



# BOOK OF PROGRAMS

## ICoRER 2019 in conjunction with The 12th RCEnE

International Conference on  
Renewable Energy Research & Challenge 2019 &  
The 12th Regional Conference on Energy Engineering 2019

“EMPOWERING AND DRIVING  
THE SUSTAINABLE FUTURE.”

12th-14th NOVEMBER 2019.  
BANYUWANGI, INDONESIA





## The Effect of Activated Carbon Addition on Woody Cutting Waste Briquette Combustion Quality

Qurrotin A. M. O. Arifianti\*<sup>1</sup>, Ufafa Anggarini<sup>2</sup>, Akbar Nafis<sup>3</sup>, Elita F. Nugrahani<sup>4</sup> and Kuntum K. Ummatin<sup>5</sup>

<sup>1,2,3,4,5</sup>Engineering Management, Universitas Internasional Semen Indonesia, INDONESIA  
(E-mail: qurrotin.arifianti@uisi.ac.id, ufafa.anggarini@uisi.ac.id, elita.nugrahani@uisi.ac.id, kuntum.ummatin@uisi.ac.id)

### INTRODUCTION

Activated carbon is a type of carbon activated at a certain temperature to produce a high inner surface area and have complex pores. With these characteristics, activated carbon is very suitable for applications that require large contact areas, such as adsorption processes, reactions, catalysts and so on. Some literature shows that activated carbon is mostly applied as an adsorbent. P. Oleszczuk et al. (2012) used a mixture of activated carbon and amendment charcoal to dissolve Polycyclic Aromatic Hydrocarbons (PAHs) in sewage sludge. The results show that activated carbon and charcoal were able to effectively reduce the concentration of PAHs in water. D. Wind (2014) created activated carbon from sour cherry plants (*Prunus cerasus* L.) to remove basic textile dyes.

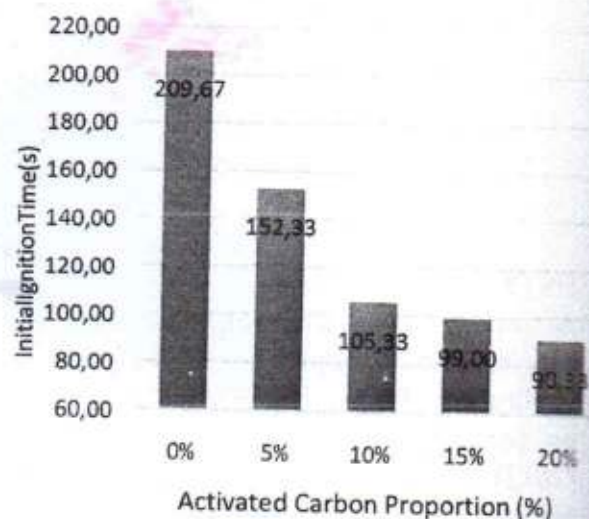
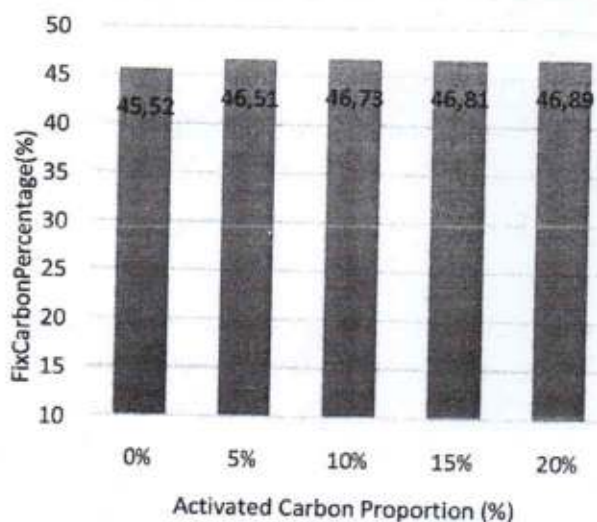
In addition to the adsorption properties, activated carbon has a greater heating value compared to carbon charcoal. M. Carrier et al. (2012) compares the characteristics of activated carbon and carbon charcoal made from sugarcane bagasse. The results of the comparison showed that activated carbon had a higher fixed carbon content than sugarcane bagasse char, which was 69%. While sugar cane charcoal had a fixed carbon content of only 36.2%. The higher the carbon content, the greater the calorific value. W. S. Chen et al. (2011) utilized activated carbon waste captured by air pollution regulators. The activated carbon was then washed using deionized water and mixed into organic sludge fuel. The results showed that there was a significant increase in heat value and carbon content in the fuel when residual activated carbon was added. The highest heating value that could be achieved is 4515 kcal / kg. In addition, other studies showed that the calorific value of unburned carbon in activated carbon waste was more than 4000 kcal / kg, thus activated carbon had the potential to be used as an alternative fuel (Chen, W.S., Chang, F.C., Shen, Y.H., Tsai, M.S., 2011), (Tsai, W.T., Chang, J.H., Hsien, K.J., Chang, Y.M, 2009).

The aim of this present study was to increase the calorific value of woody cutting waste briquette by adding activated carbon. The previous experiments showed that the highest calorific value reaches only 3630 Cal/gr. In this research, activated carbon was made of palmyra palm fiber using H<sub>3</sub>PO<sub>4</sub> as an activator solvent. U. Anggarini and A. Rahmat (2018) observed that H<sub>3</sub>PO<sub>4</sub> solvent was able to



produce higher area than NaOH and KOH solvent. The surface area of activated carbon produced by  $H_3PO_4$  solvent is 373,5675  $m^2/gr$ . Meanwhile, NaOH and KOH solvent resulted area of 33,87878  $m^2/gr$  and 218,8230  $m^2/gr$ , respectively. There are four different proportion of activated carbon used in the experiment, for example, 5%, 10%, 15%, and 20% with 10% tapioca flour binder. The woody cutting waste were carbonized and sieved into 50-100 mesh. The briquette performance were tested using proximate analysis, bomb calorimeter, and combustion analysis.

## RESULTS AND DISCUSSION



(a)

(b)

**Figure 1** (a) Fix Carbon (b) Initial Ignition Time

Figure 1(a) shows that the higher activated carbon proportion, the fix carbon would be greater. It was mainly due to activated carbon created through the combustion process many times, thus more organic material contained in activated carbon evaporated and increased fix carbon of briquette. According to Figure 1(b), variation of 20% activated carbon had the fastest initial ignition time. Meanwhile, variation of 5% activated carbon needed a longer time to ignite. It occurred since a large amount of activated carbon provides a high surface area, thus briquette was more reactive. Moreover, based on the result, there was an obvious difference in calorific value between before and after adding activated carbon. It increased from 3630 Cal/gr to 4500 Cal/gr. Meanwhile, there was no significant calorific value difference for each variation (5%, 10%, 15%, and 20%) since the value ranged from 4528 to 4592 Cal/ gr. Both result proved that the addition of activated carbon could increase briquette calorific value.

**Keywords:** Activated Carbon, Briquette, Calorific Value, Palmyra Palm Fiber, Reactive, Woody Waste





# ICoRER 2019 in conjunction with The 12th RCEnEE 2019

**CALL FOR PAPER**

International Conference on Renewable Energy Research & Challenge 2019 & The 12th Regional Conference on Energy Engineering 2019  
Banyuwangi, East Java, Indonesia

## Theme

### "EMPOWERING AND DRIVING THE SUSTAINABLE FUTURE"

#### Renewable Energy Resources

- Exploration of Renewable Energy Resource
- Spatial Renewable Energy Mapping and Planning

#### Renewable Energy Technology

- Renewable Energy Conversion and Technology
- Renewable Energy Integration, Smart Grid and Energy Network
- Energy Storage

#### Sustainable Energy System

- Life Cycle Assessment (LCA)
- Life Cycle and Impact Assessment (LCIA)
- Business Models and Financing Schemes
- Best Practice Policies
- Energy Efficiency in Industry – Road to Proper
- Energy Efficiency and Technology Community and Environmental Impact of Renewable Energy Implementation

## Energy Symposium

Topic : Indonesia's Readiness to Face Energy Disruption and Transition

- Will be held on 13th November 2019, 06.00 pm - 09.30 pm.
- Symposium Event will held parallel with Gala Dinner.
- Free for Conference Participants and Visitor.
- Facilities : Gala dinner, Seminar kit and Certificate.

## Keynote Speakers

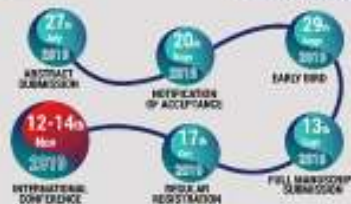
-  **Prof. Tetsuya Kida**  
Nagasaki University, Advanced Functional Material
-  **Ir. FX. Sutijastoto, MA**  
Director's General of New, Renewable Energy and Energy Conservation
-  **Dr. Rudolf Raach**  
Sector Renewable Energy Property, GT
-  **Prof. Shigeru Fujino**  
Global Innovation Center, Kyushu University  
Advanced Project Director
-  **Prof. Otagaki Hideo**  
Institute of Advanced Energy  
Kyoto University
-  **Prof. Tatemoto Jun**  
Department of Energy and Environmental Engineering, Kyushu University

## Speakers of Symposium

-  **Dr. (H.C.) Dahlan Iskan**  
National Figure
-  **Dr. H. Emil Elestianto Dardak, M.Sc.**  
Deputy Governor of East Java
-  **Ir. FX. Sutijastoto, MA**  
Director's General of New, Renewable Energy and Energy Conservation
-  **Abdullah Azwar Anas, S.Pd., S.S., M.Sc.**  
Regent of Banyuwangi

**12-14 NOVEMBER 2019**  
**eL ROYALE HOTEL BANYUWANGI**  
**EAST JAVA, INDONESIA**

## Important Dates



		Registration Fees	
Conference	CATEGORIES	REGULAR	EARLY BIRD
LOCAL	STUDENT	IDR 2.500.000	IDR 2.000.000
	NON STUDENT	IDR 3.500.000	IDR 3.000.000
	INDUSTRY	IDR 4.500.000	IDR 4.000.000
	VISITOR	IDR 1.500.000	
INTERNATIONAL	STUDENT	USD 300	USD 250
	NON STUDENT	USD 400	USD 350
	INDUSTRY	USD 500	USD 450
	VISITOR	USD 150	
<b>Energy Symposium</b>			
PARTICIPANTS (Symposium only)		IDR 300.000	
CONFERENCE PARTICIPANTS AND VISITOR		FREE CHARGE	
<b>Green Exhibition</b>			
LOCAL PARTICIPANTS		IDR 5.500.000	IDR 5.000.000
INTERNATIONAL PARTICIPANTS		USD 675	USD 640

Selected papers will be published in AEJ (Asian Engineering Journal) or E3S Web of Conferences (indexed by Scopus)

**E3S** Web of Conferences

indexed by

**Scopus**



## Preface 1<sup>st</sup> ICoRER 2019

The 1<sup>st</sup> International Conference on Renewable Energy Research and Challenge (ICoRER 2019) in conjunction with Regional Conference on Energy (RCEnE 2019) has been organized by the Department of Engineering Physics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia with the support by JICA Project for AUN/SEED-Net. The conference was held on November 12–13, 2019 in Banyuwangi, Indonesia. The aim is to distribute research outcomes on renewable energy and related area.

ICoRER and RCEnE 2019 presented five international honorable keynote speakers from representative institutions: i) Dr. Rudolf Rauch, Director Renewable Energy Program GIZ; ii) Ir. Miftahul Jannah., M.M, Director of Operation 2 PT. *Pembangkitan Jawa-Bali*, Indonesia; iii) Prof. Shigeru Fujino, Global Innovation Center, Advanced Project Division, Kyushu University; iv) Prof. Ohgaki Hideaki, Institute of Advanced Energy, Kyoto University; and v) Prof. Tanimoto Jun, Department of Energy and Environmental Engineering, Kyushu University. Pursuing the international network of researchers and industrial applications, this event invited overseas colleagues to share their best research works as well as local academia and industrial engineers. Over 100 representatives from various institutions participated in this event, involving more than 140 abstracts submitted. After a rigorous selection process, the Scientific & Editorial Board of ICoRER 2019 decided to publish 40 papers in E3S Web of Conferences, an open-access proceedings in environment, energy and earth sciences, managed by EDP Sciences, Paris, and indexed on Scopus, Scimago, Conference Proceedings Citation Index-Science (CPCI-S) of Clarivate Analytics's Web of Science, DOAJ (Directory of Open Access Journals). Meanwhile, the papers from RCEnE 2019 are published in the Scopus indexed, Asean Engineering Journal.

The Proceedings of the 1<sup>st</sup> ICoRER, 2019 consists of 40 selected articles, amount six articles from Mauritius, Philippines, Thailand, and 27 articles were the results of joint research by Indonesian and overseas scholars. In the collaboration research, 49 institutions were involved 15 of which were from abroad Indonesia. The overseas institutions are from: Australia, Estonia, Germany, India, Latvia, Lithuania, Malaysia, Philippines, P.R. China, Saudi Arabia, Siera Leone, Sweden, Taiwan - ROC, Thailand, and United Kingdom. Each of the papers submitted in E3S Web of Conferences was reviewed by at least two experts using the double-blind system. The

published papers have passed all necessary improvement requirements in accordance to the Web of Conferences standard, reviewer's comments, SI (*Système International d'Unités*), similarity tests by Turnitin program (with the highest threshold of 20 %), 90 % of references must be at least dated from 15 years, and reflected on Google, as well as editing procedure by professional editors from four countries (Indonesia, Latvia, Singapore, and Sweden).

We would like to express our gratitude to the official committee, scientific & editorial boards, organizing partners, and "*Rumah Paper Kita*" as editing and proofreading services. A very special thanks to AUN/SEED-Net for financially supporting this conference as well as assistance on the conference agenda. Finally, we would like to briefly acknowledge all presenters and attendees for their efforts sharing the beautiful ideas and useful research outcomes to inspire further research and collaborations. We hope this time, all papers can be rearranged into the collection of scientific works as a first publication of ICoRER 2019 and everyone will be proud of this result.

Surabaya, Indonesia – in Covid 19 Pandemy  
September 10, 2020



Assoc. Prof. Gunawan Nugroho, PhD

**Conference Chair**

**Principal Editor:** Roy Hendroko Setyobudi (Malang, IDN)

**Board of Editor:** Muhammad Danang Birowosuto (Singapore, SGP), Rangga Kala Mahaswa (Yogyakarta, IDN), Yahya Jani (Kalmar, SWE), and Zane Vincēviča-Gaile (Riga, LVA)

### SCIENTIFIC and EDITORIAL BOARD

- Galih Bangga, Universitat Stuttgart, DEU.
- Haryo Wibowo, Institute of Energy and Power Engineering, Zhejiang University of Technology, CHN.
- Jonathan Plentz, Leibniz-IPHT, DEU.
- Lutfan Sinatra, King Abdullah University of Science and Technology (KAUST), SAU.
- Maizirwan Mel, International Islamic University Malaysia. MYS.
- Muhammad Danang Birowosuto, CNRS International NTU Thales Research Alliance (CINTRA), SGP.
- Novia Risa, Universitas Gadjah Mada and RP ("*Rumah Paper Kita*"- Our House of Papers) Editage & Proofreading Services, IDN.
- Olga Anne, Klaipeda University, LTU.
- Peeyush Soni, Indian Institute of Technology Kharagpur, IND.
- Praptiningsih Gamawati Adinurani, Merdeka University of Madiun and RP Editage Services, IDN.
- Rangga Kala Mahaswa, Universitas Gadjah Mada and RP Editage Services, IDN.
- Roy Hendroko Setyobudi, University of Muhammadiyah Malang and RP Editage Services IDN.
- Ridho Hantoro, Institut Teknologi Sepuluh Nopember, IND.
- Ruri Agung Wahyuono, Institut Teknologi Sepuluh Nopember, IND.
- Tsitsino Turkadze, Akaki Tsereteli State University, GEO.
- Yahya Jani, Linnaeus University, SWD.
- Zahrah Nurfadhilah, Universitas Gadjah Mada and RP Editage Services, IDN.
- Zane Vincēviča-Gaile, University of Latvia, LVA





**VENUE**



**Gunawan Nugroho: Conference Chair**  
**Roy H Setyobudi: Principal Editor**







# 1<sup>st</sup> ICoRER 2019

Theme: "Empowering and Driving the Sustainable Future"

## ORGANIZED By:



**ITS**  
Institut  
Teknologi  
Sepuluh Nopember



**AUN/SEED-Net**



## Supported By:



**print&print**



## Sponsored By:



**XVAUTOMATION**



**skkmigas**

**pgn SAKA**  
power to discover

## Co-Sponsored By:



**ICoRER 2019** in conjunction with  
**The 12th RCEnE 2019**

International Conference on Renewable Energy Research & Challenge 2019 & The 12th Regional Conference on Energy Engineering 2019  
 Banyuwangi, East Java, Indonesia

**12-14 NOVEMBER 2019**  
**eL ROYALE HOTEL BANYUWANGI**  
**EAST JAVA, INDONESIA**



Organized by: 



**Theme:**  
**“Empowering and Driving the Sustainable Future”**

**Opening ceremony by:**  
**Prof. Dr. Ir. Mochamad Ashari M. Eng**  
**Rector of ITS, Surabaya**



**ICoRER 2019 in conjunction the 12<sup>th</sup> RCEnE**  
**PARTICIPANTS**



# Keynote Speakers



Prof. Dr. Jun Tanimoto,  
Kyushu University, Japan



Prof. Dr. Shigeru Fujino,  
Kyushu University, Japan



Prof. Dr. Ohgaki Hideaki,  
Kyoto University, Japan



Dr. Rudolf Rauch  
Director Renewable Energy  
Programme Indonesia/Asean, GIZ



Ir. Miftahul Jannah, M.M,  
Director of Operation 2  
*PT. Pembangunan Jawa-Bali, Indonesia*



Presenters on Energy Symposium  
1<sup>st</sup> ICoRER and 12<sup>th</sup> RCeneE 2019

**Theme Symposium:**  
**“Indonesia’s Readiness to Face  
Energy Disruption and Transition”**



**PARALEL SESSION**



Gandrung Barong Kemiren Jaripah



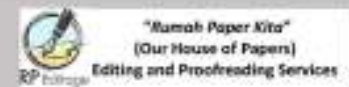
Jejer Gandrung

**Traditional Dance**





The Proceedings of the 1st ICoRER, 2019 consists of 40 selected articles, amount six articles from Mauritius, Philippines, Thailand, and 27 articles were the results of joint research by Indonesian and overseas scholars. In the collaboration research, 47 institutions were involved 15 of which were from abroad Indonesia. The overseas institutions are from: Australia, Estonia, Germany, India, Latvia, Lithuania, Malaysia, Philippines, P.R. China, Saudi Arabia, Siera Leone, Sweden, Taiwan - ROC, Thailand, and United Kingdom



Please email to the Contact Person below.  
 If you need a proceedings cover the 1st ICoRER 2019 above:  
 Roy Hendroko Setyobudi  
 Email: roy\_hendroko@hotmail.com  
 Phone/ WA: +62 815 9555 028



# CERTIFICATE *Of Appreciation*

028/ICoRER/XI/2019

PROUDLY PRESENTED TO

## Qurrotin Ayunina Maulida Okta Arifianti

### as Presenter in

International Conference on Renewable Energy Research & Challenge 2019 & The 12th  
Regional Conference on Energy Engineering 2019  
held by Departemen of Engineering Physics, Faculty of Industry  
Sepuluh Nopember Institute of Technology  
12th-14th November, 2019  
Banyuwangi, East Java, Indonesia

HEAD OF DEPARTMENT OF  
ENGINEERING PHYSICS



Agus Muhamad Hatta, S.T., M.T., Ph.D.

NIP. 197809022003121002

CHAIRMAN OF  
GENERAL CONFERENCE



Gunawan Nugroho, S.T., M.T., Ph.D.

NIP. 197711272002121002



Gresik, 16 Agustus 2022

Nomor : 787/KI.05/03-01/08.22  
Lampiran : -  
Perihal : **Klarifikasi**

Kepada Yth.  
**Kepala LLDIKTI Wilayah VII**  
Di Tempat

Dengan hormat,  
Sehubungan dengan pengajuan Jabatan Akademik Dosen (JAKAD) Universitas Internasional Semen Indonesia pada dosen berikut :

Nama : Ufafa Anggarini, S.Si., M.Si.  
NIDN : 0719038901  
Program Studi : Teknik Kimia  
Jabatan yang diajukan : Lektor 300

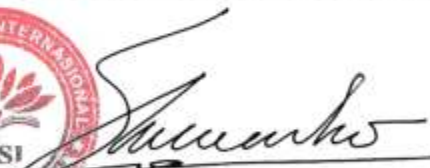
Maka dengan ini kami sampaikan bahwa pengajuan JAKAD dosen tersebut terdapat catatan revisi bahwa sertifikat atas nama dosen tersebut di atas pada karya ilmiah berupa prosiding diminta untuk disertakan. Akan tetapi, dosen tersebut tidak mendapat sertifikat disebabkan bukan sebagai penulis pertama ataupun sebagai presenter pada judul karya ilmiah berikut :

1. Optimization of non-autoclaved aerated concrete using phosphogypsum of industrial waste based on the taguchi method
2. The potential use of volcanic deposits for geopolymer materials
3. The Effect of Activated Carbon Addition on Woody Cutting Waste Briquette Combustion Quality

Sehingga sertifikat tidak dapat dilampirkan pada karya ilmiah tersebut di atas. Oleh karena hal tersebut, mohon agar diproses pengajuan JAKAD dosen tersebut dari Asisten Ahli ke Lektor.

Demikian surat permohonan ini dibuat untuk digunakan sebagaimana mestinya. Atas perhatian dan kerjasama yang diberikan, kami sampaikan terima kasih.

Hormat kami,  
Universitas Internasional Semen Indonesia



Prof. Dr. Ing. Herman Sasongko  
Rektor

## Statement of Peer review

In submitting conference proceedings to *Web of Conferences*, the editors of the proceedings certify to the Publisher that

1. They adhere to its **Policy on Publishing Integrity** in order to safeguard good scientific practice in publishing.
2. All articles have been subjected to peer review administered by the proceedings editors.
3. Reviews have been conducted by expert referees, who have been requested to provide unbiased and constructive comments aimed, whenever possible, at improving the work.
4. Proceedings editors have taken all reasonable steps to ensure the quality of the materials they publish and their decision to accept or reject a paper for publication has been based only on the merits of the work and the relevance to the journal.

Title, date and place of the conference

---

**Title:** 1st International Conference on Renewable Energy Research and Challenge (ICoRER 2019)

**Date:** November 12–13, 2019

**Place:** el Royale Hotel, Banyuwangi, East Java, Indonesia

**Website:** <https://icorer2019.com/>

### Proceedings editor(s):

---

Principal Editor: Roy Hendroko Setyobudi (Malang, IDN)

Board of Editor: Muhammad Danang Birowosuto (Singapore, SGP), Rangga Kala Mahaswa (Yogyakarta, IDN), Yahya Jani (Kalmar, SWE), and Zane Vincēviča-Gailė (Riga, LVA)

---

### Date and editor's signature

Malang, Sept 10, 2020

Roy Hendroko Setyobudi



# The Effect of Activated Carbon Addition on Woody Cutting Waste Briquette Combustion Quality

Qurrotin Ayunina Maulida Okta Arifianti<sup>1,\*</sup>, Ufafa Anggarini<sup>2</sup>, Akbar Nafis<sup>1</sup>, Erny Rosita Sari<sup>1</sup> and Elita Fidiya Nugrahani<sup>1</sup>

<sup>1</sup>Department of Engineering Management, Faculty of Industrial and Agroindustry Technology, Universitas Internasional Semen Indonesia, Kompleks PT. Semen Indonesia (Persero) Tbk, Jl. Veteran, Kb. Dalem, Sidomoro, Kebomas, Gresik 61122, East Java, Indonesia.

<sup>2</sup>Department of Chemical Engineering, Faculty of Industrial and Agroindustry Technology, Universitas Internasional Semen Indonesia, Kompleks PT. Semen Indonesia (Persero) Tbk, Jl. Veteran, Kb. Dalem, Sidomoro, Kebomas, Gresik 61122, East Java, Indonesia.

**Abstract.** This study aims to increase the calorific value of woody cutting waste briquette by adding activated carbon. The previous experiments showed that the highest calorific value of woody cutting waste briquette reached only 3 630 kCal kg<sup>-1</sup>. In this research, activated carbon was made of Palmyra palm fiber using H<sub>3</sub>PO<sub>4</sub> as an activator solvent. There are four different proportion of activated carbon used in the experiment, for example, 5 %, 10 %, 15 %, and 20 % with 10 % tapioca flour binder. The woody cutting waste were carbonized and sieved into 50 mesh to 100 mesh. The briquette performance was tested using proximate analysis, bomb calorimeter, and combustion analysis. The addition of activated carbon in briquette could increase the calorific value from 3 630 kCal kg<sup>-1</sup> to around 4 500 kCal kg<sup>-1</sup>.

**Keywords:** Activated carbon, briquette, calorific value, palmyra palm fiber, reactive, woody waste.

## 1 Introduction

Activated carbon is a type of carbon activated at a certain temperature to produce a high inner surface area and have complex pores. With these characteristics, activated carbon is very suitable for applications that require large contact areas, such as adsorption processes, reactions, catalysts and so on. Some literature shows that activated carbon is mostly applied as an absorber. According to [1] used a mixture of activated carbon and amendment charcoal to dissolve Polycyclic Aromatic Hydrocarbons (PAHs) in sewage sludge. The results showed that activated carbon and carbon were able to effectively reduce the concentration of water in PAH pores. Angin [2] created activated carbon from sour cherry plants (*Prunus cerasus* L.) to remove basic textile dyes.

---

\* Corresponding author: [qurrotin.arifianti@uisi.ac.id](mailto:qurrotin.arifianti@uisi.ac.id)

In addition to the absorption properties, activated carbon has a greater heating value compared to carbon charcoal. Carrier et al., [3] compared the characteristics of activated carbon and carbon charcoal made from sugarcane bagasse. The results of the comparison showed that activated carbon had a higher fixed carbon content than sugarcane bagasse char, which was 69 %. While sugar cane charcoal had a fixed carbon content of only 36.2 %. The higher the carbon content, the greater the calorific value. Chen et al., [4] utilized activated carbon waste captured by air pollution regulators. The activated carbon was then washed using deionized water and mixed into organic sludge fuel. The results showed that there was a significant increase in heat value and carbon content in the fuel when residual activated carbon was added. The highest heating value that could be achieved is 4 515 kCal kg<sup>-1</sup>. In addition, other studies showed that the calorific value of unburned carbon in activated carbon waste was more than 4 000 kCal kg<sup>-1</sup>, thus activated carbon had the potential to be used as an alternative fuel [5].

The aim of this present study was to increase the calorific value of woody cutting waste briquette by adding activated carbon. The previous experiments showed that the highest calorific value reaches only 3 630 kCal kg<sup>-1</sup>. In this research, activated carbon was made of palmyra palm fiber using H<sub>3</sub>PO<sub>4</sub> as an activator solvent. H<sub>3</sub>PO<sub>4</sub> was chosen since it was able to produce higher area than NaOH and KOH solvent based on the earlier experiment. The surface area of activated carbon produced by H<sub>3</sub>PO<sub>4</sub> solvent is 373.567 5 m<sup>2</sup> g<sup>-1</sup>. Meanwhile, NaOH and KOH solvent resulted area of 33.878 78 m<sup>2</sup> g<sup>-1</sup> and 218.823 0 m<sup>2</sup> g<sup>-1</sup>, respectively. There are four different proportion of activated carbon used in the experiment, for example, 5 %, 10 %, 15 %, and 20 % with 10 % tapioca flour binder. The woody cutting waste were carbonized and sieved into 50 mesh to 100 mesh. The briquette performance were tested using proximate analysis, bomb calorimeter, and combustion analysis.

## 2 Methodology

### 2.1 Preparation of raw materials and activated carbon production

As aforementioned, the main purpose of this research is to increase the existing briquette quality by adding activated carbon in some various of percentage. The raw material used to produce activated carbon was Palmyra palm fiber (as can be seen in Figure 1). The fiber was collected and dried naturally under the sun and also in the oven to facilitate the carbonization process. The carbonization process was carried out by burning it in the reactor with a temperature of around 400 °C to 500 °C. The charcoal produced from this process was then sieved to a size of 50 mesh to 100 mesh.



**Fig. 1.** Palmyra palm fiber waste.





**Fig. 2.** Activation process.

The next step, the charcoal was impregnated with 30 % of NaOH in a stirrer for 24 h. NaOH saturated raw materials before it was activated. Subsequently, it was filtered using distilled water until the pH reached 7 and dried using an oven at a temperature of 105 °C for 1 h which aimed to eliminate the NaOH content left in the ingredients. Activated carbon process was performed by adding H<sub>3</sub>PO<sub>4</sub> over 24 h to create pores. Figure 2 shows the process of activated carbon. Then the material was rewashed and dried at 105 °C. Eventually, the activated carbon was heated at 300 °C to remove the remaining content

## 2.2 Briquette production

The woody waste char was crushed up to 50 mesh to 100 mesh using pulverizer mill. There was four variation of mixture which the detailed could be seen in Table 1. The binder percentage was made of tapioca starch. The adhesive percentage was chosen as 10 % since it had great performance based on various literatures. The briquette geometry was 3.5 cm × 3 cm (diameter × height). The molding process used a briquetting hydraulic press (BHP), with two tons power. The next step was drying the briquette in the oven to evaporate the water content. Figure 3 shows the prototype of briquettes.

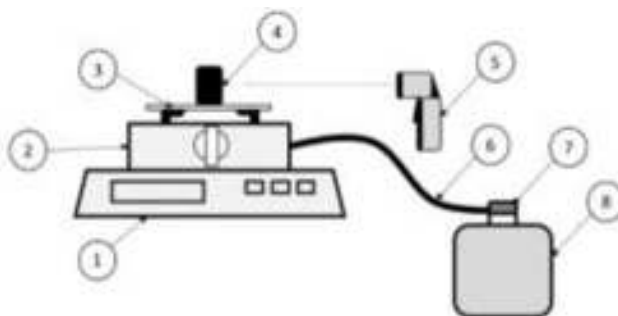
**Table 1.** Distribution of composition for each variation

No	Charcoal percentage	Activated carbon percentage	Adhesives percentage
1	85 %	5 %	10 %
2	80 %	10 %	10 %
3	75 %	15 %	10 %
4	70 %	20 %	10 %



**Fig. 3.** Briquettes prototype

Three types of test conducted in this research consist of proximate test, combustion test, and bomb calorimeter test. Physics characteristics comprising moisture content, ash content, volatile matter, and fixed carbon content as well as calorific value were examined in Tekmira Bandung. The test output was compared to Indonesian National Standard (SNI). As shown in Figure 4, to perform combustion test, the plate was heated for around two minutes. The briquette then was put on the hot plate and the initial ignition time was observed until ember appeared. Infrared thermometer was used to monitor the temperature distribution of the briquettes for every one minute. The duration of combustion process was accounted until the briquette altered to ash. This procedure was replied three times. Table 2 shows the design of experiment.



**Fig. 4.** Installation Scheme for Combustion Test (1): digital balance; (2): portable gas stove; (3): iron sheet; (4): briquette; (5): infrared thermometer; (6): gas hose; (7): regulator; (8): gas holder).

**Table 2.** Design of Experiment

Input data		Output data
Constant variable	Independent variable	Measured data
<ul style="list-style-type: none"> <li>• Briquette Dimension</li> <li>• Raw Material and Briquette Mass</li> <li>• Briquette Drying Temperature</li> <li>• Ratio of tapioca flour and water</li> </ul>	<ul style="list-style-type: none"> <li>• Ratio between activated carbon and woody cutting waste char</li> </ul>	<ul style="list-style-type: none"> <li>• Physic Characteristics</li> <li>• Inial Ignition Time</li> <li>• Combustion Temperature</li> <li>• Briquette Mass Difference During Combustion Process</li> <li>• Calorific Value</li> </ul>

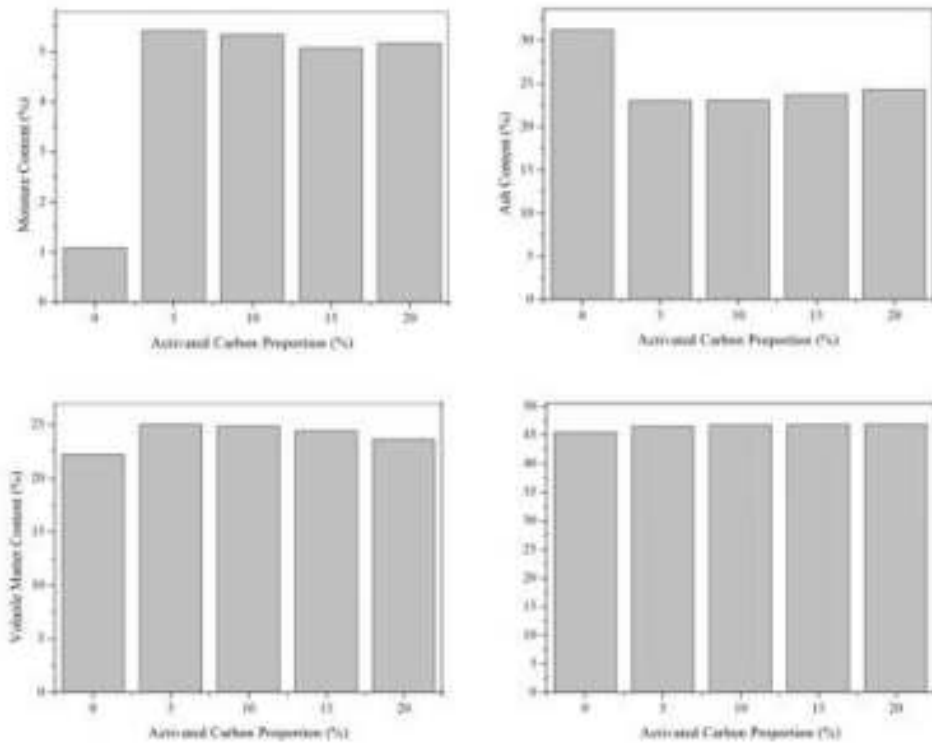
### 3 Results and discussion

#### 3.1 Proximate test

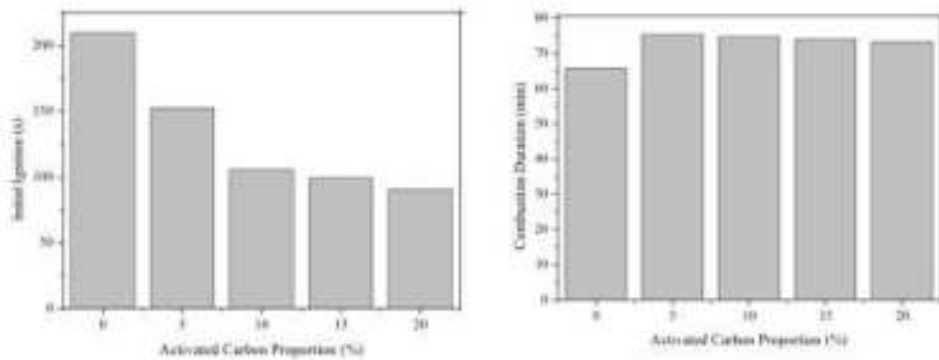
Figure 5 shows the proximate test results. It contains the information about the physic characteristics of briquette with and without adding activated carbon. The moisture content of the briquette combined with activated carbon stood around 5%. These values were under the Indonesia National Standard which the maximum limit is 8%. Ash content increased slowly over the activated carbon percentage. 5% of activated carbon in briquette possessed 23.03%, which was the lowest ash content among the variation. Meanwhile, the highest ash content was found in 20% activated carbon variation and reached up to 24.31%. Compare to the briquette contained pure woody waste char, it was obtained that the activated carbon briquette had lower ash content. It was true since mostly in the briquette



without activated carbon addition was made of twigs and leaves which tended to produce higher ash content [7]. According to [8], leaves contained the highest silica content.



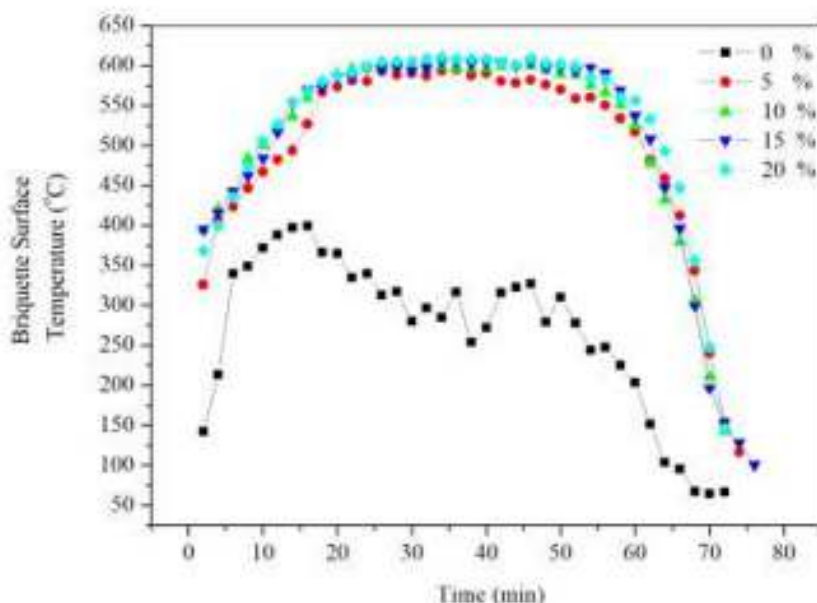
**Fig. 5.** Proximate analysis results.



**Fig. 6.** Combustion test result (a: Initial ignition time; b: Combustion duration)

### 3.2 Combustion Characteristics

As shown in Figure 6 Fig. 6. Combustion test result (a: Initial ignition time; b: Combustion duration), 20 % of activated carbon percentage had the shortest initial ignition time, while there was the longest initial ignition time in the briquette with 0 % activated carbon. It occurred since activated carbon had a wider area. Therefore, this briquette containing more activated carbon could be ignited more rapidly. Figure 6 also illustrates the duration of combustion process. 0 % of activated carbon briquette had the shortest combustion time period. The main reason is due to the lowest moisture content among other types.



**Fig. 7.** Temperature distribution on briquette surface on combustion test with variation of activated carbon

Figure 7 provides the information about the temperature distribution during the combustion process. There was a significant temperature difference between briquette with and without activated carbon. The highest temperature of briquette with 0 % activated carbon was only 452 °C. Meanwhile, briquette with activated carbon almost reached 620 °C. Based on the result [9], the biochar containing a lower fixed carbon causes a modest temperature. The highest fixed carbon was around 60 % and the combustion temperature could reach approximately 600 °C.

### 3.3 Calorific value

Based on the Table 3, the addition of activated carbon in briquette could increase the calorific value from 3 630 kCal kg<sup>-1</sup> to around 4 500 kCal kg<sup>-1</sup>. Moreover, the higher content of activated carbon, the calorific value was also greater. The obtained result was similar to other findings. The briquette with greater fixed carbon content was prone to produce higher calorific value [10, 11].



**Table 3.** Calorific value of each variation

No	Variation	Result (kCal kg <sup>-1</sup> )
1	0 %	3 630
2	5 %	4 578
3	10 %	4 592
4	15 %	4 577
5	20 %	4 528

## 4 Conclusion

The addition of activated carbon in briquette could increase the calorific value from 3 630 kCal kg<sup>-1</sup> to around 4 500 kCal kg<sup>-1</sup>. However, the activated carbon briquette still could not meet the Indonesian National Standard, especially related to ash content, fixed carbon, and calorific value.

This work was funded by LPPM UI SI in 2019 through Hibah Riset Terapan scheme with number: 04/KP.03/03-01.03.01/03.19. The title of the research is Karakteristik Briket Sampah Organik UI SI dengan Variasi Penambahan Arang dan Karbon Aktif Siwalan.

## References

1. W.S. Chen, F.C. Chang, Y.H. Shen, M.S. Tsai, *Bioresour. Technol.*, **102**:5406–5410(2011).  
<https://www.sciencedirect.com/science/article/pii/S0960852410018092>
2. W.T. Tsai, J.H. Chang, K.J. Hsien, Y.M. Chang, *Bioresour. Technol.*, vol. 100, pp. 406–412(2009).  
<https://www.sciencedirect.com/science/article/pii/S0960852408005336>
3. Y. Yuliah, M. Kartawidjaja, S. Suryaningsih, K. Ulfi, Fabrication and characterization of rice husk and coconut shell charcoal based bio-briquettes as alternative energy source. *IOP Conf. Ser. Earth Environ. Sci.*, **65**:1–8(2017).  
<https://iopscience.iop.org/article/10.1088/1755-1315/65/1/012021/meta>
4. A. Enders, K. Hanley, T. Whitman, S. Joseph, J. Lehmann, *Bioresour. Technol.*, 114:644–653(2012).  
<https://www.sciencedirect.com/science/article/pii/S0960852412004403>
5. K. Kasmira, L. Lahming, R. Fadilah, *Jurnal Pendidikan Teknologi Pertanian*, **4**:49–55(2018). [in Bahasa Indonesia]. <https://ojs.unm.ac.id/ptp/article/view/6232>
6. P. Oleszczuk, S.E. Hale, J. Lehmann, G. Cornelissen, *Bioresour. Technol.*, **111**., 84–91(2012). <https://www.sciencedirect.com/science/article/pii/S0960852412002593>
7. D. Angin, *Bioresour. Technol.*, **168**:259–266(2014).  
<https://www.sciencedirect.com/science/article/pii/S0960852414002715>
8. M. Carrier, A.G. Hardie, Ü. Uras, J. Görgens, J.H. Knoetze, *J. Anal. Appl. Pyrolysis*, **96**:24–32(2012).  
<https://www.sciencedirect.com/science/article/pii/S016523701200037X>
9. Agriculture Organization of the United Nations, Simple technologies for charcoal making, Forestry Dept and Agriculture Organization of the United Nations:

- Mechanical Wood Products BranchFood & Agriculture Org. (1983).  
<https://books.google.co.id/books?id=Ww-hfFDy1WYC&dq>
10. T.P. Ding, J.X. Zhou, D.F. Wan, Z.Y. Chen, C.Y. Wang, F. Zhang, *Geochimica et Cosmochimica Acta*, **72**,5:1381–1395(2008).  
<https://www.sciencedirect.com/science/article/pii/S0016703708000276>
  11. W. Nuriana, N. Anisa, *Energy Procedia*, **47**,295–302(2014).  
<https://www.sciencedirect.com/science/article/pii/S1876610214002446>