Physical properties and calorific value of briquettes produced from Palmyra palm waste with molasses binder

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Abstract. This work aims to produce briquette made from Palmyra palm waste using molasses as a binder. The amount of binder to charcoal ratios was studied. The physical properties i.e., density, moisture content, ash content, volatile matters, fixed carbon, calorific value and cooking efficiency were investigated. It was found that the amount of binder had a significant effect on the quality and properties of the briquette. The results showed that the amount of binder decreased with moisture content and ash content decreased while density and calorific value increase. All briquettes produced with molasses binder pass the criteria of the Thai Community Product Standard (tcps 238/2547). These results provide an alternative energy for household use.

Keywords: Briquette, Palmyra palm, molasses, physical properties, Calorific value

1. Introduction

The demand for fuel energy has been increasing over the years in developing countries. However, non-renewable source of energies are depleted rapidly. So, a decreasing availability source has been concerned. A number of researches tend to study the utilization of agricultural waste and residues. Energy in the form of charcoal has been the most conventional source of renewable energy in developing countries. Large amount of agricultural waste and residues are generated annually. The utilization of them instead of firewood as alternative energy source could help due to its environmental friendliness and preventing deforestation.

However, charcoal has many drawbacks which can be overcome by way of compression into a uniform solid with binder and water either by hand or press machine for briquette production to improve fuel quality giving more practical and economical. This is to increase strength, durability, long time burning and reduce cost of transportation, handling and storage. Moreover, it is a desirable fuel because of non-sparking and smokeless fire. Briquettes have been developed as an option for value addition of biomass wastes being sustainable energy development such as rice husk [1], sawdust [2-3], banana tree waste [4-5], bagasse [6], organic waste [7] and coconut shell [8]. Binding agents such as cassava starch [1], molasses [3,9] and clay [5-6] have been employed. Briquette quality and properties were influenced by the proportion of binders [5]. A study by Canage, et. al. [10] reported that higher amount of molasses increase fixed carbon, volatile matters and moisture content while ash content decrease.
Palmyra palm is one of the sources of biomass available in Thailand. It generated large amount of trash. The strategy is to minimize a plenty of waste achieving zero waste by value addition. Moreover, it could help enhance environmental protection and conservation. So, Palmyra palm waste can be utilized as a raw material for the production of charcoal briquette as a fuel in a household use to reduce the wood charcoal consumption. Molasses, by-product obtained from the sugar manufacturing process, is highly viscous, inexpensive and easily available which are the characteristic required to use as an excellent binder.

This research work intent to produce briquettes developed from Palmyra palm waste with molasses as binding agent including study their quality and properties to determine the compatibility and effectiveness of these briquettes.

2. Methodology

2.1. Raw materials
Palmyra palm waste which is the agriculture waste for this study was collected from cultivated areas in Kanchanaburi province, Thailand. Sample was dried on sunlight to reduce moisture before being carbonized in a 200 liter drum pyrolyzer to obtain charcoal. For the binder ingredient, three conditions of molasses contents were prepared at the ratios of 5%, 10% and 15% of the weight of charcoal.

2.2. Methods of briquette production
After carbonization, the charcoal prepared was milled and sieved to obtain fine powder. The fine powder charcoal was then homogeneously mixed manually with molasses, as binding agent, at the different mixing ratio of 5%, 10% and 15% w/w, followed by adding water as required. Thereafter, the mixtures were briquetted via the cold extrusion process with a designed shape. The resulting briquettes were dried in an oven at a temperature of 100 °C for 48 hours to reduce moisture content.

2.3. Characterization
The quality and properties of briquettes produced i.e., density, moisture content, ash content, volatile matters, fixed carbon and calorific value were determined according to the ASTM standard. Data analysis was done with SPSS statistical software to test the difference for the parameters in briquettes produced. The results were assessed to be statistically significant when P<0.05.

3. Results and discussion
All briquette mixtures obtained from Palmyra palm waste and molasses binder at the proportion of 5, 10 and 15% w/w could keep well the cylinder shape along the extruder machine showing that these briquettes have good forming ability. The briquettes obtained have a uniform black color, cylindrical shape of 100 mm length, 40 mm diameter and 10 mm with hollow holes in the middle in order to let air penetrate inside enhancing combustion process as shown in Figure 1. They have smooth surface without crack indicating that 5% w molasses contents mixed with Palmyra palm waste charcoal was enough to coat the surface. While some of briquettes produced from others agriculture waste required a large proportion of binder, such as tamarind peel using tapioca starch and molasses as a binder at a ratio of 33-100% w/w [11], water hyacinths using molasses at the ratio of 166-233% w/w [9]. In this study, briquettes can be formed cylindrical shape without adding molasses. However, it is brittle and easily broken. The addition of molasses as binder improved the endurance of the briquette to breakage. Therefore, the briquette production is necessary to use the binding agent in order to store and transport to users and use as fuel.

The effects of the Palmyra palm waste charcoal and molasses binder proportions on the briquettes at various properties are discussed in detail according to the values obtained in Table 1.
3.1. Densities
Densities of all briquettes obtained are displayed in Table I. The densities were in the range of 0.99-1.02 g/cm³. Comparison between each briquette indicated that briquette mixed 5 % w/w molasses had the highest density followed by 10 % and 15 % w/w, respectively. So, density increased as molasses proportion decreased. However, there were no significant differences (p>0.05) on density of briquettes prepared from the different molasses contents. Density is an important property of briquette. High density is desirable because the higher value of density, the easier for transportation, handling and storage.

3.2. Moisture content
The moisture contents were in the range of 5.84 - 6.32%. Sample prepared using 5% w/w molasses gave the lowest moisture content. As the molasses proportion increased, the moisture content of the briquette also increased. Due to the molasses has a hygroscopic property, moisture can be trapped inside the briquette. This result corresponds to the study by Carnage et al. [10]. The different molasses proportions significantly influenced on moisture content of the briquettes (p<0.001). However, samples prepared at the proportions of 10% and 15% w/w had no significant different. High moisture content causing ignition and combustion are difficult [12]. In addition, it results in a lower calorific value [13]. However, the moisture content of all briquettes met the standard of the Thai Community Product Standard (tcps 238/2547) because briquette should have the moisture content not exceeding 8 %.
3.3. Ash content
Ash content is one of the factors for prediction of burning efficiency. High ash content causes incomplete combustion. Sample prepared at 5% w/w molasses content gave the lowest ash content. As increasing molasses proportion, the higher ash content was found because it is known to mainly contain inorganic particles. This was also observed in the study by Tanui et al. [14]. The different molasses proportions were significantly impacted on ash content of the briquettes (p<0.05). However, samples prepared at the ratios of 10% and 15% w/w were no significant differences. It is useful when briquette has small amount of ash content because it is easy to eliminate after use.

3.4. Volatile matters
Table 1 shows the effect of molasses proportion on the volatile matters content. The volatile matters of briquettes produced using molasses for 5%, 10% and 15% w/w were 44.58, 42.97 and 46.95% respectively. The volatile matters varied significantly with different molasses proportions used in the briquette production (p<0.001). Briquette produced from 10% molasses content had the least volatile matters while 15% molasses content briquette had the highest volatile matters. High volatile matters mean they are easily ignite but may burn with a smoke flame. Low volatile matters mean they are fire hardly but burn very cleanly.

3.5. Fixed content
The fixed carbon content implies to the carbon residue after volatile matter is released. High quality of briquette requires the higher amount of fixed carbon content. The volatile matters of briquettes produced using molasses at 5%, 10% and 15% w/w were 43.64, 45.06 and 40.16% respectively. The fixed carbon content influenced significantly with different molasses proportion used in briquette production (p<0.001). As compare to the volatile matters result, the briquettes having higher volatile content had lower fixed carbon content. The fixed carbon content adversely related to the volatile matters content of the briquettes.

3.6. Calorific value
Calorific value is the measurement of thermal efficiency released by the briquette during combustion. High calorific value means high quality briquette. The calorific values obtained from this study are in the range of 6,689.80-6,915.08 cal/g. The sequence of the calorific values was briquette produced using 5% w/w of molasses first, followed by 10% and finally 15%. The different molasses proportions affected significantly the calorific value of the briquettes (p<0.01). However, samples prepared using 10% and 15% w/w of molasses were no significant differences. High binder content resulted in decreased calorific value due to the calorific value of molasses, which is 2,450 cal/g [15], has lower than that of conventional charcoal. Furthermore, using high amount of molasses containing hygroscopic property also tends to reduce the calorific value. Similar results can be found in the other studies [3, 14]. Comparing with others, the calorific value of the briquette obtained from Palmyra palm waste having molasses binder was higher than that obtained from other charcoals [13, 16]. In addition, the calorific value of the briquette was higher in comparison with the Thai Community Product Standard (tcps 238/2547) indicating that the values obtained were acceptable especially for the application of the briquette as a fuel.

From above results infer that other effects like moisture content, ash content could also contribute to the lower in calorific value. Several studies discussed that high moisture and ash content in briquettes will lower calorific value [10, 16-17]. This is in agreement with this study which revealed that high moisture and ash content belonging to high molasses proportion resulted in low calorific value.

Briquettes produced in this study were tested cooking efficiency by boiling water. The results showed that water can be boiled with all conditions briquettes produced. Moreover, they could burn for a long time without spark, soot and were smokeless. All results in this study have shown the potential of converting Palmyra palm waste into an alternative fuel source.
4. Conclusions
Briquette produced from Palmyra palm waste with molasses as binder was developed at various binder proportions. Altering the molasses to charcoal proportions affected the quality and properties of the briquettes. Increasing the amount of molasses increased the moisture content and ash content but decreased calorific value and density. The briquette with 5% w/w molasses showed desirable characteristics in terms of density, moisture, ash content and calorific value. All briquettes in this study produced meet the criteria of the Thai Community Product Standard (t cps 238/2547). All results have revealed the potential of these briquettes developed from Palmyra palm waste and molasses binder into alternative fuel energy for household use.

Acknowledgement
This research work was supported by Budget Bureau. The authors would like to express their sincere appreciation to Mr. Sanit Iamcharoen for the assistance in the use of Briquette extruder machine and Dr. Kittima Prukpousana for the suggestion of data analysis in SPSS statistical software. The authors would like to give special thanks to Faculty of Science and Technology, Kanchanaburi Rajabhat University, Thailand.

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