Physicochemical Characteristics of Corn Silk as Biomass Fuel Feedstock

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Abstract. The potentials of corn silk in terms of its physicochemical properties and its heating value have been investigated. The sample was originated from Badas village, district of Kediri, East Java, Indonesia. The original material underwent a drying process in the oven at 100 ℃ for 90 minutes. The dry materials were continuously pulverized and filtered to reach the mesh size of 60. Subsequently, the sample was tested according to the proximate standard to specify its physical properties, while its elemental composition was investigated under the energy-dispersive X-ray (EDX) spectrometry procedure. The results showed that corn silk contains the moisture, volatile matter, fixed carbon, and ash in respective value, i.e., 8.6 (wt%, as received), 72.2, 22.4, and 5.4 (wt%, dry basis). The EDX test showed that C and O present as the dominant element. The gross calorific value assessed by using adiabatic bomb calorimeter was 19.50 MJ/kg.

Keywords: Corn silk, physical properties, chemical properties, biofuel, feedstock

1. Introduction
Energy is a basic human need, which is continuously increasing, especially in densely populated countries [1]. The energy consumption by type in Indonesia during the years of 2010-2015 was still dominated by fuel (gasoline, diesel oil, kerosene, avtur, and avgas) that reached 25%, followed by natural gas (11%), electricity (11%), coal (6.2%), and liquefied petroleum gas (LPG) (4.8%) [2]. Fossil fuel is one of the nonrenewable energy sources which has been supplied all the energy needs of various sectors. In fact, numerous energy resources in Indonesia, which are hydropower, geothermal, natural gas, coal, peat, biomass, biogas, wind, ocean energy, solar, and others can be utilized as alternative energy, replacing dependence on fossil fuels that are increasingly limited in reserves.

Indonesia has the potential of renewable energy resources that was quite large with a fairly diverse in variations. The most potential renewable energy resource in Indonesia is hydropower that followed by ocean thermal energy conversion (OTEC) and biomass energy. One of the biomass energies with the most potentials in Indonesia is the agricultural waste, such as rice husk, rice straw, bagasse, corn cobs,
corn stalks, and plantation wastes. Recently, the corn waste becomes one of the biomass materials that
draws a great deal of interest of the researchers.

According to the latest data released by the Central Bureau of Statistics [3], the corn land area in
Indonesia in 2017 reached 5,375,387 hectares and produced corn at around 51.78 quintals per hectare.
Corn silk productivity reached 527 kg per hectare [4]. Based on these data, the overall corn silk
production in the year 2017 can be estimated at around 2.85 million tons. This product is a considerable
amount considering that the corn production continues throughout the year.

The majority part of the corn plant that commonly utilized as energy were corn stover and corn seeds
[5,6], while the part of the corn plant that rarely used as energy resource was the corn silk. Corn silk has
a lot of potentials to be utilized as a variety of products. The corn silk is mostly used for urine laxative,
lowering blood pressure, and as the adsorbent material. In the field of energy, corn silk is used as a
superior electrode [1,7]. However, the potential of corn silk as fuel raw materials has not been
investigated yet. Therefore, it is critical to conduct in-depth research to understand the potential of corn
silk as a renewable fuel feedstock that is expected to be a long-term energy reserve. This study aimed to
provide basic information about the potential of corn silk as fuel by investigating its physical and
chemical properties, as well as its heating value.

2. Methods

2.1. Proximate and heating value analysis

The proximate test was conducted in agreement with the ASTM standard method of D 2961-17, D
31575-17, D 3172-13, and D 3174-12 to achieve the appropriate moisture, volatile matter, fixed carbon,
and ash. The calorific value of biomass was tested through the use of adiabatic bomb calorimeters, in
which 0.5 gram of the sample subjected to apparatus in accordance with the ASTM D 5865-13.

2.2. Element analysis
The energy-dispersive X-ray (EDX) spectrometry was occupied to evaluating the chemical elements of
the biomass. The image of a scanning electron microscope (SEM) was gained through the apparatus of
FEI Inspect S50 equipment in coordination with the capability of X-ray microanalysis (AMETEK
EDAX TSL). The effect of surface-electron-charging which may distort the image was eliminated by
means of coated the sample with gold.

3. Results and Discussion

3.1. Physical properties and heating value

The proximate and heating value of corn silk depicted in Table 1.

| Parameters          | Unit  | ar* | db** |
|---------------------|-------|-----|------|
| Total moisture      | % wt  | 8.6 |      |
| Volatile matter     | % wt  | 66.0| 72.2 |
| Fixed carbon        | % wt  | 20.5| 22.4 |
| Ash                 | % wt  | 4.9 | 5.4  |
| Gross calorific value | kcal/kg | 4259 | 4660 |

*ar: as received, **db: dry basis

Table 1 shows the content of moisture (water) in corn silk is 8.60 (wt%, ar), volatile matter when in
a fresh condition is 66.0 wt%, and 72.2 wt% when in the dry condition, the carbon content in a fresh
condition is 20.5 wt% and 22.4 wt% in the dry condition. This content was an essential parameter for
biomass fuel [8,9]. The water content (moisture) was a fundamental property that affects the combustion
characteristics of biomass [9], it is mainly because the energy required to release the moisture before the
The combustion process takes place would reduce the temperature in the combustion chamber. This fact significantly influenced the initial burning temperature and overall efficiency of the system. The next parameter that fundamentally recognized was the content of volatile matter, in which it affected the thermal characteristic of solid fuel. The volatiles released the rate and its amount determined the flame stability and overall combustion characteristic in the furnace.

GCV (gross calorific value) is defined as the quantity of releasing heat, includes the latent heat of condensed water from formation vapor when a unit mass of the fuel is burnt completely [10,11]. For this purpose, the combustion products are cooled under standard conditions. Table 1 indicates the GCV of corn silk was 4660 kcal/kg or equivalent with 19.50 MJ/kg. This value was lower than municipal solid waste [12] and synthetic waste [13], in which their GCV were 25.78 and 33.87 MJ/kg, respectively. However, when comparing this GCV of corn silk with aquatic and terrestrial plant biomass, then corn silk was comparable or higher than that of both types of biomass. The aquatic biomass from the class of microalgae, i.e., *Nannochloropsis oculata*, *Isochrysis galbana* and from the class of macroalgae, i.e., *Sargassum spp*, their respective GCV were 16.80 [8,14], 16.22 [15], and 10.6 MJ/kg [16]. The corn silk’s GCV also higher than sugar cane straw, bagasse, and cotton residue, in which their GCVs were 17.19, 14.258, and 16.90 MJ/kg, respectively [15]. Moreover, this GCV of corn silk was comparable to beech wood and spruce wood that GCV’s value of 19.3 and 19.5 MJ/kg, in that order [11]. This result confirms that the potential of corn silk as a fuel raw material.

### 3.2. Chemical Properties

The EDX spectrograms of corn silk biomass, its elemental composition, and the scanning area are shown in Figure 1. The average measurement results are depicted in Figure 2.

![Figure 1](image1.png)

**Figure 1.** The EDX spectrograms (A), chemical composition (B), and scanning area (C) of corn silk biomass.
Figure 2. Chemical properties of corn silk. Error bar represented the relative standard error of the mean from 3 replications

Figure 2 reveals that the carbon and oxygen in corn silk are present in the predominant value. The carbon content in corn silk is 45.83 (w,t%), and the oxygen content is 46.43 (w,t%). These both elements of C and O significantly influenced the combustion performance of the biomass. Carbon was the primary contributor to fuel energy generation because it was reacted with oxygen by means of exothermic reaction resulted in carbon dioxide and releasing the amount of energy. Meanwhile, oxygen that released during thermal degradation of biomass material acted as an oxidizer that led to increase the material reactivities. Therefore, a high amount of C and O in the corn silk biomass had offered its potential as a fuel feedstock. Besides, in the inorganic elemental point of view, the presence of a significant amount of potassium (K) in this material will contribute to the decreasing ash melting point in the biomass combustion system[17].

4. Conclusions

The fundamental properties of corn silk regarding its potential as fuel feedstock have been characterized. Physical properties investigation revealed that it had a high amount of volatile. The energy content of corn silk that represented as GCV was higher than that of aquatic biomass and that of several land plantation. The elemental analysis indicated that the corn silk was containing a great amount of carbon and oxygen, in which both have almost the same content. Finally, because of the high volatile matter content of corn silk, it may be possible to be a raw material for gasification or co-firing with other solid fuels to improve the fuel reactivity.

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