

# PROCEEDING

## The 8<sup>th</sup> Joint Conference on Renewable Energy and Nanotechnology 2019 (JCREN 2019)

ISBN 978-979-18011-3-3

November 5-6, 2019

Gowa Campus, Hasanuddin University,  
Indonesia



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# PROCEEDING

## The 8<sup>th</sup> Joint Conference on Renewable Energy and Nanotechnology 2019 (The 8<sup>th</sup> JCREN 2019)

Improving International Networks and  
Research Collaboration

Gowa Campus, November 5 – 6, 2019

Department of Mechanical Engineering  
Faculty of Engineering  
Universitas Hasanuddin  
Indonesia

**PROCEEDING**  
**The 8<sup>th</sup> Joint Conference on Renewable Energy and  
Nanotechnology 2019**  
**(The 8<sup>th</sup> JCREN 2019)**

**Improving International Networks and Research Collaboration**

**Organized by :**

Universitas Hasanuddin

**Co-organized by :**

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**Setting Layout :** Muh. Firdan Nurdin

**Publisher :**

Department of Mechanical Engineering, Faculty of Engineering, Universitas Hasanuddin, Indonesia

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Jalan Poros Malino, Km. 6, Bontomarannu, Gowa, Sulawesi Selatan, Indonesia, 92171

<https://eng.unhas.ac.id/mesin/id/page/1033174/jcren-2019.html>

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ISBN 978-979-18011-3-3



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# Message from Chair of JCREN 2019

Assoc. Prof. Andi Erwin Eka Putra



We are pleased to welcome all participants of The 8<sup>th</sup> Joint Conference on Renewable Energy and Nanotechnology (JCREN 2019). This joint conference is held following the successful 1<sup>st</sup> JCREN in Bangkok, 2<sup>nd</sup> JCREN in Hiroshima, 3<sup>rd</sup> JCREN in Kanchanaburi, 4<sup>th</sup> JCREN in Matsuyama, 5<sup>th</sup> JCREN in Kuala Lumpur, 6<sup>th</sup> JCREN in Bangkok, and 7<sup>th</sup> JCREN in Yamaguchi. This year, The 8<sup>th</sup> JCREN 2019 is taking place in Makassar, Indonesia from 5<sup>th</sup> to 6<sup>th</sup> of November 2019 in the Engineering Campus of Hasanuddin University.

In line with Hasanuddin University's commitment to increase international academic cooperation, joint conference program such as JCREN is a top priority in improving international networks and research collaboration. Through international conferences, it is expected that researchers in the eastern part of Indonesia can interchange information so that it can add insight and maturity of scientific thinking. International conferences can also be a means to establish cooperation among field research, especially those from abroad.

We would like to convey our deepest gratitude to Prof. Yukihiro Matsumura, Prof. Shyam S. Pandey, and Prof. Tawatchai Charinpanitkul as Keynote Speakers and for their kind supports for the success of this joint conference. We would like to send our gratitude to all international and local Steering Committee for their valuable contribution to JCREN 2019.

We would like to express our gratitude to all participants and we would like all of you to enjoy your time here in Makassar. While participating in JCREN, we hope that you will expand your network, add friends and engage in the many productive discussions that will be held at this conference.

A handwritten signature in black ink, appearing to read 'Andi Erwin Eka Putra', with a horizontal line underneath.

# Words for the JCREN2019

JCREN2012-2014 Japanese Chair

JCREN2015-2019 Vice Chair

Yukihiko MATSUMURA



Since the first JCREN in Bangkok, we have been continuing this conference every year, and it is already 8<sup>th</sup> meeting. We can count it as second one in Higashi- Hiroshima, third one in Kanchanaburi, fourth one in Matsuyama, fifth one in Kuala Lumpur, and sixth one in Bangkok, and seventh one in Ube. The rotation is Thailand-Japan-other country since the 3<sup>rd</sup> conference. This meeting is thus the 2<sup>nd</sup> "other country" conference for JCREN, and it is in Indonesia.

The 4<sup>th</sup> conference in Matsuyama was where we decided to have this conference in Indonesia some day. Prof. Nomura, the chair of the conference was working with Indonesian researcher, who participated in it. In this way, we are extending our network from one country to another, inviting more and more participants. This is actually what we intended. Networking of researchers allows us to achieve more than what we can do independently.

It is also true for the research field. It is by association with other field that you get inspiration, and magic of synergy arises. Thus, we started to provide a stage for renewable energy researchers and nanotechnology researchers to co-act. Now it is not only these two fields, but also many other fields that is joining the performance. I hope this JCREN2019 can be a wonderful stage for you to enjoy association with researchers from other fields.

Finally, I would like to thank Dr. Andi Erwin Eka Putra, Universitas Hasanuddin, to be the chair of this conference and to invite all of us to this wonderful city of Makassar. The success of this conference really owes his efforts. My sincere thanks go to all the staffs in Universitas Hasanuddin who helped this conference organization and all the organizing committee members. If it were not for their kind help and cooperation, this conference could never be held. Hope you enjoy this conference, extend your network, and more and more collaboration come out.

A handwritten signature in black ink that reads "Y. Matsumura". The signature is written in a cursive style and is positioned above a faint green watermark that says "JCREN".

## Message for JCREN2019 from Thailand

Prof. Tawatchai Charinpanitkul



With the total population of more than 270 Million and consisting of more than 17,000 islands with over 1.9 million square miles of land, Indonesia is the 4th largest country with growing potential. Abundant unique natural resources and excellent human resource are strength of this great country. To serve the continuous growth of the country and the whole region, Indonesia has contributed a lot in developing and supplying energy, food, technology and many issues. Among those emerging issues, Renewable Energy and Nanotechnology have drawn attentions from multi-lateral collaboration among many stakeholders. With the dedication of Universitas Hasanuddin, it is a great opportunity that JCREN could be expanded to become a broader and energetic network among Indonesia, Japan, Malaysia, Philippines, Thailand, and other alliance countries. The 8<sup>th</sup> JCREN or JCREN2019 has been well organized in the beautiful campus of Department of Mechanical Engineering, Universitas Hasanuddin situated in Makassar, Sulawesi Island, which is the biggest city in the Eastern part of Indonesia. All arrangement of JCREN2019 has followed the same objective as that of the previous JCRENs, which has focused on providing academic and cultural exchange as well as fostering young generation for contributing to the whole society. As a result, continual and innovative topics covering Renewable Energy, Nanotechnology, Chemical Engineering, Environmental Engineering, Mechanical Engineering, and other relevant fields are emphasized to stimulate the intimate and friendly meeting among academia, researchers and industrial entrepreneurs. New opportunities in utilizing new knowledge and experiences would be shared and discussed in either oral or poster sessions in JCREN2019. Additionally, a technical excursion would also provide good opportunity for all participants to broaden their vision. With all mentioned aspects, I am confident that JCREN2019 would certainly remark some impressive memories for all.

I would like to take this opportunity to extend my sincere gratitude to all organizing committee members, especially, Prof. Andi Erwin E. Putra and all colleagues of Universitas Hasanuddin as well as all alliance institutions for their dedication to the successful JCREN2019. Certainly, many respectful supports from all industrial partners would also be acknowledged. Last but not least, I am confident that the success of JCREN2019 would help strengthen our multilateral collaboration in the field of Renewable Energy and Nanotechnology which would be beneficial to our global society.

(Prof. Tawatchai Charinpanitkul)  
Associate Dean for Academic Affairs  
Faculty of Engineering, CHULALONGKORN University, Thailand

A handwritten signature in cursive script that reads "T. Charinpanitkul".

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# Characterization of Pyrolysis and Gasification Product of Cashew Nut Shell Waste

Andi Erwin Eka Putra<sup>1</sup>, Inong Oskar<sup>2</sup>, Hairul Arsyad<sup>1</sup>, Novriany Amaliyah<sup>1</sup>

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## Abstract

This research examines the characteristics of pyrolysis and gasification product of cashew nut shell waste. Pyrolysis products such as charcoal, oil, and tar were analyzed using proximate testing, scanning electron microscope, x-ray diffraction, and chromatography at pyrolysis temperature of 600°C and 900°C. The gasification products such as tar and gas were analyzed using chromatography at the addition of oxygen and the absence of oxygen and heating time was observed. The result shows that charcoal products of pyrolysis obtained higher heating value (HHV) equal to 6853 kcal/kg and 6474 kcal/kg at 600° and 900°C of pyrolysis temperature respectively. Scanning electron microscope result of charcoal shows a non-uniform pore size of 2 to 10 µm. Oil viscosity was obtained at 0.9528 cP and tar content was dominated by phenol compound group of 46.52%. The gas content of the gasification product of cashew nutshell waste was dominated by propane of 44.20% with a higher heating value of 938.24 kcal/kg. The heating time with the addition of oxygen takes a longer time of 10% to 45% than in the absence of oxygen.

## 1. Introduction

The cashew tree (*anacardium occidentale*) is a tropical evergreen tree that originally came from Northern South America. Later on, this plant grows in some tropical countries including Indonesia. In Indonesia, it is locally named as *Jambu Mete* and mainly planted in several regions including west Sumatra, Lampung, north and southeast Sulawesi, west Nusa Tenggara, central and east Java[1]. The cultivation process is relatively easy. Data reported by Indonesian ministry of agriculture on 2009, there are 570,000 ha of cashew tree cultivated area with production of cashew nut around 142,000 metric tons/year[2]. The main products of the cashew are pseudo fruit (cashew apple) and cashew nut. The cashew nut consist of the shell nut and the kernel. The shell of the nut is approximately 1/8 inch thick and become a potential agriculture byproduct to produce cashew nutshell liquid.

Previous studies have reported the utilization of cashew nutshell liquid (CNSL). A single cylinder compression ignition engine was successfully operated using neat CSNL with various blends of oxygenated, alcohols, and vegetable oils[3]. In material application, CSNL was used as bio-resin, that when it combined with glass or carbon, the composite materials will have a greater renewable content and minimizing greenhouse gases typically associated with petroleum based resin[4][5]. The cashew nutshell extract was also reported as the most prominent source of antioxidants compare to coconut oil and groundnut hull[6]

Several attempts have been made to produce CSNL. A number of researches have reported pyrolysis method of cashew nutshell. Pyrolysis process comprises the thermal degradation of materials in the absence of an oxidizing agents leading to the formation of solid (char), liquid (bio-oils), and gaseous products. Two step pyrolysis of cashew nutshell in a fixed bed pyrolysis reactor with temperature of 175°C was reported produced dark brown oil and combustible oil fraction.

These oils were found to have a unique characteristic with the presence of long linear chain in the compounds, which is become an excellent solubility in diesel oil and light lubrication oils[7]. CNS oil with caloric value of 40 MJ/kg, near to that of petroleum fuel was produced in a packed bed vacuum pyrolysis unit. At pyrolysis temperature of 500°C, the optimum yielding of the maximum percentage of oil was obtained[8]. In a laboratory-scale fixed bed reactor, a feasibility of obtain solid and liquid fraction usable as a fuel was demonstrated at the pyrolysis temperature between 400 and 600 °C[9].

At the higher temperature rather than pyrolysis process, studies of the gasification process of cashew nutshell have been explored. Gasification is a thermochemical process at high temperature (800 – 1100°C) in the presence of gasifying agents such as air, steam, and oxygen to produce a gaseous products. A simple downdraft fixed bed gasifier was developed to consider the potential use of cashew nutshell as replacement fuel for wood. A high energy content and similar chemical composition of gas was obtained and generated less waste[10].

## 2. Experimental

The experimental apparatus scheme is shown in fig.1. A 0.5 g of cashew nutshell was put in the reactor then heated using a burner. In the pyrolysis step, cashew nutshell was heated at vacuum condition of -15 Psi until temperature reach 600 °C and 900 °C. The pyrolysis of cashew nutshell generated products such as gas, oil, and char. At the gasification step, an oxygen of 10% and 25% was injected in the reactor respectively at the same temperature of pyrolysis step. The gasification generated products of gas and char. Pipeline was used to distribute and separate oil and gas products of pyrolysis and gasification process. The proximate analysis (moisture, ash content, volatile matter, fixed carbon, and heating value) of char produced after pyrolysis was analyzed, and a scanning electron microscope (SEM) was used to study the surface feature of char produced. A viscometer was used to analyze oil and tar product. Gas composition characterization of gasification product was conducted using gas chromatograph.

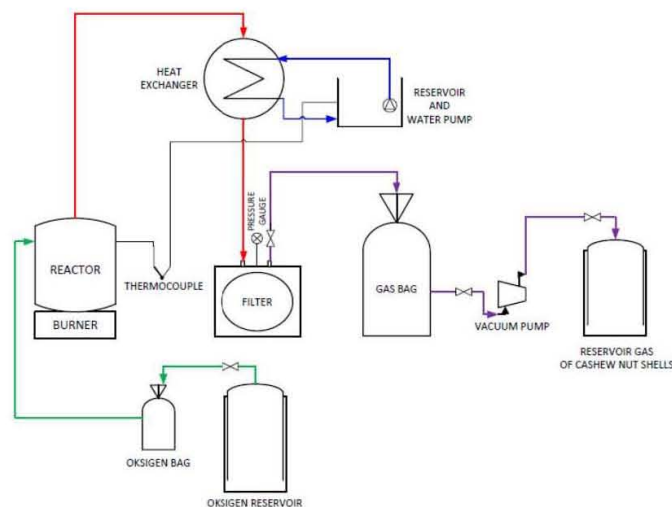


Fig. 1 Experimental apparatus scheme

### 3. Result and Discussion

#### 3.1. Proximate Analysis

Table 1 summarized the solid products characteristics that were determined in this study. Char present a moisture in a range of 2.72 to 3.81 %, decrease around 80% at gasification step with temperature of 600°C with addition of 10% O<sub>2</sub>. Low moisture content can ensure good quality gas production[11]. In the pyrolysis step, increasing temperature from 600°C to 900°C resulted decreasing content of volatile matter and moisture content, while increasing fixed carbon and ash content. These trends are in accordance with those studies reported in literature[9]. In the gasification process, increasing temperature will decrease moisture content and fixed carbon, while ash content and volatile matter tend to increase. At the gasification temperature of 600°C, the addition of O<sub>2</sub> from 10% to 25% result in the decreasing of moisture content and fixed carbon, while ash content and volatile matter were slightly increase. A high HHV of 7020 Kcal/kg was obtain in gasification step with addition of 25% of O<sub>2</sub>.

Table 1. Characteristic of char produced

Condition	Composition (%)				HHV (Kcal/Kg)
	Moisture	Ash	Volatile Matter	Fixed Carbon	
raw CNS	13.61	1.77	73.67	10.95	1962
600	3.78	12.64	26.04	57.55	6853
600 + 10% O <sub>2</sub>	3.81	9.88	28.19	58.12	6923
600 + 25% O <sub>2</sub>	3.64	10.16	28.3	57.9	7020
900	2.77	15.79	22.4	59.04	6474
900 + 10% O <sub>2</sub>	2.72	13.97	22.06	61.25	6583
900 + 25% O <sub>2</sub>	2.84	14.22	20.41	62.52	6606

#### 3.2. Scanning Electron Microscope analysis (SEM)

SEM pictures of char product at temperature of 600 °C and 900 °C is shown in fig.2 and 3. The average pore diameter was found in a range of 2 µm to 10 µm.

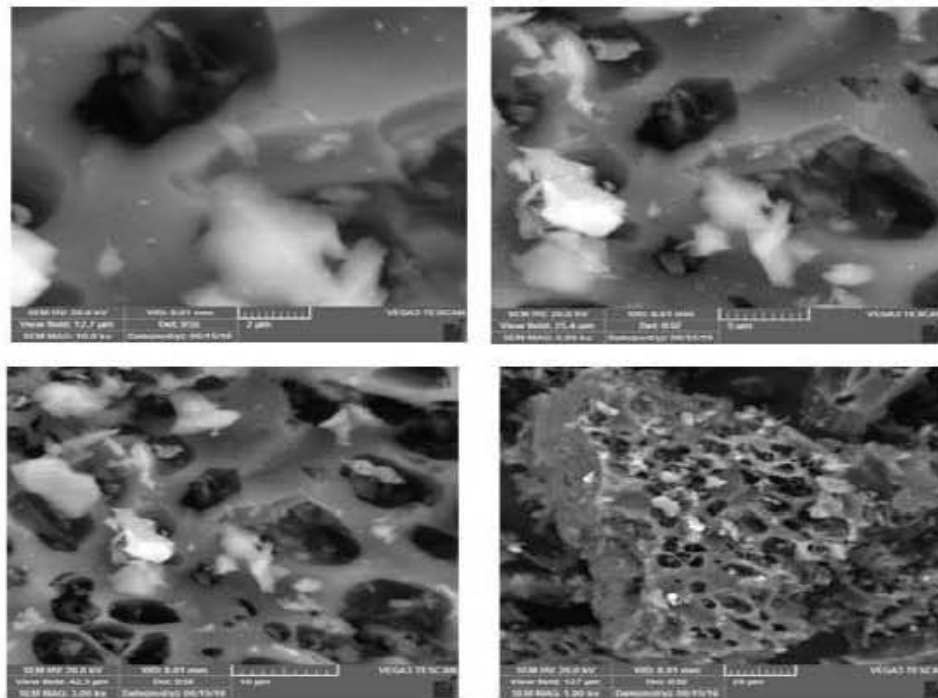


Fig. 2 SEM picture of char produced at 600 °C

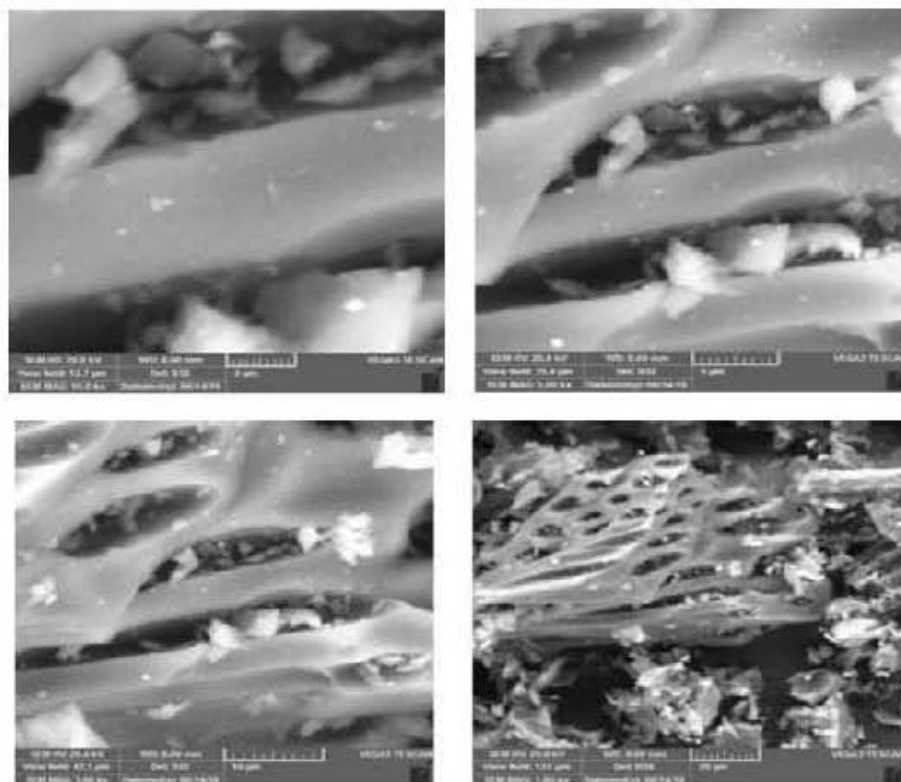


Fig. 3 SEM picture of char produced at 900 °C

### 3.3. Liquid and Tar product

Oil produced from pyrolysis product then analyzed using viscometer to obtain viscosity. It was found that CNS oil has a viscosity of 0.9528 cP. Tar product from pyrolysis process analyzed using GCMS-QP2010 Ultra Shimadzu. The peak is shown in figure 4. Strong peak was observed at 91° contained Phenol 3-pentadecyl with are of 14.85%. The high level of phenol also reported in the previous study[6].

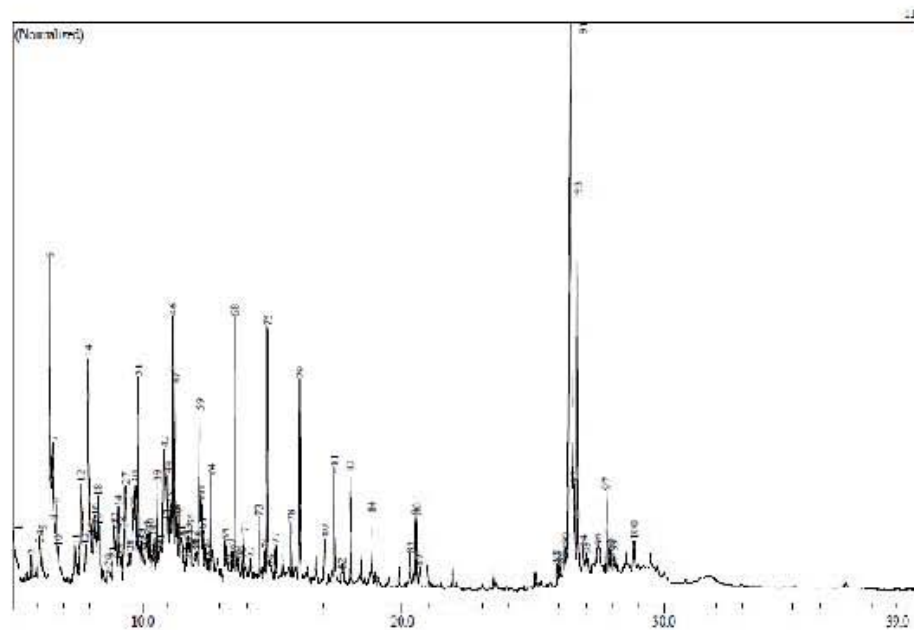


Fig. 4 Gas Chromatography peak of Tar from pyrolysis product

### 3.4 Gas product

Characterization of gas produced from pyrolysis and gasification of cashew nutshell was conducted using gas chromatograph (GCMS-ASTM D2163). The gas product obtained consist of some hydrocarbons such as methane, ethane, propane, n-butane, iso butane, n-pentane, and iso pentane. These values are presented in table 2.

Table 2. Gas composition of cashew nutshell

Component	Result (%liquid volume)
Methane	22.68
Ethane	22.4
Propane	44.2
n-Butane	2.71
iso butane	6.96
n-pentane	0.26
iso pentane	0.76

#### 4. Conclusion

Cashew nutshell products have been studied using pyrolysis and gasification step. A higher heating value (HHV) of 7020 Kcal/kg in gasification step with addition of 25% of O<sub>2</sub>. SEM pictures of char produced at temperature of 600 °C and 900 °C shown at average pore diameter of 2 μm to 10 μm. High phenol composition was detected at tar product, while viscosity of liquid product was observed at 0.9528 cP. Some hydrocarbon detected at gas product from gasification step.

#### 5. References

- [1] N. Jadid *et al.*, "Traditional pattern of cashew cultivation: A lesson from Sumenep-Madura, Indonesia," *AIP Conf. Proc.*, vol. 1908, no. November, 2017.
- [2] M. Yuliana, N. Y. Tran-Thi, and Y. H. Ju, "Effect of extraction methods on characteristic and composition of Indonesian cashew nut shell liquid," *Ind. Crops Prod.*, vol. 35, no. 1, pp. 230–236, 2012.
- [3] G. Kasiraman, V. Edwin Geo, and B. Nagalingam, "Assessment of cashew nut shell oil as an alternate fuel for CI (Compression ignition) engines," *Energy*, vol. 101, no. x, pp. 402–410, 2016.
- [4] E. Ferri and D. Talentino, "Bio-resins from cashew nutshell oil," *Reinf. Plast.*, vol. 55, no. 3, pp. 29–31, 2011.
- [5] S. Rwahwire, B. Tomkova, A. P. Periyasamy, and B. M. Kale, *Green thermoset reinforced biocomposites*. Elsevier Ltd, 2019.
- [6] A. Prakash, V. Vadivel, S. F. Banu, P. Nithyanand, C. Lalitha, and P. Brindha, "Evaluation of antioxidant and antimicrobial properties of solvent extracts of agro-food by-products (cashew nut shell, coconut shell and groundnut hull)," *Agric. Nat. Resour.*, vol. 52, no. 5, pp. 451–459, 2018.
- [7] P. Das, T. Sreelatha, and A. Ganesh, "Bio oil from pyrolysis of cashew nut shell- characterisation and related properties," *Biomass and Bioenergy*, vol. 27, no. 3, pp. 265–275, 2004.
- [8] P. Das and A. Ganesh, "Bio-oil from pyrolysis of cashew nut shell - A near fuel," *Biomass and Bioenergy*, vol. 25, no. 1, pp. 113–117, 2003.
- [9] J. Ábrego, D. Plaza, F. Luño, M. Atienza-Martínez, and G. Gea, "Pyrolysis of cashew nutshells: Characterization of products and energy balance," *Energy*, vol. 158, pp. 72–80, 2018.
- [10] N. Tippayawong, C. Chaichana, A. Promwangkwa, and P. Rerkkriangkrai, "Gasification of cashew nut shells for thermal application in local food processing factory," *Energy Sustain. Dev.*, vol. 15, no. 1, pp. 69–72, 2011.
- [11] A. Mohod, S. Jain, and A. Powar, "Cashew Nut Shell Waste: Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification," *ISRN Renew. Energy*, vol. 2011, no. 03, pp. 1–4, 2011.