"Biopellet" as One of Future Promising Biomass-based Renewable Energy: a Review

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Abstract. The depletion of fossil energy reserves and not environmentally friendly fossil energy emissions makes it necessary to use renewable energy as an alternative to replacing fossil energy. Biopellet is one of the renewable energy based on biomass that exists in Indonesia. Biopellets are produced from a base of abundant biomass. Thus, biopellets have the potential and promise to continue to be used as fuel by humans. The literature review includes the characteristics of biopellets and the application of biopellets as fuel. Biopellets can be made by mixing biomass with an adhesive with a concentration of 15% (w/w) then stirred until homogeneous and put into a pellet mill for printing. The pellets were dried in an oven for 30 minutes. Biopellet characteristically has complied with SNI 8021-2014 for parameters of ash content, fixed carbon content, caloric value, water content, and volatile matter content. The application of biopellet as a stove material also shows good performance for heat, efficiency, and emission parameters. In conclusion, biopellet is a renewable energy fuel based on biomass that has potential in the present and promising in the future.

1 Introduction

The world's international fossil energy sources are dwindling. The depletion of fossil energy is due to population growth that continues to increase [1]. Then, fossil energy is also known as an energy that is not environmentally friendly since it produces greenhouse gas emissions such as CO2, NOx, and SOx [2]. Therefore, renewable energy is needed as an alternative to fossil energy. In Indonesia, new and renewable energy (NRE) continues to be developed and optimized to support the national energy supply with a portion of NRE of higher than 17% by 2025 [3].

Renewable energy is divided into three, namely liquid, solid, and gas. Liquid, solid, and gas renewable energy such as bioethanol [4], biodiesel [5], biopellet [6], bio briquette [7], and biogas [8], respectively. One of the abundant renewable energy potentials in Indonesia is biomass-based renewable energy. Zentrum für rationelle Energieanwendung und Umwelt (ZREU) has calculated the potential of biomass resources in Indonesia to be around 146.7 million tons/year. Biomass can be produced from sugarcane bagasse, soybean stover, peanut

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shell waste, palm oil waste biomass (husk, fiber, empty fruit bunches, palm oil mill effluent), coconut stems and midribs, and agricultural waste corn (corncobs, corn stalks, and leaves) can be used as alternative fuels [9]. The results of burning biomass produce biogenic CO2, which is more environmentally friendly than the combustion of fossil fuels which produce fossil CO2 [10]. Biomass fuel from wood waste is a low-cost and economical energy source [11,12].

The existing biomass-based fuel used in Indonesia is biopellet. The biopellet was produced by a densification process using a pellet mill machine to increase densities [13] and caloric value [14]. Biopellet production was from materials containing cellulose [15], often of which come from agricultural wastes such as wood, corn waste [16], and oil palm empty fruit bunches [17]. The adhesive is an essential ingredient in the manufacture of biopellets. The use of adhesives aims to increase the bond between particles [18]. One adhesive that is familiar is tapioca since of its easy availability and low price [19]. Therefore, biopellet is potential energy in the present and promising in the future.

This study aimed to determine a literature review on biopellets as biomass-based renewable energy fuel that has potential and is promising in the future. The study covers the characteristics of biopellets based on the Indonesian national biopellet standard and the application of biopellets as stove fuel.

2 Writing method

The stages of article writing carried out:

1) Preparation
   The author formulates a problem or setting a theme that will be discussed in the article on biopellets as energy
2) Formulation of a theoretical framework
   The author develops a theoretical framework for research that has been carried outs on the characteristics of biopellets and the application of biopellets as fuel
3) Article writing
   The writing process uses references to proceedings and international journal articles. At this stage, the author describes the biopellet as potential and promising energy starting from the background of the problem, the purpose of writing the article, then the results and discussion.

3 Results and discussion

3.1 Biopellet production

3.1.1 Preparation of raw materials

Biomass or dry biomass waste and adhesives (usually using flour). Adhesive concentration 15% (w/w). 15% of 1000 g of dry biomass, which is 150 g of flour, is dissolved in 500 g of tap water, then homogenized [20].

3.1.2 Biopellet production

The biomass is mixed with adhesive with a 15% (w/w) concentration, then stirred until homogeneous and put into a pellet mill for printing. The resulting pellets are dried using an oven for 30 minutes [20].

3.1.3 Characterization of biopellet

The biopellet characterization refers to the test method of the Indonesian National Standard (SNI) 8021:2014 [21], as shown in Table 1. Meanwhile, the standard geometry of the product is cylindrical, namely 0.4-0.7 cm in diameter and 2.5-3.6 cm in length [22].

Table 1. Characterization of biopellet according to SNI 8021-2014.

No	Parameters	Methods	Units	Standard
1	Ash Content	Burned in the furnace at 650 °C for 5 hours	%	<1.5
2	Fixed Carbon Content	100% - (fixed carbon content + ash content + water content)	%	>14
3	Caloric Value	Bomb Calorimeter	cal/g	>4000
4	Water Content	Dried in a oven with temperature 105 °C for 3 hours	%	<12
5	Volatile Matter Content	Burned in the furnace at 950 ° C for 10 minutes	%	<80

3.2 Ash content

The following Table 2 shows the ash content of the biopellets.

Table 2. Ash content of biopellets.

No	Biopellets	Ash content (%)	Referenc e
1	Rice husk waste biopellet	12.98	[20]
2	Teakwood waste biopellet	1.22	[23]
3	Cacao pod husk biopellet	7.48	[24]
4	Water hyacinth biopellet	6.71	[25]
5	Hardwood chip reject biopellet	2.52	[26]
6	Camellia oil cake biopellet	2.12	[26]
7	Mulberry tree biopellet	1.96	[26]
8	Toothache tree biopellet	3.26	[26]

The eight biopellets have met the Indonesian national biopellet standard SNI 8021:2014 for the ash content parameter (<15%). Ash in biopellets is a mineral that cannot be burned after the combustion process and contributes to a decrease in the quality of biopellets [27]. Ash contains elements of silica, magnesium, potassium, and calcium are affect the caloric value of combustion [28]. Rice husk biomass contains high silica [29]. The higher the silica in the biomass, the higher the ash content; as a result, it can reduce the caloric value of combustion [18].

3.3 Fixed carbon content

The following Table 3 shows the fixed carbon content of the biopellets.

Table 3. Fixed carbon content of biopellets.

No	Biopellets	Fixed carbon content (%)	Referenc e
1	Rice husk waste biopellet	11.72	[20]
2	Teakwood waste biopellet	18.06	[23]
3	Cacao pod husk biopellet	9.29	[24]
4	Water hyacinth biopellet	6.68	[25]
5	Hardwood chip reject biopellet	15.11	[26]
6	Camellia oil cake biopellet	21.36	[26]
7	Mulberry tree biopellet	16.23	[26]
8	Toothache tree biopellet	7.76	[26]

The value of fixed carbon content of teakwood waste biopellet, hardwood chip reject biopellet, camellia oil cake biopellet, and mulberry tree biopellet has met the Indonesian national biopellet standard SNI 8021:2014 for the parameter of fixed carbon content (>14%). Meanwhile, the fixed carbon content of rice husk waste biopellet, cacao pod husk biopellet, water hyacinth biopellet, and toothache tree biopellet did not meet SNI 8021:2014. The small value of carbon content is thought to be due to the high ash content and volatile matter content [19]. Fixed carbon content dramatically affects the amount of caloric value. The higher the fixed carbon content, the caloric value; therefore, the biopellet will be better [30].

3.4 Caloric value

The following Table 4 shows the caloric value of the biopellets.

Table 4. Caloric value of biopellets.

No	Biopellets	Caloric value (cal/g)	Referenc e
1	Rice husk waste biopellet	4013.00	[20]
2	Teakwood waste biopellet	4642.20	[23]
3	Cacao pod husk biopellet	4308.42	[24]
4	Water hyacinth biopellet	3790.49	[25]
5	Hardwood chip reject biopellet	4299.23	[26]
6	Camellia oil cake biopellet	4896.34	[26]

7	Mulberry tree biopellet	3702.11	[26]
8	Toothache tree biopellet	3582.69	[26]

The caloric value of rice husk waste biopellet, teakwood waste biopellet, cacao pod husk biopellet, hardwood chip reject biopellet, camellia oil cake biopellet has met the Indonesian national biopellet standard SNI 8021:2014 for the caloric value parameter (>4000 cal/g). Meanwhile, the caloric value of water hyacinth biopellet, mulberry tree biopellet, and toothache tree biopellet did not meet SNI 8021:2014. The low caloric value is due to the high ash value, high volatile content, and small fixed carbon content [19,30]. The caloric value of the biopellet is influenced by the energy content of the biomass, the moisture content, and the ash content of the biopellet [31]. Caloric value is the essential parameter to determine the quality of biopellets. The higher the caloric value, the better the quality of the biopellet [32].

3.5 Water content

The following Table 5 shows the water content of the biopellets.

Table 5. Water content of biopellets.

No	Biopellets	Water content (%)	Reference
1	Rice husk waste biopellet	8.88	[20]
2	Teakwood waste biopellet	13.70	[23]
3	Cacao pod husk biopellet	8.05	[24]
4	Water hyacinth biopellet	4.83	[25]
5	Hardwood chip reject biopellet	7.60	[26]
6	Camellia oil cake biopellet	7.24	[26]
7	Mulberry tree biopellet	8.30	[26]
8	Toothache tree biopellet	7.87	[26]

Of the eight biopellets, only the water content of teakwood waste has not met the Indonesian national biopellet standard SNI 8021:2014 for water content (<12%). Water content is one of the parameters determining pellet quality that affects the caloric value of combustion, combustion power, ease of ignition, and the amount of smoke produced during combustion [31]. The greater the water content in the fuel, the smaller the caloric value, and vice versa [33]. The greater the water content in the fuel, the greater the amount of smoke produced during combustion, and vice versa [31].

3.6 Volatile matter content

The following Table 6 shows the volatile matter content of the biopellets.

Table 6. Volatile matter content of biopellets.

No	Biopellets	Volatile matter content (%)	Referenc e
1	Rice husk waste biopellet	66.42	[20]
2	Teakwood waste biopellet	60.12	[23]
3	Cacao pod husk biopellet	75.18	[24]
4	Water hyacinth biopellet	81.78	[25]
5	Hardwood chip reject biopellet	82.37	[26]
6	Camellia oil cake biopellet	76.52	[26]
7	Mulberry tree biopellet	81.81	[26]
8	Toothache tree biopellet	88.98	[26]

The values of the volatile matter content of rice husk waste biopellets, teakwood waste biopellets, cacao pod husk biopellets, and camellia oil cake biopellets have met the Indonesian national biopellet standard SNI 8021:2014 for the parameter volatile matter content (<80%). Meanwhile, the volatile matter content of water hyacinth biopellet, hardwood chip reject biopellet, mulberry tree biopellet, and toothache tree biopellet have not met SNI 8021:2014. The volatile matter content is an indicator of the amount of smoke produced during combustion in the form of biopellets [32]. The higher the amount of volatile matter in the biopellet, the more smoke is produced during the combustion process [19], and the fuel efficiency decreases [34].

3.7 Application of biopellets as stove fuel

Harsono et al. [35] reported that a biomass stove using coffee husk waste biopellet with dimensions of 25 cm x 25 cm x 28.5 cm and a combustion capacity of 260 grams has a good performance. The heat generated on the stove 10, 20, and 40 holes respectively are 308.292, 310.601, and 316.880 kJ. The energy required to raise the temperature of an object is affected by differences in mass, heat, and temperature [36–38]. The thermal efficiency produced on stoves 10, 20, and 40 respectively were 16.39%, 15.96%, and 15.38%. The thermal efficiency of the biomass stove is obtained from the comparison between the heat for evaporation of water and the heat generated by the biopellet [39].

Stoves that produce emissions from the highest to the lowest are a 10-hole stove of 298 ppm, a 20-hole stove of 289 ppm, and a 40-hole stove of 273 ppm [35]. In the combustion process, incomplete combustion often occurs that produces carbon monoxide (CO). A high CO level is an indication of an incomplete combustion process [37,40]. The higher the flame temperature, the higher the heat generated, which can minimize wasted CO [38,41]. The biopellet stove has passed the CO emission test because CO emissions do not exceed the maximum limit of 67 g/kg or the equivalent of 67000 ppm [42]. The 40 hole stove has the lowest emissions. This is because the 40 hole stove has the highest operating temperature. The best performing biomass stove is a 40-hole biomass stove.

Hadi and Andreas [43] reported that the price of biopellet is Rp. 1500 per kg, kerosene is Rp. 8000 per liter, and LPG is Rp. 15000 per 3 kg. Therefore, the energy cost per month is IDR 45000 if use biopellets. That is equivalent to 9 kg of LPG and 5.6 liters of kerosene per month. One small family can reduce fossil fuels and LPG use by biopellets as the primary energy source for household activities.

4 Conclusions

Biopellet characteristically has complied with SNI 8021-2014 for parameters of ash content, fixed carbon content, caloric value, water content, and volatile matter content. The application of biopellet as a stove fuel also shows good performance for heat, efficiency, and emission parameters. One small family can reduce fossil fuels and LPG 9 kg of LPG and 5.6 liters of kerosene per month if using biopellets as the primary energy source. Biopellet is a fuel that is easy to make, good quality, environmentally friendly, and has economic value. This proves that biopellet is a biomass-based renewable energy fuel that has potential in the present and promising in the future.

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