

QUALITY EVALUATION OF COCONUT SHELL ACTIVATED CARBON AND ITS APPLICATION AS PRECURSOR FOR CITRONELLAL-SCENTED AROMATIC BRIQUETTE

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ABSTRACT

Coconut shell, as a lignocellulosic material, has a great potential to be developed as a briquette for energy production. In this research, the aromatic briquette is obtained from a mixture of carbon and activated carbon from coconut shell waste using citronellal as an aromatic additive. A tremendous advantage can be gathered compared to the use of other briquettes. The methods used are carbonization and activation of coconut shell raw material followed by the production of briquette with carbon, activated carbon, adhesive, and aromatic addition. The activated carbon quality results meet all the requirements set by the Indonesian National Standard through a series of analysis procedures. Moreover, the briquette surface successfully adsorbs the citronellal aromatic group. The proximate analysis of briquette, consisting of moisture, ash content, volatile matter content, and fixed carbon, were 8-11%, 2-3%, 8-14.5, 82-87%, respectively. Meanwhile, the briquette's density, compressive strength, and calorific value were 0.7-0.8; 222-393 kg, and 6400-6700 Kcal/kg. This green aromatic-functionalized briquette produced from a mixture of carbon and activated carbon offers an alternative energy source for a society that mainly gives an economic benefit.

Keywords: Activated Carbon, Aromatic Briquette, Alternative Energy, Coconut Shell,

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INTRODUCTION

Activated carbon is an advanced material and has the potential to be developed in the future due to its superior properties, including high porosity, surface area, and surface reactivity.¹ This material has a wide application in many fields such as adsorbent, catalyst, drug delivery, and wastewater treatment. Furthermore, the preparation procedure of activated carbon from highly available natural ingredients generates a low-cost production process that is very profitable from an industrial perspective, primarily when the raw material utilizes biomass of agricultural and forestry waste. Several raw materials from agricultural and forest materials include coconut shell, palm shell, rice husk, sawdust waste, corn waste², apricot kernels³, wood and bamboo⁴, sugarcane bagasse⁵, and many more were reported and found to be an excellent source for activated carbon. In addition, the conversion of waste into value-added material like activated carbon will undoubtedly create a more desirable path in waste management compared to the commonly-used incineration process that emits harmful gas to the environment.⁶ Therefore, the lignocellulosic materials waste as alternative energy would provide a tremendous advantage from an environmental aspect. The coconut shell is one kind of biomass waste that has been used as a source of activated carbon for various applications, including diazonin-pesticide removal⁷, a composites materials reinforced with PP and encapsulated with resin⁸, volatile organic compounds (VOC) removal⁹, phenol adsorption¹⁰, Na-Ion batteries¹¹, and others application. Along with providing a high purity and density of activated carbon, Indonesia's high abundance of coconut shells offers a cost-effective production process that simultaneously improves society's economy. The production of activated carbon generally begins with carbonization and activation that result in a high surface area material. The character and quality of activated carbon are usually affected by activators used during the activation process. The activation generally uses chemical (i.e., H₃PO₄¹², H₂SO₄¹³) and physical activators (i.e., water vapor and CO₂¹⁴). However, a steam activator, which uses only water, is preferred nowadays for its green approach that requires no chemical

additives. In order to improve the value of the resulting activated carbon, the material was modified into an aromatic briquette. This type of briquette releases a specific scent when burned, depending on the aromatic compounds present in its structure. The modification with the aromatic compound can be applied to carbon and activated carbon that have good adsorption capacity. Without aromatic addition, the briquette usually produced from coke¹⁵, sludge¹⁶, biomass waste^{17,18}, or hybrid^{19,20,21} is quite limited for energy production. Based on the explanation, this research aims to the study quality evaluation of activated carbon from coconut shells as a precursor of citronellal-scented aromatic briquette.

EXPERIMENTAL

Material and Equipments

In the present study, the materials used were coconut shell, distilled water, ethanol, 0.1 N iodine solution, 1% starch solution, and 0.1 N Na₂S₂O₃. The prepared catalysis material was analyzed using a Surface area analyzer (BET JWGB Meso 112, China), an Ultimate analyzer (LECO, China), Universal testing machine, and a scanning electron microscope (SEM-ZEISS).

Activated Carbon Production

The coconut shell was put inside a carbonization reactor at a temperature of 400°C to obtain carbon material, labeled as AT. The carbon (AT) activation in a reactor at a temperature of 800°C for three h using water (labeled as BT), which was later vaporized by the supersteam function in the reactor (codded with ST). The contact times employed during the activation process were varied into 60, 120, and 180 mins. The water vapor pressure during the reaction was controlled at 0.5 kg/cm²-1.7 kg/cm² range.

Activated carbon yield

The yield of activated carbon is determined using the following equation:

$$\text{Yield (\%)} = \frac{a}{b} \times 100\%$$

Remarks a: activated carbon weight (g)

 b: carbon weight (g)

Preparation of Aromatic Briquette

The preparation of the aromatic briquette began with the sieving of carbon and activated carbon to obtain a fine solid particle (40 mesh). In this regard, activated carbon was added with a dropwise citronellal. Afterward, carbon and activated carbon were weighed and mixed with a composition ratio of 97.5%: 2.5 % and 95%:5 %, respectively. There are two different methods of forming briquette. The first one is mixing and stirring carbon with a starch solution until homogeneous before adding the mixture with activated carbon in a briquette machine maker. The second is a direct mixing of carbon, activated carbon, and the starch solution stirred until homogenous and put into the briquette machine maker. The mixture was hydraulically pressed until a good shape aromatic briquette was formed and dried for four days. The product was then burned and assessed for its quality.

Quality Evaluation of Activated Carbon and Aromatic Briquette: SNI 06-3730-1995

Moisture Content

One gram of solid samples was put into a crucible and heated for four h at 105°C, respectively. Afterward, each crucible was put inside a desiccator for 10-15 minutes before weight measurement using an analytical balance. The following equation determines the moisture content:

$$\text{Moisture (\%)} = \frac{a-b}{a} \times 100\%$$

Remarks a: initial sample weight (g)

 b: final sample weight (g)

Volatile Matter Content

Solid samples were put into a crucible, weighed for their initial weight, and then heated at 950°C in a furnace for 10 min. Each crucible was then put inside a desiccator for 10-15 min and weighed using an analytical balance. The volatile matter content is determined using the following mathematical equation:

$$\text{Volatile Matter (\%)} = \frac{a-b}{a} \times 100\%$$

Remarks a: initial sample weight (g)
b: final sample weight (g)

Ash Content

Similar to the previous method, ash content was analyzed gravimetrically. Each sample was put into a crucible and then heated at 700°C for four h. The crucible was then put inside a desiccator and weighed using an analytical balance. The ash content is determined using the equation below:

$$\text{Ash content (\%)} = \frac{b}{a} \times 100\%$$

Remarks a: initial sample weight (g); b: final sample weight (g)

Fixed Carbon

Fixed carbon was calculated by subtracting 100% from the sum of volatile matter and ash content percentages. The fixed carbon is determined using the equation below:

$$\text{Fixed carbon (\%)} = 100\% - (a + b)$$

Remarks a: ash content; b: volatile matter

Iodine Adsorption

Each solid sample was weighed 0.25 g and put into an erlenmeyer flask. It was then added with a 25 mL of 0.00960N iodine solution, shaken for 15 min, and filtered. 10 mL of the filtrate solution was titrated with 0.098N Na₂S₂O₃ using a starch indicator until the blue color disappeared. The iodine adsorption test was conducted twice for each sample and determined by following the equation:

$$\text{Iodine adsorption (mg/g)} = A \frac{(B \times N \text{Na}_2\text{S}_2\text{O}_3) : \text{NIod} \times df \times 12.693}{a}$$

Remarks A: filtrate volume (mL)
B: Na₂SO₃ volume (mL),
df: diluting factor,
a: sample weight (g),
12.693: iodine number according to 1 mL Na₂SO₃ solution

Characterization

This study captured the surface morphologies of all materials using SEM. The pore characteristics of samples were analyzed using a surface area analyzer. Meanwhile, elemental analysis was carried out using an ultimate analyzer to quantitatively determine the composition of all solid materials (i.e., C, H, O, N, S).

Compressive Strength Test

A compressive strength test is a material's capacity to resist reducing size from a load. This test was conducted using Universal Testing Machine (UTM) with the following equation:

$$P = Mb \times A$$

Remarks: P = compressive strength (kgf/cm²)
Mb = the received load (kgf)
A = surface area (cm²)

Density Test

Density is the ratio of mass to volume from a specific sample, measured by the dry air volume and its weight.

$$\text{Density} = \text{mass} / \text{volume}$$

(Concentration was estimated according to the standard curve equation)

RESULTS AND DISCUSSION

Carbon and Activated Carbon Characterization

The characterization and quality of activated carbon are analyzed based on the methods set by Indonesian National Standard (SNI 06-3730-1995). Through a comparison with the established standard, the quality of the prepared activated carbon can be assessed. The yields obtained from carbon and activated carbon production were each determined. Various products can be generated when raw material is pyrolyzed or carbonized in a low-oxygen condition at a specific temperature. Accordingly, in this study, the yield of carbon as the desired product was only 34.5212 % ± 0.34 out of the total raw materials employed. The

result depicts that there are side products released during the preparation of carbon, such as wood vinegar (the result of pyrolysis vapor condensed). The pyrolysis process breaks the lignocellulosic material in several stages, from cellulose and hemicellulose at low temperatures to lignin at higher temperatures. Subsequently, the whole process will generate carbon with an increased purity^{22,23}, which is then activated using a chemical or physical activator in a reactor. In this work, steam was used as the activator. This activator has been frequently used in several former research and has shown promising results.²⁴ The yield of activated carbon obtained from these procedures is presented in Fig.-1.

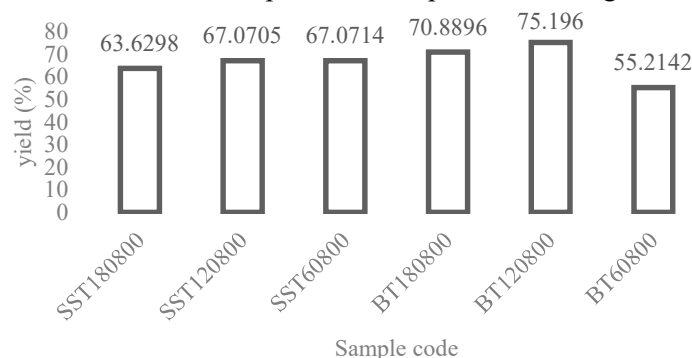


Fig.-1: Yield of Activated Carbon after Carbonization and Activation Process at the Various Condition

In Fig.-1, the yield of activated carbon displayed various values in the range of 55-75%, depending on the reactor condition. The highest yield was produced from an activation process done without supersteam treatment for 120 min (BT 120800). The decrease of yield with the addition of supersteam during the activation process is most likely due to the undesirable oxidation of carbon that releases CO_2 and H_2O , which may also occur with prolonged reaction time. Simultaneously, this explains the decrease of activated carbon yield in 180 min reaction time, as it facilitates a more prolonged contact between steam and carbon that allows oxidation. However, overall, this study found that the yield of activated carbon obtained from coconut shells was higher than that obtained from tea waste (18-24%).²⁵

Table-1: Proximate Analysis of Each Activated Carbon Produced from Coconut Shell Prepared at the Various Condition

Sample	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
Coconut shell	12.3294±0.1608	0.9508±0.0311	76.6901±0.4854	22.3589
Coconut carbon	2.2532±0.1485	3.0411±0.0312	23.3662±0.2797	73.5926
SST180800	1.9602±0.5905	18.7546±0.7727	4.2385±0.9473	77.0068
SST120800	0.4033±0.0139	21.0495±3.0393	3.6765±0.5124	75.2738
SST60800	1.1234±0.0552	21.2082±1.4099	3.5881±0.0850	75.2036
BT180800	0.8493±0.0430	25.5146±1.8410	3.6103±0.3095	70.8750
BT120800	1.4325±0.4557	20.0819±8.4541	4.1238±0.2616	75.7942
BT60800	0.1565±0.0663	24.5381±4.4077	3.1578±0.1660	72.3040
SNI 06-3730-1995	Maximum 15	Maximum 10	Maximum 25	Minimum 65

An increased number of pores and diffusion of an oxidizing agent can be expected as the activation process occurs. The activation will subsequently lead to several changes of character exhibited by activated carbon (Table-1). The coconut shell-activated carbon quality will be evaluated based on the parameters set by Indonesian National Standard. Table-1 showed that the moisture contents of all samples complied with the standard (<15%). High moisture content indicates the high tendency of activated carbons to adsorb water molecules from the atmosphere, commonly named hygroscopic property. The water adsorption is very likely to occur, mainly as several steps in the preparation of activated carbon were performed in an open room. The fact that water did not evaporate although exposed to high temperature during the carbonization

process suggests that the molecule was strongly bounded on the surface of all activated carbons. Similar satisfying results were found in the volatile matter (3-4%) and fixed carbon (70 – 77%) analysis of all activated carbons. A low-value volatile matter is desired in activated carbon, primarily if used as an adsorbent, as it depicts the absence of contaminant on the material's surface or pore-clogging. The removal of the volatile matter was simultaneously taken place during physical activation, where these impurities were inevitably carbonized. In contrast to volatile matter, fixed carbon value, which indicates purity, is expected to be high in all activated carbon. For this reason, the value of fixed carbon analysis is inversely correlated with volatile matter and ash content. However, although the volatile matter is seen to have met the requirement of the established standard, the ash content of all activated carbon, unfortunately, surpassed the limit value. A high value of ash content may suggest the occurrence of undesirable excessive oxidation during the activation process, which will subsequently affect the adsorption capacity of the produced activated carbon due to partially filled pores by metallic minerals from coconut shell ash. The activation process consists of several stages. Firstly, as steam is flown to the sample's surface, it diffuses into the pore of carbon, where it is adsorbed. In this step, a reaction between the adsorbed activating agent and carbon will occur to release carbon dioxide. Afterward, the next stage is desorption and diffusion back to the atmosphere. Based on these stages, related to the contact period between reactants and activating agents, it is foreseeable to find different results with varying steam times. However, steam as an activator is generally more profitable for its environmentally friendly process. After all, no chemical reagent was used.

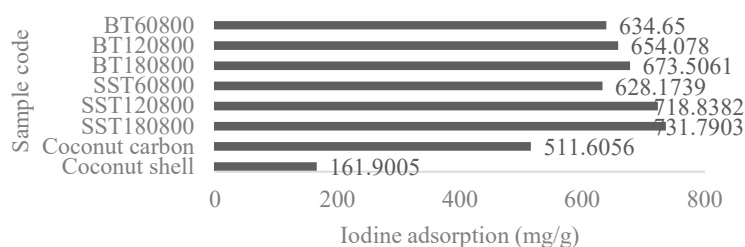


Fig.-2: Analysis of Iodine Adsorption by Activated Carbon from Coconut Shell with a Various Treatment

The activation process may lead to pore formation and enlargement.²⁶ The prolonged activation process is predicted to facilitate more contact time between carbon and activator, thus, creating a more optimum process. From Fig-2, it is seen that the highest value of iodine adsorption is displayed by activated carbon produced with a 180 min reaction time using supersteam. Compared to raw materials and carbon, the adsorption value of all activated carbons produced with varying activation times shows a significant increase. However, the value is still below the required standard (> 750 mg/g). The iodine value may have been due to a non-optimum activation process resulting from an incomplete raw material breakdown and pore formation. The high ash content, which results in closed pores, may also be another possible reason for all activated carbons' low iodine adsorption value. In the present work, an ultimate analysis was also conducted to quantitatively determine the C, H, O, N, and S composition in all carbon samples (Table-2). The result shows that C, with 79 – 85% content, is the main component of all materials. Meanwhile, oxygen, sulfur, hydrogen, and nitrogen are present in the activated carbon in a small portion.

Table-2: Ultimate Analysis of Activated Carbon from Coconut Shell with Various Treatment

Samples	Total sulfur (%)	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Oxygen (%)
SST180800	0.023	82.68	2.52	0.19	12.537
SST120800	0.039	80.87	2.58	0.19	14.061
SST60800	0.042	85.58	2.19	0.33	9.958
BT180800	0.040	79.68	2.76	0.14	15.680
BT120800	0.040	85.54	2.26	0.30	9.820
BT60800	0.036	85.43	2.26	0.31	10.204

Figure-3 presents the surface morphology of the samples captured by SEM. It can be seen that the structure of activated carbon is mainly regular with external and internal pores. However, an open pore structure,

which was due to a prolonged activation process, can also be detected in the surface image. Impurities were seen to occupy several pores, which may have been the reason for the activated carbons' low adsorption capacity.

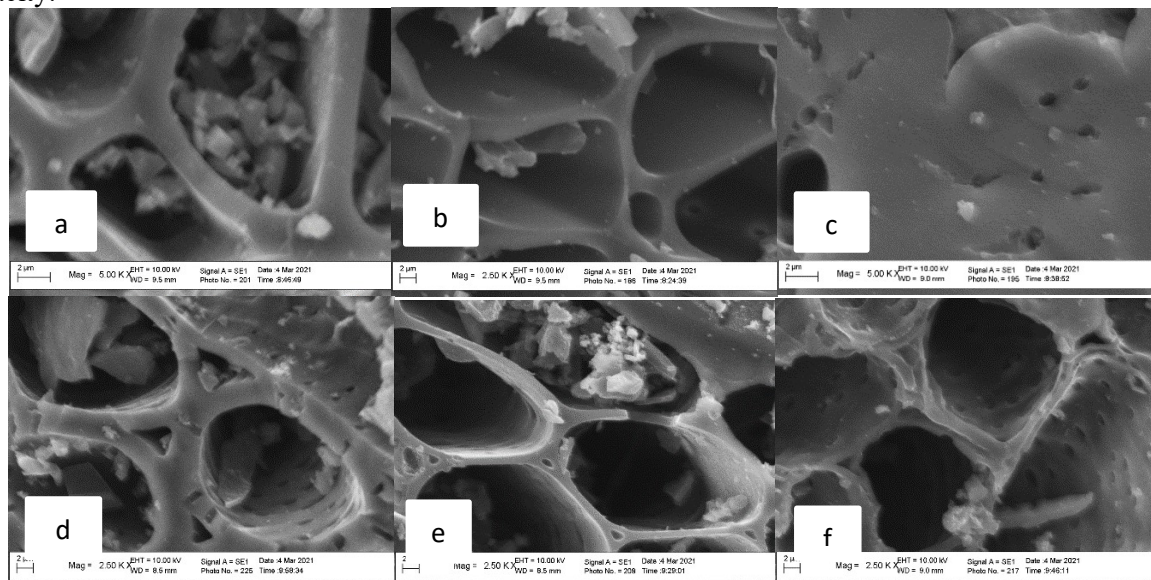


Fig.-3: The Surface Morphology Analysis of Activated Carbon from Coconut Shell with Various Treatment; (a) BT60800, (b) BT120800, (c) BT180800, (d) SST60800, (e) SST120800, (f) SST180800

All materials' pore volume, pore size, and specific surface area characters are quantified through BET calculation, as seen in Table-3.

Tabel-3: The Pore Volume, Pore Size, and Specific Surface Area of Activated Carbon Prepared from Coconut Shells with Various Treatments.

Sample	Pore Volume ($\text{cm}^3 \text{g}^{-1}$)	Pore Size (nm)	Surface Area Spesific ($\text{m}^2 \text{g}^{-1}$)
SST180800	0.276	2.304	479.851
SST120800	0.265	2.237	474.693
SST60800	0.274	2.323	471.129
BT180800	0.300	2.466	486.563
BT120800	0.247	2.344	421.746
BT60800	0.244	2.323	420.412
Coconut carbon	0.055	3.405	64.984

Carbon and activated carbon from coconut shells were shown to possess different surface area values and pore volume. The activated carbon surface area ($420\text{--}470 \text{ m}^2/\text{g}$) is much higher than its non-activated counterpart ($64.984 \text{ m}^2 \text{g}^{-1}$). Likewise, while the pore volume of carbon is only $0.005 \text{ cm}^3 \text{g}^{-1}$, it increases to $0.2 - 0.3 \text{ cm}^3 \text{g}^{-1}$ after the activation process. These results indicate the precise effect of the activation process on carbon material, which subsequently leads to the increasing value of the surface area and pore volume. These increases are linear with extended activation time. Steam as an activator would react with carbon and create pore within its structure during the activation process. This process is intensified by using a supersteam that effectively produces H_2 and O_2 , expanding the pore more optimally. Naturally, with prolonged activation time, more extended contact between carbon and activator will facilitate more pores to be formed and enlarged. As the pore multiplies, the accessibility of adsorbate into the pore of activated carbon enhances. Therefore, the iodine adsorption capacity of the support material increases as well. This explanation shows the linear correlation between surface area or pore volume and carbon adsorption capacity. Fig.-4 displayed that the pore size distribution of BT and SST-activated carbons lie in the range of $2.237\text{--}2.466 \text{ nm}$.

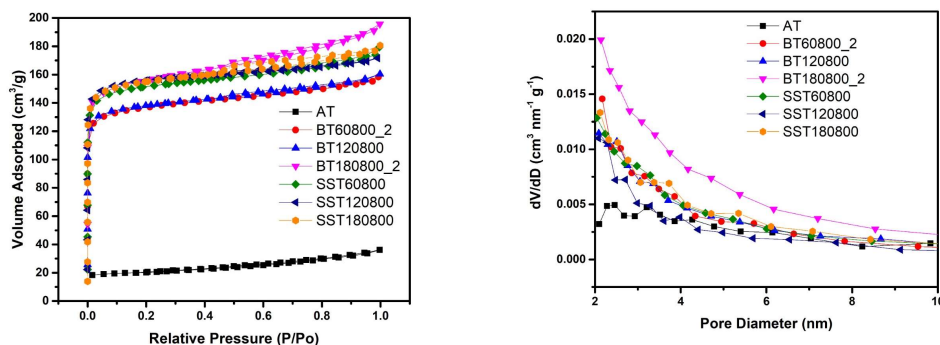


Fig.-4: N₂ Adsorption-Desorption Isotherm Graph of Carbon and Activated Carbon Samples (Left) and Pore Distribution of the Samples Using BJH Method (Right)

As shown in Fig.-4, the desorption adsorption isotherm graph for each activated carbon sample follows the Type I model, which corresponds to microporous structure according to IUPAC classification. However, aside from micropores, the pore size distribution graph depicts the presence of meso-size pores with pore diameters of 2 to 10 nm. Mesopores play a crucial role in improving the adsorption strength of carbon, especially in a solution.⁷

Aromatic Briquette of Carbon and Activated Carbon from Coconut Shell

The aromatic briquette of coconut shell activated carbon was analyzed for various parameters, including proximate analysis, calorific value, density, and compressive strength of the product.

Table-4: Number of Citronellal Drops in Each Activated Carbon

Samples	Number of drops
Activated carbon mixed 2.5 %	157
Activated carbon mixed 5 %	300
Activated carbon separated 2.5 %	136
Activated carbon separated 5 %	324

In Table-4, it is seen that material with a more significant portion of activated carbon received more drops of citronellal. As suggested by the high value of a surface area and iodine adsorption capacity, material with a higher amount of activated carbon will naturally provide more adsorption sites for citronellal. With aromatic addition, briquette will release a unique and calming scent to the atmosphere upon burning. Accordingly, it will be helpful for relaxation purposes. Several parameters for briquette quality evaluation (proximate test) were presented in Fig.-5.

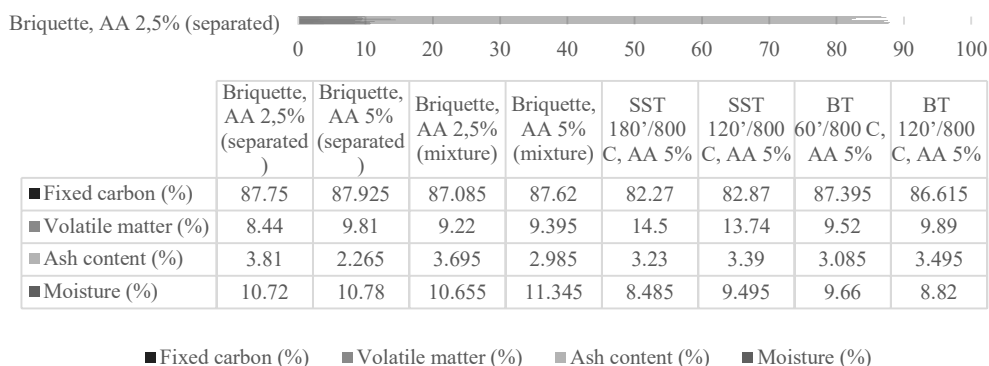


Fig.-5: The Proximate Analysis of Aromatic Briquette of Carbon and Activated Carbon from Coconut Shell

One of the indicators of a good quality briquette is low moisture. This briquette moisture will affect its heating value and flash point, reduce its stability, slow down its combustion process, and promote the growth of fungi.²⁷ Fig.-5 displays the moisture content of all briquettes (8-11%) that slightly exceeds the limit value from the Indonesia National Standard (max. 8%). Although this result is possibly due to the high

hygroscopic property of carbon and activated carbon, the moisture may also come from the content of adhesive (starch solution) that was added during briquette production, which indeed contains water. In overcoming the high moisture, good accuracy in preparing and drying briquette products may be needed for future study. Like moisture, ash content is also considered an essential indicator in evaluating the quality of briquettes. The higher the ash content, the lower the calorific value of the briquette, which is undesirable. Fortunately, in contrast to moisture, the ash contents exhibited by all briquettes (2-3%) were able to meet the maximum standard of a good quality briquette (<8%). A great result was obtained in the volatile matter analysis of all briquettes products. The presence of high volatile matter in briquette decreases combustion speed and generates high smoke and gas output upon burning. In this study, the briquette's volatile matter content (8 – 14%) can meet the requirement set by Indonesian National Standard (<15%). By applying the value of ash content and volatile matter in a simple subtraction equation, the fixed carbon of all briquette samples can be determined (82-87%). This percentage of fixed carbon indicates a good source of energy that will be released alongside CO₂ during the combustion of the briquette. Fixed carbon, moisture, ash content, and volatile matter collectively affect the quality of the briquettes produced.

Table-5: The Quality of Several Briquette Products from Various Raw Materials Following Previous Research

Samples	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed carbon (%)	Calorific value (Kcal/kg)	Ref
Fiber and coconut shell carbon	5-6%	2-4	15-16	78-79	5400-5900	27
Durian and banana peel carbon	7-13	8-17	10-20	60-70		28
Bamboo carbon	9.23	14.5	8.44	68.15	6036	29
Coal	30.72	5.74	40.31	40.71	5844	29
Coal carbon	11.2	13.08	19.1	59.27	5933	29
Wood	11.86	3.0	69.39	17.79	4055	29
Coconut fiber carbon	6.4-6.8	3.8-3.9	34.24	55.1-55.3	5700-5800	30
Coconut shell carbon	4.6-4.7	2.3	27-30	61-65	6500-6800	30
Oil palm empty bunches of carbon	15-16	17-18	22-24	42-44	4900-5100	31
Oil palm shells carbon	8-8.9	6-7	11-17	67-72	6400-6800	31
Rice husk carbon	5.6	2.3	7.6	89.4	-	32
Corn carbon	29.09	1.23	24.9	71.4	-	32
Coconut shell carbon	0.4 (in moisture)	1.83	23.2	74.04	-	32
Indonesian national standard	<8	<8	<15	64-77	>5000	

The characteristics of briquettes produced from coconut shells were thoroughly compared with other briquettes that were prepared from different natural ingredients in former research (Table-5). Overall, it can be seen that many of the proximate analysis results, especially moisture content and volatile matter parameters, displayed by these briquettes did not comply with the Indonesian National Standard. This is most likely due to the addition of adhesive for carbonization. However, the quality of briquettes, which includes calorific value, duration of combustion, and flame intensity, is influenced by not only one but several proximate parameters. For instance, the calorific value of briquette is heavily dependent on the materials' fixed carbon and volatile matter characters. While it increases with higher fixed carbon, the calorific value of each briquette inversely correlates with the volatile matter property.

Aside from proximate analysis, all briquettes were tested for their density and compressive strength. As revealed in Table-6, the highest density and compressive strength were found in briquette mixed with 5% activated carbon and prepared without supersteam (BT 60°/800 C, AA 5%). As discussed previously, the same briquette also exhibited the best proximate analysis result, with the highest fixed carbon (87%) and the lowest moisture, ash content, and volatile matter among the other prepared briquette. The data shows a reason for better-quality briquette with higher density value and compressive strength. However, the density of briquette synthesized in this study is still relatively low compared to the product obtained from rice husk (0.898 g/cm³), as reported by Siswanto.³³ On the other hand, a compressive strength test was done to determine the strength of briquettes in resisting size reduction from a load with a certain pressure. In the

present work, coconut shell briquettes were found to possess compressive strength that ranges from 222 to 393 kg.

Table-6: The Density, Compressive Strength, and Calorific Value of Coconut Shell Briquette

No	Samples	Density (g/cm ³)	Compressive Strength (kg)	Calorific Value
1	Briquette separated, AA 2,5%	0.808	222	6482
3	Briquette separated, AA 5%	0.822	296.8	6492
5	Briquette mixed, AA 2,5%	0.839	228.2	6529
7	Briquette mixed, AA 5%	0.856	284	6527
9	SST 180'/800 C, AA 5%	0.809	423	6677
11	SST 120'/800 C, AA 5%	0.799	323	6663
13	BT 60'/800 C, AA 5%	0.869	393.6	6656
15	BT 120'/800 C, AA 5%	0.825	382	6671

The briquette's compressive strength and density are affected by the content of its raw material, which, in this case, is a coconut shell. The coconut shell has a high hardness and density level, which will naturally be passed on to its briquette product. With higher compressive strength, briquettes will have a better durability.³⁴ Calorific value describes the energy released during the combustion process. A high calorific value is favorable in fuel or other energy sources. The calorific value of coconut shell briquettes was found to be 6482-6677 Kcal/g, which can be considered an improvement compared to the majority of briquettes synthesized in previous research (Table-5). Several factors that may affect the density and compressive strength of briquette products are the amount of adhesive, forging strength, the particle size of the material, and the properties of the raw materials used.^{35,36} Some additives, such as wax, and sodium nitrate, may increase the ignition speed of briquettes. In contrast, other adhesives such as molasses, tar, and kaolin play a role in maintaining the shape of briquettes. In addition, the addition of fillers into the briquette may increase weight and extend the burning time.³⁷ The activated carbon from coconut shell was successfully produced, acts as an adsorbent, and gives a positive effect to the briquette aromatic.³⁸ The present study has shown the great potential of aromatic briquette to be developed, especially as an aromatic energy source. Aside from providing alternative energy, it may also disseminate positive vibes through its aroma for therapeutics effect. However, improvements are still necessary for carbonization and overall briquette preparation methods. With several refinements applied to the preparation method, a high-quality aromatic briquette is expected to be obtained from coconut shells as a cost-effective raw material.

CONCLUSION

In the present study, activated carbon prepared from coconut shells was found to be an effective starting material to produce citronellal-scented aromatic briquettes. The proximate analysis of the resulting briquette, which includes moisture content, ash content, volatile matter, and fixed carbon, was shown to be 8-11%, 2-3%, 8-14.5%, and 82-87%, respectively, and have shown to comply the required value set by the Indonesian National standards. The briquette density ranges from 0.7-0.8 gcm⁻³ with 222-393 kg compressive strength. Moreover, the calorific value of the coconut shell briquette, which is 6482-6671 Kcal/kg, was found to be higher than other briquettes that were synthesized with different natural ingredients. Therefore, aromatic briquette produced from coconut shell-activated carbon demonstrates a promising potential to be developed in the future.

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