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Volume 1034

2021

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2nd International Conference on Mechanical Engineering Research and Application (iCOMERA 2020) 7th–9th October 2020, Malang, Indonesia

Accepted papers received: 16 December 2020

Published online: 18 March 2021

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Preface

Design, Structure and Control

IOP Conference Series: Materials Science and Engineering

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Preface

To cite this article: 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1034** 011001

Preface

The iCOMERA conference showcases research result and industrial findings and provides a great opportunity for global industrial executives, practitioners, scientists, academicians, and scientists for sharing knowledge and ideas in all aspects of mechanical and industrial engineering. The iCOMERA also provides opportunity and room for focus group discussion among stakeholders to address the current and future global challenge, particularly in the industrial sector. Due to the COVID-19 pandemic situation all around the globe, we have organized this conference in virtual form for all Indonesian and international participants.

The Mechanical Engineering Department – Brawijaya University organizes the iCOMERA conference every other year, taking turn with the National Conference SAINTEK. Therefore, postponing iCOMERA to the next year would have destroyed the already fixed agenda of ME conferences. On the other hand, nobody really knows when this pandemic will finally be over and chances are that the pandemic will stay with us during 2021, too. We also had commitments already taken and signed, such us publication with IOP – Material and Science Engineering, UB Alumni and with some colleagues who wanted to joint this conference. For all these reasons the iCOMERA committee has decided to keep the original schedule, which was on 7-9 October and shifting to virtual format.

We have tried to keep the virtual conference as close as possible to the real one. Each speaker has 15 minutes to present his/her paper, with 10 minutes allocated for presentation and 5 minutes for Question and Answer. We have hired professionals to carry out the conference using Zoom Application to anticipate all unexpected problems which may occur and we were not aware of.

It was then quite a surprise that despite all those difficulties, 249 contributors submitted articles to the conference, which is even a higher number than what was registered for the previous iCOMERA edition in 2018. Out of the 249 papers, 32 were rejected, and 217 articles have been chosen for publication in the IoP Conference Series: Material Science Engineering. The high number of participants states to the fact that the iCOMERA conference is becoming popular in the engineering community. This is the result of the good service given in the previous iCOMERA 2018 by the organizing committee. All this hard work should be preserved to make the iCOMERA conference series sustainable and make it a fixed event in the engineers' international conference agenda.

Thank You,

Ir. Djarot B. Darmadi, MT., PhD.

Head of Mechanical Engineering Department.

IOP Conf. Series: Materials Science and Engineering 1034 (2021) 011001 doi:10.1088/1757-899X/1034/1/011001

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COUNTRY

United Kingdom

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SUBJECT AREA AND CATEGORY

Engineering
- Engineering (miscellaneous)

Materials Science
- Materials Science (miscellaneous)

PUBLISHER

IOP Publishing Ltd.

H-INDEX

48

PUBLICATION TYPE

Conferences and Proceedings

ISSN

17578981, 1757899X

COVERAGE

2009-2021

INFORMATION

Homepage

How to publish in this journal

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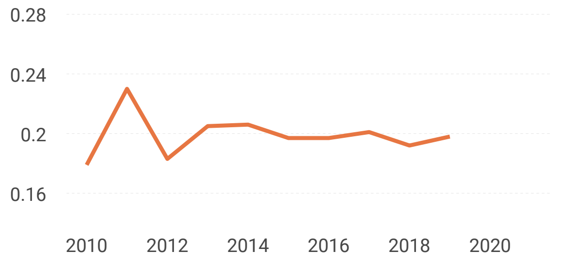

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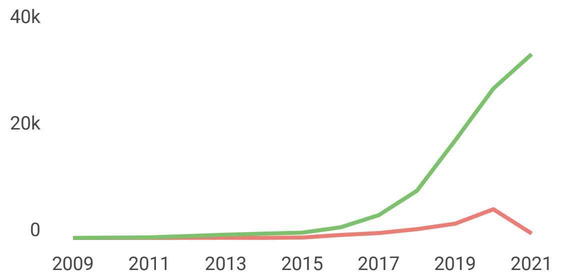

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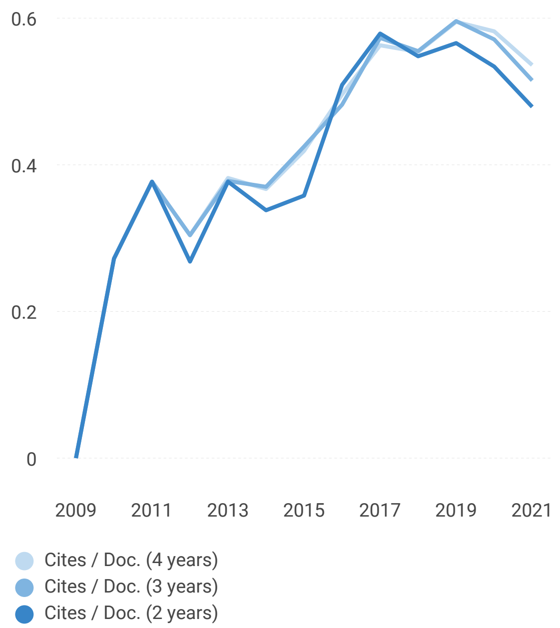

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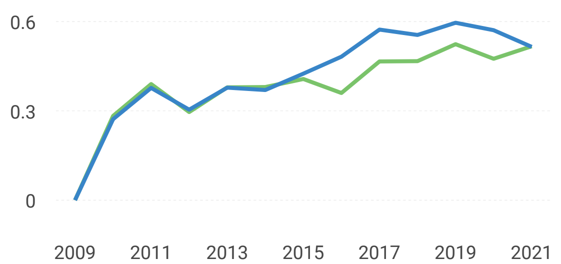

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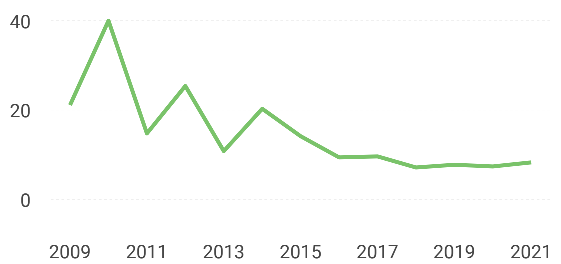

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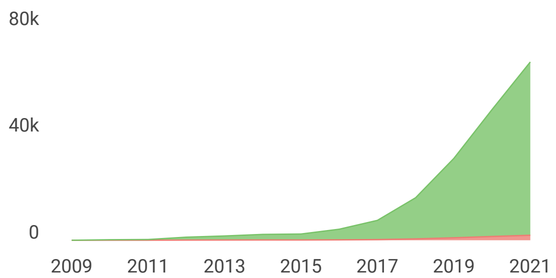

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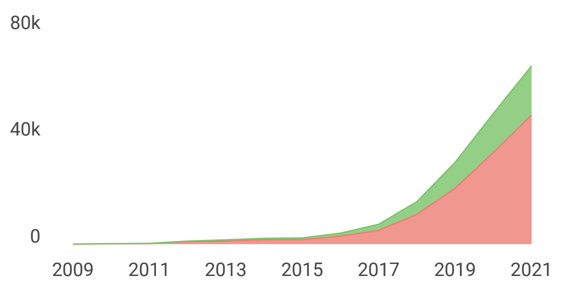

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Publisher: Institute of Physics Publishing
ISSN: 1757-8981 E-ISSN: 1757-899X
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"Innovative Research in Engineering for 21st Century"

October 7-8, 2020

The Mechanical Engineering Department of Brawijaya University, Indonesia

This is to certify that

Gabriel J. Gotama, Willyanto Anggono, Sutrisno, Fandi D. Suprianto, Ninuk Jonoadji, F.X. Yulio Arifin

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Investigation of briquette derived from Pterocarpus indicus leaves and rejected pineapples as inedible sources of renewable energy

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To cite this article: Gabriel J. Gotama *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1034** 012074

Investigation of briquette derived from *Pterocarpus indicus* leaves and rejected pineapples as inedible sources of renewable energy

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Abstract. The previous studies have shown the potential of using *Pterocarpus indicus* leaves, which are wastes, as biomass material for briquette production. However, the use of tapioca as a binder may negatively affect the availability of food resources. An alternative to tapioca was proposed in this study by substituting it with rejected pineapples which are considered as wastes. Series of investigations were conducted to understand the potential of briquette made of *Pterocarpus indicus* leaves with rejected pineapple as the binder. The investigations included bomb calorimeter test to determine the proportion of biomass to the binder that generates the highest calorific value, the proximate and ultimate analyses, and the investigation of optimum particle size of biomass and condensing pressure related to the briquette's combustion characteristics. The results showed that 95% biomass and 5% binder to have the largest calorific value of 4169.76 kcal kg^{-1}. Results from both proximate and ultimate analyses endorse the use of rejected pineapple as a substitute for tapioca binder. Briquette with the optimal combustion characteristics was obtained with condensing pressure of 2 MPa and biomass size of 60 mesh (250 µm).

Keywords: biomass, briquette, combustion characteristic, *Pterocarpus indicus*, waste

1. Introduction

Biomass is one of several sources of renewable energy available as a substitute for the conventional fossil fuel to fulfil the ever-increasing demand for energy [1,2]. Biomass comes in a wide variety from various living organisms and industrial wastes and it may be considered as a carbon-neutral source of energy [3]. With the decrease in the fossil fuel reserve [4], concern towards greenhouse gas emissions from fossil fuels [5], and the demand for a more sustainable generation of energy [6], studies related to biomass utilization such as briquette [7-10] have become more relevant [11]. However, due to the huge diversity of biomasses, their differing qualities, and processes to utilize them [12], each biomass and the methods to utilize it need to be studied individually.

Previous studies have discovered the potential of briquette made from *Pterocarpus indicus* leaves in Indonesia [9,13]. The leaves from *Pterocarpus indicus* trees are considered as wastes as they fall in the street and become litters to be burned. The appearance of *Pterocarpus indicus* trees in Indonesia and their leaf wastes are shown in **Figures 1a** and **1b**, respectively. The burning of these leaves contributes towards greenhouse gases and at the same time wastes a potential source of energy that can be used instead. Previous studies [9,13] have suggested that turning the leaves to a more compact form of briquette raises the quality of the leaves as fuel, as opposed to directly combusting them. Furthermore, compared to some other biomass briquettes, previous studies [9,13] found that briquette derived from *Pterocarpus indicus* leaves has a larger heating value and thus provide more energy when used.

While previous investigations [9,13] resolved the main issue of eliminating litters by turning the leaves into briquette, the proposed briquette has a shortcoming; the studies used tapioca flour as a binder for the briquette. Tapioca is an edible resource and therefore the use of it in briquette manufacturing competes with the availability of food resources [14-16]. In the current state of the world where food waste becomes prevalent and some regions suffer from famine [17,18], the use of food resources to manufacture briquette is highly discouraged. Therefore, to preserve the availability of food resources, a substitute for tapioca flour as a binder for briquette needs to be investigated.

Figure 1. The appearance of a) *Pterocarpus indicus* trees in a street of Indonesia, and b) their leaves that become litters in the street

One possible substitute for tapioca binder is rejected pineapple as it has natural fibre and sugary content similar to tapioca flour. Rejected pineapples are pineapples that have undergone the sorting process and deemed not tradable due to their subpar quality. These pineapples are commonly separated from the consumable fruits and left to become mouldy and unsightly to look, as seen in **Figure 2**, and therefore can be considered as inedible wastes. The use of these rejected pineapples as the binder will help to clean the environment from wastes. Furthermore, the preceding investigation [7] found that rejected papaya can be used to substitute tapioca flour as a binder with a considerable quality compared to other common briquettes; suggesting that rejected pineapple may have similar prospect to replace tapioca as well.

The current study aims to discover the effect of changing the binder from tapioca to rejected pineapple and its viability as a renewable source of energy. This study extensively investigated the briquette quality using bomb calorimeter, proximate and ultimate analyses, and combustion characteristic tests. The bomb calorimeter test was performed to determine the change of calorific value from using tapioca to rejected pineapple under various ratio of biomass to the binder. The proximate and ultimate analyses were performed to understand the potential of the briquette to be practically used. The combustion characteristics test was performed to determine the best manufacturing parameters to produce briquette from *Pterocarpus indicus* leaves and rejected pineapple.

Figure 2. Rejected pineapples that have been left to become mouldy and unsightly to see

2. Experimental method

The raw materials for the briquette manufacturing, *Pterocarpus indicus* leaves and rejected pineapples, were obtained without any substantial cost. Most of them are readily available to be picked as they are considered as wastes. To reduce the moisture content of these materials, they are exposed to sunlight for a week. After sufficient sunlight exposure, the leaves were shredded into smaller pieces for various particle sizes intended in this study. As for the pineapples, they were smashed to become a viscous-liquid substance, as seen in **Figure 3**. The smashed rejected pineapples were used as the binding agent for the shredded leaves by combining them in a mould and afterwards compacted using a hydraulic pressure to become a briquette.

Figure 3. Smashed rejected pineapple that turned into a viscous-liquid substance suitable as a binder for briquette

The first investigation performed on the briquette was the bomb calorimeter test using 1341 Plain Coat oxygen bomb calorimeter. The test was conducted to determine the calorific value of the briquette for various proportions of biomass and binder and compare them with briquette bonded with tapioca. The proportion of the briquette's composition was varied from 75% biomass and 25% binder up to 95% biomass and 5% binder with 5% increments of the biomass proportion. After acquiring the proportion of biomass to binder that gives the highest calorific value, the said briquette was analysed for proximate and ultimate analyses under ASTM standards. Lastly, the combustion characteristics of the briquette were investigated for its combustion rate, flame temperature, burning time, and ignition time. The final investigations were conducted by manipulating the size of biomass and the pressure used to condense the briquette. The particle size of the biomass was varied for 20 mesh, 40 mesh, and 60 mesh which are about 800 µm, 425 µm, and 250 µm, respectively. The pressure was varied for 2 MPa and 1 MPa. The combinations of these parameters were studied to find the combination that yields the ideal combustion characteristics. The tests were conducted for three repetitions and averaged to ensure that the results are significant.

3. Results and discussion

The results for the bomb calorimeter tests are given in **Figure 4**. **Figure 4a** shows the increase of calorific value with lower binder proportion. As the individual calorific value of the rejected pineapple is less compared to the calorific value of the *Pterocarpus indicus* leaf wastes, the additional proportion of the leaf wastes raised the calorific value of the briquette altogether. The calorific value of the rejected pineapple alone was found to be 233.32 kcal kg^{-1}. As for the *Pterocarpus indicus* leaf wastes, its calorific value was found to be 4909.89 kcal kg^{-1} [13]. The highest calorific value of 4169.76 kcal kg^{-1} was achieved with briquette composed of 95% biomass and 5% binder. To see how the briquette bonded with rejected pineapple fares with other briquettes, comparison for various types of briquette is shown in **Figure 4b**. Compared to the briquette that is bonded with tapioca [13], *Pterocarpus indicus* leaves briquette bonded with rejected pineapple has less calorific value. However, the calorific value of this briquette is still within an acceptable range when compared to other briquettes [19-21], including with *Pterocarpus indicus* leaves-rejected papaya briquette [7]. Changing the binder from tapioca to rejected pineapple was expected to reduce the overall calorific value as the calorific value of tapioca is much larger than the rejected pineapple with a value of 3574.47 kcal kg^{-1} [13].

The results for proximate analysis are shown in **Table 1** and the results for the ultimate analysis are shown in **Table 2**. The results for the proximate analysis show that the volatile matter in the briquette is much higher compared to its fixed carbon. Higher volatile matter compared to fixed carbon in proximate analysis indicates that this briquette is easily ignited and therefore suitable to be used for daily use. The gross calorific value in the proximate analysis without drying is in close agreement with the result obtained from the bomb calorimeter test. The sulphur content is considered as acceptable [7] and indicates that the emissions produced by the briquette when combusted are not corrosive. As for the ultimate analysis, the results suggested that the combustible elements in this briquette (carbon and hydrogen) form much of the briquette as high as a combined of 49.19 %wt. These elements contribute to the calorific value results that are obtained in the proximate analysis and bomb calorimeter test. The results of both proximate and ultimate analyses support the use of briquette from *Pterocarpus indicus* leaves and rejected pineapple as fuel.

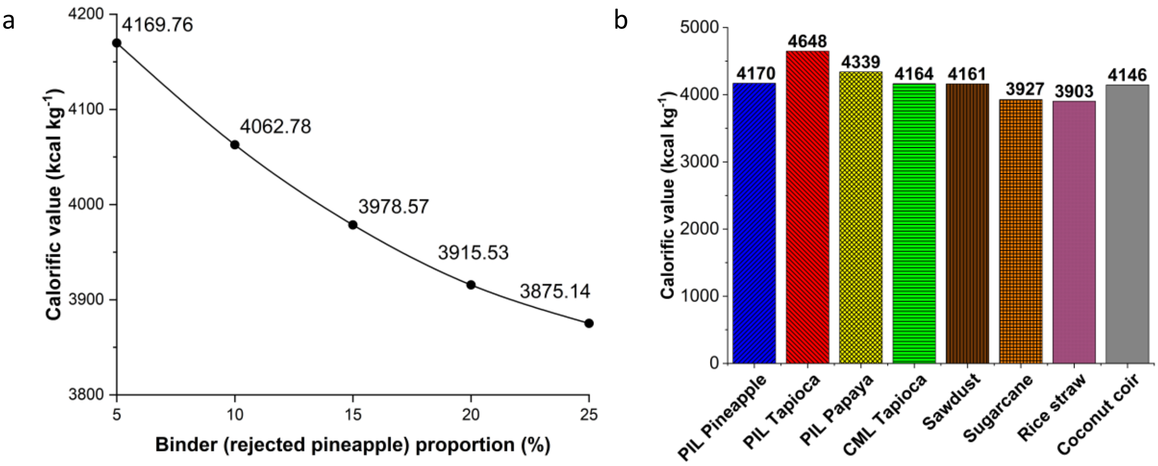

Figure 4. Comparison of a) the calorific value of briquettes for various proportions of biomass to the binder, b) the calorific value of briquettes for various biomasses and binders [7,13,19-21] with PIL is short for *Pterocarpus indicus* leaves and CML is short for *Cerbera manghas* leaves

Table 1. The proximate analysis of *Pterocarpus indicus* leaves and rejected pineapple briquette

Parameters	Unit	As Received	Dried Basis	Test Method
Total moisture	[%wt]	12.66	-	ASTM D 2961 – 17
Ash content	[%wt]	6.65	7.61	ASTM D 3174 – 12
Volatile matter	[%wt]	64.99	74.41	ASTM D 3175 – 18
Fixed carbon	[%wt]	15.70	17.98	ASTM D 3172 – 13
Total sulphur	[%wt]	0.20	0.23	ASTM D 4239 – 18
Gross calorific value	[kcal kg^{-1}]	4173	4777	ASTM D 5865 - 13

Table 2. The ultimate analysis of *Pterocarpus indicus* leaves and rejected pineapple briquette

Parameters	Unit	As received	Test Method
Carbon	[%wt]	44.27	ASTM D 5373 – 16
Hydrogen	[%wt]	4.92	ASTM D 5373 – 16
Nitrogen	[%wt]	3.40	ASTM D 5373 – 16
Oxygen	[%wt]	27.90	ASTM D 3176 – 15

The effects of particle size and pressure towards the combustion characteristics are shown in **Figure 5**. The investigations used four different combustion characteristics to determine the optimal hydraulic pressure and particle size to manufacture the briquette. **Figure 5a** gives the combustion rate of the briquette produced with various particle sizes and condensing pressures. The combustion rate indicates the rate of the briquette mass to be consumed when combusted. The larger the combustion rate, the faster the rate at which the briquette reduces to ashes. The results suggested the reduction of combustion rate with finer shredded biomass and larger condensing pressure. The lowest combustion rate of 0.00255 g s^{-1} was achieved by using a combination of 2 MPa condensing pressure and 60 mesh biomass particle size.

Figure 5b gives the flame temperature of the briquette produced with various particle sizes and condensing pressures. Flame temperature shows the peak temperature that the briquette may reach when combusted. High flame temperature is desired as it increases the rate of heat transfer from the combusted briquette. The results suggested that finer shredded biomass and larger condensing pressure increase the maximum flame temperature of the briquette. The peak flame temperature of 553 °C was achieved by using a combination of 2 MPa condensing pressure and 60 mesh biomass particle size.

Figure 5c gives the burning time of the briquette produced with various particle sizes and condensing pressures. The burning time shows the time needed for the briquette from ignition to completely reduce to ashes. This parameter is highly correlated with the combustion rate; with lower combustion rate resulting in longer burning time. The results suggested that finer shredded biomass and larger condensing pressure prolong the burning time of the briquette. The longest burning time of 4372 seconds was achieved by using a combination of 2 MPa condensing pressure and 60 mesh biomass particle size.

Figure 5d gives the ignition time of the briquette produced with various particle sizes and condensing pressures. Ignition time gives the information related to the time required for the briquette to be combusted. The longer the ignition time, the harder it is for the fuel to be accidentally ignited, making it safer. The results suggested that finer shredded biomass and larger condensing pressure increase the ignition time. The longest ignition time of 278 seconds was achieved by using a combination of 2 MPa condensing pressure and 60 mesh biomass particle size.

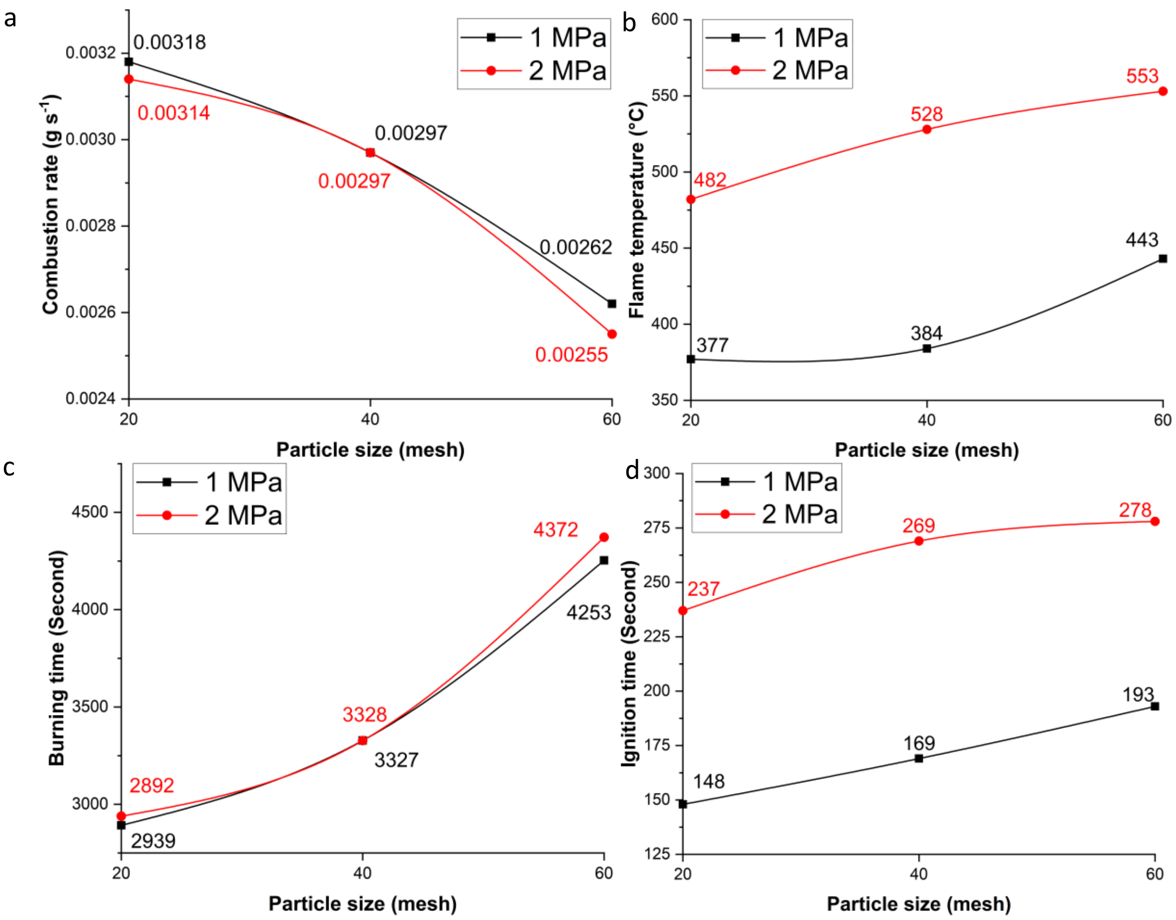

Figure 5. The combustion characteristics of *Pterocarpus indicus* leaves and rejected pineapple briquette. a) combustion rate, b) flame temperature, c) burning time, d) ignition time

4. Conclusion

The results of this study suggested that the best proportion of biomass to the binder that gives the highest calorific value (4169.76 kcal kg^{-1}) is 95% and 5%, respectively. The use of rejected pineapple as a substitute for tapioca binder leads to the reduction of the overall calorific value of the briquette as the calorific value of rejected pineapple is less compared to tapioca. However, the calorific value of briquette bonded with rejected pineapple still fares well in comparison with other briquettes. For the proximate and ultimate analyses, the results of both analyses support the use of briquette from *Pterocarpus indicus* leaves and rejected pineapple as a renewable source of energy. The results from combustion characteristics investigations suggest that the best manufacturing parameters for the briquette are 2 MPa condensing pressure and 60 mesh (250 µm) biomass particle size. These 2 parameters resulted in a briquette with a combustion rate of 0.00255 g s^{-1}, the flame temperature of 553°C, burning time of 4372 seconds, and ignition time of 278 seconds.

5. Acknowledgements

The authors are grateful for the supports provided by Petra Christian University, Indonesia and Directorate General of Higher Education, Ministry of Research, Technology and Higher Education of the Republic of Indonesia for this study.

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