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Research Article

EFFECTS OF TORREFACTION PROCESS ON PHYSICAL PROPERTIES AND OPERATING COST OF BIOMASS POWDER

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ABSTRACT:
The cassava rhizome was used as raw material. The torrefaction process was experimented in 2 cases. In the first case, the cassava rhizome was chopped. The temperature and residence times of torrefaction process were determined at 250 ºC and 90 minutes, respectively. Then, torrefied cassava rhizome was minced. In the second case, the cassava rhizome was chopped and minced. Then, it was torrefied at the same temperature and residence times of the previous case. The lower heating value (LHV), moisture content, particle size and operating cost were studied in both cases. The results were found that the highest LHV of torrefied cassava rhizome ranged from 21.9±0.07 MJ/kg to 22.55±1.39 MJ/kg. The lowest moisture content of torrefied cassava rhizome ranged from 1.41±0.73% to 1.05±0.27%. In addition, the total production cost of case1 was the cheapest (3.57 baht/kg), its cost differed from that of case2 by 9.8% (3.92 Baht/kg). It was concluded that, torrefaction process should be started with chopping, torrefying and followed by mincing. The operating cost, particle size and cost per energy output were decreased by using torrefying process (case1).

Keywords: *Biomass, torrefaction, heating value, production cost*

1. INTRODUCTION

Biomass is regarded as another alternative energy source because it is clean energy and available worldwide. However, biomass properties need to be improved to produce higher quality fuel which is suitable for combustion application and transportation. In many years, one of the most effective processes for upgrading biomass is torrefaction. This process is a thermochemical process conducted at a low temperature ranging from 200 ºC to 300 ºC, and at a low heating rate [1-3]. The low heating value of torrefied product was studied by many researchers [4-7]. The physical property of torrefied biomass was small particle size and brittleness. The grinding energy of torrefied biomass was reduced [8-11]. In this research, two arrangement torrefaction process were compared. The thermosyphon torrefaction reactor was used in process. The lower heating value (LHV), moisture content, particle size and operating cost were studied in each case. Moreover, the costs per energy output of torrefied cassava rhizome were investigated.

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2. EXPERIMENTAL APPARATUS

2.1 Raw material preparation and torrefaction process

The cassava rhizome with particle size of 5 mm was used in this study the moisture content of the sample was controlled at a range of 9 ± 1% wet basis (w.b.). The weight of samples was measured by a digital scale with 0.1 g readability (AND, EM-150KAL). The sample was prepared by drying in a hot air oven at a temperature of 105 ºC for 24h before loading into a thermosyphon torrefaction reactor. The torrefaction processes were carried out in 2 cases as shown in Fig. 1. In the first case, the cassava rhizome was chopped to reduce the size to 1 – 5 cm. Then, the temperature and residence times of torrefaction process were determined at 250 ºC and 90 minutes, respectively. After that, torrefied cassava rhizome was minced to 5 mm to reduce its size. In the second case, the cassava rhizome was chopped and minced. Then, it was torrefied at the same temperature and residence time as in the previous case. The moisture content, LHV, particle size and operating cost were determined after finishing each case. The products from each method were compared in term of physical properties and production cost to find the best procedure. The experiments were repeated to ensure the repeatability and reliability of the data at a level of 95% (confidence).

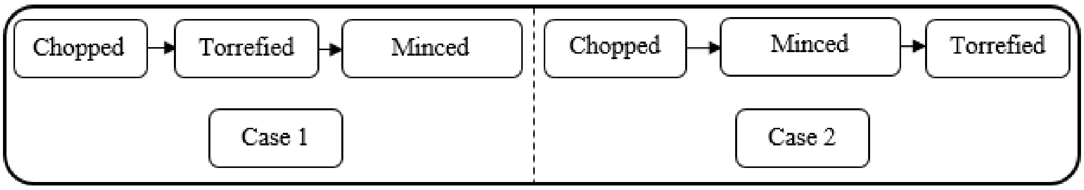


Fig. 1. Two case of torrefaction process in this study.

2.2 Physical properties of torrefied product

Physical properties of torrefaction products of each case including moisture content, low heating value and particle size were tested as follows.

Moisture content

Moisture content of torrefaction products was determined by using ASTM E871-82 standard [12]. The samples were weighted (APTP-452, 0.01 g accuracy). Moisture content analysis for torrefied moisture content was performed according to the PFI standard by drying the samples overnight (24h) at 105 ºC in a drying cabinet (Binder-RE115, ±0.3 ºC accuracy). The moisture content of the samples can be calculated as follows:

$$M,\% = \frac{W_1 - W_2}{W_1} \times 100 \tag{1}$$

Where, M is moisture content (%), W_1 is initial weight of the sample (g), and W_2 is the weight of the sample after heating (g).

Lower heating value (LHV)

Lower heating value was investigated by using ASTM E711-87 standard [13]. LHV was collected by a bomb calorimeter (Parr 6300, 0.01% accuracy). The moisture content of sample can be calculated as follows:

$$LHV, \frac{\text{MJ}}{\text{kg}} = HHV(1-M) - 2.447\frac{\text{MJ}}{\text{kg}} \tag{2}$$

Where, LHV is lower heating value (MJ/ kg), HHV is higher heating value (MJ/kg).

Particle size analysis

Particle size analysis was carried out by using ASTM D422 standard [14]. Particles size was tested by sieve analysis (SSQ-YO6322, 2800 rpm, and sieve size from 3.35 to 0.053 mm). This methodology was studied to compare products from each torrefaction process. It can be calculated as follow:

$$Sieve.retained, \% = \frac{S}{W} \times 100\, percent \tag{3}$$

Where, S is weight of sieve (kg), W is total weight (kg).

2.3 Operating cost analysis

Chop process

The operating cost (chop and mince) of each process was analyzed by using a watt-hour meter. The operating cost was determined by

$$C, \frac{\text{Baht}}{\text{kg}} = E \times K \tag{4}$$

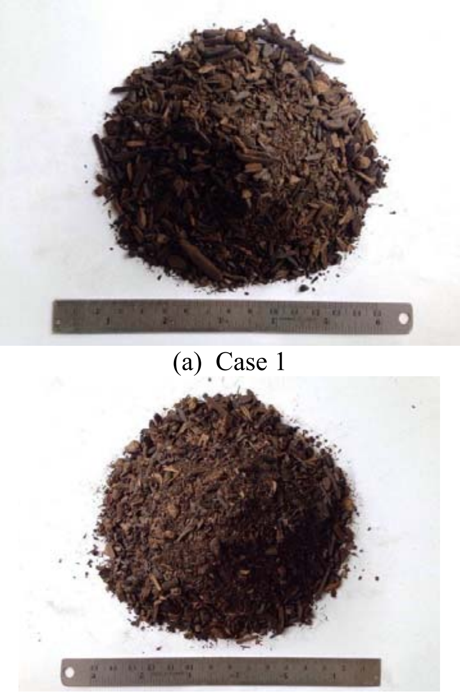
Where, C is operating cost (Baht), E is energy consumption (kWh) and K is electricity price (Baht/kWh).

Torrefaction process

The operating cost (torrefaction process) of each torrefaction process was analyzed by using LPG price. The operating cost was determined by

$$L, \frac{\text{Baht}}{\text{kg}} = \frac{W \times G}{M} \tag{5}$$

Where, L is operating cost (torrefaction process) (Baht), W is weight of LPG (kg), G is price of LPG (26.33 Baht/kg) and M is weight of torrefied product (kg).



(a) Case 1

(b) Case 2

Fig. 2. The products from torrefied process.

3. RESULTS AND DISCUSSIONS

3.1 Physical properties of torrefied products

Moisture content

The products from torrefied process were shown in Fig. 2. The physical observations of torrefied products were brittle, fragile and reduced in mass compares with raw material. Fig. 3 showed moisture content of torrefaction products. It shows moisture contents of the raw material with torrefied product case1 and torrefied product case2. The moisture content of cassava rhizome (raw material) was 8.33 ± 0.43%. From the test, it was found that the torrefaction process had significant effect on moisture content of cassava rhizome. Moisture content of case1 and case2 was sharply decreased to 1.41 ± 0.73% and 1.05 ± 0.27%, respectively (after torrefaction process). The effect of the torrefaction process was about the same as the results reported by Bridgeman et al. [9].

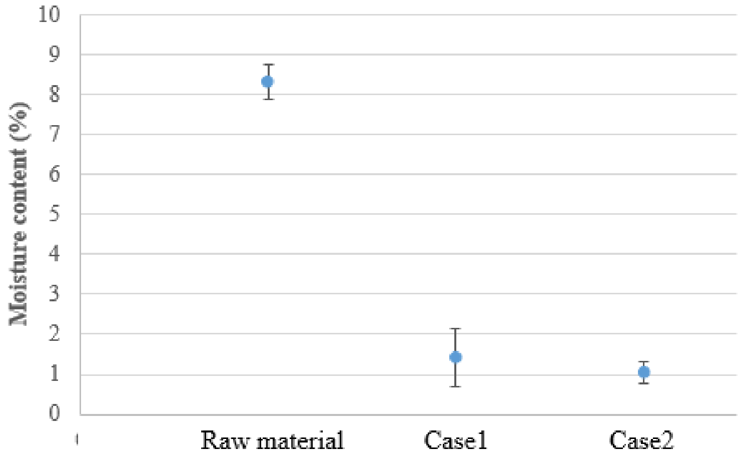


Fig. 3. Moisture content of raw material and torrefied products.

Lower heating value (LHV)

LHV of torrefied products was an important parameter. The higher LHV, the more energy can be stored or transported at the same amount of volume. Fig.4 shows LHV of cassava rhizome after the torrefaction process. From the result, it was found that the LHV of case1 and case2 increased from 19.18 ± 0.14 (raw material) to 21.9 ± 0.07 and 22.55 ± 1.39 MJ/kg, respectively. Consequently, the increase in energy density of the torrefied products is relative high up to 12 - 15%. The results yield the same characteristics reported by Prins et al. [4-5]. However, the difference in LHV between case1 and case2 were statistically insignificant as shown in the Figure below.

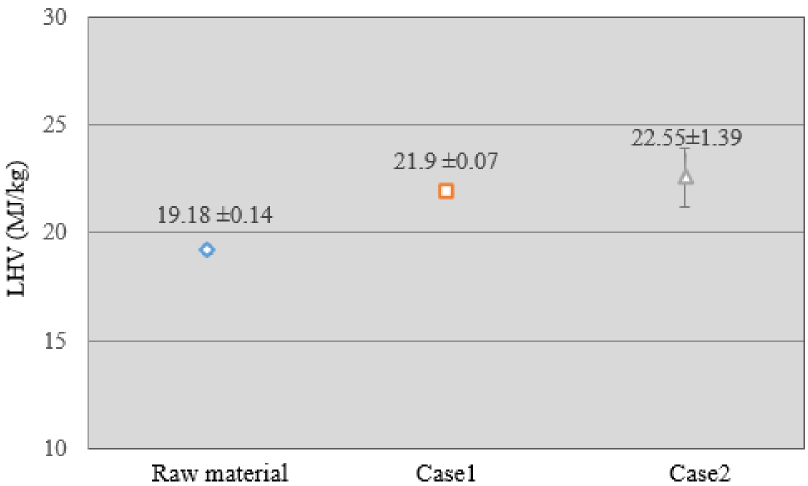


Fig. 4. The lower heating value of raw material and torrefied products.

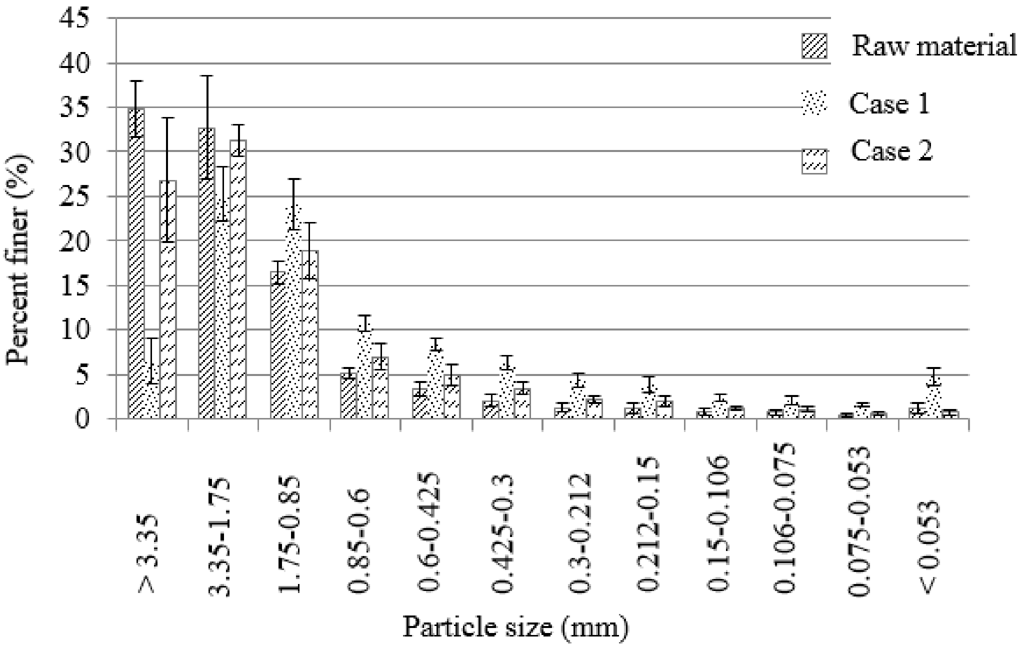


Fig. 5. The particle size of raw material and torrefied products.

Particle size analysis

This section was investigated to compare between the products from case1 and case 2 torrefaction processes. From the results, it was found that particle size distribution of raw material and case 2 was quite similar and the most particle size in case 2 was 1.7-3.35 mm. On the other hand, the results from case1was clearly differenced. It was seen that, highest volume of particle size for case1 is 0.85-3.35 mm. In the torrefaction process of case1, raw material was chopped, torrefied and followed by minced. So, in this case, the torrefied cassava rhizome was brittle and broken easily. The particle size after sieving was smaller than the particle size of the raw material and case2. The results were shown in Fig. 5.

Operating cost analysis

This section investigates operating cost of torrefied process. The costs of chopping, torrefying and mincing were separately calculated in each case. From Fig. 6, the results show that costs of chopping and torrefying were 0.07 and 3.34 Baht/kg, respectively. Similar data were shown in case1 and case2. Consequently, in mincing process, the cost of case1 was lower than that of case2, because of easy mincing after torrefaction process. It was concluded that the total production cost of case1 was the cheapest (3.57 Baht/kg), which was less than that of case2 by 9.80% (3.92 Baht/kg).

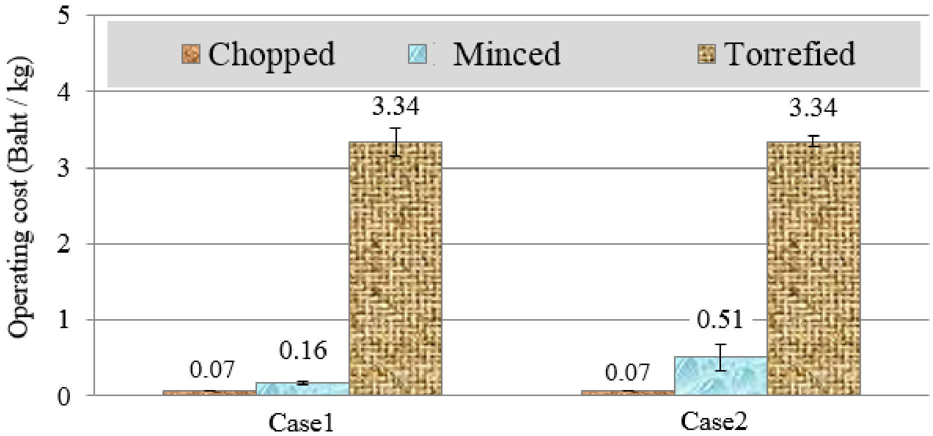


Fig. 6. Operating cost of each process.

Table 1: Comparison data.

Parameters	Case1	Case2
Moisture content	1.41%	1.05%
LHV	21.90 MJ/kg	22.55 MJ/kg
Total production cost	3.57 Baht/kg	3.92 Baht/kg
Costs per energy output	0.163 Baht/MJ	0.173 Baht/MJ

4. CONCLUSION

In this research, the physical properties of torrefied cassava rhizome had been tested and reported. The torrefaction process highly affected moisture content of cassava rhizome. Moisture contents of case1 and case2 were sharply decreased from 8.33 ± 0.43% (raw material) to 1.41 ± 0.73% and 1.05 ± 0.27%, respectively (after torrefying process). The LHV of case1 and case2 increased from 19.18 ± 0.14 (raw material) to 21.9 ± 0.07 and 22.55 ± 1.39 MJ/kg, respectively. Consequently, the increase in energy density of the torrefied products was much higher, up to 12 - 15%. Moreover, the total production cost of case1 was the cheapest (3.57 Baht/kg) which was different from case2 by 9.80% (3.92 Baht/kg). It was concluded that, torrefaction process should be started with chopping, torrefying and followed by mincing. The operating cost, particle size and cost per energy output were decreased by using torrefying process (case1).

5. ACKNOWLEDGEMENTS

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