


Paper 13 Not open access : Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading

Silahkan klik google drive utk full access:

<https://drive.google.com/file/d/1550mraJTquRPRHSWO0hsaqNiJRdWTf5h/view?usp=sharing>





Journal of Natural Fibers >
 Volume 17, 2020 - Issue 1

Enter keywords, authors, DOI, ORCID e





Submit an article

Journal homepage

176
Views

14
CrossRef
citations to date

1
Altmetric

Short Communications
Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading
 Edi Syafri , Anwar Kasim, Alfi Asben, P. Sentharamaikannan  & M.R. Sanjay 
 Pages 122-131 | Published online: 07 May 2018
[Download citation](#) <https://doi.org/10.1080/15440478.2018.1470057> 

<https://www.tandfonline.com/doi/abs/10.1080/15440478.2018.1470057?journalCode=wjnf20>

Editorial board

EDITOR-IN-CHIEF

Ryszard M. Kozłowski

Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB)

Poznan, Poland

CO-EDITORS

Alcides Leao

University of Sao Paulo

Sao Paulo, Brazil

Malgorzata Lochynska

Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB)

Poznan, Poland

Roger M. Rowell

University of Wisconsin

Madison, WI, USA

EDITORIAL BOARD

Mirta Inés Aranguren - INTEMA, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

Somaye Akbari - Amirkabir University of Technology (Polytechnic Tehran), Tehran, Iran

K. Murugesh Babu - Bapuji Institute of Engineering and Technology, Davangere, India

Prabir Kumar Banerjee - Indian Institute of Technology, New Delhi, India

Justyna Baraniak - Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB), Poznan, Poland

Nahum Ben-Yehuda - Bar Ilan University, Qedumim, Israel

Lucas F. Berti - Universidade Tecnológica Federal do Paraná - Curitiba, Curitiba, PR, Brasil

Andrzej K. Bledzki - West Pomeranian University of Technology Szczecin, Szczecin, Poland

Judit Borsa - Budapest University of Technology and Economics, Budapest, Hungary

Navin Chand - SIRT Sagar Group of Institutions, Materials Research Society India, Bhopal, India

Lucian Copolovici - Aurel Vlaicu University, Arad, Romania

Emília Csiszár - Budapest University of Technology and Economics, Budapest, Hungary

Zdzislaw Czaplicki - Association of Polish Textile Experts, Łódź, Poland

Ian J. Davies - Curtin University, Curtin, Australia

Olivier Demangeat - N. SCHLUMBERGER & CIE, Guebwiller, France

Michael S. Ellison - Clemson University, Clemson, SC, USA

Mohamed A. El-Esawi - Tanta University, Tanta, Egypt

Ahmed Moneeb El-sabbagh - Ain Shams University, Cairo, Egypt

Raul Figueiro - University of Minho, Minho, Portugal

Vincenzo Fiore - Università degli Studi di Palermo, Palermo, Italy

Gabriel Furtos - Babes-Bolyai University, Cluj-Napoca, Romania

Johannes Ganster - Fraunhofer-Institute for Applied Polymer Research IAP, Potsdam-Golm, Germany

Simona Gavrilas - Aurel Vlaicu University, Arad, Romania

Gianpaolo Grassi - Research Centre for Industrial Crops (CREA-CIN), Rovigo, Italy

Marta Grygorowicz - Associate Editor, Poznan, Poland

Luboš Hes - University of Liberec, Liberec, Czech Republic

Mathew R. L. Horne - BMC - Brooksby Melton College, Brooksby, UK

Lawrance Hunter - CSIR emeritus, Nelson Mandela University, Port Elizabeth, South Africa

Mohammad Jawaid - Universiti Putra Malaysia, Selangor, Malaysia

Seiko Jose - Central Sheep and Wool Research Institute Avikanagar, Rajasthan, India

Malgorzata Kania-Dobrowolska - Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB), Poznan, Poland

Boris Karpunin - "Lenprom", Interregional Public Foundation "Flax Union", Moscow, Russia

Recep Karadag - Marmara University, Istanbul, Turkey

Yutaka Kawahara - Gunma University, Kiryu, Japan

Anish Khan - King Abdulaziz University, Jeddah, Saudi Arabia

Yong K. Kim - University of Massachusetts Dartmouth, North Dartmouth, MA, USA

Cheryl Kolander - Aurora Silk, Portland, OR, USA

Thomas Luxbacher - Anton Paar GmbH, Graz, Austria

Maria Mackiewicz-Talarczyk - Institute of Natural Fibres and Medicinal Plants, Poznan, Poland

Jerzy Mankowski - Institute of Natural Fibres and Medicinal Plants, Poznan, Poland

Norma E. Marcovich - Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

György Marosi - Budapest University of Technology and Economics, Budapest, Hungary

Maria João Seixas de Melo - Universidade Nova de Lisboa, Lisbon, Portugal

Danuta Matykiewicz - Poznan University of Technology, Poznan, Poland

Arunangshu Mukhopadhyay - National Institute of Technology Jalandhar, Punjab, India

Malgorzata Muzyczek - (former) Institute of Natural Fibres and Medicinal Plants, Poznan, Poland

Rajkishore K. Nayak - RMIT University, Melbourne, Australia and Vietnam

Mohamed A. M. Negm - Cotton Research Institute, Agricultural Research Center, Giza, Egypt

Rajiv Padhye - RMIT University, Melbourne, Australia

Asis Patnaik - Cape Peninsula University of Technology, Cape Town, South Africa

Richard S. Peigler - University of the Incarnate Word, San Antonio, Texas, USA

Marcin Praczyk - Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB), Poznan, Poland

Chidambaram Prakash - Sona College of Technology, Salem, Tamil Nadu, India

Debora Puglia - Università degli Studi di Perugia (UNIPG), Perugia, Italy

John A. Rippon - former CSIRO, Torquay, Victoria, Australia

Derval dos Santos Rosa - Federal University of ABC, Santo André - SP - Brazil

Katarzyna Schmidt-Przewozna - Institute of Natural Fibres and Medicinal Plants, Poznan, Poland

Cecilia Sirghie - Aurel Vlaicu University, Arad, Romania

Andrés Simbaña Villarreal - Pontificia Universidad Católica del Ecuador Sede, Ibarra, Ecuador

Daniel Sorlino - University of Buenos Aires, Buenos Aires, Argentina

Marek Szostak - Poznan University of Technology, Poznan, Poland

Igor Uschapovsky - All Russian Research Institute for Flax Production (VNIIML), Tver, Russia

Xungai Wang - Deakin University, Geelong, Australia

Yu Fu Wang - Institute of Bast Fiber Crops (IBFC), Chinese Academy of Agricultural Sciences, Changsha, China

Aleksandra Wawro - Institute of Natural Fibres and Medicinal Plants-National Research Centre (IWNiRZ-PIB), Poznan, Poland

Adam Wisniewski - Military Institute of Armament Technology, Zielonka, Warszawa, Poland

Wei Wu - Shanghai Gatta Fashion Ltd., Shanghai, China

Journal metrics



Usage

- **175K** annual downloads/views



Citation metrics

- **3.507 (2021)** Impact Factor
- **Q1** Impact Factor Best Quartile
- **3.760 (2021)** 5 year IF
- **5.6 (2021)** CiteScore (Scopus)
- **Q1 (2021)** CiteScore Best Quartile
- **1.270 (2021)** SNIP
- **0.480 (2021)** SJR

Journal of Natural Fibers

COUNTRY United States Universities and research institutions in United States Media Ranking in United States	SUBJECT AREA AND CATEGORY Materials Science Materials Science (miscellaneous)	PUBLISHER Taylor and Francis Ltd.	H-INDEX 37
PUBLICATION TYPE Journals	ISSN 1544046X, 15440478	COVERAGE 2004-2021	INFORMATION Homepage

Submit paper for publication
How to Publish Paper, free cost publication, ugc care journal policy follow IJNRD Research Journal
Open

Journal of Natural Fibers

2004 2007 2010 2013 2016 2019

% International Collaboration

2004 2007 2010 2013 2016 2019

Citable documents Non-citable documents

2004 2007 2010 2013 2016 2019

Cited documents Uncited documents

2004 2007 2010 2013 2016 2019

Journal of Natural Fibers
Q2
Materials Science (miscellaneous)
best quartile
SJIR 2021
0.48
powered by scimagojr.com

Show this widget in your own website
Just copy the code below and paste within your html code:
<https://www.scimagojr.com>

SCImago Graphica
Explore, visually communicate and make sense of data with our new data visualization tool.

Submit paper for publication
How to Publish Paper, free cost publication, ugc care journal policy follow IJNRD Research Journal
Open

Hasil penelitian - edisyafri11@ x Scopus preview - Scopus - Jour x Journal of Natural Fibers x WhatsApp Web x Journal of Natural Fibers journal x +

scopus.com/sourceid/130154

Gmail Maps YouTube Gmail Edi Syafri - YouTube News

Scopus Preview Author Search Sources Create account Sign in

Source details

Feedback Compare sources

Journal of Natural Fibers
 Scopus coverage years: from 2004 to Present
 Publisher: Taylor & Francis
 ISSN: 1544-0478 E-ISSN: 1544-046X
 Subject area: Materials Science: Materials Science (miscellaneous)
 Source type: Journal

View all documents Set document alert Save to source list

CiteScore 2021 5.6
 SJR 2021 0.480
 SNIP 2021 1.270

CiteScore CiteScore rank & trend Scopus content coverage

Improved CiteScore methodology
 CiteScore 2021 counts the citations received in 2018-2021 to articles, reviews, conference papers, book chapters and data papers published in 2018-2021, and divides this by the number of publications published in 2018-2021. Learn more

Type here to search 23°C Sebagian cerah 11:37 06/04/2023

List of Contents

Volume 17, 2020 – issue 1

About this journal Browse all articles & issues Latest issue

< **Volume 17, 2020** Vol 16, 2019 Vol 15, 2018 Vol 14, 2017 >

< sue Issue Issue Issue Issue >
 5 4 3 2 1

Download citations Download PDFs Download issue Browse by section (All)

Articles

Article
Ultrasonic assisted improved dyeing of cellulosic fabric using Vat Blue 4 >
 Shahid Adeel, Muhammad Saeed, Aqsa Abdullah, Samreen Gull Khan, Noman Habib, Muhammad Kamran & Mohammad Zuber
 Pages: 1-8
 Published online: 10 Apr 2018

Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading >

Edi Syafri, Anwar Kasim, Alfi Asben, P. Senthamaraiannan & M.R. Sanjay

Pages: 122-131

Published online: 07 May 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1938 KB\)](#) | [EPUB](#) |

Articles



Article

Investigation on the application of *Musa acuminata* leaf methanol extract on cellulose fabric >

B Mothilal, C. Prakash, V Ramesh Babu, C. Ganapathy & S. Sivamani

Pages: 122-131

hed



Article

Socio-ecological perspectives of Himalayan Giant Nettle (*Girardinia diversifolia* (Link) Friis) in Nepal >

Bijay Raj Subedee, Ram Prasad Chaudhary, Yadav Uprety & Tashi Dorji

Pages: 9-17

Published online: 03 Apr 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1193 KB\)](#) | [EPUB](#) |



Article

Development and investigations of kapok fiber based needle punched nonwoven as eco-friendly oil sorbent >

Govindarajan Thilagavathi, Chinnathambi Praba Karan & Ramamoorthi Thenmozhi

Pages: 18-27

Published online: 06 Apr 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1142 KB\)](#) | [EPUB](#) |



Article

Correlation between the mechanical behavior and chemical, physical and thermal characteristics of wool: a study on Tunisian wool >

Takwa Bouagga, Taoufik Harizi, Faouzi Sakli & Marina Zoccola

Pages: 28-40

Published online: 18 Apr 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1593 KB\)](#) | [EPUB](#) |



Article

Sonochemical fabrication of nanocryatalline titanium dioxide (TiO₂) in cotton fiber for durable ultraviolet resistance >

Mohammad Neaz Morshed, Xiaolin Shen, Hridam Deb, Shamim Al Azad, Xingya Zhang & Ruixue Li

Pages: 41-54

Published online: 12 Jun 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(2075 KB\)](#) | [EPUB](#) |

) Article

Microwave-assisted improvement in dyeing behavior of chemical and bio-mordanted silk fabric using safflower (*Carthamus tinctorius* L) extract >

Shahid Adeel, Khadija Naseer, Sadia javed, Saqib Mahmmod, Ren-Cheng Tang, Nimra Amin & Saba Naz

Pages: 55-65

Published online: 25 Apr 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1206 KB\)](#) | [EPUB](#) |

) Article

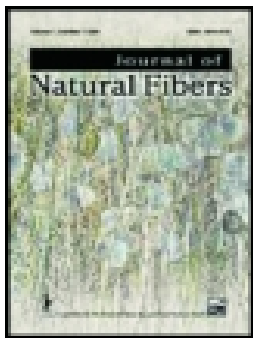
Development and characterization study of silk filament reinforced chitosan biocomposite >

Ravindra D. Kale, Vikrant G. Gorade & Omkar Parmaj

Pages: 66-74

Published online: 25 Apr 2018

[Abstract](#) | [Full Text](#) | [References](#) | [PDF \(1621 KB\)](#) | [EPUB](#) |



Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading

Edi Syafri, Anwar Kasim, Alfi Asben, P. Senthamaraikannan & M.R. Sanjay

To cite this article: Edi Syafri, Anwar Kasim, Alfi Asben, P. Senthamaraikannan & M.R. Sanjay (2018): Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading, Journal of Natural Fibers, DOI: [10.1080/15440478.2018.1470057](https://doi.org/10.1080/15440478.2018.1470057)

To link to this article: <https://doi.org/10.1080/15440478.2018.1470057>



Published online: 07 May 2018.



Submit your article to this journal [↗](#)



Article views: 7






View related articles [↗](#)



View Crossmark data [↗](#)



Studies on Ramie cellulose microfibrils reinforced cassava starch composite: influence of microfibrils loading

Edi Syafri ^a, Anwar Kasim^b, Alfi Asben^c, P. Senthamarai Kannan ^d, and M.R. Sanjay ^e

^aDepartment of Agricultural Technology, Agricultural Polytechnic, Payakumbuh, West Sumatra, Indonesia;

^bDepartment of Agricultural Product Technology, Andalas University Kampus Limau Manis, West Sumatra, Indonesia;

^cDepartment of Mechanical Engineering, Andalas University Kampus Limau Manis, West Sumatra, Indonesia;

^dDepartment of Mechanical Engineering, Kamaraj College of Engineering and Technology, Virudhunagar, India;

^eDepartment of Mechanical Engineering, Ramaiah Institute of Technology, Bengaluru, India

ABSTRACT

Composites were fabricated from Ramie cellulose microfibrils (RCMF) with cassava starch as matrix and glycerol as a plasticizer. Different composites were fabricated with microfibrils loadings of 0, 2, 4, 8, and 10 wt%. The Particle Size Analyzer results show the average size of RCMF as 1.573 μm . The addition of RCMF considerably influenced the physical, crystalline, thermal, and tensile properties of composites. The addition of RCMF enhanced the crystallinity index (CI) from 32% to 36.67%. Thermogravimetric analysis and tensile test results showed improvement in thermal stability and tensile strength of composite up to 6 wt% microfibrils addition.

KEYWORDS

Cassava starch; Ramie cellulose microfibrils; thermal stability; tensile strength

关键词

木薯淀粉; 纤维素微纤维; 热稳定性; 抗拉强度


摘要

以Ramie纤维素微纤维 (RCMF) 为原料, 以木薯淀粉为基质, 甘油为增塑剂, 制备了复合材料。用微纤维负重量分别为0、2、4、8和10WT%制备不同的复合材料。粒度分析结果表明, Ramie纤维素微纤维的平均粒径为1.573 μm 。苧麻纤维素微纤维的加入显著影响了复合材料的物理、结晶、热、拉伸性能。苧麻纤维素微纤维的加入使结晶度指数 (CI) 从32%提高到36.67%。热重分析和拉伸试验结果表明, 复合材料的热稳定性和拉伸强度提高到6重量%的微纤维。

Introduction

The inventions of biodegradable materials are necessary for overcoming today's environmental pollution. Thus, many of the researchers are focusing on natural-fiber-reinforced polymer composites instead of synthetic-fiber-reinforced composites (Senthamarai Kannan et al. 2015; Rajesh Jesudoss Hyness et al. 2018). Moving toward natural fibers, most of the researchers are still using matrix material as synthetic resins. So, the resultant composites are partially biodegradable material. To make completely bio degradable material, we have to move toward the biodegradable matrix. Cassava (*Manihotesculenta*) starch is one of the commercially available biodegradable matrices throughout the world (Tongdeesontorn et al. 2011). However, the cassava starch is brittle in nature which results in poor mechanical properties; to overcome this difficulty, plasticizers are added to the starch which may decrease the brittleness of the material and enhance the process ability. On the other hand, it may reduce the degradation temperature of starch (Chang et al. 2006). In addition to these, starch has higher water absorption nature. Reinforcement of natural fiber is one of the efficient

CONTACT P. Senthamarai Kannan  senthamarai kannan1991@gmail.com; senthamaraimech@kamarajengg.edu.in

 Department of Mechanical Engineering, Kamaraj College of Engineering and Technology, Virudhunagar 626001, Tamilnadu, India.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/wjnf.

© 2018 Taylor & Francis Group, LLC

methods to improve the performance of the starch-based composite. The hydrophilic character of natural fiber may disturb the bonding between fiber and matrix which may be considerably reduced by surface modification of fibers (Saravanakumar et al. 2014). The fiber size also plays an important role in the composite properties (Kathiresan. and Sivaraj 2015; Sanjay et al. 2018). In this study, we have characterized the Ramie cellulose microfibrils (CMF)-reinforced cassava starch composites through TGA, FTIR, XRD, SEM, tensile testing and water absorption test for checking the effect of microfibrils loading on the physical, chemical, thermal, and tensile properties.

Materials and methods

Materials

Cassava starch (Cap Tani, Indonesia), Glycerol (PT Cisadane Raya Chemicals, Tangerang Indonesia), and CMF were used to manufacture the composite. NaOH, KOH, NaClO₂ were utilized for the preparation of CMF.

Preparation of Ramie cellulose microfibrils

Various processes involved in preparation of CMF are illustrated in Figures 1 and 2 which presents different forms of Ramie.

Composite preparation

The procedure followed by the Tongdeesoontorn et al. was adopted with some modification for preparation of thermoplastic starch (TPS) composites (Figure 3) (Tongdeesoontorn et al. 2011). Cassava starch of 10 g and glycerol of 2.5 g (plasticizer) were dissolved in 140 ml of water and then 0, 0.2, 0.4, 0.6, 0.8, 1 g of Ramie CMF were mixed with this solution for making different composite varieties as noted in Table 1. The (Cassava starch/glycerol/CMF) solutions were heated up to 100°C with continuous stirring (350 rpm) to gelatinization and then poured into a glass mould (20 × 20 × 0.5 cm³). The mould setup is placed in ultrasonic bath for removing voids from composite and then is positioned in an oven at 40°C for 5 h.

Particle size analyzer

The particle sizes of CMF were finalized by Particle Size Analyzer (DelsaNano C) with the capacity to measure 0.6 nm to 30 mm. The samples were mixed with demineralized water and then laser light was passed through this solution and the scattering angle was measured to find the particle size. Experiments were done at 25°C and Delsa Nano software was used for data processing.

Thermogravimetric analysis (TGA)

The thermal stability of composites was measured by the TGA 4000 (Perkin Elmer) instrument. The samples were heated from room temperature to 400°C with the heating rate of 10°C/min. Nitrogen gas was passed with the mass flow rate of 40 ml/min during the experimentation (Prithiviraj et al. 2016).

Fourier transformed infrared spectroscopy (FTIR)

The FTIR (Perkin Elmer) spectrums of composites were documented to find the structural difference between composites. The spectrums were recorded from 4000 to 600 cm⁻¹ wave number range at room temperature with the resolution of 4 cm⁻¹ (Kathiresan et al. 2016).

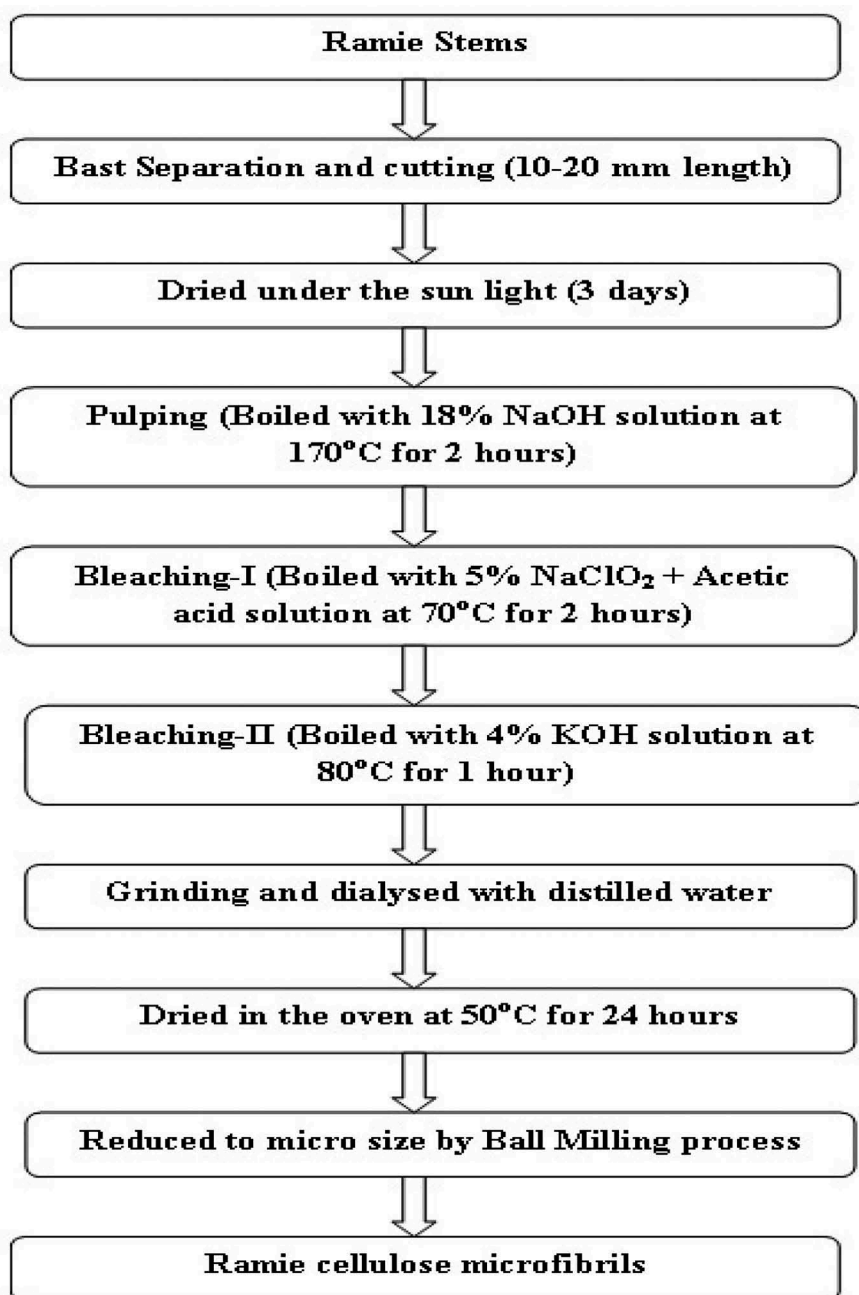


Figure 1. Preparation of Ramie cellulose microfibrils.

X-ray diffraction (XRD) analysis

Crystallinity index (CI) is the important parameter which influences the tensile properties of the composites. In order to investigate the effect of microfibrils loading on the CI of the composites, the X-ray diffractograms of composite were recorded by PANalytical's X-ray diffractometer in the 2θ range of 10.0181° to 99.9781° . The experimentation conditions were: Generator Settings (30 mA, 40 kV), continuous scanning with the step size of $2\theta = 0.001^\circ$, and measurement temperature (25°C).



Figure 2. (a) Chopped Ramie fibers, (b) pulped Ramie powder, (c) bleached Ramie powder.

The CI was assessed through the following equation (Manimaran et al. 2018):

$$I_c = \left(1 - \frac{I_{am}}{I_{002}} \right) \times 100 \% \quad (1)$$

where I_{002} is the intensity of crystalline peak, and I_{am} is the intensity of amorphous peak in the XRD spectrum.

Tensile testing

The tensile strength, young's modulus, and strain (%) of composite were measured by a Com-Ten of 95T Series tensile testing machine. The tests were conducted as per the guidelines of ASTM D 638-1 (Tongdeesoontorn et al. 2011). All the trials were carried out at crosshead speed of 2 mm/min in the ambient temperature.

Results and discussion

Particle size analyzer

The combined pulping, bleaching, and grinding processes converted Ramie cellulose fiber into CMF with an average size of 1.573 μm which is used as reinforcement in composites. Figure 4(a) shows the size distribution of microfibrils.

Thermogravimetric analysis (TGA)

The TGA curves of the composites were presented (Figure 4(b)) to understand the effect of CMF on the thermal stability of composites. From Table 2 it was established that the initial degradation temperature (IDT), final degradation temperature (FDT), and inflection point of composites increased up to 6 wt% on microfibrils addition and after that, it decreased. The first phase happened between 90 and 115°C, which is related to the loss of moisture and related impurities in the composites (Sadanand et al. 2017). The second phase of mass loss occurred between 280°C and 345°C which may be due to the decomposition of cellulose, hemicellulose, and lignin in the composite (Alireza Ashori & Reza Bahrami 2014) The final, tailing phase from 345°C to 500°C indicated the degradation of the charred residue.

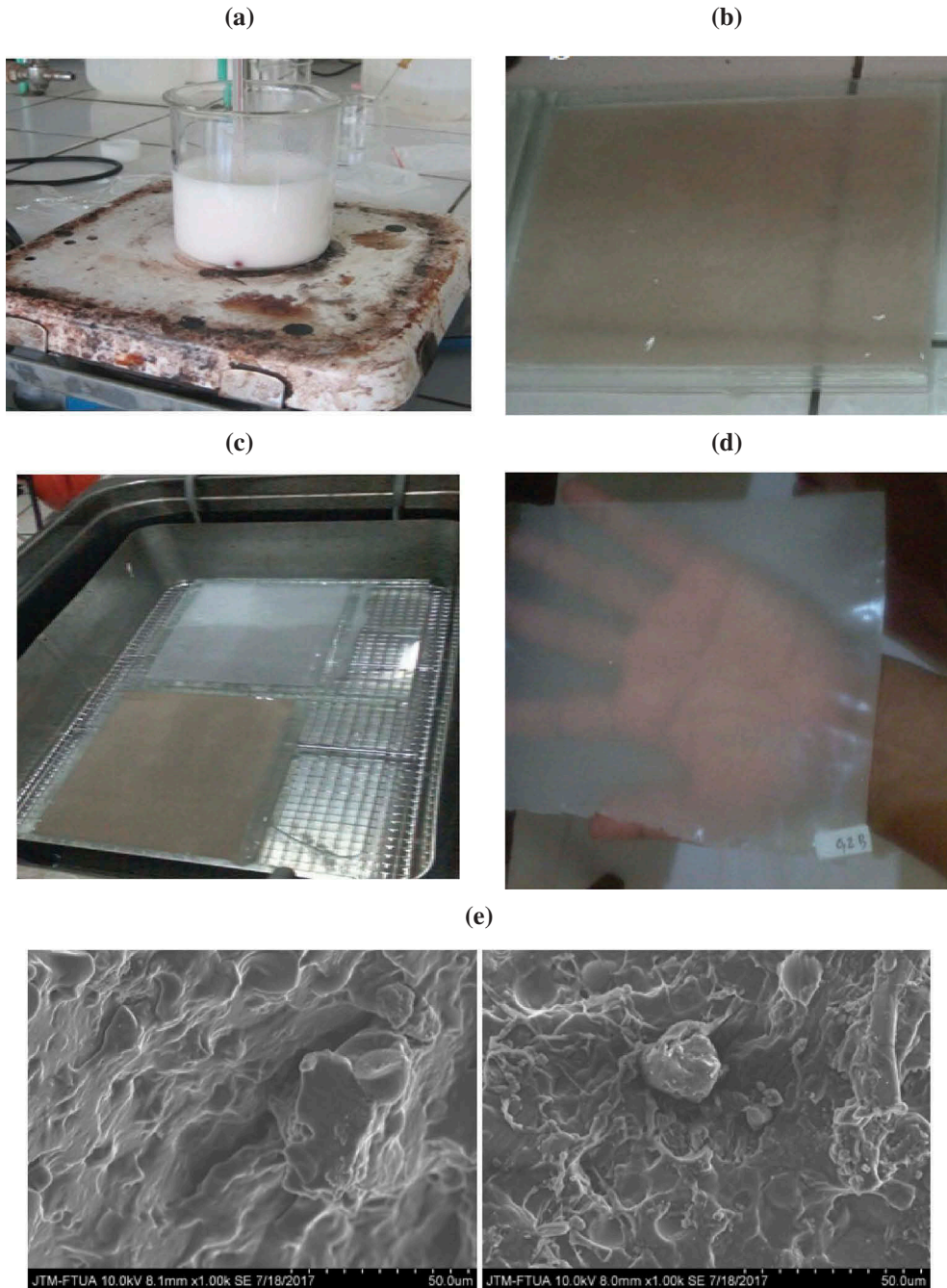


Figure 3. (a) Cassava starch/glycerol/CMF solution (before gelatinization), (b) poured into the mould, (c) mould placed in the ultrasonic bath, (d) composite (after removed from mould), and (e) SEM images of Ramie cellulose microfibrils-reinforced cassava starch composites.

Fourier transformed infrared spectroscopy (FT-IR)

The chemical functional groups existing in the CMF-reinforced cassava starch composites were investigated by FT-IR (Figure 5(a)). FT-IR spectra of all the specimens have similar bands which show that cassava starch is not chemically affected or modified by the glycerol or the fiber loading

Table 1. Composition of Ramie cellulose microfibrils-reinforced cassava starch composites.

Composite	Composition (g/140 ml distilled water)		
	Cassava starch (g)	Glycerol (g)	Ramie CMF (g)
TPS + 0% CMF	10	2.5	0
TPS + 2% CMF	10	2.5	0.2
TPS + 4% CMF	10	2.5	0.4
TPS + 6% CMF	10	2.5	0.6
TPS + 8% CMF	10	2.5	0.8
TPS + 10% CMF	10	2.5	1

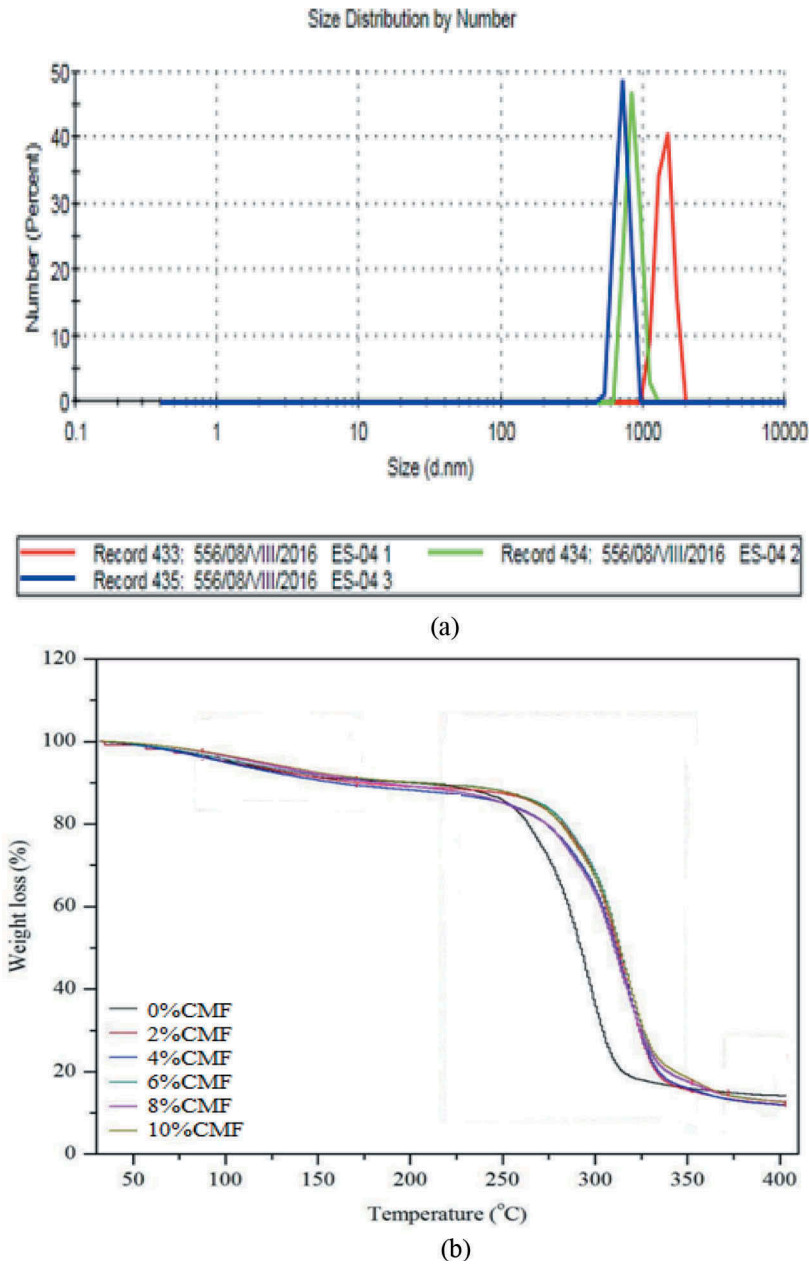
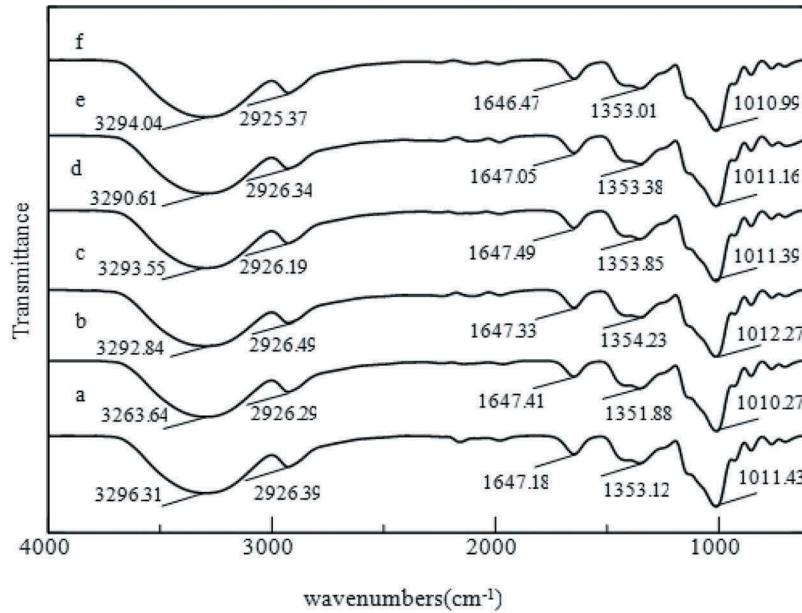


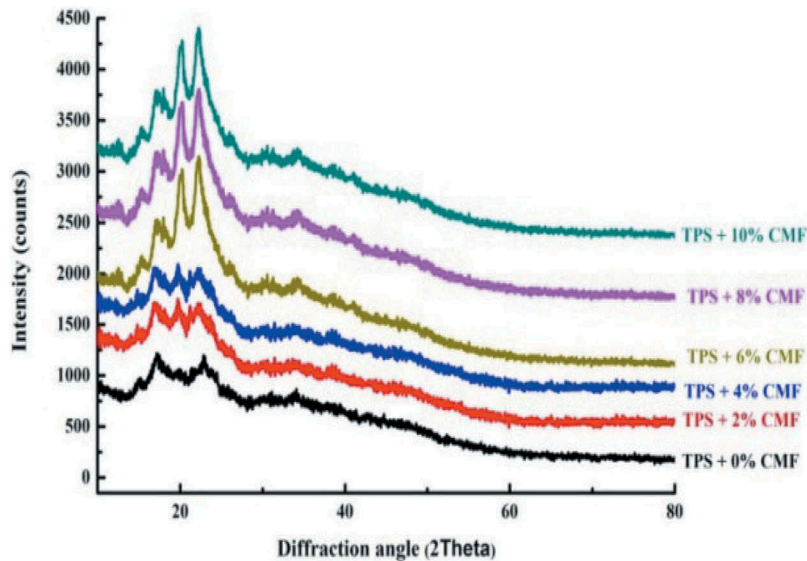
Figure 4. (a) Distribution of size CMF Ramiemicrofibrils, (b) TGA of RCMF reinforced cassava starch composites.

Table 2. Thermal degradation parameters of RCMF-reinforced cassava starch composites.

Composite	IDT (°C)	FDT (°C)	Inflection point (°C)	Char content (%)	Moisture content (%)
TPS + 0% CMF	281.46	336.61	310.62	11.56	9.42
TPS + 2% CMF	285.29	338.71	316.67	12.15	10.71
TPS + 4% CMF	286.87	340.14	316.92	11.99	11.27
TPS + 6% CMF	291.41	342.42	318.98	12.63	9.72
TPS + 8% CMF	288.78	338.77	316.42	12.56	10.31
TPS + 10% CMF	271.71	339.78	313.82	12.67	10.73



(a)



(b)

Figure 5. (a) FTIR analysis of Ramie cellulose microfibrils reinforced cassava starch, (b) XRD analysis of Ramie cellulose microfibrils reinforced cassava starch.

during the composite manufacturing (Edi Syafri et al. 2017). From Figure 5(a) it can be detected that five distinct bands were existing in all the samples nearby 3296, 2926, 1647, 1353, and 1011 cm^{-1} (Senthamaraikannan et al. 2015). The band around 3296 cm^{-1} specify the occurrence of O–H groups in cassava starch and microfibrils which illustrate that composites are reactive to water molecules because of the existence of hydroxyl groups (Kishanji et al. 2017). The band raised nearby 2926 cm^{-1} belongs to the C–H stretching vibrations. The band around 1647 cm^{-1} validates the occurrence of water in the composites. The bands formed between 1353 cm^{-1} and 1647 cm^{-1} are an indication of the occurrence of strong and broad –C–O stretching, which is the alcohol groups of cellulose (Syafri et al. 2017). The bands around 1353 cm^{-1} and 1010 cm^{-1} are corresponding to the C–OH bending vibrations. Table 3 presents the band positions and assignments of chemical groups in the CMF-reinforced cassava starch composites.

X-ray diffraction (XRD) analysis

X-ray diffraction (XRD) analyses were executed to find out the influence of microfibrils content on the CI of the composites. The XRD spectrums of the CMF-reinforced cassava starch composites are shown in Figure 5(b). Two important peaks were detected at $2\theta = 16.6^\circ$ (amorphous phase) and $2\theta = 22.3^\circ$ (crystalline phase) indicating the presence of cellulose type-I which signifies its semi crystalline nature. The minor peak at $2\theta = 16.6^\circ$ is attributed to (2 0 0) crystallographic plane contributing toward amorphous fraction and the major peak at $2\theta = 22.3^\circ$ is ascribed to (0 0 2) crystallographic plane showing the occurrence of both amorphous and crystalline fractions. From Table 4 it was recognized that the composite with a higher microfibrils content have a higher CI. CMF are orientated materials than cassava starch, which influenced the crystallinity of the composites (Edi Syafri et al. 2017).

Tensile testing

The tensile behavior of CMF-reinforced cassava starch composites are shown in Table 5. It is detected that the tensile strength and young's modulus of composites enhanced with addition of microfibrils content up to 6 wt%; after that, it decreased which may be due to the lack of interfacial bonding between the microfibrils and cassava starch above 6 wt% microfibrils addition (Tongdeesoontorn et al. 2011). If the microfibrils content is more than 6 wt%, the cassava starch matrix will not be sufficient to dissolve the microfibrils and so tensile strength and young's modulus of composites were reduced. However, strain rate of composites decreased with addition of microfibrils content. The 6 wt% microfibrils added composite delivered favorable properties than other composites which directs enhanced stress transfer between the microfibrils to the matrix and interfacial bonding in this composite (Sanjay et al. 2018)

Table 3. Peak positions and assignments of chemical groups in the Ramie cellulose microfibrils-reinforced cassava starch composites.

Peak positions (Wavenumber (cm^{-1}))							Allocations
Ideal FTIR peak position	TPS + 0% CMF (a)	TPS + 2% CMF (b)	TPS + 4% CMF (c)	TPS + 6% CMF (d)	TPS + 8% CMF (e)	TPS + 10% CMF (f)	
3600–3100	3296.31	3263.64	3292.84	3293.55	3290.61	3294.04	O–H stretching vibration of cellulose molecules
2960–2850	2926.35	2926.29	2926.49	2926.19	2926.34	2925.37	
1740–1600	1647.18	1647.41	1647.33	1647.49	1647.05	1646.47	Presence of water
1320	1353.12	1353.88	1353.23	1353.85	1353.38	1353.01	C–OH bending vibrations
1050–1020	1011.43	1010.27	1012.27	1011.39	1011.16	1010.99	C–OH stretching

Table 4. The crystallinity index of RCMF-reinforced cassava starch composites.

Composite	Crystallinity index (%)
TPS + 0% CMF	23.91
TPS + 2% CMF	26.24
TPS + 4% CMF	28.46
TPS + 6% CMF	34.56
TPS + 8% CMF	35.72
TPS + 10% CMF	36.67

Table 5. Mechanical properties of the Ramie cellulose microfibrils-reinforced cassava starch composites.

CMF Ramie contents	Tensile strength (MPa)	Tensile modulus (MPa)
TPS + 2% CMF	5.65	188.45
TPS + 4% CMF	6.37	235.31
TPS + 6% CMF	7.41	261.22
TPS + 8% CMF	5.25	234.82
TPS + 10% CMF	4.88	181.81

Conclusion

CMF-reinforced composites were produced with the main aim to create completely biodegradable composites with better performance. The addition of CMF considerably improved the performances such as thermal stability, tensile strength, and CI of the composites. However, no noteworthy chemical functional group modification was found on the FTIR spectrums. The tensile strength of the composites was improved from 1.65 ± 0.21 MPa to 7.41 ± 1.63 MPa (6 wt%) and tensile stability was enhanced from 281.46°C to 291.41°C (6 wt%).

ORCID

Edi Syafri  <http://orcid.org/0000-0002-5784-6694>

P. Senthamaraiannan  <http://orcid.org/0000-0002-5136-2269>

M.R. Sanjay  <http://orcid.org/0000-0001-8745-9532>

References

- Ashori, A., and R. Bahrami. 2014. Modification of physico-mechanical properties of chitosan-tapioca starch blend films using nano graphene. *Polymer-Plastics Technology and Engineering* 53:312–18. doi:10.1080/03602559.2013.866246.
- Chang, Y. P., A. Abd Karim, and C. Seow. 2006. Interactive plasticizing antiplasticizing effects of water and glycerol on the tensile properties of tapioca starch films. *Food Hydrocolloids* 20 (1):1–8. doi:10.1016/j.foodhyd.2005.02.004.
- Kathiresan, M., P. Pandiarajan, P. Senthamaraiannan, and S. S. Saravanakumar. 2016. Physicochemical properties of new cellulosic *Artisditahystrix* leaf fiber. *International Journal of Polymer Analysis and Characterization* 21 (8):663–68. doi:10.1080/1023666X.2016.1194636.
- Kathiresan., M., and P. Sivaraj. 2015. Preparation and characterization of biodegradable sugarcane bagasse nano reinforcement for polymer composites using ball milling operation. *International Journal of Polymer Analysis and Characterization* 21 (5):428–35. doi:10.1080/1023666X.2016.1168061.
- Kishanji, M., G. Mamatha, K. Obi Reddy, A. VaradaRajuluand, and K. Madhukar. 2017. In situ generation of silver nanoparticles in cellulose matrix using *Azadirachta indica* leaf extract as a reducing agent. *International Journal of Polymer Analysis and Characterization* 22 (8):734–40. doi:10.1080/1023666X.2017.1369612.
- Manimaran, P., P. Senthamaraiannan, K. Muruganathan, and M. R. Sanjay. 2018. Physicochemical properties of new cellulosic fibers from *Azadirachta indica* plant. *Journal of Natural Fibers* 15 (1):29–38. doi:10.1080/15440478.2017.1302388.

- Prithviraj, M., R. Muralikannan, P. Senthamarikannan, and S. S. Saravanakumar. 2016. Characterization of new natural cellulosic fiber from *PerotisIndica* plant. *International Journal of Polymer Analysis and Characterization* 21 (6):669–74. doi:10.1080/1023666X.2016.1202466.
- Rajesh JesudossHyness, N., N. J. Vignesh, P. Senthamarikannan, S.S.Saravanakumar, and M. R. Sanjay. 2018. Characterization of new natural cellulosic fiber from *Heteropogoncontortus* plant. *Journal of Natural Fibers* 15 (1):146–53. doi:10.1080/15440478.2017.1321516.
- Sadanand, V., F. A. Tia Hua, V. Rajulu, and B. Satyanarayana. 2017. Preparation and properties of low cost cotton nanocomposite fabrics with in situ generated copper nanoparticles by simple hydrothermal method. *International Journal of Polymer Analysis and Characterization* 22 (7):587–94. doi:10.1080/1023666X.2017.1344916.
- Sanjay, M. R., P. Madhu, M. Jawaidd, P. Senthamarikannan, S. Senthil, and S. Pradeep. 2018. Characterization and properties of natural fiber polymer composites: a comprehensive review. *Journal of Cleaner Production* 172:566–81. doi:10.1016/j.jclepro.2017.10.101.
- Saravanakumar, S. S., A. Kumaravel, T. Nagarajan, and I. Ganesh Moorthy. 2014. Investigation of physico-chemical properties of alkali-treated prosopis juliflora fibers. *International Journal of Polymer Analysis and Characterization* 19:309–17. doi:10.1080/1023666X.2014.902527.
- Senthamarikannan, P., S. S. Saravanakumar, V. P. Arthanarieswaran, and P. Sugumaran. 2015. Physicochemical properties of new cellulosic fibers from bark of *acacia planifrons*. *International Journal of Polymer Analysis and Characterization* 21 (3):207–13. doi:10.1080/1023666X.2016.1133138.
- Syafri, E., A. Kasim, H. Abrial, and A. Asben. 2017. Effect of precipitated calcium carbonate on physical, mechanical and thermal properties of cassava starch bioplastic composites. *International Journal on Advanced Science, Engineering and Information Technology* 7 (5):1950–54. doi:10.18517/ijaseit.7.5.1292.
- Tongdeesoontorn, W., L. J. Mauer, S. Wongruong, P. Sriburi, and P. Rachtanapun. 2011. Mechanical and physical properties of cassava starch-gelatin composite films. *International Journal of Polymeric Materials and Polymeric Biomaterials* 61:778–92. doi:10.1080/00914037.2011.610049.