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The Utilization of Cashew Shell Residues and Grease Waste for Charcoal Briquette Production

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Abstract

This study aims to investigate appropriate utilization of mixing grease waste (GW) from a canteen’s grease trap with cashew shell charcoal (CSC) to produce briquette fuel by weight (GW: CSC) in the ratio 1:2, 2:2, 3:2 and 4:2. All different mixing ratios used starch paste as binding agent. The physical and chemical properties of briquette fuel were analyzed to verify its heating value components as specified by the American Society for Testing and Material (ASTM). In addition, in terms of heat utilization efficiency and pollution aspects, the content of carbon monoxide (CO) emissions from combustion were measured. The result of this study shows that the mixture of all components could produce charcoal briquette fuel. All the different mixing ratios have heating values exceeding the minimum requirement under the Thai Community Product Standard (tcps 238/2004). The high heating value ranged from 7724-8109 cal g^{-1} on a dry basis. The heat utilization efficiency of briquette fuel was between 5.15-12.43 min. The charcoal briquette in 4:2 ratio had the least time of boiling at 5.15 min. In regard to air pollution aspect, the average concentration of CO emissions from briquette fuel were 151.6, 232.4, 210.5 and 292.5 ppm in the ratio 1:2, 2:2, 3:2 and 4:2, respectively. The heating value of briquette fuel was higher than the heating value of other briquette fuel reported in previous studies. Therefore, the cashew shell mixed with grease waste would make an viable alternative energy source for incinerators, that can also minimize waste.

Keywords: Charcoal briquette; Cashew shell; Grease waste

Introduction

Thailand's accelerating economic and industrial development has led to a growing energy shortage [1]. Thus, alternative sources of energy in various forms are being sought as substitutes for fossil-fuels, especially from biomass available locally in large volumes, including waste from industry and agriculture. Since the agricultural sector is the base of Thailand's economy, biomass can be derived from the cultivation of dedicated energy crops and from biomass wastes. Major sources of biomass in Thailand are sugar cane, rice husk, cassava, oil palm, rubber trees, and wood waste, all of which can be used cost-effectively for energy production [2].

Cashew is an important agricultural crop in Thailand, and is a major economic crop in Thapla District, Uttaradit Province, northern Thailand. The nuts are processed into many kinds of value-added processed products, generating processing wastes such as cashew shells, which contains some fats and oils.

Cooking activities in households, canteens and restaurants generate significant amounts of wastewater that also contain fats, oils and grease. Poor wastewater management results in soil and water contamination and environmental pollution. Reuse of grease waste is one way to mitigate the environmental burden, while reducing the total volume of the waste by converting them into useful products. As a result of this utility the waste becomes much more valuable. Although the fats, oils and grease contained in the wastewater are complex organic compounds that are slow to biodegrade, energy density of these components may range from 7,448-9,148 cal g^{-1}, with 0-2 % water, 2.36-2.50 % fixed carbon, and 95.30-97.64 % volatile matter (all percentages by weight). The calorific value of the grease component is comparable to heavy fuel oil (9,900 cal g^{-1}) [3].

Compressed charcoal briquettes are regarded as an energy innovation and considered as an alternative renewable energy source, offering an effective substitute for natural charcoals. Crop residues and wastes from agriculture and agro-industry, including sugar cane bagasse, coconut shells, palm shells, fruit peels, rice straw, cassava roots and chaff can all be used to produce compressed charcoal briquettes [4]. This research aims to assess the use of cashew shell and grease waste as raw materials to produce charcoal briquette fuel, including fuel quality and environmental impact at various ratios.

Materials and methods

This research uses the waste, including cashew shells and grease waste to produce briquettes as an alternative fuel, and determines the optimum ratio of raw materials. The mixtures were analyzed by proximate analysis, combustion of fuel, and measurement of heat utilization efficiency and carbon monoxide emissions.

1) Briquette preparation

The cashew shells used for the experiment were obtained from a cashew shell processing product community enterprise in Thapla District, Uttaradit Province. The shells were sun-dried for a few days to reduce moisture, then burned in a steel drum, ground and milled to a powder, then sieved. The fat and oil waste sample used in the study was obtained from a grease trap from a canteen at Uttaradit Rajabhat University. The bulk sample was collected from grease waste floating on the wastewater in the trap, and random sampling was done in one part of four as proxy sub-samples from the bulk sample. The sub-samples were analyzed to determine their calorific value and proximate analysis.

The cashew shell charcoal was mixed with grease waste to produce briquettes in the ratios of 1:2, 2:2, 3:2, and 4:2 (GW:CSC) by cold compression using a hydraulic press. All the different mixing ratios used starch paste as a binding agent. Because of its convenience and simplicity, this research used the wet compression technique without heat. Since the grease waste is semi-solid containing oil, compression with heat would not be an appropriate method, since the grease waste would melt on exposure to heat. Moreover, the wet compression technique without heat requires less compression than when using heat. However, the compression technique without heat requires drying out before use.

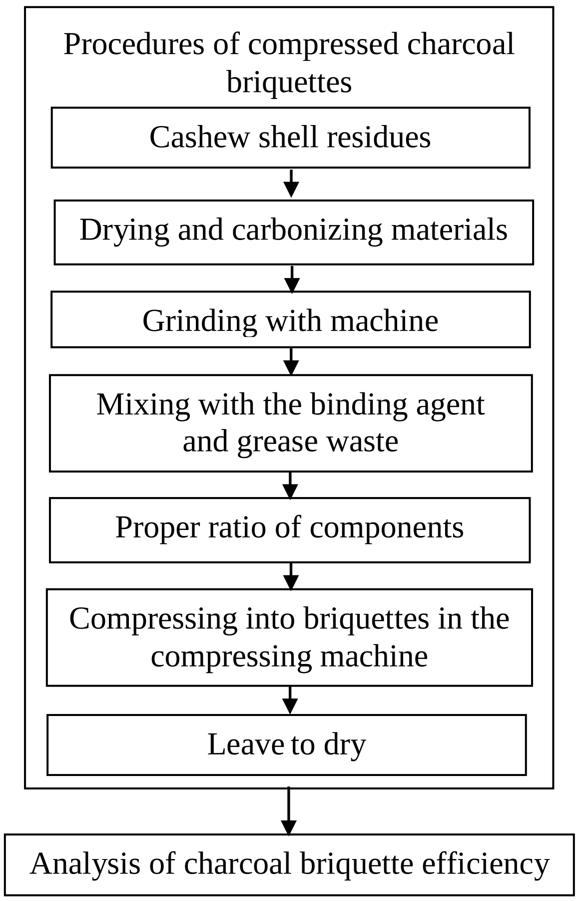

Figure 1 Procedure of production of compressed charcoal briquettes from cashew shell residues mixed with grease waste.

2) Characterization of charcoal briquettes

The cashew shell materials and grease waste were analyzed to determine their characteristics. The physical and chemical properties of briquette fuel from cashew shell were analyzed using heating efficiency and quality of fuel such as moisture, ash, volatile matter, fixed carbon contents, CHON/S and heating value. Analysis of materials properties and charcoal briquette mixed with grease waste to be used in the method including ASTM D3173-03 (2008), ASTM D 3174-04, ASTM D 3175-07, ASTM D 3172-07a, ASTM D 5373-02, ASTM D 3179-02, ASTM D 3177-02(2007), ASTM D 3176-89 (2002) and ASTM D 5865-07a. The results of this study were reported on an as-received basis and dry basis of materials characteristics. After compressing the mixture into bars, the briquette fuel was analyzed to verify its heating value components as specified by ASTM, namely percentage of moisture content, ash, volatile organic content, fixed carbon, sulphur content and calorific value content. In addition, in term of the heat utilization efficiency and pollution potential, the average CO concentration of emission from combustion was also measured.

3) Heat efficiency test

The heat efficiency test of the briquette represents its efficiency in converting the fuel to useful heat [5]. The experiment of testing is water boiling and assigning the same amount of fuel and water then record the number of frequency of water boiling. About 400 g of briquette fuel was used in each ratio. The heat utilization efficiency was calculated simultaneously at all ratios by measuring the time required to boil 1 L of water to 100 ^{o}C on a charcoal stove. This method also allows evaluation of the fuel’s stability during combustion. The utilization efficiency of using each kind of fuel ingredients was evaluated following the formula of heat utilization efficiency prescribed by the Department of Energy Development and Promotion, National Energy Administration, Thailand [5].

4) Air pollution

The gas emission from combustion was tested for each ratio using 400 g briquettes. The combustion test replicated typical usage in the household kitchen. Firewood was used to start combustion; the briquettes were then introduced into the stove and allowed to burn for 3 min. CO concentrations were then measured continuously for 30 min with the stove covered. The gauge sensor was placed at a height of at least double the length of the chimney's diameter. The single gas analyzer, SGA91-CO model, was used for measurement.

Results and discussion

1) Raw material characteristics

Moisture levels reflected the specific biomass used [6]. In this study, the moisture of cashew shell was low (5.5 %) with low ash (2.6 % on an as-received basis, or 2.7 % on a dry basis). The biomass materials with high moisture must contains quite low solid material of fuel mass. Its effect to induce the heat potential with has an effect of burning efficiency [6]. The volatile matter was 76.7 % and 81.1 % (as-received basis and dry basis, respectively). Fixed carbon content on an as-received basis was 15.2 %, or 16.2 % on a dry basis; as a rule, biomass fuels should have levels of fixed carbon ranging from around 10-20 % [6]. The amounts of CHON/S of cashew shell on an as-received /dry basis) were 55.2 % (58.5 %), 7.5 % (7.2 %), 34.2 % (31.1 %), 0.45 % (0.48 %) and 0.04 % (0.04 %), respectively. The highest heating value on an as-received and dry basis were 5,339 and 5,650 cal g^{-1}, respectively. The lowest heating values were 4,954 cal g^{-1} on an as-received basis and 5,276 cal g^{-1} on a dry basis. On an as-received basis, the biomass contained 65.60 % water by weight, 1.38 % ash, 39.2 % volatile matter, 0.62 % fixed carbon and caloric value of 2,667 cal g^{-1}. Also analyzed on a dry basis, the grease was found to contain 0.33 % ash, 97.41 % volatile matter, 2.46 % fixed carbon, 0.7 % sulphur and a caloric value of 7,368 cal g^{-1} (Table 1). The grease waste has useful fuel characteristics: i.e. high heating value, and low levels of ash and sulphur. However, the combination of cashew shell and grease waste generated high levels of volatile matter, which can cause environmental impacts.

Table 1 The characterization of raw material (N = 3)

Composition	Cashew shell		Grease waste		ASTM method
	As-received	Dry basis	As-received	Dry basis	
Approximate analysis (wt %)					
Moisture content	5.5	-	65.60	-	D3173-03
Ash content	2.6	2.7	1.38	0.33	D3174-04
Volatile matter	76.7	81.1	39.20	97.41	D3175-07
Fixed carbon	15.2	16.2	0.56	2.46	D3172-07a
Ultimate analysis (wt %)					
Carbon (C)	55.2	58.5	-	-	D5373-02
Hydrogen (H)	7.5	7.2	-	-	D3179-02
Oxygen (O)	34.2	31.1	-	-	D3177-02
Nitrogen (N)	0.45	0.48	-	-	D3176-89
Sulphur (S)	0.04	0.04	-	0.70	D 4239
High heating value (cal g^{-1})	5339	5650	2667	7368	D 5865-07a
Low heating value (cal g^{-1})	4954	5276	-	-	D 5865-07a

2) Characteristics of briquette fuel

Compression increases the energy density of a fuel and reduces costs of transport and storage. Various GW:CSC ratios (1:2, 2:2, 3:2 and 4:2 GW: CSC) were tested for their compression characteristics. The compressed charcoal briquettes were cylindrical with a smooth skin and length of 7 cm and diameter 4 cm.

The properties of the briquette fuel were analyzed using heating efficiency and quality of fuel such as moisture, ash, volatile matter, fixed carbon and heating value. High quality fuel is typified by a high content of fixed carbon, high density and high heat, and low amount of moisture, ash and volatile matter. It was found that fuel briquettes produced from the GW/CSC combination contained reduced ash, fixed carbon and sulphur, but higher levels of volatile matter and heat value, depending on the ratio of ingredients. The ratio 3:2 contained the highest moisture content (23.7 %) and volatile matter (48.8 % and 64.0 %). The amount of ash in ratios 1:2, 2:2, 3:2 and 4:2 on an as-received (dry basis) were 4.7 % (6.0 %), 3.7 % (4.8 %), 3.3 % (4.3 %) and 3.5 % (4.5 %), respectively. The fixed carbon was highest for the 1:2 ratio, with 37.2 % and 47.2 % on an as-received and dry basis, respectively. The ratio 3:2 contained the highest levels of sulphur.

The heating value of mixing briquette as-received basis was highest for the 4:2 ratios (6,243 cal g^{-1}). The low heating value was 5,817 cal g^{-1} on an as-received basis and 7,686 cal g^{-1} on a dry basis in the 4:2 ratio (Table 2). That means the heating value will depend on the value of grease, because fat and oil have a very high heating value (7,368 cal g^{-1}). This is consistent with research on biofuel using crude oil sludge which found that the heating value depends on the proportion of crude oil sludge [7]. For the Thai Community Product Standard for charcoal briquettes, the best charcoal briquette should have a heating value above 5,000 cal g^{-1} and moisture content not over 8 % by weight [8]. However, this study found excessive moisture (11.1 %) in cashew shell briquettes, which reduces heating value and causes crackling in the fire. Researchers in India have reported production of briquette fuel from cashew shell mixed with cow dung, sawdust and wheat chaff, with moisture content within the range of 5.0-10.4 % and heating value between 13.4-17.8 MJ kg^{-1} [9]. This compares with coconut shell charcoal mixed with cassava root, which yields heating values ranging from 4,514.13-6,588.09 cal g^{-1} [10]. In another study which mixed fat, oil and grease from a restaurant grease trap with sawdust to produce briquette fuel, the resulting briquette fuel had a heating value between 6,117-7,065 cal g^{-1} and volatile matter 87.81-90.44 % [3].

The heating value comparison of mixing briquette as received basis and dry basis found that the heating values were significantly different between ratios ($p < 0.05$). The results indicate that the 4:2 ratio had the highest heating value on a dry basis. The high heating value was non-significant for the 2:2, 3:2 and 4:2 ratios (Table 3).

The low ash content means that charcoal briquettes can be almost totally burned, leaving little ash and dust, which can cause pollution and create a disposal problem. It was found that the charcoal briquettes from cashew shell and grease waste provided a heat value similar to coal and higher than that of firewood and other charcoal briquettes at all ratios. However, emissions of volatile compounds during combustion using a stove was indicated by large amounts of smoke. Therefore, the stove may not be suitable for use with this material due to air pollution and health hazards.

Table 2 Composition of cashew shell briquettes in each ratio (N = 15)

Composition	As-received basis					Dry basis				
	100 %	**1:2**	**2:2**	**3:2**	**4:2**	**100 %**	**1:2**	**2:2**	**3:2**	**4:2**
Proximate analysis (wt%)										
Moisture	11.1	21.3	23.2	23.7	22.6	-	-	-	-	-
Ash content	5.2	4.7	3.7	3.3	3.5	5.8	6.0	4.8	4.3	4.5
Volatile matter	26.6	36.8	42.8	48.8	48.1	29.9	46.8	55.7	64.0	62.1
Fixed carbon	57.1	37.2	30.3	24.2	25.8	64.3	47.2	39.5	31.7	33.4
Ultimate analysis (wt%)										
Carbon (C)	76.4	66.5	65.8	61.8	63.3	85.9	84.5	85.7	81.0	81.8
Hydrogen(H)	4.3	7.3	8.8	10.0	8.3	3.4	6.2	8.1	9.6	7.5
Oxygen (O)	0.62	0.70	0.71	0.67	0.70	0.70	0.89	0.92	0.88	0.90
Nitrogen (N)	13.4	20.7	20.9	24.0	24.1	4.1	2.2	0.32	3.9	5.2
Sulphur (S)	0.11	0.13	0.12	0.24	0.10	0.12	0.17	0.16	0.31	0.13
High heating value (cal g^{-1})	6,533	6,079	6,157	6,187	6,243	7,349	7,724	8,017	8,066	8,109
Low heating value (cal g^{-1})	6,321	5,704	5,706	5,675	5,817	7,173	7,406	7,606	7,619	7,686

3) Heat utilization efficiency

The test of the heat utilization efficiency of the briquette fuels found that compressed charcoal produced from 4 ingredients at every ratio tested could be ignited within 1 minute. The ignition time was tested by burning briquettes weighing around 0.4 kg until the fuel stopped burning. On ignition, the outer surface of the briquettes immediately began to combust. The briquette fuel ratios 4:2 was started with the fire and released the most smoke. The briquette fuel in the 2:2 and 4:2 ratio had the most rapid time to boiling of 5.30 and 5.15 min, respectively (Figure 2). While briquette fuels produced from local plants such as Sensitive Plant (Mimosa), Siam weed, Jatropha, water hyacinth, firewood and Manila Tamarind wood have boiling times ranging from 13 to 15 min [11], the best fuel should generate minimal smoke and odour while burning. The briquette fuel in 1:2 and 4:2 ratio had long ignition durations of around 1 h 48 min (108 min) and 1 h 30 min (90 min), respectively (Figure 3).

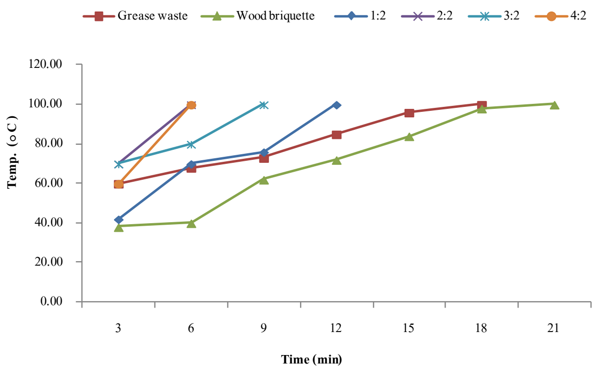

Figure 2 Time to boiling.

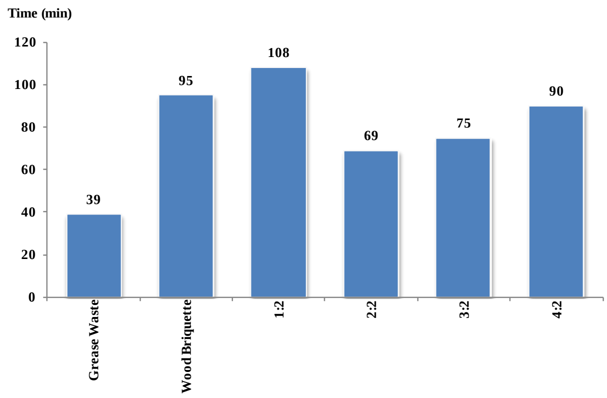

Figure 3 Duration of burning.

Table 3 Heating value of mixing briquette fuel (N = 15)

Ratio	High heating value (cal g^{-1})		Low heating value (cal g^{-1})	
	As-received basis	Dry basis	As-received basis	Dry basis
0:2	$6,533^{a}$	$7,349^{c}$	$6,321^{a}$	$7,173^{c}$
1:2	$6,079^{b}$	$7,724^{b}$	$5,704^{c}$	$7,406^{b}$
2:2	$6,157^{b}$	$8,017^{a}$	$5,706^{c}$	$7,606^{a}$
3:2	$6,187^{b}$	$8,066^{a}$	$5,675^{c}$	$7,619^{a}$
4:2	$6,243^{b}$	$8,109^{a}$	$5,817^{b}$	$7,686^{a}$

Note: Same superscript letter means the difference in value is statistically non-significant at $p < 0.05$.

4) Gas Emission

The factors of combustion are fuel, oxygen and temperature. Complete combustion would result in only carbon dioxide and water as the products of combustion. However, in reality, full combustion is rarely possible, and incomplete combustion leads to air pollution and serious health impacts. This study considered health impacts resulting from carbon monoxide emissions resulting from incomplete combustion of carbon-based compounds. The gas has no color, no smell, and is non-allergenic, but can be fatal if inhaled even at low concentrations. Emissions of CO in this study ranged between 151.6-346.1 ppm, with a high content in the 4:2 ratio (292.5 ppm); however, CO emissions from of cashew shell briquette fuels was still below those of wood briquette (Figure 4). In a previous study using scum (fat, oil and grease) from a restaurant's grease trap, mixed with sawdust to produce briquette fuel, CO emissions ranged between 217-302 ppm [3].

The charcoal briquette used in the study was low in sulphur (0.10-0.24 %) and so combustion does not pose serious risk of pollution from sulphur oxides.

The carbon monoxide concentration offered to organizations involving with ambient air standard acceptance. The air standard of occupational safety and health administration guideline (OHSA) which defined threshold limit value -ceiling (TLV-C) at 200 ppm. The result showed the CO concentration in the combustion area was higher than the recommendation.

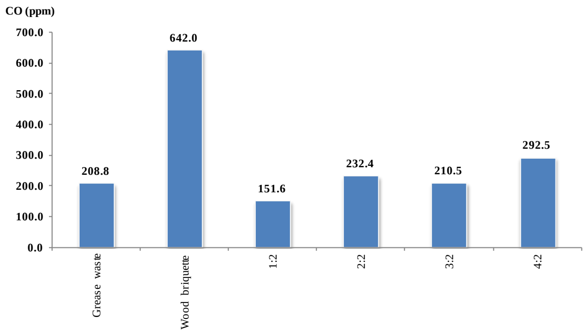

Figure 4 Average CO content from briquette fuel.

Conclusion

The heating value of briquette fuel was close to that of coal and other fuels such as wood straw, with a heating value higher than other briquette fuel as indicated in previous studies. The heating values of briquettes mixed in the ratio of 2:2, 3:2 and 4:2 were not significantly different, while the 2:2 and 4:2 ratios had the most rapid time to boiling at 5.30 and 5.15 min, respectively. The briquette fuel ratio of 1:2 was more suitable for utilization in the household because it released the lowest amount of CO and had the longest duration of burning. However, its use in a typical charcoal bucket stove is not recommended because of its high volatile matter content and CO emissions. Therefore, further studies should focus on utilization of grease waste as an alternative fuel, e.g. as a supplementary fuel for burning municipal solid wastes in the incinerator.

Acknowledgements

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References

[1] Potential of biomass in Thailand. Department of Alternative Energy Development and Efficiency, 2008. [Online] Available from: http://www.dede.go.th/dede/index.php

[2] Ladpala, S., Ketjoy, N., Rakwichian, W., Intanon, P. Performance evaluation of a 25kWe biomass power generation system prototype for community in Thailand. International Journal of Renewable Energy, 2007, 2(2),

[3] Donkrasin, N. Scum (Fat, oil and grease) from a restaurant's grease trap with sawdust to produce briquette fuel. M.Sc Thesis (Technology of environmental Manage-ment), Mahidol University, 2002.

[4] Chumsang, C. Upan, P. Production of charcoal briquettes from palmyra palm waste in Kirimat District, Sukhothai Province, Thailand. Applied Environmental Research, 2014, 36(3), 29-38.

[5] National Energy Administration. Improved biomass cooking stove for household use. National Energy Administration, Ministry of Science, Technology and Energy, Bangkok, 1984.

[6] Biomass Clearing House, Energy for Environment Foundation. Biomass. Q Print Management: Bangkok. ISBN 974-94991 -0-7, 2006.

[7] Boonkok, T. Efficiency enhancement of bio-Fuel using crude oil sludge. MS Thesis (Environmental Science), Naresuan University, 2006.

[8] TISI. [Online] Available from: http://app.tisi.go.th/otop/otop.html

[9] Wilaipon, P. Rengngiab, S. Biomass briquettes produced from coal and maize cob. Research Report, Faculty of Engineering, Naresuan University, 2008.

[10] Phutteesakul, R. The production of charcoal briquette by coconut shell and cassava Rhizome.MS Thesis (Industrial Education), Graduate School, Srinakharinwirot University, 2010

[11] Engineering Association of Thailand. Proceeding of 1st National Environmental Conference 17-19 January 2002. 636.