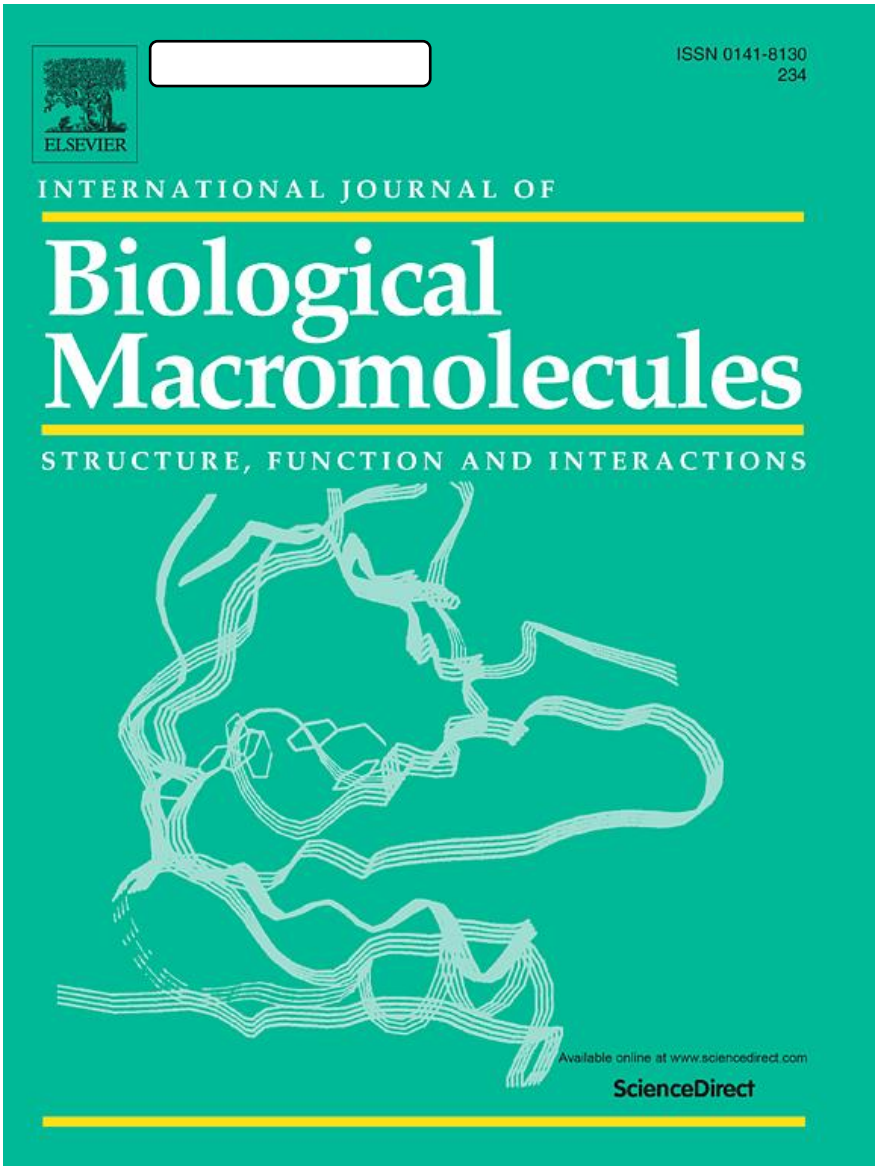
Paper 5 Not open access : Characterization and properties of cellulose microfibers from water hyacinth filled sago starch biocomposites

Silahkan klik google drive utk full access:
https://drive.google.com/file/d/1GEMcoZR0G4EHXRkhpa3wkcSbesGgwnsH/view?usp=sharing



International Journal of Biological Macromolecules 137 (2019) 119–125

Contents lists available at ScienceDirect

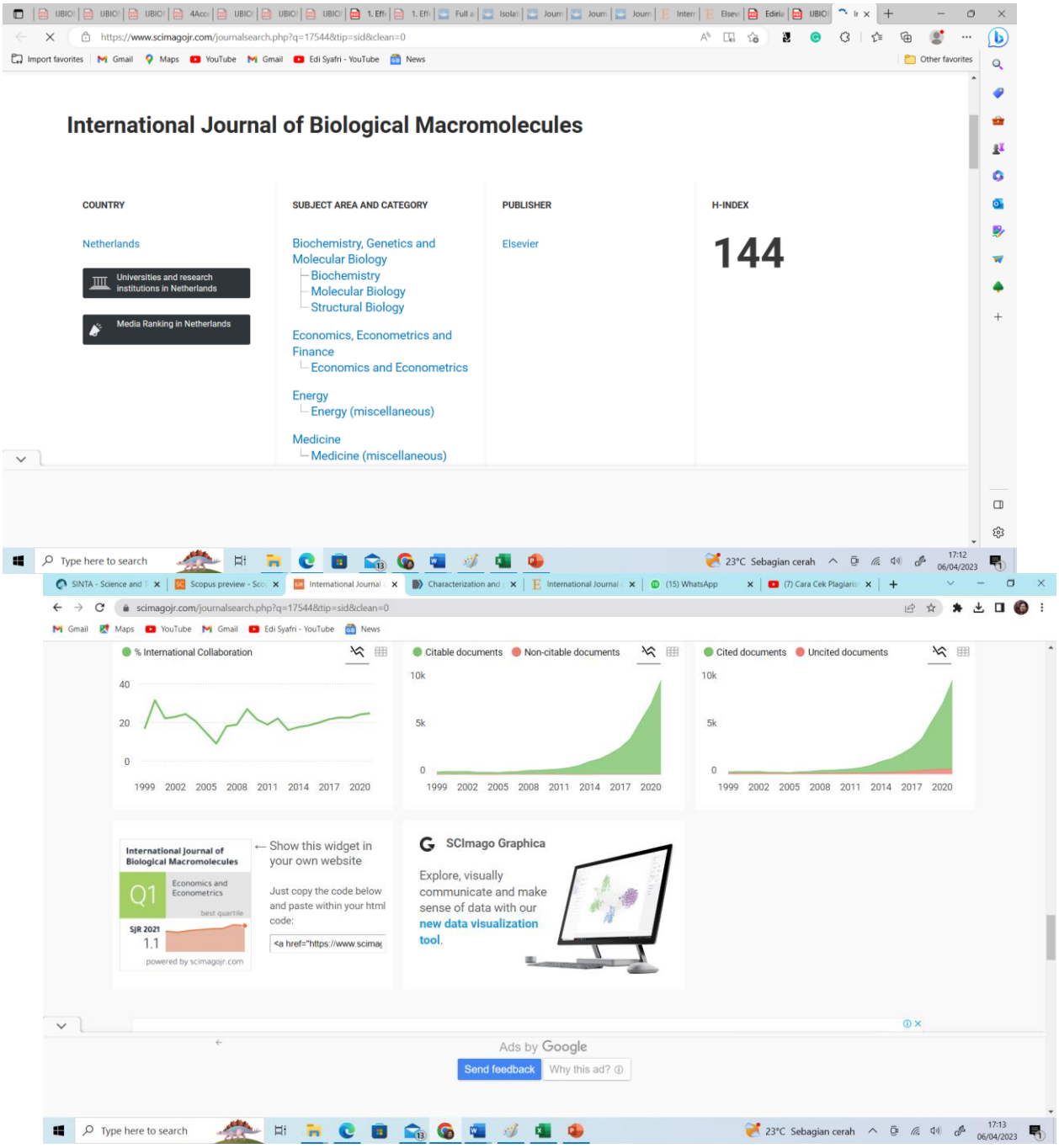
International Journal of Biological Macromolecules

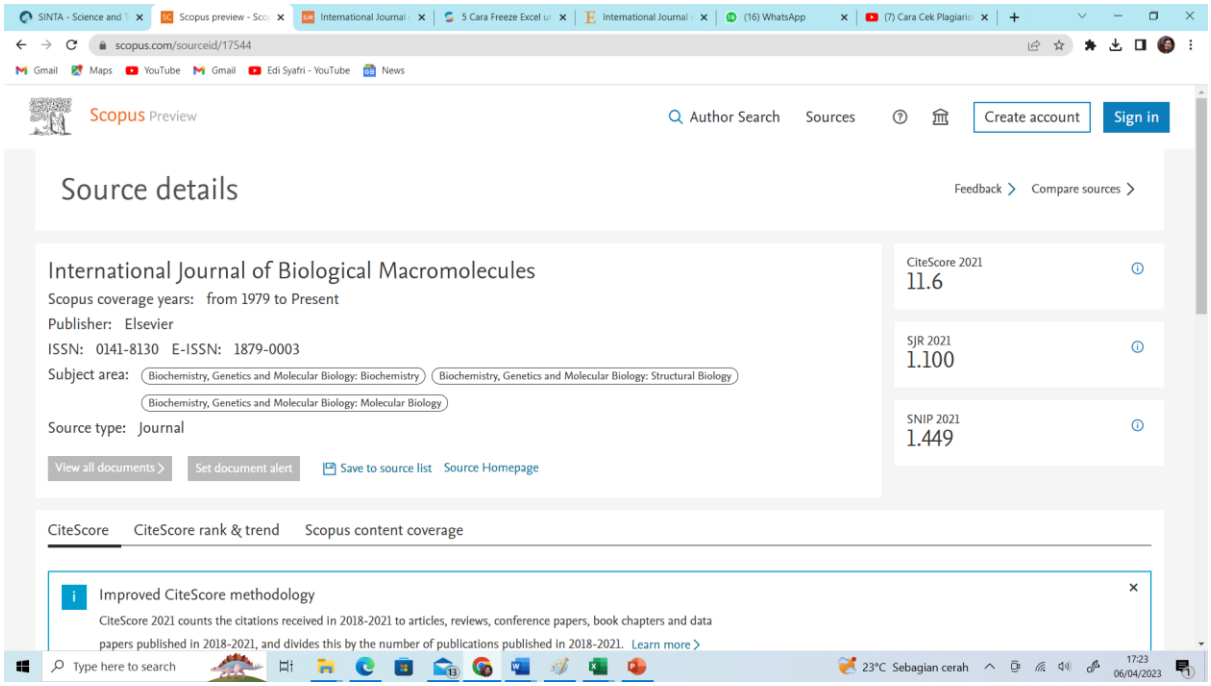
journal homepage: http://www.elsevier.com/locate/ijbiomac

Characterization and properties of cellulose microfibers from water hyacinth filled sago starch biocomposites

Edi Syafri [a,*], Jamaluddin [a], Sentot Wahono [b], Irwan A. [a], Mochamad Asrofi [c], Nasmi Herlina Sari [d], Ahmad Fudholi [e]

https://www.sciencedirect.com/science/article/abs/pii/S0141813019336803?via%3Dihub


https://www.scimagojr.com/journalsearch.php?q=17544&tip=sid&clean=0
International Journal of Biological Macromolecules
COUNTRY
Netherlands
Universities and research institutions in Netherlands
Media Ranking in Netherlands
SUBJECT AREA AND CATEGORY
Biochemistry, Genetics and Molecular Biology
Biochemistry
Molecular Biology
Structural Biology
Economics, Econometrics and Finance
Economics and Econometrics
Energy
Energy (miscellaneous)
Medicine
Medicine (miscellaneous)
PUBLISHER
Elsevier
H-INDEX
144
% International Collaboration
Citable documents
Non-citable documents
Cited documents
Uncited documents
International Journal of Biological Macromolecules
Q1
Economics and Econometrics
best quartile
SJR 2021
1.1
powered by scimagojr.com
Show this widget in your own website
Just copy the code below and paste within your html code:
SCImago Graphica
Explore, visually communicate and make sense of data with our new data visualization tool.
Ads by Google
Send feedback
Why this ad?



List Of Contents

Microcapsules based on octenyl succinic anhydride (OSA)-modified starch and maltodextrins changing the composition and release property of rose essential oil

Zuobing Xiao, Yanxiang Kang, Wenjing Hou, Yunwei Niu, Xingran Kou
Pages 132-138

Article preview

Research article ○ Abstract only

Preparation of *Chlorella vulgaris* polysaccharides and their antioxidant activity *in vitro* and *in vivo*

Mengen Yu, Mengjiao Chen, Jiangli Gui, Shudan Huang, ... Yongjun Zhang
Pages 139-150

Article preview

Research article ○ Abstract only

Molecular cloning, expression, and functional characterization of 70-kDa heat shock protein, DnaK, from *Bacillus halodurans*

Fatemeh Vahdani, Hossein Ghafouri, Sajjad Sarikhan, Reza Khodarahmi
Pages 151-159

FEED

Research article ○ Abstract only

The rheological properties and emulsifying behavior of polysaccharides sequentially extracted from *Amana edulis*

Yu-Hang Ji, Ai-Mei Liao, Ji-Hong Huang, Kiran Thakur, ... Zhao-Jun Wei
Pages 160-168

Article preview

Research article ○ Abstract only

Effect of Lentinan on Peyer's patch structure and function in an immunosuppressed mouse model

Yiping Jiang, Xiangling Li, Yun Wu, Lian Zhou, ... Wei Xiao
Pages 169-176

Article preview

Research article ○ Abstract only

Antioxidant capacity and prebiotic effects of *Gracilaria* neoagaro oligosaccharides prepared by agarase hydrolysis

International Journal of Biological Macromolecules 137 (2019) 119–125

Contents lists available at ScienceDirect

International Journal of Biological Macromolecules

journal homepage: http://www.elsevier.com/locate/ijbiomac

Characterization and properties of cellulose microfibers from water hyacinth filled sago starch biocomposites

Edi Syafri [a,*], Jamaluddin [a], Sentot Wahono [b], Irwan A. [a], Mochamad Asrofi [c], Nasmi Herlina Sari [d], Ahmad Fudholi [e]

[a] Department of Agricultural Technology, Agricultural Polytechnic, Payakumbuh, West Sumatra 26271, Indonesia
[b] Department of Agriculture and Horticulture, Agricultural Polytechnic, Payakumbuh, West Sumatra 26271, Indonesia
[c] Laboratory of Material Testing, Department of Mechanical Engineering, University of Jember, Kampus Tegalboto, Jember 68121, East Java, Indonesia
[d] Department of Mechanical Engineering, Mataram University, Jl. Majapahit No. 62, Mataram, NTB 83126, Indonesia
[e] Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 18 May 2019
Received in revised form 18 June 2019
Accepted 24 June 2019
Available online 25 June 2019

Keywords:
Water hyacinth fiber
Cellulose microfibers
Sago starch
Natural fiber
Biocomposites
Bioplastics

ABSTRACT

The cellulose microfibers (CMF) from water hyacinth (WH) fiber as a filler in sago starch (SS) biocomposites was investigated. The CMF was isolated by pulping, bleaching and acid hydrolysis methods. The addition of CMF in sago matrix was varied i.e. 0, 5, 10, 15 and 20 wt%. Biocomposites were made by using solution casting and glycerol as a plasticizer. The biocomposites were also determined by tensile test, FTIR, X-Ray, thermogravimetric, SEM, and soil burial tests. The results show that the SS15CMF sample has the highest tensile strength of 10.23 MPa than those other samples. Scanning Electron Microscope (SEM) images show that the strong interaction was formed between CMF WH and matrix. Fourier Transform Infra-red (FTIR) indicated that the functional group of biocomposites was a hydrophilic cluster. The addition of CMF WH in sago starch biocomposites lead to the moisture barrier, crystallinity, and thermal stability increased; it is due to the pure sago starch film was more rapidly degraded than its biocomposites.

1. Introduction

Synthetic plastic become serious problem in every country due to its not environmentally friendly and resulting in waste pollution. These cases were released Jambeck et al. [1] that Indonesia is the biggest country which produce plastic in ocean after China [1]. This is an emergency phenomenon due to its effect in environment and society. Thus, many researchers interest to develop the manufacturing bioplastic from starch in one last decade.

Starch is a kind of biopolymer which can be obtained by extraction from vegetable ingredients containing carbohydrates such as tuber and cereal. Manufacturing starch-based bioplastic has been got a lot of attention due to its biodegradability, low cost and abundant in earth [2]. The finding of biodegradable material is needed to overcome the waste pollution of synthetic plastic. Two last decades, many researchers focused on natural fiber-reinforced polymer composites rather than synthetic fiber-reinforced composites [3,4]. Most of polymer researchers still use synthetic resin as a composite polymer matrix. The disadvantage of composite from resin matrix is only partial degradation in environment. Therefore, to make fully biodegradable materials, we have to use biodegradable matrix derived from natural materials as well. Sago starch is one of the material candidates for biodegradable matrix due to its commercially available throughout the world [5].

However, sago starch is brittle and resulting in poor mechanical properties. To overcome this weakness, plasticizer is added to starch which can reduce the fragility of the material and improve the capability process [6]. Apart from this, starch has a higher moisture absorption and low thermal stability properties. The addition of cellulose fibers in starch matrix is one of the efficient methods to improve the performance of starch-based composites. The hydrophilic character of cellulose fiber and starch can produce a good hydrogen bonding between the two. Fiber size also plays an important role in properties of biocomposites [7,8]. The smaller fiber size then resulting in higher contact surface area [9].

Nowadays, biocomposite based starch matrix have used as an alternative food packaging in substituting the synthetic plastic [10,11]. These previous studied have reported that the main advantage of starch matrix is low cost, abundant and biodegradability in environment [3,12]. The tensile strength, thermal stability and moisture barrier of biocomposite to increased [13,14]. Furthermore, several studies reported about the addition of cellulose fiber in microscale reinforced starch matrix. Various sources of cellulose fiber were used to filled starch matrix biocomposites such as oil empty fruit bunch, okara fiber, micro scale pulp water hyacinth

* Corresponding author.
E-mail addresses: edi.syafri@politanipyk.ac.id (E. Syafri), asrofi.teknik@unej.ac.id (M. Asrofi), n.herlinasari@unram.ac.id (N.H. Sari), a.fudholi@ukm.edu.my (A. Fudholi).

https://doi.org/10.1016/j.ijbiomac.2019.06.174
0141-8130/

Fig. 1. Isolation process of CMF WH: a) raw WH, b) pulping in digester process, c) pulped WH, d) bleached WH, and e) CMF WH after hydrolysis.

[15–20]. They just given pulping treatment in resulting micro cellulose fiber. This treatment is considered to be insignificant to increase the surface adhesion between fibers and matrix. Therefore, in this study, we have isolated the CMF WH by pulping, bleaching and hydrolysis treatment. According to previous report, three stage treatments above give several advantages such as higher crystallinity and cellulose content [17–19,21]. Then, CMF WH was prepared and filled in sago starch matrix to produce biocomposites. They were characterized through SEM, tensile test, X-ray diffraction (XRD), FTIR, Thermogravimetric Analysis (TGA), moisture absorption and soil burial test.

2. Materials and methods

2.1. Materials

Water hyacinth fiber was obtained from Payakumbuh, Indonesia. The isolation of MFC WH fiber was explained in methods. Sago starch was purchased at local market in Padang, Indonesia. Glycerolunder Brataco brand with density 1.255–1.260 g/mL was purchased from PT Cisadane Raya Chemicals, Tangerang Indonesia. All chemical reagent (pure analyst) for CMF isolation such as NaOH, KOH, $NaClO_2$, acetic acid and H_2SO_4, were supplied from Faculty of Agriculture Technology, Andalas University, Indonesia.

2.2. Preparation isolation of CMF WH

The isolation of CMF WH can be seen in. 1. The WH stem was separated from leaves and roots. Then, it was cut along 10–20 mm and dried under the sun for 3 days with water content 9–10% [17–19]. The lignin and hemicellulose of WH fiber were removed by pulping digester (simple digester pulp) in 18% NaOH solution at 170 °C and 7–9 kg/cm^2 for 2 h [22]. The pulped WH fiber was rinsed by distilled water until free from alkali and continued by bleaching process with 5% $NaClO_2$: acetic acid at 70 °C for 2 h. After that, the bleached WH fiber was neutralized then it was hydrolyzed by 30% H_2SO_4 for 30 min. The final product of CMF WH was in dried granule fiber as in Fig. 1e.

2.3. Fabrication of CMF WH/SS biocomposites

The fabrication of biocomposites referred to previous report [23]. SS was dissolved by aquadest (5% w/v) and CMF WH (% w/w from SS) with different composition in matrix (see Table 1). Glycerol (30% w/w from SS) was added as a plasticizer. Then, they were mixed become biocomposite solution at 90 °C under constant stirring (300 rpm) until gelatinized. The biocomposites gel was casted in rectangular acrylic

Table 1
The composition of CMF WH/SS biocomposites.

Samples	Glycerol (g)	SS (g/40 ml) Mineral water	CMF WH (Wt% from dry starch basis)
SS film	0.6	2	0
SS5CMFWH	0.6	2	5
SS10CMFWH	0.6	2	10
SS15CMFWH	0.6	2	15
SS20CMFWH	0.6	2	20

Table 2
Chemical composition of WH fiber before and after treatment.

Treatment	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Extractive (%)
Raw	15.13	64.07	10.48	5.26
Pulping	14.27	68.96	8.38	3.67
Bleaching	5.09	83.06	6.74	1.34
Hydrolysis	4.49	85.85	5.55	1.53

mold (dimension: 11 × 9.5 × 0.3 cm^3). To remove an air bubble in biocomposites gel, the rectangular acrylic mold was placed in ultrasonic bath for 15 min. After that, it was dried in drying oven at 40 °C for 24 h. The biocomposites film was stored in desiccator for 24 h before characterization.

2.4. Fracture surface

The fracture surface of all samples after tensile test was observed by SEM Hitachi 3400 Seri N. The voltage was operated at 10 kV. The test was carried out in room temperature.

2.5. Tensile test

The tensile test of all biocomposites sample was determined by UTM Strograph-R1 instrument with load cell 5 kN. All samples were prepared and formed according to American Standard Testing Material (ASTM) D-638. The crosshead speed and temperature during test were monitored at 2 mm/min and 25 °C, respectively. The tensile test was carried out by three times repetition for each sample variation [24,25].

2.6. Crystallinity index

The crystallinity index (CI) of biocomposites was studied by X-Ray Diffraction (XRD) PANalytical. The XRD profile was recorded by diffractometer ray circuit. The radiation was CuKα at wave length 1.5406 Å. The ampere and voltage were operated at 30 mA and 40 kV, respectively. The 2θ degree was scanned in range 2–100° every 20°/min. The CI (%) was calculated by Segal's equation [26]:

$$CI\ (\%) = \frac{I_c - I_{am}}{I_c} \times 100 \quad (1)$$

where, I_c and I_{am} were crystalline and amorphous region, respectively. I_c was measured at 2θ = 22.6°. Meanwhile, I_{am} was determined at 2θ = 18°.

2.7. Functional groups

The functional group of all sample tested was determined by FTIR using Perkin-Elmer Frontier. All samples were formed in square film 1 cm × 1 cm. The spectrum was scanned from wavenumber 4000–600 cm^{-1} under resolution 4 cm^{-1}.

2.8. Thermal stability

Thermogravimetric analysis was conducted by thermogravimetric analyzer instrument. All samples were tested under nitrogen atmosphere as heat source with 80 mL/min of speed. The test was done in range temperature 30–600 °C. The heating rate was 20 °C/min.

2.9. Moisture absorption test

The biocomposites sample was cut 1.5 cm × 1.5 cm and dried until constant weight in oven at 40 °C for 24 h. The test was done in moisture container at relative humidity and temperature of 80% and 25 °C for 22 h, respectively. W_o and W_t were initial weight before test and final weight of sample after measured in 30 min intervals, respectively. The percentage of moisture absorption was calculated according to equation

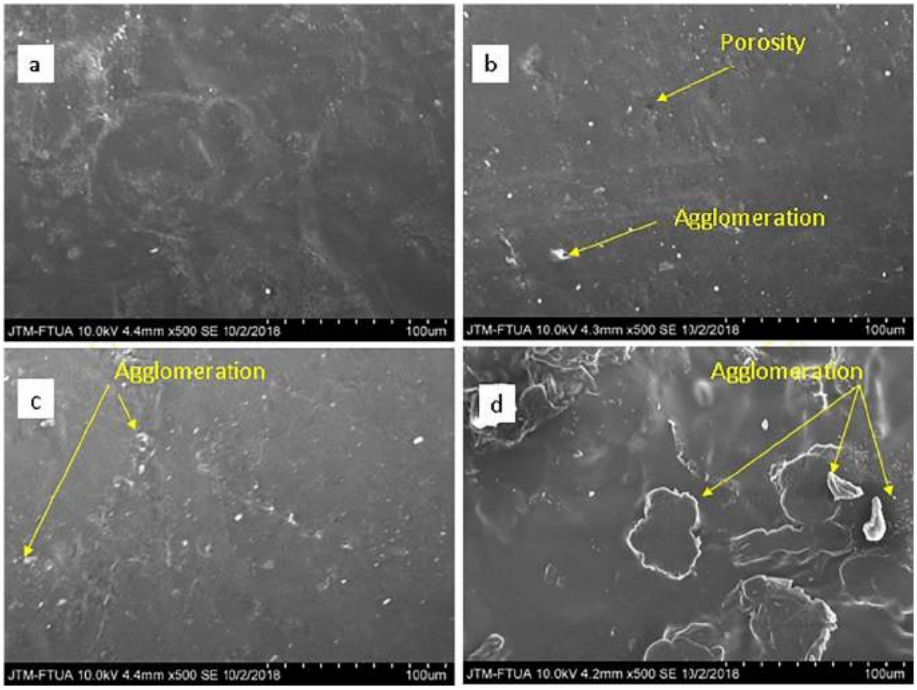


Fig. 2. Fracture surface of biocomposite: (a) SS Film, (b) SS5CMF, (c) SS10CMF and (d) SS20CMF WH.

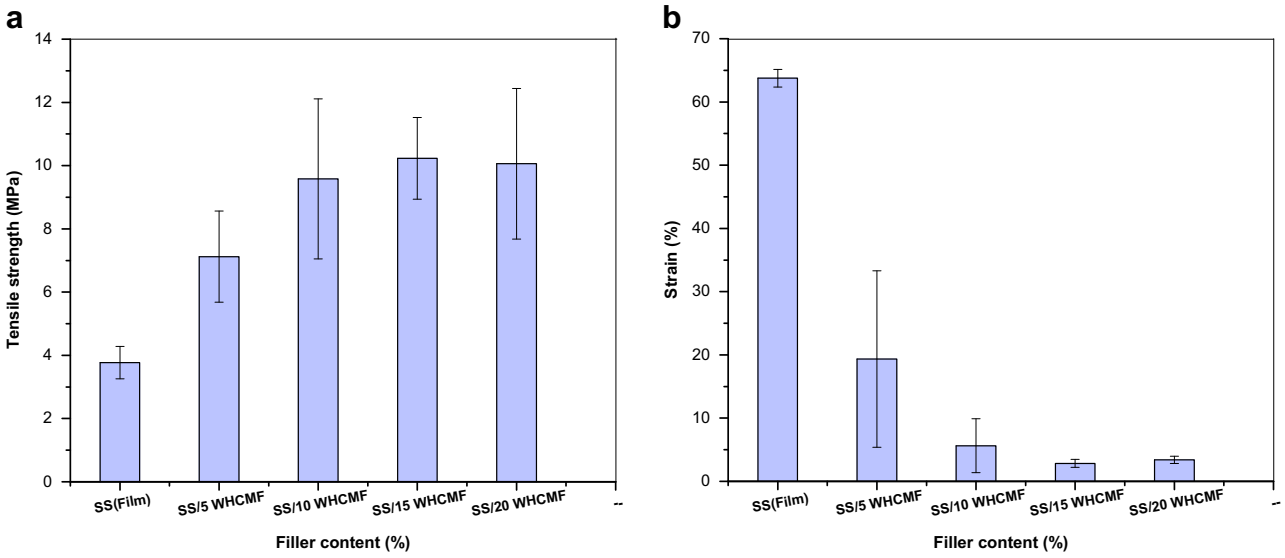


Fig. 3. (a) Tensile strength and (b) stress-strain curve of all biocomposites tested.

below:

$$Moisture\ Absorption\ (\%) = \frac{W_t - W_0}{W_0} \times 100 \quad (2)$$

2.10. Biodegradation test

Soil burial test method was used to determine the biodegradation of biocomposites sample [27]. The studied soil was the community plantation soil in Padang. The pH, water content and relative humidity were 6.5, 36.24% and 78%, respectively. All samples were dried in drying oven at 40 °C for 24 h until constant weight and then weighted for initial weight with precision balance. The samples were buried in soil for 5 and 15 days. After that, they were cleaned with distilled water and dried in oven at 40 °C for 24 h. Then, they were stored in desiccator for 24 h before final weighing. The final weighing was done by precision balance until constant weight. The percentage weight loss of all samples was determined according to equation below:

$$Weight\ loss\ (\%) = \frac{W_0 - W_t}{W_t} \times 100 \quad (3)$$

where, W_o and W_t were the sample weight before and after burial in soil, respectively.

3. Result and discussions

3.1. Chemical composition of WH Fiber

Chemical composition analysis was used to determine the percentage of cellulose, hemicellulose, lignin and extractive content in WH fiber. The chemical composition of WH fiber before and after chemical treatment is presented on Table 2. The untreated WH fiber (raw) has cellulose, hemicellulose, lignin and extractive content for 64.07, 15.13, 10.48 and 5.26 wt%, respectively. The cellulose content in raw WH fiber is lower than treated fiber. Giving chemical treatment is one of the ways to reduce the non-cellulosic content and increase the cellulose content. It can be seen that lignin and hemicellulose content decreased after pulping process with NaOH. It is due to the broken of hydrogen bond in cell wall structure of fiber [28].

Meanwhile, there is a significant improvement of cellulose content after bleaching and hydrolysis process (Table 2). The cellulose content increased 14% from pulping to bleaching process due to the removal of hemicellulose and lignin content in WH fiber. Lignin reacted with $NaClO_2$ and resulting in soluble lignin chloride compound [29]. After hydrolysis process, the cellulose content of CMF WH fiber has 85.85%. This value is higher than previous study which reported about WH cellulose fiber prepared by double acid hydrolysis [17–19].

3.2. Fracture morphological of biocomposites

Fracture morphology of biocomposites after tensile test is displayed by Fig. 2. Generally, the morphological of biocomposite without filler (SS film) is uniform, homogeneous and no porosity formation [30]. The addition of 5 and 10 wt%CMF WH in SS matrix shows an agglomeration fiber and porosity (Fig. 2b and c). It is indicated that in several

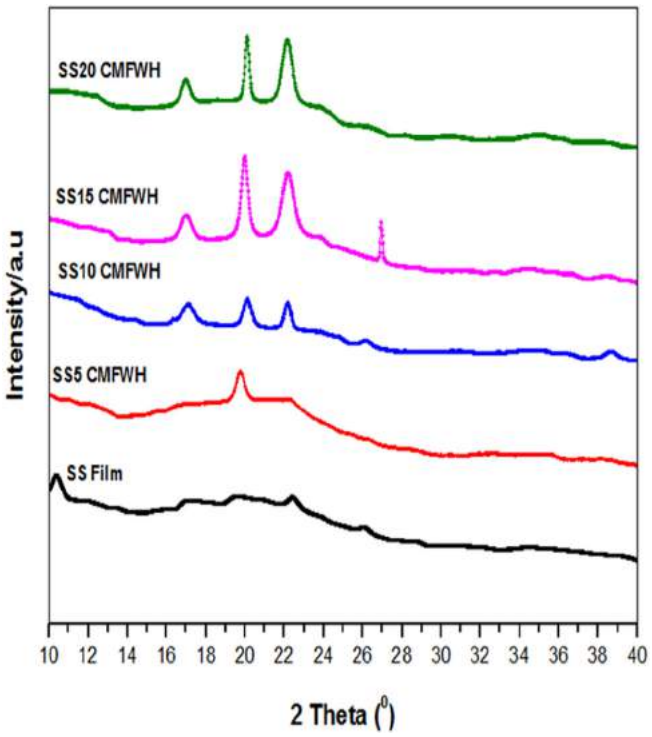


Fig. 4. XRD pattern of all biocomposites tested.

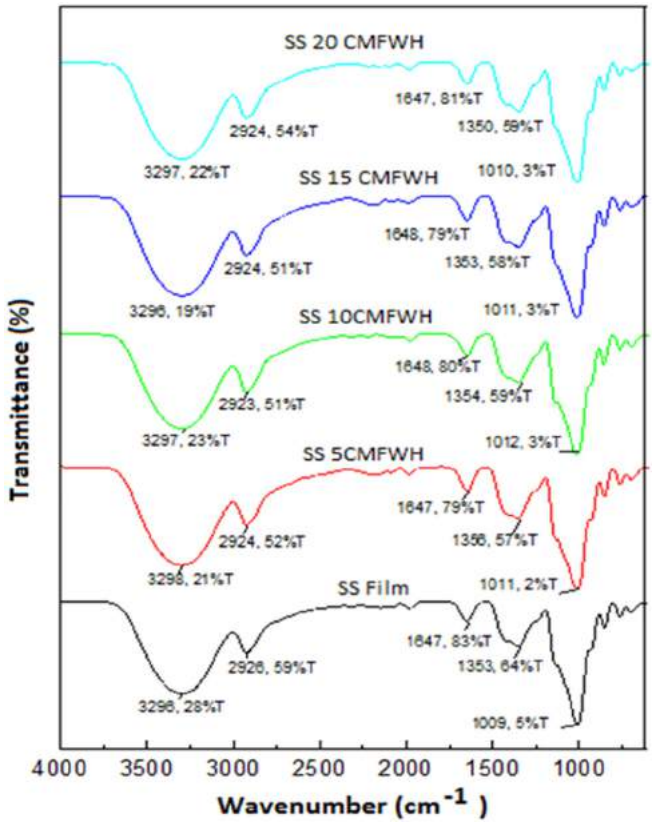


Fig. 5. FTIR spectra of all biocomposites tested.

fracture point occurs a bad adhesion bonding between cellulose fiber and matrix. However, the presence of cellulose fiber in starch matrix improved the mechanical properties of biocomposites than SS film. Fig. 2d displays non-homogeneous distribution of cellulose fiber in matrix due to unperfect mixing of biocomposites during fabrication. According to the previous report, unperfect mixing able to provoke the agglomeration, porosity and bad adhesion bonding [17–19]. This phenomenon is affected in decreasing tensile test.

3.3. Tensile strength

The tensile strength and strain at break of SS film and its biocomposites are showed by Fig. 3. The tensile strength increased with the addition of CMF WH in SS matrix (Fig. 3a). It can be seen that the tensile strength of SS film is 3.77 MPa. It is lower than its biocomposites due to there is no reinforcement in this sample. After addition as much 5, 10 and 15 wt%, the tensile strength increased significantly become 7.12, 9.58 and 10.23 MPa, respectively. This improvement is followed by decreasing of strain value (Fig. 3b). This is due to a good interaction between cellulose fiber and starch [31]. Another phenomenon occurs in SS20CMFWH sample. There is a decreasing in tensile strength from 10.23 to 10.06 MPa. This phenomenon due to inhomogeneous distribution of fiber in starch matrix [32]. This case is agreement with SEM and XRD observation.

3.4. Crystallinity index analysis

Fig. 4 shows diffraction pattern of SS film and its biocomposites. It can be seen that all biocomposites have same pattern and the crystalline area appeared with the addition of CMF WH in SS matrix. It is indicated that biocomposites material included in semi-crystalline structure [30]. At Fig. 4, SS films did not show sharp peaks. It is indicated due to there is no presence of cellulose fiber in matrix. Different phenomena are shown by biocomposites sample. There are several peaks in the range $2\theta = 16–24°$ especially for SS15CMFWH and SS20CMFWH sample. The CI of SS film, SS5CMFWH, SS10CMFWH SS15CMFWH, SS20CMFWH was 14.01, 19.48, 19.95, 40.72, 33.98%, respectively. This case proves that the presence of cellulose fiber in matrix give a rise the peaks and increasing CI. It can be seen that the highest CI is owned by SS15CMFWH and SS20CMFWH sample. According to previous research, increasing CI also trigger an increase in tensile strength [17–19]. This is indicated by the presence of cellulose fiber chains inhibit the movement of starch polymers and resulting in brittle biocomposites [33]. This result is supported by the lower strain value with increasing cellulose fraction in matrix (Fig. 3).

3.5. Functional group analysis

The chemical functional groups in CMF WH filled sago starch matrix based biocomposites are presented in Fig. 5. IR spectra of all samples had similar bands. There is no significant different between SS film

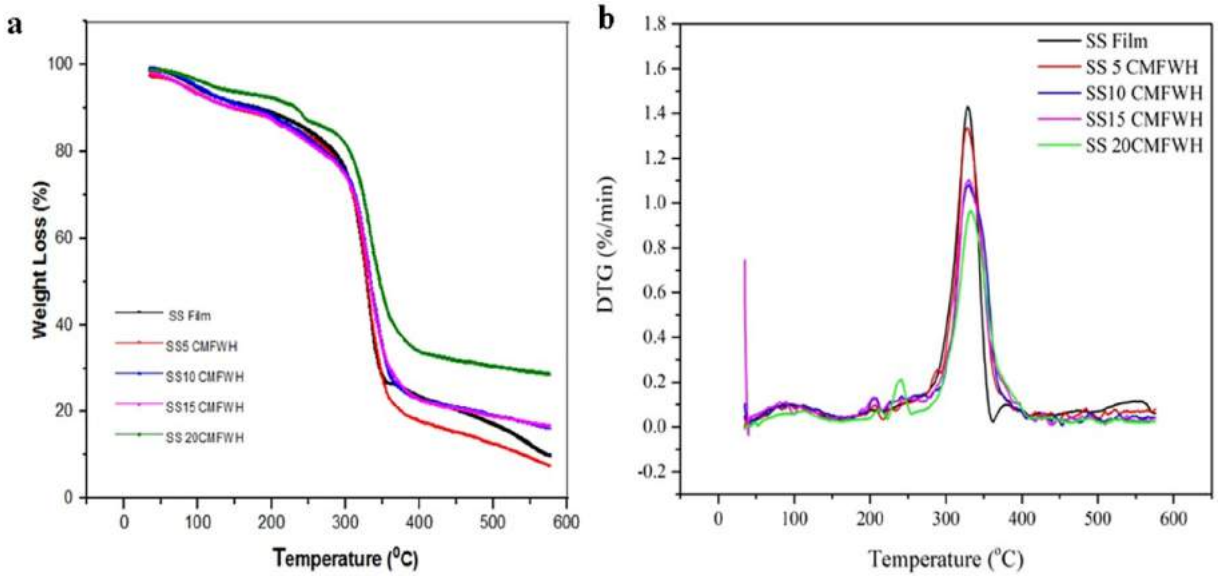


Fig. 6. (a) TGA and (b) DTG curve of all biocomposites tested.

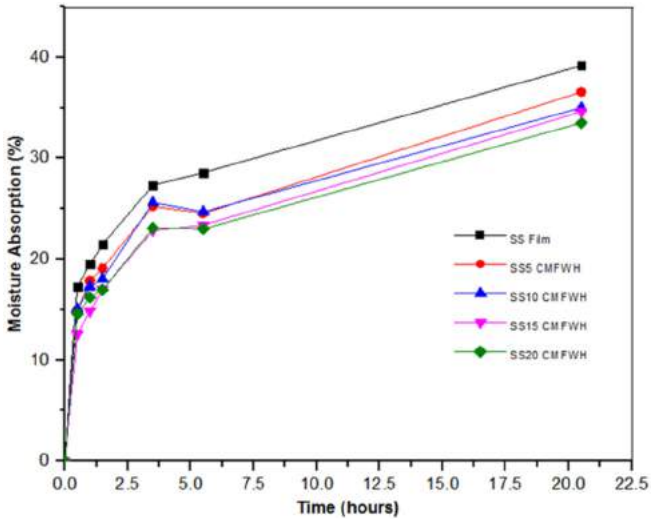


Fig. 7. Moisture absorption percentage of all biocomposites tested.

and its biocomposites. This phenomenon indicated that the addition of glycerol or CMF WHF in sago matrix is not affecting the wavenumber shift [22,23].

There are five different bands exist in all biocomposites sample i.e. 3298, 2926, 1647, 1353 and 1009 cm^{-1}. The bands around 3298 $cm^{-1}$is indicated by OH stretching groups from SS and CMF WH due to the presence of hydroxyl groups in in both of these materials [17–19,34]. The vibration stretching CH occurred in band around 2926 cm^{-1}. Meanwhile, the band around 1647 cm^{-1} indicated by the OH water absorption of natural hydrophilic starch and cellulose [15,16]. This band appear in all sample tested. The band at 1353 cm^{-1} and 1647 cm^{-1} indicated of a strong and broad of CO stretch which is a cellulose alcohol group [35].

3.6. Thermal stability

Thermal analysis of CMF WH filled starch based biocomposite is shown in Fig. 6. There are three stage degradation temperature. The first stage occurs below 100 °C due to moisture loss in all biocomposites sample [36]. At the second stage, the degradation temperature starts from 225 until 350 °C. During this process, the ether bonds and unsaturated structures occur condensation between hydroxyl groups of starch chains. In this stage, starch, cellulose and glycerol structure were all degraded. The last stage occurs at temperatures above 350 °C due to the residual disintegration produced in the previous conditions [37]. From all stage, we can conclude that the highest thermal stability was in SS20CMFWH sample with a remaining mass of 30.6% (Fig. 6a). This result is supported by DTG curve (Fig. 6b).

It can be seen that the SS20CMFWH sample has the highest thermal degradation of 332.71 °C with a thermal degradation rate of 0.95%/min. It is due to good interaction of hydrogen bonding between CMF and SS matrix [30]. This phenomenon was contradictive with SS film. SS film has the lowest thermal stability. Its degradation temperature is about 328.08 °C with a degradation rate of 1.43%/min. This case is similar with previous report [38]. Previous study reported about the addition of fiber into starch matrix was successful improved thermal stability. This is due to good adhesion bonding between fiber and starch which resulting in little of sample weight loss [39].

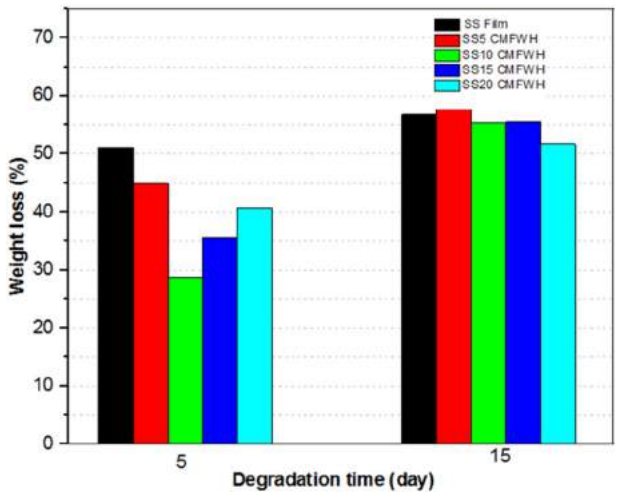


Fig. 8. The weight loss of all biocomposites tested due to biodegradation in soil.

3.7. Moisture absorption

The disadvantage of cellulose and starch-based biocomposites is the high absorption of moisture due to its hydrophilic character. Fig. 7 displays the percentage of moisture absorption for 22 h. It can be seen that there is a significant different between SS film and its biocomposites. At the beginning, the sample absorbs a moisture in high capacity. The moisture absorption percentage of SS Films, SS5CMFWH, SS10CMFWH, SS15CMFWH and SS20CMFWH at 3.5 h is 28.58, 24.55, 24.71, 23.37 and 23.01%, respectively. Moisture absorption rate decrease towards to the saturation point at 5.5 h.

It can be seen that addition of CMF WH in SS matrix reduce the moisture absorption. The lowest moisture absorption was in SS20CMFWH samples. This is due to CMF is an organic substance has less hydrophilic than SS. Another reason was indicated the role of CMF WH as barrier agent of water molecule when diffusing in to matrix.

3.8. Soil burial test

Biodegradation testing of biocomposites was carried out by burying the sample in the soil. The percentage weight loss due to biodegradation is presented in Fig. 8. The highest percentage of weight loss was in SSFilm and SS5CMFWH after 15 days. This phenomenon is indicated by the absence of fibers in SS matrix. This sample easily broken down by microorganisms. Another case occurred in SS20CMFWH sample where it has the lowest weight loss. This is due to the role of CMF WH in SS matrix as a barrier agent to prevent microorganisms. Previous research also showed the similar case that the addition of montmorillonite in poly (butylene succinate) matrix reduced the biodegradation rate [40].

4. Conclusions

The biocomposites based CMF WH and SS matrix was successfully produced through solution casting method. The presence of CMF WH in SS improved tensile strength, thermal stability and CI. The maximum tensile strength was 10.23 MPa achieved by SS15CMFWH sample. There is no significant change in functional group with the addition of fiber in matrix. The lowest moisture absorption was in SS20CMFWH for 23.01%. The addition of fiber in matrix also reduced the biodegradation rate in soil. This biocomposites is suggested for food packaging application due to its excellent properties and environmentally friendly.

Acknowledgments

The authors thanks to Ministry of Research, Technology and Higher Education of the Republic of Indonesia for PDUPT scheme in the year of 2018 to support the funding of this research.

References

[1] J.R. Jambeck, R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, K.L. Law, Plastic waste inputs from land into the ocean, Science 347 (2015) 768–771.
[2] O.V. López, C.J. Lecot, N.E. Zaritzky, M.A. García, Biodegradable packages development from starch based heat sealable films, J. Food Eng. 105 (2011) 254–263.
[3] S. Wahono, A. Irwan, E. Syafri, M. Asrofi, Preparation and characterization of ramie cellulose nanofibers/caco3 unsaturated polyester resin composites, J. Eng. Appl. Sci. 13 (2018) 746–751.
[4] P. Senthamaraikannan, S.S. Saravanakumar, V.P. Arthanarieswaran, P. Sugumaran, Physico-chemical properties of new cellulosic fibers from the bark of Acacia planifrons, Int. J. Polym. Anal. Charact. 21 (2016) 207–213.
[5] W. Tongdeesoontorn, L.J. Mauer, S. Wongruong, P. Sriburi, P. Rachtanapun, Effect of carboxymethyl cellulose concentration on physical properties of biodegradable cassava starch-based films, Chem. Cent. J. 5 (2011) 1–8.
[6] Y.P. Chang, A.A. Karim, C.C. Seow, Interactive plasticizing–antiplasticizing effects of water and glycerol on the tensile properties of tapioca starch films, Food Hydrocoll. 20 (2006) 1–8.
[7] M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, F. Hafizulhaq, Mechanical properties of a water hyacinth nanofiber cellulose reinforced thermoplastic starch bionanocomposite: effect of ultrasonic vibration during processing, Fibers 6 (2018) 40.
[8] M.R. Sanjay, P. Madhu, M. Jawaid, P. Senthamaraikannan, S. Senthil, S. Pradeep, Characterization and properties of natural fiber polymer composites: a comprehensive review, J. Clean. Prod. 172 (2018) 566–581.
[9] H. Abral, V. Lawrensius, D. Handayani, E. Sugiarti, Preparation of nano-sized particles from bacterial cellulose using ultrasonication and their characterization, Carbohydr. Polym. 191 (2018) 161–167.
[10] N. Sumrith, S.M. Rangappa, R. Dangtungee, S. Siengchin, M. Jawaid, C.I. Pruncu, Biopolymers-based nanocomposites: properties and applications, Bio-based Polymers and Nanocomposites, Springer Cham 2019, pp. 255–272.
[11] M.K. Marichelvam, M. Jawaid, M. Asim, Corn and rice starch-based bio-plastics as alternative packaging materials, Fibers 7 (2019) 32.
[12] M.R. Sanjay, G.R. Arpitha, L.L. Naik, K. Gopalakrishna, B. Yogesha, Applications of natural fibers and its composites: an overview, Nat. Resour. 7 (2016) 108.
[13] O.V. López, L.A. Castillo, M.A. García, M.A. Villar, S.E. Barbosa, Food packaging bags based on thermoplastic corn starch reinforced with talc nanoparticles, Food Hydrocoll. 43 (2015) 18–24.
[14] M. Asem, W.M.F.W. Nawawi, D.N. Jimat, Evaluation of water absorption of polyvinyl alcohol-starch biocomposite reinforced with sugarcane bagasse nanofibre: optimization using two-level factorial design, IOP Conference Series: Materials Science and Engineering, 368, 2018, p. 012005.
[15] H. Abral, M.H. Dalimunthe, J. Hartono, R.P. Efendi, M. Asrofi, E. Sugiarti, S.M. Sapuan, J.W. Park, H.J. Kim, Characterization of tapioca starch biopolymer composites reinforced with micro scale water hyacinth fibers, Starch-Stärke 70 (2018) 1–8.
[16] H. Abral, G.J. Putra, M. Asrofi, J.W. Park, H.J. Kim, Effect of vibration duration of high ultrasound applied to bio-composite while gelatinized on its properties, Ultrason. Sonochem. 40 (2018) 697–702.
[17] M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, F. Hafizulhaq, Characterization of the sonicated yam bean starch bionanocomposites reinforced by nanocellulose water hyacinth fiber (WHF): the effect of various fiber loading, J. Eng. Sci. Technol. 13 (2018) 2700–2715.
[18] M. Asrofi, H. Abral, Y.K. Putra, S.M. Sapuan, H.J. Kim, Effect of duration of sonication during gelatinization on properties of tapioca starch water hyacinth fiber biocomposite, Int. J. Biol. Macromol. 108 (2018) 167–176.
[19] M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, J.W. Park, H.J. Kim, Isolation of nanocellulose from water hyacinth fiber (whf) produced via digester-sonication and its characterization, Fibers Polym. 19 (2018) 1618–1625.
[20] Z.Q. Fu, M. Wu, X.Y. Han, L. Xu, Effect of okara dietary fiber on the properties of starch-based films, Starch-Stärke 69 (2017), 1700053.
[21] P. Manimaran, P. Senthamaraikannan, M.R. Sanjay, M.K. Marichelvam, M. Jawaid, Study on characterization of furcraea foetida new natural fiber as composite reinforcement for lightweight applications, Carbohydr. Polym. 181 (2018) 650–658.
[22] E. Syafri, A. Kasim, H. Abral, A. Asben, Cellulose nanofibers isolation and characterization from ramie using a chemical-ultrasonic treatment, J. Nat. Fibers 2018 (2018) 1–11.
[23] E. Syafri, A. Kasim, H. Abral, G.T. Sulungbudi, M.R. Sanjay, N.H. Sari, Synthesis and characterization of cellulose nanofibers (CNF) ramie reinforced cassava starch hybrid composites, Int. J. Biol. Macromol. 120 (2018) 578–586.
[24] N.H. Sari, R.M. Sanjay, G.R. Arpitha, C.I. Pruncu, S. Siengchin, Synthesis and properties of pandanwangi fiber reinforced polyethylene composites: evaluation of dicumyl peroxide (DCP) effect, Compos. Commun. 15 (2019) 53–57.
[25] N.H. Sari, I.N. Wardana, Y.S. Irawan, E. Siswanto, Corn husk fiber-polyester composites as sound absorber: nonacoustical and acoustical properties, Adv. Acoust. Vib. 2017 (2017) 1–7.
[26] L.G.J.M.A. Segal, J.J. Creely, A.E. Martin Jr., C.M. Conrad, An empirical method for estimating the degree of crystallinity of native cellulose using the X-ray diffractometer, Text. Res. J. 29 (1959) 786–794.
[27] V. Pimpan, K. Ratanarat, M. Pongchawanakul, Preliminary study on preparation of biodegradable plastic from modified cassava starch, J. Sci. Res. Chulalongkorn Univ. 26 (2001) 117–126.
[28] J. Chandra, N. George, S.K. Narayanankutty, Isolation and characterization of cellulose nanofibrils from arecanut husk fibre, Carbohydr. Polym. 142 (2016) 158–166.
[29] C.J. Chirayil, J. Joy, L. Mathew, M. Mozetic, J. Koetz, S. Thomas, Isolation and characterization of cellulose nanofibrils from Helicteresisora plant, Ind. Crop. Prod. 59 (2014) 27–34.
[30] H. Kargarzadeh, N. Johar, I. Ahmad, Starch biocomposite film reinforced by multiscale rice husk fiber, Compos. Sci. Technol. 151 (2017) 147–155.
[31] L. Lendvai, J. Karger-Kocsis, Á. Kmetty, S.X. Drakopoulos, Production and characterization of microfibrillated cellulose-reinforced thermoplastic starch composites, J. Appl. Polym. Sci. 133 (2016) 1–8.
[32] N.R. Savadekar, S.T. Mhaske, Synthesis of nano cellulose fibers and effect on thermoplastics starch based films, Carbohydr. Polym. 89 (2012) 146–151.
[33] M.L. Sanyang, S.M. Sapuan, M. Jawaid, M.R. Ishak, J. Sahari, Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films, BioResources 11 (2016) 4134–4145.
[34] K. Kaewtatip, J. Thongmee, Studies on the structure and properties of thermoplastic starch/luffa fiber composites, Mater. Des. 40 (2012) 314–318.
[35] M. Mahardika, H. Abral, A. Kasim, S. Arief, M. Asrofi, Production of nanocellulose from pineapple leaf fibers via high-shear homogenization and ultrasonication, Fibers 6 (2018) 28.
[36] S.Y. Lee, D.J. Mohan, I.A. Kang, G.H. Doh, S. Lee, S.O. Han, Nanocellulose reinforced PVA composite films: effects of acid treatment and filler loading, Fibers Polym. 10 (2009) 77–82.
[37] J. Raabe, A.D.S. Fonseca, L. Bufalino, C. Ribeiro, M.A. Martins, J.M. Marconcini, G.H.D. Tonoli, Biocomposite of cassava starch reinforced with cellulose pulp fibers modified with deposition of silica (SiO2) nanoparticles, J. Nanomater. 2015 (2015) 1–9.
[38] S.Y.Z. Zainuddin, I. Ahmad, H. Kargarzadeh, I. Abdullah, A. Dufresne, Potential of using multiscale kenaf fibers as reinforcing filler in cassava starch-kenaf biocomposites, Carbohydr. Polym. 92 (2013) 2299–2305.
[39] J. Prachayawarakorn, S. Chaiwatyothin, S. Mueangta, A. Hanchana, Effect of jute and kapok fibers on properties of thermoplastic cassava starch composites, Mater. Des. 47 (2013) 309–315.
[40] Y.J. Phua, N.S. Lau, K. Sudesh, W.S. Chow, Z.M. Ishak, Biodegradability studies of poly (butylene succinate)/organo-montmorillonite nanocomposites under controlled compost soil conditions: effects of clay loading and compatibiliser, Polym. Degrad. Stab. 97 (2012) 1345–1354.