned to the right until the sample broke. The applied force data can be seen on the dial gauge. The tensile strength calculation formula is as follows:

Tensile strength (N/mm2) = σ/A

Where:

σ = Force required (N)

A = Surface area (mm2)

2. Bioplastic elongation (elongation at break) (Gibson, 1994)

The elongation test was conducted using a tensile tester that adheres to the ASTM D 695-90 standard. The test procedure involved cutting the sample to a width of 3 cm and a length of 8 cm. The sample was mounted in a tensile vise, with the test sample being 4 cm long. The dial gauge was then set to 0 (zero). The dial gauge was then turned on, and the handle was slowly turned to the right until the sample broke. The change in length of the tested sample was then recorded.

The elongation calculation formula is as follows:

Elongation (%) = (Film elongation (mm))/(Initial length (mm)) x 100%

3. Elasticity (Young's modulus) (Gibson, 1994)

Elasticity is the stress that a test object will reach before it breaks. The test sample will pass through a maximum load, at which point localized deformation will occur, causing a reduction in cross-sectional size and an increase in the length of the test sample, without any increase in mass. Elasticity is obtained from the ratio of elongation to tensile strength of the sample. The elasticity formula is as follows:

Elasticity = (Tensile Strength (N/mm2))/(Elongation (%))

4. Biodegradation of Bioplastics (Harnis and Darni, 2011)

Biodegradability can be assessed based on the length of degradation time by degrading microorganisms (Pradipta, 2012). Biodegradation testing of biodegradable plastics is performed by weighing the bioplastic before proceeding to the next step. The biodegradable plastic sample is then placed in a container and compost soil is added.

The weight of the bioplastic is recorded and its water content is measured. The formula for determining the water weight is:
Water weight (%) = initial weight x water content (%)

The initial weight is then subtracted from the water weight to obtain the dry solid weight of the sample. The plastic is then left for one week. After another week of being left in the soil, the plastic is removed, cleaned, and the water content of the bioplastic is measured. This determines the percentage of water weight in the biodegradable plastic. The weight after backfilling is subtracted from the water content to obtain the dry solid weight. The formula for the percentage of mass loss or weight loss is as follows:
Shrinkage = (a1-a2)/a1 x 100%
Where:
a1 = weight before storage
a2 = weight after storage

5. Functional Group Test (FT-IR) (Averous, 2004)

FTIR testing aims to determine the functional groups of compounds contained in biodegradable plastic. The test is performed by cutting the biodegradable plastic into 5 cm and 8 cm wide strips, which are then adjusted to the size of the infrared spectrum tester on a holder set at a wavelength of 4000-650 cm1. The FT-IR spectrum is read and recorded using a spectrophotometer at room temperature. The data obtained is a spectrum image, which shows the relationship between transmittance and wavenumber. From the obtained data, the functional groups present in the tested material, namely biodegradable plastic, can be identified.

Result and Discuss

The mechanical properties of the bioplastic composites have been analyzed, including tensile strength, elongation at break, and elasticity. Research variables such as swelling, WVTR, biodegradation, and FTIR are currently being conducted in the laboratory. The following are the analysis results of several bioplastic composite variables.

1. Tensile Strength

The diversity analysis of the composite variation treatment with other polysaccharides and PVA concentration showed a significant effect on the tensile strength of the resulting bioplastic composites.
The results of the tensile strength diversity analysis can be seen in Table 1.

Table1: Tensile strength of biothermoplastic composites of taro starch and other polysaccharides (MPa)

			Concentration	PVA (%)
Variation treatment of taro starch composites with other polysaccharides	**Ratio**	**0 (P1)**	**5 (P2)**	**10 (P3)**
Glucomannan (G)	25:75 (R1)	9.25	14.13	21.84
Glucomanan (G)	50:50 (R2)	5.41	9.18	10.01
Glukomannan (G)	75:25 (R3)	3.67	8.01	8.21
Carrageenan (K)	R1	5.57	16.78	22.61
Carrageenan (K)	R2	3.62	9.56	12.30
Carrageenan (K)	R3	3.67	8.15	9.44
Chitosan (T)	R1	2.24	4.09	6.64
Chitosan (T)	R2	3.60	5.57	7.31
Chitosan (T)	R3	5.57	7.57	9.45

Note: The same letter after the average value indicates no significant effect.

Tensile strength is defined as the ability of a bioplastic composite to withstand a load without damage or deformation. The tensile strength of a bioplastic composite is calculated by dividing the maximum force by the initial cross-sectional area before damage (deformation) occurs. Tensile strength measurements can also calculate elasticity and Young's modulus. From tensile strength testing, elongation at break and elasticity are obtained (Harsojuwono and Arnata, 2017).

Table 1 shows the tensile strength in this study, which ranged from 2.24 to 22.61 MPa. The lowest tensile strength was found in the taro starch:chitosan ratio of 25:75 with 0% PVA, namely 2.24 MPa, which was not significantly different from all taro starch:chitosan composites at all ratios and all PVA concentrations, and all taro starch:carrageenan variations at 0% PVA concentration. The highest tensile strength was found in the taro starch:carrageenan ratio of 25:75 with 10% PVA concentration, namely 22.61 MPa, which was not significantly different from the taro starch:glucomannan ratio of 25:75 with 10% PVA concentration.

The tensile strength in this study did not meet the minimum requirement of 24.7 MPa. This result is higher than that of Yanthi et al. (2022) which is 17.60 MPa using 8.33% cellulose acetate as a reinforcing material and [10]. which is 10.29 MPa using a composite material of cassava starch: chitosan ratio of 25:75. In this treatment, compatibility and cross-linking have occurred optimally, originating from straight bonds of amylose, branched bonds of amylopectin and cross-linking from the presence of carrageenan and other materials used in the manufacture of this composite. The following image is an illustration of the cross-linking that may occur between taro starch-glycerol-carrageenan and PVA.

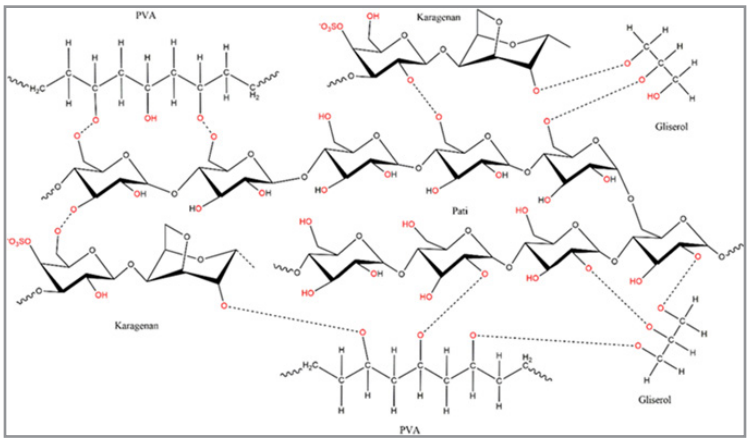

Figure 1: Estimated mechanism of interaction of functional groups of taro starch and carrageenan bioplastic composites

2. Elasticity

Analysis of the diversity of composite treatments with other polysaccharides and PVA concentrations showed a significant effect on the elasticity of the resulting bioplastic composites. The results of the elasticity diversity analysis are shown in Table 2.

Table 2: Elasticity of biothermoplastic composites of taro starch and other polysaccharides (MPa)

		Concentration	PVA (%)	
Variation treatment of taro starch composites with other polysaccharides	**Ratio**	**0 (P1)**	**5 (P2)**	**10 (P3)**
Glucomannan (G)	25:75 (R1)	102.52 c	125.64 b	215.49 a
Glucomanan (G)	50:50 (R2)	56.20 e	88.13 d	121.14 b
Glukomannan (G)	75:25 (R3)	28.70 f	105.36 c	78.19 d
Carrageenan (K)	R1	55.47 e	197.17 b	230.57 a
Carrageenan (K)	R2	28.26 f	80.62 d	105.66 c
Carrageenan (K)	R3	35.25 f	56.56 e	79.68 d
Chitosan (T)	R1	13.26 f	30.39 f	79.68 d
Chitosan (T)	R2	36.85 f	37.28 f	65.34 e
Chitosan (T)	R3	37.97 f	82.11 d	78.69 d

Note: The same letter after the average value indicates no significant effect.

Table 2. shows that the elasticity range of taro starch and other polysaccharide bioplastic composites ranges from 13.26 to 230.57 MPa. The highest elasticity was found in the taro starch:-carrageenan polymer treatment with a 25:75 ratio and 10% PVA, at 230.57 MPa, which was not significantly different from the taro starch:glucomannan composite with a 25:75 ratio. The lowest elasticity was found in the taro starch:chitosan treatment with a 25:75 ratio and 0%, at 13.26, which was not significantly different from most other taro starch and polysaccharide treatments.

Elasticity is defined as the ratio between tensile strength and elongation at break, or the amount/amount of stress applied to a packaging material/bioplastic to allow it to stretch. The Indonesian National Standard (SNI 7818:2014) requires a range of 400–1120 MPa. The bioplastic composite in this study did not meet the requirements of SNI 7718:2016 (Table 4).

[14] stated that increased elasticity is due to the presence of intermolecular forces between starch chains and other composite materials. Low elasticity is caused by a lack of compatibility between the polymer molecules in the composite materials. This occurs in bioplastic composites made from taro starch and chitosan.

3. Elongation at Break

Analysis of variance of composite variations with other polysaccharides and PVA concentrations showed no significant effect on the elongation at break of all bioplastic composites produced. The results of the elongation at break analysis are shown in Table 5.

Table 3: Elongation at Break of Taro Starch and Other Polysaccharide Biothermoplastic Composites(%).

		Concentration	PVA (%)	
Variation treatment of taro starch composites with other polysaccharides	**Rasio**	**0 (P1)**	**5 (P2)**	**10 (P3)**
Glucomannan (G)	25:75 (R1)	9.00 a	11.50 a	10.56 a

Glucomanan (G)	50:50 (R2)	9.94 a	10.56 a	8.14 a
Glukomannan (G)	75:25 (R3)	12.77 a	7.64 a	10.56 a
Carrageenan (K)	R1	10.62 a	9.08 a	9.98 a
Carrageenan (K)	R2	12.78 a	11.88 a	11.63 a
Carrageenan (K)	R3	10.56 a	14.53 a	11.98 a
Chitosan (T)	R1	16.90 a	13.47 a	9.77 a
Chitosan (T)	R2	9.98 a	14.90 a	11.19 a
Chitosan (T)	R3	14.68 a	9.63 a	11.97 a

Note: The same letter after the average value indicates no significant effect.

Bioplastic quality is also determined by the elongation at break, defined as the increase in length of a package/bioplastic under the influence of a load (Harsojuwono and Arnata, 2017). The elongation at break is inversely proportional to the tensile strength. The Indonesian National Standard (SNI) requirement for elongation at break is 21–220%, meaning that the results of this study did not meet the requirements, ranging from 7.64 to 16.90%. This indicates that the formed bioplastic composite is unstable and not yet homogeneous.

Essentially, elongation at break is influenced by differences in the macrostructure and microstructure of bioplastic composites (Nayiroh, 2013). According to Harsojuwono and Arnata (2017), macrostructure and microstructure are influenced by the degree of crystallinity, cross-linking, glass transition point and melting point, molecular mass, and polydispersity, or the distribution of molecular mass. Meanwhile, according to Zhong and Kang (1998), elongation at break that is too high or too low occurs due to disruption of compatibility and homogeneity, resulting in an imbalance of functional groups due to the comparison of material concentrations and process temperatures that are too extreme, resulting in molecular dispersion that affects mechanical properties, including elongation at break.

4. Thickness Swelling

Analysis of the variation in composite treatments with other polysaccharides and PVA concentrations showed no significant effect on the thickness swelling of all bioplastic composites produced. The results of the thickness swelling analysis of the bioplastic composites are shown in Table 4.

Table 4: Thickness Swelling Values of Taro Starch and Other Polysaccharide Bioplastic Composites (%)

		Concentratiion	PVA (%)	
Variation treatment of taro starch composites with other polysaccharides	**Ratio**	**0 (P1)**	**5 (P2)**	**10 (P3)**
Glucomannan (G)	25:75 (R1)	39.63 d	58.84 d	84.54 c
Glucomanan (G)	50:50 (R2)	64.14 c	62.00 c	45.25 d
Glukomannan (G)	75:25 (R3)	48.64 d	54.11	54.11 d
Carrageenan (K)	R1	50.46 d	74.31 c	71.93 c
Carrageenan (K)	R2	41.68 d	44.76 d	66.99 c
Carrageenan (K)	R3	72.12 c	74.16 c	65.10 c
Chitosan (T)	R1	196.76 a	122.10 b	119.63 b
Chitosan (T)	R2	45.90 d	83.05 c	101.64 b
Chitosan (T)	R3	67.76 c	85.78 c	64.11 c

Note: The same letter after the average value indicates no significant effect.

Thickness swelling is defined as the water absorption of a packaging/bioplastic/bioplastic composite. The thickness swelling value is closely related to the molecular weight of the materials used to make the bioplastic composite. In this study, the thickness swelling values ranged from 41.68 to 196.76%. The thickness swelling values for these composites were all high. This is because all the materials used were hydrophilic. The thickness swelling value in this study did not meet the international plastics standard (EN 317), which is 1.44%.

5. Biodegradation

Analysis of the diversity of treatments for composite variations with other polysaccharides and PVA concentrations showed no significant effect on the biodegradation of all bioplastic composites produced. The results of the biodegradation diversity analysis of the bioplastic composites are shown in Table 5.

Table 5: Biodegradation Value of Taro Starch and Other Polysaccharide Biothermoplastic Composites (days)

		Concentration	PVA (%)	
Variation treatment of taro starch composites with other polysaccharides	**Ratio**	**0 (P1)**	**5 (P2)**	**10 (P3)**
Glucomannan (G)	25:75 (R1)	7	5.5	7

Glucomanan (G)	50:50 (R2)	6.5	7	6
Glukomannan (G)	75:25 (R3)	7	6	7
Carrageenan (K)	R1	7	7	6.5
Carrageenan (K)	R2	6	7	5.5
Carrageenan (K)	R3	6	7	7
Chitosan (T)	R1	7	7	7
Chitosan (T)	R2	7	7	7
Chitosan (T)	R3	6.5	6.5	7

Note: The same letter after the average value indicates no significant effect.

Bioplastic is plastic derived from renewable materials (biobased) or biodegradable and/or compostable plastic. This biopolymer decomposes into CO2, H2O, and organic compounds or biomass under natural conditions or stimulated by the enzymatic action of microorganisms (Kumar and Thakur, 2017).

The results of this study indicate that bioplastics decompose in soil within 5.5 to 7 days. Referring to SNI 7188:7 (2016), all bioplastics met the standard, which states that bioplastics must lose at least 60% of their weight within 7 days (BSN, 2016). This also meets the international bioplastics standard, the American Society for Testing Materials (ASTM 5336), which requires a maximum of 60 days for complete decomposition in soil (Averous, 2009). All materials used in this phase of the study are readily biodegradable, so all composites were fully degraded within 7 days.

Biodegradation is the decomposition or transformation of chemical compounds in bioplastics into simpler components, or even decomposition by microorganisms in the soil. There are two principles of biodegradation: the first stage and the final stage. The first stage is the decomposition of bioplastic molecules, where only a portion of the molecules is transformed into simpler components. Ultimate biodegradation is the complete decomposition of chemical molecules to form CO2, H2O, and other organic compounds.

6. Functional Groups of Composites with the Best Characteristics

The results of functional group analysis through wavenumber identification using FTIR spectroscopy on taro starch, chitosan, and the taro starch-chitosan bioplastic composite are shown in Figure 8.

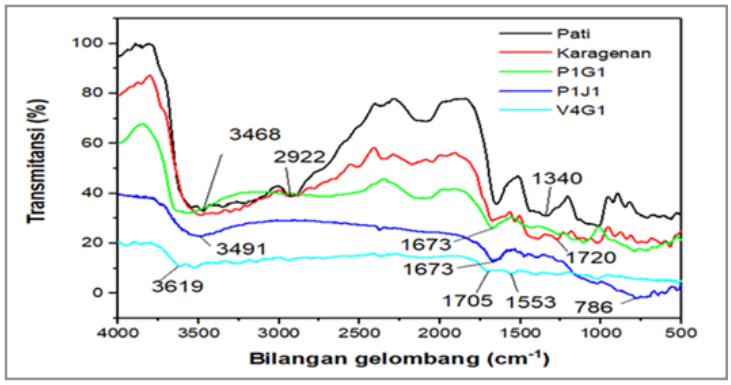

Figure 2: Wave number spectagram of taro starch, carrageenan, starch-carrageenan bioplastic composite with glycerol and taro starch-carrageenan bioplastic composite, glycerol-PVA.

Figure 2 shows a similar graphic pattern, differing only in the wavenumber peaks. The functional groups present in this study can be identified using the functional group comparison wavenumber and standard wavenumber, as shown in Table 8.

Table 6 shows the wavenumbers and functional groups present in taro starch. There are seven main wavenumbers with seven functional groups present in taro starch.

Table 6: Functional groups, compound types and standard wave numbers

Functional groups	Compound types	Wave numbers (cm-1)
C-H	Alkana	2850-2960, 1350-1470
C-H	Alkena	3020-3080, 675-1000
C-H	Aromatic	3000-3100, 675-870
C-H	Alkuna	3300
C=C	Alkena	1640-1680
C=C	Alkuna	2100-2260
C=C	Aromatic (ring)	1500-1600
C-H	Alkana	2850-2960, 1350-1470

C-O	Alcohol, eter, asam karboksilat, ester	1080-1300
C=O	Aldehid, keton, asam karboksilat, ester	1690-1760
O-H	Alcohol, fenol (monomer)	3610-3640
O-H	Alcohol, fenol (ikatan H)	200-3600
N-H	Amina	3300-3500
C-N	Amina	1180-1360
C=N	Nitril	2210-2260
-NO2	Nitro	1515-1560, 1345-1385

The wavenumbers of the functional groups of the starch:carrageenan = 25:75 bioplastic composite with 1% glycerol and 10% PVA are in the range of 1269 - 3657 cm-1, while the functional groups of the starch:carrageenan = 25:75 bioplastic composite with 1% glycerol are in the range of 1343 - 3702 cm-1. Furthermore, the composite material consisting of starch has functional groups at wavenumbers of 1010-1651 cm-1 and carrageenan is in the range of 1637 - 3702 cm-1.

Table 7 shows that the wavenumbers of the starch:carrageenan = 25:75 biothermoplastic composite with 1% glycerol 10% PVA are in the range of 1269 - 3657 cm-1 with functional groups O-H, C=O, C=C and C-O. Meanwhile, the biothermoplastic composite of starch:carrageenan=25:75 with 1% glycerol and without using 6% PVA, each is in the wave number range of 1343-3702 cm-1 and 1477 – 3466 cm-1 with O-H, C=O and C-O functional groups. The constituent material of the bioplastic composite in the form of starch is in the wave number range of 1010-1651 cm-1 with C=C and C-O functional groups, while carrageenan is in the wave number of 1673 - 3702 cm-1 containing O-H and C=C.

Table 7: Wave numbers and functional groups of starch, carrageenan, starch:carrageenan bioplastic composite = 25:75 with 1% glycerol and with 6% PVA

Wave number standard	Functional group standard	Starch	Carrageenan	Biothermoplastic composite starch:-carrageenan = 25:75 and 1% glycerol	Biothermo-plastic composite starch:-carrageenan = 25:75, 1% glycerol, 6% PVA
2500 – 4000	NH, CH and OH		O-H at 3702	O-H alcohol at 3702	O-H alcohol at 3657
1500 – 2000	C=O, C=N and C=C	C=C (alkena) at 1651	C=C (cincin aromatic) at 1673	C=O dan C=C pada 1673	
	C=O dan C=C at 1733				
400 – 1500	C-O (alcohol, eter,asam karboksilat, ester)	C-O at 1010, 1343		C-O (eter, carboksilat) pada 1343	C-O (eter, carboksilat) at 1269
	C-H (alcana)				

Conclusion

Variations in bioplastic and polyvinyl alcohol composite materials significantly affected the tensile strength, elongation at break, and elasticity of the taro starch-other polysaccharide composites produced. The taro starch:carrageenan ratio of 25:75 with a PVA concentration of 10% produced the best bioplastic composite characteristics.

Acknowledgement

This research was funded through the Udayana Superior Research activity from the 2022 Udayana University PNBP funds.

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