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Research Paper

Enhanced Biomass Characteristics Index in palm biomass calorific value estimation

Tang Jiang Ping [a,*], Lam Hon Loong [a], Mustafa Kamal Abdul Aziz [b], Noor Azian Morad [b]

[a] Centre of Excellance for Green Technologies, University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor, Malaysia
[b] Centre of Lipid Engineering and Applied Research, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia

HIGHLIGHTS

- Relationships among biomass bulk density, moisture content and calorific value.
- An index for each biomass material is proposed to reflect the relationships.
- Specific index range predicts the similar physical properties of biomass material.

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ABSTRACT

Oil palm industry contributes a huge amount of valuable crude palm oil, and simultaneously producing a large quantity of plantation waste or biomass, which will be utilized as fuel. In order to give a clear insight of the energy output estimation from the biomass, a comprehensive study on the physical properties of the biomass: bulk density and moisture content is crucial. In a conventional approach, these properties are obtained through empirical methods on individual sample basis. However, the conventional empirical methods have several drawbacks: (i) require a huge amount of experimental results to construct biomass properties' curve (ii) data variation affects the accuracy of analysis result. These create a limitation in properties estimation and further affecting the optimum biomass utilization. To tackle this issue, there is a need to search for a direct representation of the properties. A Biomass Characteristics Index (BCI) is proposed to represent the relationship between bulk density and moisture content. A numerical framework is developed to determine the BCI. This index is used to estimate the biomass bulk density and moisture content before the calorific value calculation. A regression graph is plotted to illustrate the relationship among those values with respect to different appearance shapes of biomass. The result shows that different size and shape of biomass has its own specific BCI. The classification of biomass according to its specific BCI can forecast the related bulk density and moisture content. Therefore, it reduces the hassle, especially in terms of time constraint to get those values through conventional empirical method. This will increase the overall biomass operational management efficiency.

1. Introduction

Biomass, such as agricultural residues, has been widely transformed from waste to reusable matter. In particular, it is used as an alternative fuel source for power generation. Thermal processes (gasification, pyrolysis, combustion) convert biomass into specific form (pellet, bulk, and granule) for energy generation purpose (combine heat and power, co-firing). Currently, biofuel has evolved from first generation to third generation. The first generation biofuel is obtained directly from traditional food feedstock such as sugarcane and corn or direct burning of solid biomass. It involved less processing technology, yet the quantity is limited and is not a cost effective solution for environment. Thus, second generation biofuel is created. A wide options of feedstock are available through forestry residues, agricultural residues, energy crops, food waste, industrial waste and municipal waste. Due to the moisture content in the raw materials and as they come in different shapes, these materials are heavily dependent on post processing (shredding, densifying, pulverizing and handling) and conversion technologies (gasification, pyrolysis, combustion) to be used as fuel source. Nevertheless, the processes and technologies involved are able to increase the amount of fuel for the power generation plant as compared to the first generation. For example, gasification of

* Corresponding author.
E-mail address: kebx3tjn@nottingham.edu.my (J.P. Tang).

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biomass converts the maximum available energy content to increase the efficiency of power generation [1]. By utilizing those residues mentioned above, it also has the potential to save the environment. Finally, third generation comes into play with algae biomass, which is also a non-food feedstock. It produces biofuel which is called advanced biofuel [2]. However, it is facing several challenges ranging from technical, economical to geographical issues in the current stage. The developing tropical countries such as Southeast Asia countries, which although are blessed with rich forest resources and have abundant supply of agricultural residues, are unfortunately, have yet to take a leap forward to upgrade from first generation biofuel to second generation, not to mention the third generation. The reason behind the lag is primarily due to the lack of willingness to pour in investment in biomass utilization technology, hence the immature technologies. Given that Southeast Asian countries have plenty of bio residues at low cost or even no cost at all; direct burning without any advanced processing is deemed to be preferable as there is no additional cost incurred. Therefore, the development of biomass technologies in Southeast Asia is far lagging behind as compared to European countries, which have lesser natural resources and limited land area, and are usually facing severe weather.

2. Literature review

In Malaysia, palm oil mill left over a huge amount of waste after the fresh fruit bunches have been processed for the oil extraction. Among those residues, the most reusable matters are empty fruit bunch (EFB) and palm kernel shell (PKS) [3]. The factor that determines the usefulness of these biomass is the calorific value. Higher calorific value indicates higher efficiency as an energy source [4]. Before biomass can be sent into the plant for conversion or power generation, storage and transportation issues of raw feedstock have to be taken into account. The questions of where to store and how to send are closely related to the physical characteristics of biomass – the moisture content and bulk density. Both properties are interrelated and linked to the structure and physical shape of biomass. Moisture content is the quantity of water that contains in the biomass material, while bulk density is defined as the ratio of biomass mass over its volume. Limitations to raw biomass are high moisture content, low bulk density and therefore lower calorific value. Low bulk density leads to the difficulties of material handling, storage, transportation [5], while the higher moisture contents decrease the calorific value of biomass [6]. For instance, oil palm empty fruit bunch (EFB) bulk density is lower when it has more moisture within. Empty fruit bunch with higher moisture content is more difficult to be compacted, thus occupies more spaces which increase the total volume. The final bulk density will get lower and this will increase the difficulties of storage and transportation [7]. Besides this, bulk density changes with types, size and shape of the biomass itself. Refer to Figs. 1 and 2, the appearance and shape of raw empty fruit bunch is totally different from shredded bunch. Therefore, bulk density of a dry raw empty fruit bunch is definitely lower than shredded empty fruit bunch because smaller particle size of biomass occupies lesser space with same weight of mass.

Besides moisture content, air volume also influences bulk density. Free air space (FAS) is measured on solid organic waste during composting process. The distribution of air in the waste will affects the performance of composting [8]. Free air space represents the ratio of air volume over global volume (air, water, solid). A pycnometer will be used for free air space measurement. At higher bulk density, the air voids will be displaced as the solid becomes more compacts. This shows a linear relationships between free air space and bulk density for manure compost [9] There are various studies related air porosity to bulk density [10] and the

Fig. 1. Raw empty fruit bunch.

Fig. 2. Shredded fiber from empty fruit bunch.

relationships are established on different biomass types. Therefore, it is possible that biomass has air voids trap inside the material itself especially for the fibrous biomass like empty fruit bunch. The space in between the particle of biomass material is a perfect spot for air voids.

Moisture content and bulk density have been studied separately depends on the application area (refer to Table 1), either the pretreatment process or end product (mostly is pellet). The focus of the research is targeted on the performance of final product rather than the raw biomass itself.

There is no integration on both properties to indicate the initial biomass appearance and shape before the biomass pre-treatment stage. Raw biomass form has essential information that determines the handling, transportation and storage issues [33]. These information can be fed into biomass supply chain for the purpose of optimized resource planning [34]. A well-planned supply chain design plays an important role to achieve the efficiency in cost and energy utilization [35].

Secondly, acquisition of bulk density and moisture content are obtained through empirical methods such as the British Standard [36]. Results from those methods may vary from sample to sample and limit by handling procedures. There is no standard or reference value of bulk density and moisture content for one particular biomass such as empty fruit bunch (EFB). In certain analysis, either one of the characteristics – bulk density, moisture content or component breakdown of biomass is involved. This shows the lack of