Electrical Energy Potential of Corn Cob as Alternative Energy Source for Power Plant in Indonesia

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Abstract

Utilization of coal as a source of electrical energy in the power plant in Indonesia was increased significantly every year, but it can damage the environment if the excessive use of it is not anticipated. This study was conducted by analyzing the potential energy of the corn cobs (CC) in every province. The conducted study is on energy content and ash content of CC. The study shows the potential of the electric energy of CC is available only in 12 provinces that enable for the operation of the power plant with a capacity of 10 MW. However, the waste CC is highly feasible to use as fuel in the power plant because it has a calorific value of about 16.92 MJ/kg which is greater than the calorific value of rice husk around 13.44 MJ/kg and rice straw around 12.56 MJ/kg, and has a ashes around 2.14 % which is very small compared to ashes of rice husk and rice straw which are 19.11% and 18.51%, respectively. The study results are expected to contribute to reducing the use of coal at the power plant.

Keywords: Corn Cob, Alternative fuel, Electrical energy, Power Plan

1. INTRODUCTION

The electrification ratio in Indonesia in 2013 was still low which about 76.96%[1]. The number shown that there were still many people did not use electricity, especially in remote areas. The blackouts happens frequently even in the urban areas due to generation capacity which was not able to serve the demand of the peak load. To avoid the environmental impact caused by the use of coal as an energy source, it is suggested that the use of coal was reduced by optimizing biomass fuels that are environmentally friendly. The utilization of fossil fuels in Indonesia is still very high, which almost reach 95%. This suggests that the use of renewable (non-fossil) is only about 5%. The use of fuel oil, coal, and gas as an energy source reaches approximately 49.5%, 26% and 20.4%, respectively. Indonesia has the potential of biomass energy sources, including corn cob (CC) which has not been used as a source of electrical energy, largely discarded as waste. This study was conducted to obtain data on the energy potential of the CC as an alternative energy source to reduce the use of coal as a fuel in the power plant in Indonesia. Results of this study are expected to contribute in the development of the potential of biomass as a source of electrical energy derived from coal.

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2. EXPERIMENTAL

2.1 Analysis of Electric Energy Potential of CC

The analysis of potential electrical energy is carried out by using data on the potential of CC, calorific value (CV) of CC, and the value of Corn-to-Grain Ratio (C_{GR}). CV measurement is done by using a bomb calorimeter, while the determination of C_{GR} was performed using a digital balance. Potential of CC (W_{CC}) is determined based on the corn production (CP) with reference to the methods of previous studies[2 - 6]. The potential of CC is determined by the following equation::

$$W_{CC} = C_{GR} \times CP \times C_E \tag{1}$$

where C_E is the collection efficiency (90%). Furthermore, the potential energy of CC (EP_{CC}) can be obtained using the equation:

$$EP_{CC} = W_{CC} \times CV_{CC} \tag{2}$$

where CV_{CC} is the calorific value of CC. Actual electrical energy (EE_{ACC})) is thus given as the following equation:

$$EE_{ACC} = \frac{EP_{CC}}{C_F} \times \eta_O \tag{3}$$

where CF is the conversion factor of Joules into a watt-hour. The actual electric power of CC (PP_{ACC}) can be obtained by using the overall conversion efficiency (η_O) of biomass power plant. The η_O of CC is used about 20% closer to the η_O of rice straw around 20 - 27%[7] and rice husk around 20 - 23%[8], with equation:

$$PP_{Acc} = \frac{EE_{cc}}{C_{FP}} \times \eta_O \tag{4}$$

where C_{FP} = 365 × 24 × 3600 is conversion factor to obtain electrical power (kW) and η_O is overall conversion efficiency of biomass power plants. Meanwhile, the economic potential of CC had been estimated by determining the equivalence of the energy content of coals (Eq_{Coal}) is expressed by the following equation:

$$Eq_{Coal} = \frac{EP_{CC}}{CV_{Coal}} \tag{5}$$

where CV_{Coal} = 27 MJ/kg [6, 9].

2.2 Proximate and Ultimate Analysis of CC

Proximate and ultimate analyses are based on to the previous studies[10-16]. Proximate and ultimate analyses were carried out to determine the quality of CC as fuel for power plants. Proximate analysis of the samples was conducted to determine the CV, moisture content (MC), volatile matter (VM), fixed carbon (FC), and ash content (AC). CV was done according to the standard methods, i.e ASTM D.5865. The ultimate analysis was conducted to determine the chemical components of the sample, which contains carbon (C), hydrogen (H), nitrogen (N), sulfur (S), and oxygen (O). Determination of MC was based on ASTM Method D 3173, determination of AC is based on ASTM Method D 3174, determination of VM by using the method of ISO 562.1998, determination of FC by using the method of ASTM D.3172. Determination of C, H, and N using the method of ASTM D 5373-02 and ASTM D 3176-3179, determination of S base on the method D3177-75.

3. EXPERIMENTAL RESULTS

3.1 Electrical Energy Potential of CC

Electrical energy potential of CC is determined by using a CV of about 16.92 MJ/kg based on the results of the study. This is close to the CV of the results of previous studies, which is 16.63 MJ/kg[17] and 16.83 MJ/kg [18]. Electric energy of CC in the year 2013 can be obtained by using Eq. (1) - Eq. (4). The economic potential of CC is determined by Eq. (5), which shows the economic value of CC when it is converted into energy coal (Eq_{Coal}) and when it replaces coal as a fuel in the power plant. The results of the analysis of the electric energy and the economic potential of the CC in the year 2013 are presented in Table 1.

Table 1 shows the total potential of the CC in 2013 obtained approximately 23,020,431 tons, equivalent to 14,426,142 tons of coal. This potential will generate electrical energy (EE_{CC}) approximately 21,641 GWh and electric power (PP_{CC}) of approximately 2,472 MW. The data shows only 12 provinces that have the potential of CC which generates electrical power above 10 MW, the largest is about 1,824 MW in East Java whereas Yogyakarta has the smallest which is about 10 MW. While the others 21 provinces only have electrical power capacity which is less than 10 MW. Therefore, it can develop a 10 MW power plant with CC, as is presenter in Figure 1.

3.2 Proximate and Ultimate Analysis and CV of CC

The result of proximate and ultimate analysis and CV of CC was validated by comparing the results of the previous studies. The study shows CV and the parameters of proximate and ultimate which is almost the same as some previous studies[17-20], as in table 2. This shows the level of accuracy of the data obtained, so that the data fits to be used as a reference for future research. Based on the study results obtained that CC is very feasible to use as fuel in the power plant because it has a CV of about 16.92 MJ/kg which is greater than the CV of rice husk about 13.44 MJ/kg[5] and rice straw about 12.56 MJ/kg[2], and produce AC of about 2.13%, is very small compared to AC of rice husk and rice straw around 19.11%[5] and 18.51 %[21] respectively. Aside from the CV and AC of lower, CC also contains MC around 7.07% of lower compared to MC of rice husk which is about 10.3 - 11%[22, 23] and rice straw around 8.25 - 15%[23, 24].

Table 1. Actual electrical energy and electric power of CC in each province of Indonesia in 2012.

No	Province	CP (ton)	W_{CC} (ton)	Eq_{Coal} (ton)	EP_{CC} (TJ)	EE_{ACC} (GWh)	PP_{ACC} (MW)
1	East Java	62,950,301	16,996,581	10,651,191	287,582	15,977	1,824
2	West Java	10,280,653	2,775,776	1,739,486	46,966	2,609	298
3	Central Java	3,041,630	821,240	514,644	13,895	772	88
4	Lampung	1,741,988	470,337	294,745	7,958	442	50
5	South Sulawesi	1,514,636	408,952	256,277	6,920	384	44
6	North Sumatra	1,347,124	363,724	227,934	6,154	342	39
7	West Nusa Tenggara	654,444	173,522	108,741	2,936	163	19
8	Gorontalo	642,674	176,700	110,732	2,990	166	19
9	East Nusa Tenggara	629,386	169,934	106,492	2,875	160	18
10	West Sumatra	495,497	133,784	83,838	2,264	126	14
11	North Sulawesi	440,308	118,883	74,500	2,012	112	13
12	Yogyakarta	336,608	90,884	56,954	1,538	85	10
13	Aceh	170,123	45,167	28,305	764	42	5
14	West Kalimantan	167,285	45,933	28,785	777	43	5
15	South Kalimantan	141,649	30,258	18,962	512	28	3
16	Central Sulawesi	122,545	38,245	23,967	647	36	4
17	West Sulawesi	112,066	33,087	20,735	560	31	4
18	Bengkulu	112,285	28,018	17,558	474	26	3
19	South Sumatra	103,771	30,317	18,999	513	29	3
20	Bali	78,447	16,706	10,469	283	16	2
21	Jambi	61,873	6,904	4,327	117	7	1
22	Banten	25,571	2,651	1,661	45	3	1
23	East Kalimantan	9,940	2,684	1,682	45	3	0.4
24	Southeast Sulawesi	31,433	21,181	13,274	358	20	2
25	Riau	7,895	8,487	5,319	144	8	1
26	Central Kalimantan	9,819	2,132	1,336	36	2	0.2
27	Papua	6,393	1,726	1,082	29	2	0.2
28	Maluku	18,275	4,934	3,092	84	5	1
29	North Maluku	2,554	640	401	11	1	0.1
30	West Papua	2,049	553	347	9	1	0.1
31	Bangka Belitung	964	260	163	4	0	0
32	Jakarta	6	2	1	0	0	0
33	Kepulauan Riau	849	229	143	4	0	0
	Total	85,261,041	23,020,431	14,426,142	389,506	21,641	2,472

Table 2. Current study and previous studies for CV, proximate and ultimate analysis of CC.

Parameter	Unit	Current study	Previous studies			
			[17]	[19]	[20]	[18]
Calorific value	(MJ/kg)	16.92	16.63	-	-	16.832
Proximate Analysis						
FC	(%)	8.18	6.86	8.24	10.16	12.80
VM	(%)	82.62	84	80.66	85.67	79.10
MC	(%)	7.07	6.06	4.87	3.64	4.47
AC	(%)	2.13	3.08	6.23	3.53	7.75
Total	(%)	100	100	100	100	100
Ultimate Analysis						
C	(%)	44.07	44.43	47.63	47.63	44.60
H	(%)	6.33	7.24	4.91	4.91	6.0
O	(%)	46.9	47.67	37.72	46.48	48.07
N	(%)	0.55	0.51	0.84	0.84	0.73
S	(%)	0.02	0.15	0.14	0.14	0.06
AC	(%)	2.13	3.08	6.23	1.53	7.75
Total	(%)	100	100	100	100	100

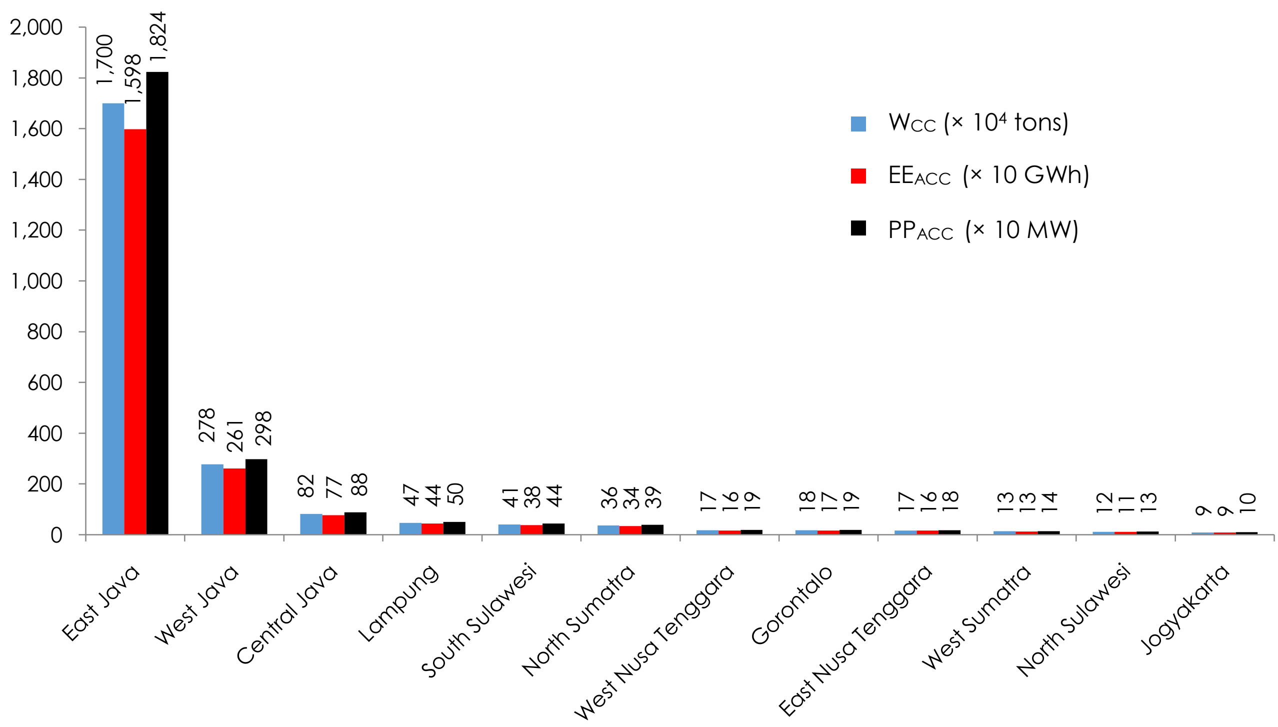

Fig.1. Actual **e**lectrical energy and electric power of CC is available on 12 provinces in Indonesia

5. CONCLUSIONS

The potential of corn cob which are available in Indonesia has not been evenly distributed in every province, only 12 provinces that have the potential of electrical energy with a capacity of about 10 to 1,824 MW. The potential enables the operation of the power plant with a capacity of 10 MW. Based on the energy content, corn cob extremely fits to be used as fuel in the power plant because it has a calorific value of about 16.92 MJ/kg which is greater than the calorific value of rice husk 13.44 MJ/kg and rice straw 12.56 MJ/kg. In addition, the corn cob generates approximately 2.14% ash content which is very small compared to ash content produced by rice husk and rice straw, which is 19.11% and 18.51%, respectively.

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