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Production of Charcoal Briquettes from Palmyra Palm Waste in Kirimat District, Sukhothai Province, Thailand

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Abstract

Palmyra palm is a significant economic crop in Kirimat District, Sukhothai Province, and generates large quantities of husks, stalks and shells as by-products and wastes, which impacts on the local environment. This study investigated (1) production of compressed charcoal briquettes from Palmyra palm husks, fruit calyx and shells, whose physical properties and thermal performance were tested and analyzed according to Thai Community Product Standard (tcps 238/2004); (2) the economic return of the production process. The results showed that 40% of shells of a mature palm fruit and 90% of the husk and fruit calyx of young palm fruit are left over. Moreover, the thermal properties of the palm husks, fruit calyx and shells were found to be similar to those of coconut shells and oil palms. In an experiment to test the properties of blends of the two products (husks and fruit calyx: shells) in 6 different mixing ratios using starch paste as binding agent, all 6 mixing ratios showed thermal values ranging from 5,281.60–6,702.00 kcal/kg, which exceeded the Thai Community Product Standard (tcps). During combustion, these briquettes produced low levels of crackling, odour and smoke emissions, and drop shatter. These characteristics make the studied briquettes appropriate for storage and transport. At a production cost of 4.83 baht/kg for a production capacity of 400kg/day, the payback period was 1.3 years. Therefore, the palm briquettes would make an alternative source of additional income and an alternative fuel substitute for wood charcoal and LPG.

Keywords: Charcoal briquette production; Palmyra palm; palm fruit calyx; shells

Introduction

For hundreds of years, the world has relied on fossils fuels for its primary energy needs. Continuous depletion of fossil reserves and price fluctuations in the world energy market has highlighted the prospect of a future energy crisis. With foresight, His Majesty King Bhumibol has long been concerned about the imminence of this energy shortage, especially considering the fast energy demand growth in Thailand. His Majesty's concern over forests stimulated the launch of a number of Royal

Initiative projects, including production of compressed charcoal briquettes as a substitute for natural charcoals. Crop residues and wastes from agriculture and agro-industry, including bagasse, coconut shells, palm shells, fruit peels, rice straw, cassava roots, chaff, can be used to produce compressed charcoal briquettes, considered as an alternative renewable energy source. Compressed charcoal briquettes are regarded as an energy innovation, due to its low environmental impact and because it adds values to unwanted by-products and crop wastes.

Palmyra palm (*Borassus flabellifer)* is locally known as the sugar palm or "Tan" or "Tan Ta Not" in Thai [1]. The palm is economically important plant in several provinces including Songkha, Phetchaburi, Suphanburi, Phitsanulok and Sukhothai and has long been used for cooking. The by-products of palm sugar production, including the exocarp – stems, fruit calyx and husks – and endocarp, are discarded as waste and adversely affect human health and the environment both in the community and along the main roads. A survey revealed that every bunch with 1-20 young fruits produces waste amounting to 90% of the original weight after the fruits is removed; 60% endocarp per seed is left over.

There has been limited research into production of compressed charcoal briquettes from the waste matter. However, several previous studies comparing various categories of crop residues and wastes indicate that Palmyra crop residues offer significant potential for production of compressed charcoal briquettes. This study therefore evaluated the potential and feasibility of producing compressed charcoal briquettes from this source to meets the Thai community product standard.

The study began with discussions between researchers and the local community to work together to utilize Palmyra palm crop residues as a valuable commodity and at the same time benefit the local environment. Based on the King's initiatives, the study combines scientific knowledge with public participation at community level, including local farmers, monasteries, educational institutions, and local administrative organizations. The study highlights the need to implement such initiatives to ensure a balance among economic, social and environmental parameters in contributing towards realizing the goal of community energy independence.

The study therefore examined the feasibility of producing compressed charcoal briquettes from Palmyra palm husks, fruit calyx and shells, and determined the economic return for the process.

Materials and methods

The study was undertaken in three stages: (1) exploration, sample collection, and training in the production process; (2) production of compressed charcoal briquettes; and (3) determination of economic returns.

1. Exploration, sample collection, and training in production process

Exploration and sample collection (Figure 1) were undertaken the study area (Kirimat District, Sukhothai Province) in March-April 2011, and training in fruit crushing and extraction processes were done in June-July 2011. The collected samples were analyzed to determine their physical properties and thermal value. The parameters to be analyzed according to ASTM standard [2, 3, 4] were moisture (ASTM D 3173), ash content (ASTM D 3174), volatile matter (ASTM D 3175), fixed carbon (ASTM D 3176), total sulphur content (ASTM D 3177), and thermal value (ASTM D 3286).

Figure 1 Palmyra palm husks, stems and young fruit calyx, and shells left over in Kirimat district, Sukhothai province

Training and practical workshops were held in production of compressed charcoal briquettes and activated carbon at community level at Wat Lai temple, Kirimat district. The training incorporated the use of local traditional wisdom in producing compressed charcoals by Nong Ma Ka Group, production techniques, machine operation and practical exercises for the major processes. The session was led by Mr. Prasert Krutchan, Group Head, and other representatives of Nong Ma La Compressed Charcoal Group from Village No. 8., Nong Ma Ka sub-district, Khokcharoen district, Lopburi Province (Figure 2).

2. Production of compressed charcoals

2.1 Construction of equipment

A *vertical charcoal kiln* was constructed from a 200 liter oil drum. The kiln comprised three components: (1) a metal mesh, 8 cm. up from the kiln base; (2) a truncated cone with the bottom base diameter of 8 inches, a top base diameter of 6 inches, and a vertical height of 30.5 cm; and (3) three 1 1/8 inch crimped spiral fins to accelerate combustion.

The *clay kiln* is a low-cost kiln that builds on a 50-year tradition of pottery-making in the locality (Figure 3).

The *charcoal grinding machine* functions using blades mounted around the axle. The machine is powered by a 1 HP two-phase electric motor and has a capacity of 50 kg/hour. The key parameters of the machine (size, number of axle blades, and blade attributes) were tailored to the characteristics, sizes and quantity of the raw materials (Figure 3).

The *charcoal powder blending machine*, where charcoal powder and binding agent are mixed, is a vertical stainless steel cylinder with 80 cm width, and 60 cm in height. The maximum loading capacity is approximately 100 kg per batch, and the machine was designed for bottom unloading. The machine is powered by a 2 HP 220 volt gear reducer motor. The blending time per 100 kg load is 20 minutes (Figure 3).

The *spiral gear charcoal compressing machine*, also operated by a 2 HP motor, has a load capacity of 150 kg per hour. When spun by the electric motor, the spiral wheel presses briquettes into the extrusion cylinder with a diameter of 5 cm, and through the nozzle attached to the other end of the extrusion cylinder (Figure 3).

Figure 2 The training and practical workshop on producing compressed charcoals

Figure 3 Charcoal Briquette Machines

2.2 Production of compressed charcoal briquettes

Six different mixing ratios of charcoal briquettes from Palmyra palm husks, fruit stems and calyx, and briquettes from shells were tested, as follows.

(1) Husk and fruit calyx 100:0 (%)

(2) Shells 0:100 (%)

(3) Husk and fruit calyx: shells 50:50 (%)

(4) Husk and fruit calyx: shells 60:40 (%)

(5) Husk and fruit calyx: shells 70:30 (%)

(6) Husk and fruit calyx: shells 80:20 (%)

For every 10 kg of charcoal powder, a binder mixture of 1 kg starch flour and 0.5–0.8 liter water was prepared. The roll rotation speed was 140 revolutions per minute, and the input capacity was 140 kg per hour. The production procedures are shown in Figure 4.

3. Cost of production of activated carbon

The costs and benefits of producing compressed charcoal briquettes were examined in terms of the per - unit costs of production.

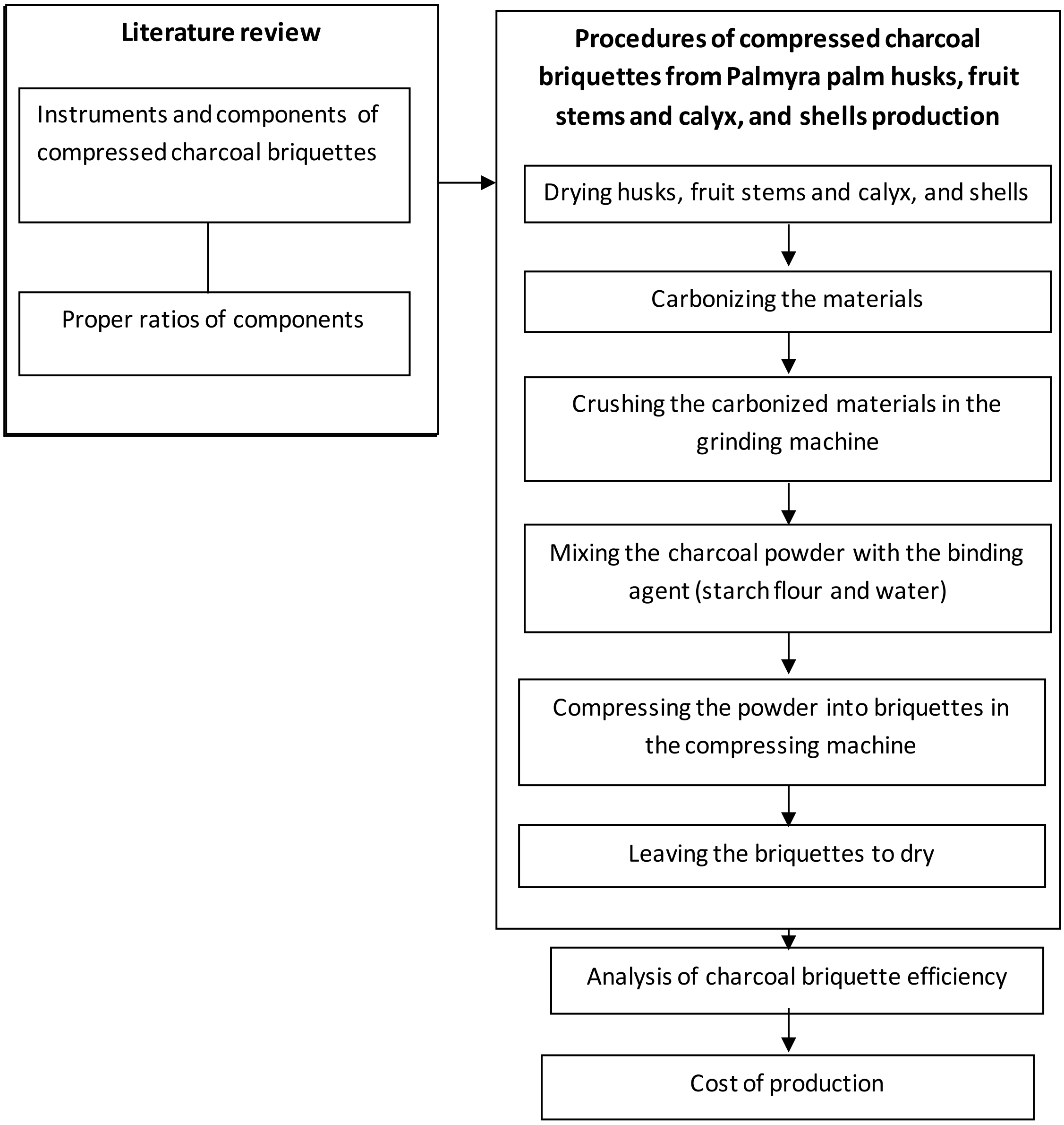

Figure 4 Procedures of compressed charcoal briquettes from Palmyra palm husks, fruit stems and calyx, and shells production

Results and discussion

1) Exploration, physical properties and thermal values

(1) Palmyra palm fruit is only borne by 10-15 year-old female trees. Fruits are borne on spathes; a single swathe typically produces a cluster of inflorescences. Every year, 10-15 such clusters are produced. Generally, one cluster has 13 palm inflorescences, each yielding 1-29 young palm fruits. Each fruit contains 2-4 seeds. The cultivated areas at Wat Lai Temple, Kirimat district, Sukhothai province include approximately 1,500 female Palmyra palms. When ripe, each fruit weighs 1-3 kg, and contains 5% of brown to black husk, 5% calyx, 25% fiber, 25% flesh, and 40% of seed by weight. During May to July, from 2,000-3,000 ripe fruits fall from the trees weekly. Accordingly, over 1 million shells are deposited in the area every year.

(2) During the months of February to May, young fruits are produced and can be harvested

2½ – 3 months after inflorescence. Each fruit contains three seed sockets. One palm plant produces an average of 10-13 bunches every year. Each bunch yields 5–20 fruits, depending on the flowering and fruit setting season. A bunch of young fruits contains 60% fruit and 40% fruit stem and calyx. One fruit contains only 10% of edible seeds (Figure 5) and generates up to 90% waste in the form of leftover stem, calyx and husks. According to the exploration, there are about 6,500 female-bearing palm trees in Ban Thung Laung, Ban Ta Pang Ma Plup, and Ban Ta Not in Kirimat district, Sukhothai province. It can be seen that there are approximately 60,000 – 80,000 bunches of palm fruits and 600,000–800,000 fruits every year.

(3) In terms of physical properties and thermal value based on ASTM (American Society for Testing and Material), it was found that palm shells contain an average 1.37% ash content, 16.80% moisture, 77.28% volatile matter, and 21.35% fixed carbon, and had a thermal value of 4,400 kcal/kg. On the other hand, young fruit stems and calyx contained 2.23% ash content, 21.70% moisture, 76.76% volatile matter and 21.01% fixed carbon, and had a thermal value of 4,500 kcal/kg (Table 1). The examination indicated that the thermal values of the yield of the husk, fruit stem, calyx and shells were similar to those of coconut and oil palm shells. [5, 6, 7, 8].

Table 1 Physical properties and thermal value of Palmyra palm of fruit stems and calyx, and shells

Parameter	Shells	Fruit stems and calyx
Moisture (%)	16.80+2.23	21.70+1.98
Ash (%)	1.37+0.03	2.23+0.09
Volatile matter (%)	77.28+4.32	76.76+4.56
Fixed carbon (%)	21.35+2.34	21.01+2.28
Heating value (kcal/kg)	4,400+5.43	4,500+5.56

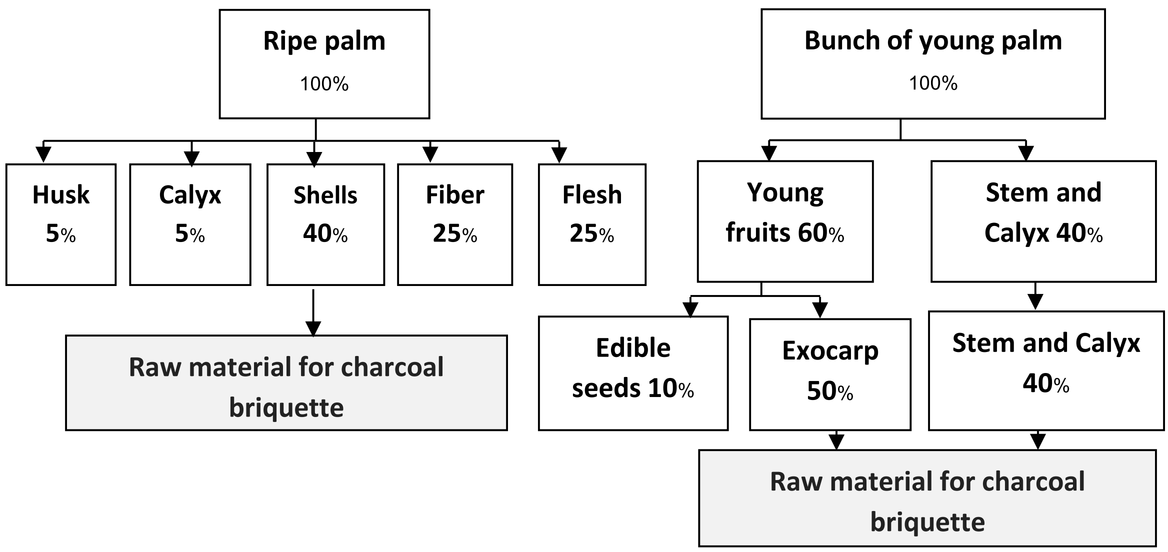

Figure 5 Percentages of component tripe palm and bunch of young palm

2) Compressed charcoal briquettes

The study showed that charcoal briquettes from husks, fruit stems and calyx (Table 2) contained 5.70% moisture, 6.41 % ash, 21.91% of volatile matter and 71.07% fixed carbon, with a thermal value of 7,300 kcal/kg, whereas charcoals from the shells contained 5.56% moisture, 4.90% ash, 15.47% volatile matter and 78.56% fixed carbon, with a thermal value of 7,500 kcal/kg. The physical properties and thermal value of both materials exceeded the requirements of the Thai Community Product Standard, which stipulates that any compressed charcoal briquettes must contain no more than 8% moisture, and possess a thermal value no less than 5,000 cal/g.

According to the test of briquette properties (Table 3), all 6 ratios of the briquettes from husk – fruit calyx and shell mixed with starch paste showed a higher thermal value than that of Thai Community Product Standard (tcps 238/2004). However, the thermal value varied from 5,281 to 6,702kcal/kg., depending on the amount of shell charcoal used. As seen from Table 3, ratio 2 using 100% of palm shells resulted in the highest thermal value (6,702 kcal/kg), whilst the ratio 1 with 100% of husks and fruit calyx charcoals showed the lowest thermal value of 5,281kcal/kg.

Table 2 Physical properties and thermal value showed that the charcoals from fruit stems and calyx and shells

Parameter	shells	stems and calyx
Moisture (%)	4.90±0.86	5.70±0.76
Ash (%)	5.56±0.64	6.41±0.34
Volatile matter (%)	15.47±1.34	21.91±2.02
Fixed carbon (%)	78.56±2.31	71.07±2.54
Heating value (kcal/kg)	7,500±4.56	7,300±5.01

Table 3 Physical properties and thermal value showed the compressed charcoal briquettes from palm husks and fruit calyx, and palm shells

Parameter	Ratio between charcoals from fruit stems and calyx : charcoals shell (%)					
	100:0	0:100	50:50	60: 40	70: 30	80: 20
Moisture (%)	11.96	8.04	8.60	10.23	9.43	9.09
Ash (%)	9.23	5.32	7.50	9.48	8.04	8.13
Volatile matter (%)	1.25	0.46	0.71	1.09	0.85	0.82
Fixed carbon (%)	77.56	86.18	83.19	81.96	81.68	79.20
Sulfur (%)	0.28	0.15	0.09	0.24	0.18	0.18
Heating value (kcal/kg)	5,281.60	6,702.00	6,246.60	6,112.10	5,966.60	5,874.70

Compared to coconut shell charcoal mixed with cassava root with thermal values ranging from 4,514.13–6,588.09 kcal/kg [9], and compared to typical wood charcoals with thermal values of 6,730 kcal/kg [10], the studied compressed briquettes with thermal value of 5,281–6,702 kcal/kg had a relatively similar thermal value to wood charcoals. Due to its high fixed carbon content, palm shells allows the compressed charcoals to achieve a high thermal value.

Regarding moisture, there were no significant difference among the 6 ratios, with values ranging from 8.04-11.96%. However, compared with firewood with 8.0% moisture and typical wood charcoals with 9.4 % moisture, the compressed charcoal briquettes contained higher moisture levels. To meet the requirements of the standard, a longer period of sun drying or a baking would help reduce the moisture content from compressed charcoals.

The fixed carbon content of the compressed briquettes from palm husk-fruit calyx and shell ranged from 77.56–86.18% (as shown in Table 3). It can be seen that fixed carbon content varies according to the amount of palm shell charcoal used. This is due to the fact that palm shells contain higher fixed carbon content than husks and fruit calyx. The studied compressed charcoals demonstrate a similar fixed carbon value compared to wood charcoals with the value of 84.6%. of all the 6 ratios, volatile matter ranges from 0.46%–1.25%, while ash content ranges from 5.32%–9.48%, showing a higher value than that of wood charcoals, which typically show a fixed carbon value of 5.4% [10].

Analysis of the unit cost of production and economic returns

The unit cost of production included the fixed cost for equipment, materials and instruments including the crushing machine, blending machine, and compressing machine. The variable costs varied depending on production capacity, utility bills, and prices of starch flour and oil drums. The production costs for each ratio of the studied activated carbons were calculated using the interpolation method. Since the raw materials, palm husks, the fruit stems, calyx and shells were all purchased at the same price, production costs were equal for all ratios at 4.83 baht/kg. The daily total batch cost of production was 1,969.44 baht to 400 kg/day. The second ratio of activated carbon with 100% palm shell and the highest thermal value gained the highest economic benefit at 5 years or 1,300 days with the production capacity 400 kg per day. However, the mixing ratio of charcoal briquettes from fruit stems and calyx as a major raw material has the advantage of adding higher values from by-products normally dumped in the community.

The study aimed to conduct a study to examine the benefits of the blends of the two raw materials which provide a naturally balanced and environmentally friendly alternative use of the by-products. The study results indicated that four percentage mixing ratios of the two materials offer particular potential: the third ratio of 50:50, the fourth ratio of 60:40, the fifth ratio of 70:30, and the sixth ratio of 80: 20. However, selection of the optimal ratio for any situation will depend on availability and price of the raw materials in the respective community. In addition to introducing an alternative use of the palm fruit stem and calyx instead of the palm shells which are only available in the community with the fruit crushing/extracting processes, the use of locally-available materials minimizes transportation costs.

The sale prices of the different studied ratios were calculated by reference to the standard price of pure coconut shell charcoals. The price setting method was employed because there has been no precedent for marketing of pure Palmyra palm shell charcoals. When compared in terms of thermal value, there was no significant difference between the coconut and the palm shell charcoals. With an analysis of the sale price of each ratio in comparison to the standard price of the coconut counterpart and their thermal value and combustion times, the total yearly economic cost was 501,954.00 baht, assuming a daily 400 kg production capacity of 260 days of production per year. The sale price of the suggested ratios were 13.05 baht/kg for the third ratio, 12.77 baht for the fourth ratio, 12.46 baht for the fifth ratio, and 12.27 baht for the sixth ratio.

Conclusion

The study indicates that manufacture of briquettes from leftover palm husks, fruit calyx and shells provides an alternative and renewable domestic energy source. It was also found that the thermal properties and efficiency of all 6 mixing ratios of palm husk, fruit calyx and palm shell briquette exceeded the requirements of the Thai Community Product Standard (Office of industrial standards. 2004). By virtue of its high energy properties, the briquette from the palm leftovers is postulated as a good fuel. With little crackle, long combustion time and low levels of odour and smoke, these types of briquettes could be suitable for use in households and restaurants. They are also durable as they are less susceptible to breakage during handling, transportation and storage.

Thus, palm waste could be used to produce fuel briquettes to substitute for wood charcoal and LPG. In addition to contributing a supplementary source of revenue for framers, briquette production helps maximize resource utilization, reduce the volume of waste and minimize their environmental impacts. Further work may explore refinements of the mixing rations to suit specific needs. These research findings may be readily implemented in communities with large quantities of palm waste, particularly in the provinces of Supanburi, Phetchaburi and Songkhla.

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