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Article

A Study of Cotton Dust Mixed with Wood Dust for Bio-Briquette Fuel

Siripol Suvunnapob[a], **Borvorn Israngkura Na Ayudhya**[b,*], **and Boonsri Kusuktham**[c]

Rajamangala University of Technology Krunghtep, 2 Nanglinchee Rd, Tungmahamaek, Sathorn, Bangkok 10120, Thailand
E-mail: [a]siripol@thaialliance.com, [b]borvorn.i@rmutk.ac.th(Corresponding author),[c]boonsri.k@rmutk.ac.th

Abstract. Various textile-industrial wastes such as cotton wastes, polyester fibres, lumps and old rags can be a source of energy. Cotton dust (CD) seems to be one of interesting bio-waste energy sources. Because its shares of the high heat energy and organic material. This paper presents physical and mechanical properties of briquette mixed with CD and wood dust (WD). The various ratios of CD:WD:Starch:Water 20:0:20:60, 16:4:20:60, 12:8:20:60, 8:12:20:60, 4:16:20:60 and 0:20:20:60 (% by weight) were investigated. The dimensional of hexagon briquette specimen was 5 cm (outer diameter) and 2.5 cm (hollow inner diameter) with the height of 10 cm was subjected to physical and mechanical tests. Results of physical performance test showed that the briquette specimens with ratio of 20:0:20:60 (% by weight) gave the lowest ignition temperature, smoke temperature and duration of flame out time of 280°C, 275°C and 6.30 min/2g respectively. However, the briquette specimens made with ratio of 4:16:20:60 (% by weight) gave the highest heat energy of 3,960 kcal/kg. The result of mechanical properties showed that briquette specimens made with the ratio of 4:16:20:60 (% by weight) was the highest compressive strength of 9.80 N/mm^2. This study indicated that CD can be used as a substitute material for bio-briquette fuels.

Keywords: Briquette fuel, cotton dust, industrial waste.

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1. Introduction

The world's trend of energy consumption has increased rapidly from 456.5 quadrillion Btu to 558.7 quadrillion Btu in the last decade. In statistic, the world's total natural gas, coal, oils, renewable and nuclear consumption increases by 1.7, 1.3, 1, 4.6 and 0.5 percent per year on average respectively [1]. The increase in demand of using energy is driven by economic growth and expanding populations. All products and services have environmental impacts, from the extraction of raw materials for production to manufacture, distribution, usage and disposal. In textile industries, total municipal solid waste generated in US by 2011 was close to 5% of the total municipal solid waste generated in US. This figure corresponds to 12.5 million tons in weight. In each process of textile industry created an industrial waste such as CD from spinning mill, carbon dioxide and wastewater from dyeing mill.

Thailand has 155 spinning mill factories in operation, total spindle approximately to 3,770,500 spindles [2]. It has been estimated that cotton residue production is 2.9 times that of lint production [3]. The main waste from spinning mills is generated from the manufacturing of yarns at the blow room and carding process. The cotton waste generated in blow room process and carding process is approximately 4.2% and 4.5% of production of yarns respectively [4]. CD is one of the textile industrial waste problems facing in the cotton and textile industries today. The current waste disposal practice is normally land-filled. Thus, this type of disposal is becoming expensive to dispose by satisfying the requirements of environmental regulations. For decades, engineers and researchers have been interested in utilizing the waste products for value added to the waste product and reduce the depletion in natural resources.

The ways of disposing CD wastes are fuel composite materials and fertilizer. CD has a high heating value of 5,967.79 kcal/kg compared with rice husk, corn waste, palm waste, wood waste and bagasse which has heating value of 2,998.23, 1,994.83, 2,761.7, 2,599.26 and 1,798.94 kcal/kg respectively [5]. Therefore, it appears that CD can be used as composite briquette fuel for heat generation in households, small scale home industries or even for power generation in large-scale industries [6, 7]. In this study, the feasibility to produce environmentally acceptable fuel briquettes from CD and WD is investigated. The conducted study aims to reveal characteristic of CD and WD in bio-briquette on the heat energy and durability. Although, similar experiments have been investigated on other bio-wastes by many researchers previously, yet it is demanded that the results can greatly be contributed to further improvement. However, several constrains were identified for the dissemination of CD energy technology such as difficulty in delivery and preparation (drying, grinding) of a sufficient amount of biomass and technological limitations of the performance and efficiency of the combustion processes are its disadvantages [8, 9, 10]. In such a constraint situation, efforts are going on to improve the use of CD by-products through the development of valued-added products.

2. Experimental Investigation

2.1. Materials and Materials Preparation

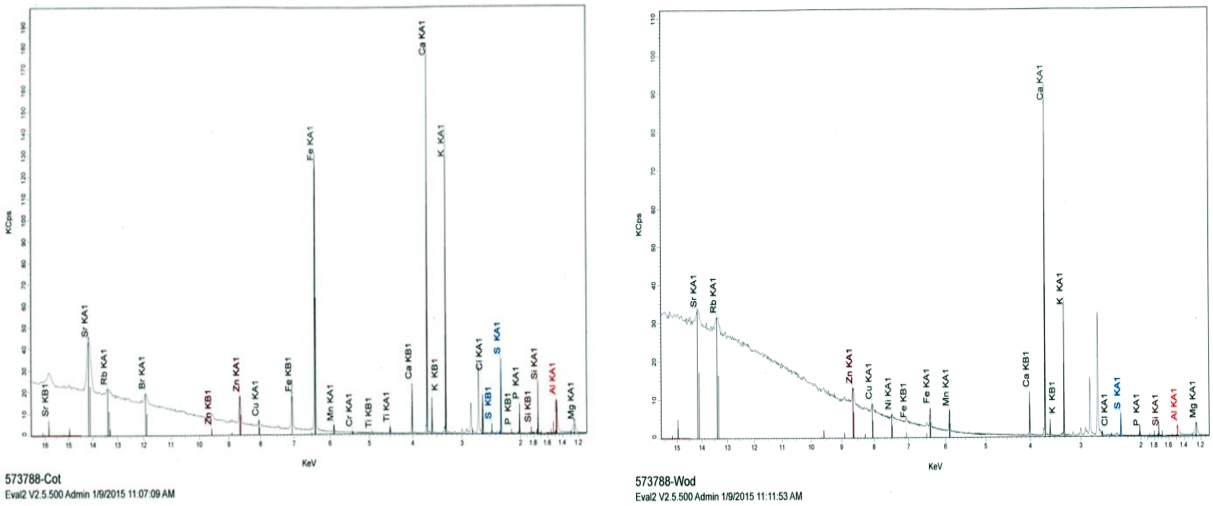
All materials used in this study were collected by academic experts. Figure 1(a) showed the cotton dust (CD) used in this study which was collected by Dust-FIL TERING Unit from blow room and carding room (Thai Alliance Textile Company). Figure 1(b) showed the wood dust (WD) which was collected from sawing process of pallet manufacture (Lek Charean Company). All materials were tested the particle size, heating performance and physical properties before producing briquette specimen. The particle sizes were tested by particle size distribution machine Mastersizer S long bed Ver. 2.19 [11]. The cassava starch was used as binder material. The mixtures of proportion of specimen were showed in Table. 1. The briquette specimens were made by briquetting press machine. The maximum pressure of 5 bars was constantly applied to each briquette specimen. Three briquette specimens were prepared for each set of experimental conditions, and the arithmetic averages of the measurements were calculated. In order to reduce moisture content, briquette specimens were oven-dried at temperature of 100 °C for 24 hour. The briquette specimens were then kept to cool down at controlled temperature and relative humidity (RH%) of 25 ± 1 °C and 30 ± 2 % respectively. Therefore, the briquette specimens had low moisture content and ease of size reduction [12]. It helped to reduce the cost of transportation, storage and resistance to fungal attack [13, 14]. Before briquette specimens were subjected to compressive strength test at regular intervals (7 days, 14 days and 28 days), the briquette specimens were kept at controlled environments till the date of test was met. This also helped to stabilize inner tensions affecting the microstructure and porosity of the briquette specimens. The keeping period of specimen was followed ASTM C39/C [15] and ASTM C918 [16]. The elemental content of CD and WD was showed in Fig. 2(a) and Fig. 2(b).


(a) (b)

Fig. 1. (a) Cotton dust; (b) wood dust.

Table 1. Mixture of proportion of briquette fuel.

No.	Mixture (% by weight)	Cotton dust (g)	Wood dust (g)	Starch powder (g)	Water (mg)
1	20:0:20:60	10	0	10	30
2	16:4:20:60	8	2	10	30
3	12:8:20:60	6	4	10	30
4	8:12:20:60	4	6	10	30
5	4:16:20:60	2	8	10	30
6	0:20:20:60	0	10	10	30



(a) (b)

Fig. 2. (a) The elemental content of CD; (b) The elemental content of wood dust.

2.2. Methods of Testing

In this study, competencies of heating performance, mechanical and physical properties of briquette specimens mixed with various ratios of CD and WD were investigated.

2.2.1. Mechanical properties

The briquette specimens were subjected to test workability of fresh composite materials. More specifically, it measured the consistency of the mixture in that specific batch. This test was performed to check the consistency of freshly made mixture. Consistency is a term very closely related to workability. It was a term which described the state of fresh mixture. It referred to the ease of mixture which the mixture flows. It was used to indicate the degree of wetness. Workability of mixture was mainly affected by consistency. Therefore, wetter mixes will be more workable than drier mixes. Addition, briquette specimens were also subjected to test compressive strength test. The maximum ultimate compressive strength of hardened briquette was determined using an TINIUS OLSEN TESTING MACHINE S/N 129315 testing machine. The rate of compression was at 20 N/mm^2/sec. The flat surfaces of both end of briquette specimen were capped with sulphur and placed on the horizontal metal plate of the machine. A motorized screw slowly reduced the distance between this metal plate and a second one parallel to it. An increased load was applied at a constant rate until the briquette specimens were failed by cracking or breaking. Compressive strength was calculated dividing the load at the fracture point by cross sectional area of plane of fracture.

The compressive resistance test provides a quick measure of the quality of pellets as soon as the briquette were produced from the briquette pressing machine and aids in adjusting the briquetting process to improve the briquette quality. The shape of briquette specimens was hexagon cylinder with hollow inside. The dimension of briquette specimens was 5 centimeters in outer diameter, 2.5 centimeters in inside hole diameter and 10 centimeters was the height of briquette specimen (see Fig. 3). The hexagon shape was chosen for preventing the briquette specimens from rolling, as well as provides easier storage. In addition, the hollow in the center allowed air to flow through when briquette specimens were burning. It helped higher burning efficiency. The methods of testing mechanical properties of briquette were complied with ASTM C143 [17] and ACI 211 [18], ASTM C192/C 192M [19] and ASTM C617 [20].

2.2.2. Physical properties

The briquette specimens were subjected to test ignition time, duration of outage time, ignition temperature and temperature smoke. The methods of testing physical of briquette were complied with UL 94 [21].

2.2.3. Heating performance properties

The briquette specimens were subjected to test heating value (kcal/kg) at dry basis, fixed carbon (% at dry basis), ash (% at dry basis) and moisture (% as dry basis). The results of heating performance were compared with the requirement of Thai community product standard (TCPS 238/2547, TCPS 657/2547) [22, 23]. The methods of testing heating performance of briquette were complied with ASTM D5865 [24], ASTM D3172 [25], ASTM D3174 [26] and ASTM D3173 [27].

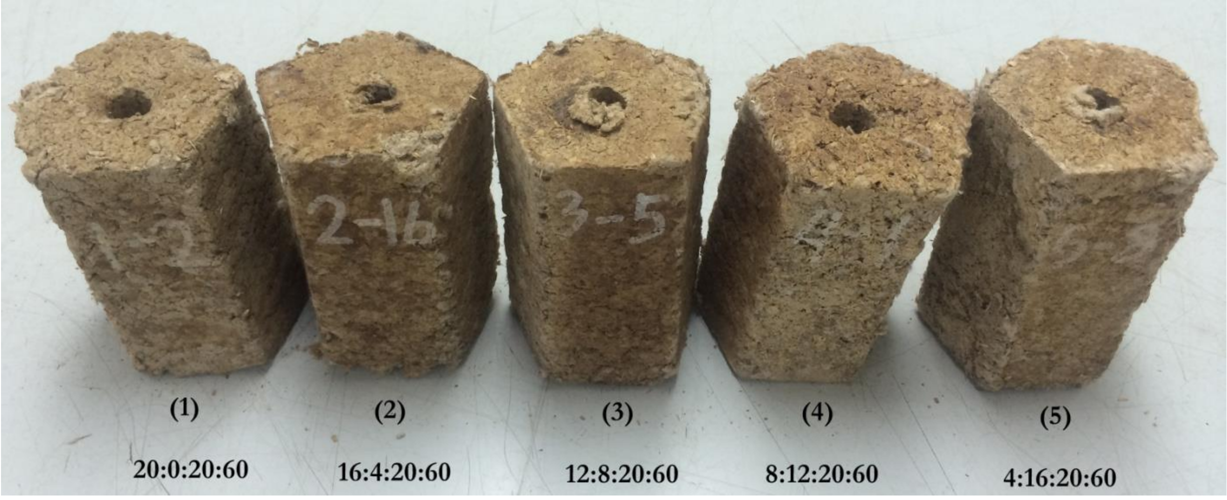
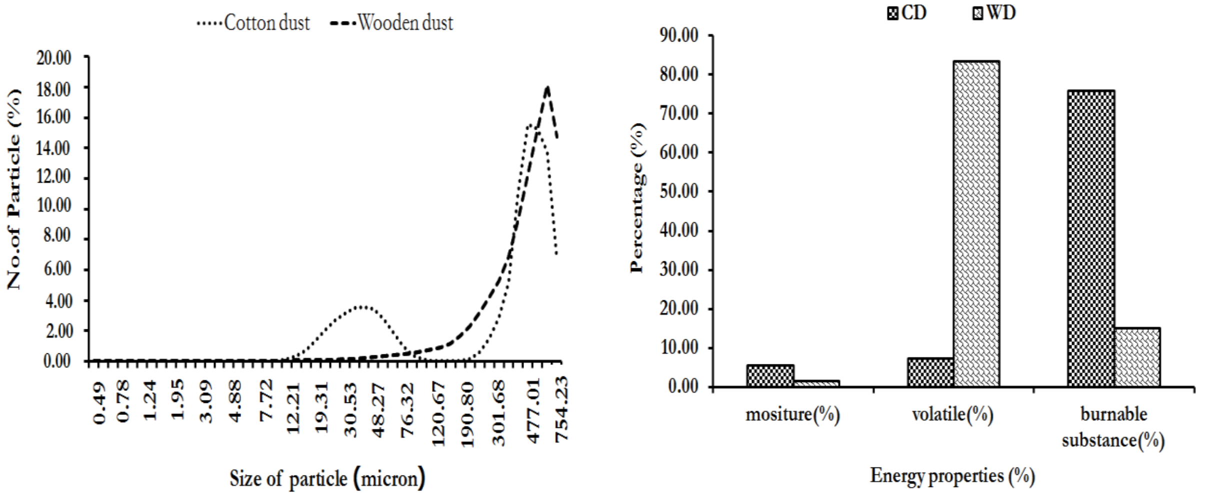


Fig. 3. The shape of briquette specimen at various mixtures.

3. Results and Discussion

Figure 4(a) showed the result of analyzed particle size and particle distribution of materials used in this study. For cotton dust (CD), it contained two ranges of data. It was called "bimodal". The first range was in between 9.00 micron to 120.67 micron. The second range was in between 140.58 micron to 754.23 micron. This was due to the length of CD was short. Addition, grime was contained cotton harvesting process such as soil, debris. For wood dust (WD), the particle size and particle distribution of WD was in the range of 1.68 micron to 754.23 micron. It was further found that particle distribution of WD was close to CD. A major faction of the WD was shifted towards higher particle size because of their rounded-like. Apart from moisture content, particle size distribution and particle size are two importance factors that affect the bulk physical properties of used materials. Particle size distribution reflects on the available surface area. Particle sizes affect the true density of the used materials and also influence durability [28, 29]. The finer or smaller the particle size, the higher will be the density. On the contrary, the lesser will be the porosity. Tabil and Sokhansanj [30] considered that particles with sizes below 0.4 mm are fine and highly compressible. Taking this criterion into account, WD had a maximum fine of 18.17%, followed by CD (15.57%). The differences in fines were mainly due to variation in screen sizes and inherent characteristic of used materials. Large particles are fissure points that caused cracks and fractures in compacts. Furthermore, large particles in compact mean inhomogeneous shrinking, which would develop crack [31]. It was further found that briquette made from coarser materials tended to expand more significantly shortly after released from the briquetting press machine. It also affected to maximum ultimate compressive strength of briquette.



(a) (b)

Fig.4. (a) The analysis of particle size and particle distribution of materials used; (b) The effect of briquetting on moisture content.

For moisture content of materials were showed in Table 2. Moisture content has strong influence on density, durability and storage. Li and Liu [32] reported that a range of moisture content for pelleting pruning wood should be in the range of 6% to 12%. In this study, it found that the moisture content of WD was still higher than Thai Community Product Standard by 2.10% by weight. While, the moisture content of CD was well within the moisture content range recommended by Thai Community Product Standard. The moisture content of the CD and WD material was compared with other wood based fuel materials as depicted in Fig. 4(b), the moisture content ranged between 5.29 to 10.10%. The highest volatile matter was WD. The highest burnable substance was CD (76.00%) followed by WD (15.05%) respectively. The difference between moisture content of CD and WD was 4.81%. However, the CD and WD material used for this study contained moderately acceptable range of moisture content that indicated better density, durability and storage.

For ash content, the CD material gave the highest remaining ash (7.35%). This moderately high ash content of CD was attributed to contamination of material. The ash content of wood was fixed at 5% to10% by weight for wood used in a commercial and large scale energy systems. The lower limit of 5% and the upper limit of 10% gave a good range for the quantities of ash produced. The requirement of Thai Community Product Standards (657/2547) governed that remaining of ash contents after-burning should be less than 10 % by weight. It found that CD and WD materials followed the requirement of Thai Community Product Standards. This ash content of WD was also relatively high for wood without contaminated with barks. However, these materials were acceptable for producing briquette fuel.

For fixed carbon (% dry basis), it found that CD gave the highest fixed carbon (16.65%). The presence of this carbon indicated an efficient fuel used and could reduce ash stabilization and significantly decreased ash volume. If the carbon contents were to be reduced it would become necessary to reburn the ash. The higher fixed carbon value, the longer burning time of briquette. Consequence, the volatile also reduced. It provided a lesser smoke. Therefore, the good quality of briquette fuel could be made. However, the amount of fixed carbon was also depended on type of materials which were used for producing briquette fuel. In this study, it also found that WD material gave the highest heat energy with 4,899.00 kcal/kg. While, CD gave heat energy of 3,567.50 kcal/kg. The heating energy of these two materials released was lower than the requirement of communities by 1,432.50 kcal/kg and 258.00 kcal/kg respectively. From obtained results showed that briquette specimens should be mixed with WD in order to provide higher heat energy. However, an increase in excessive amount of WD material caused poorly briquette formed.

Table 2. The characteristic of materials used.

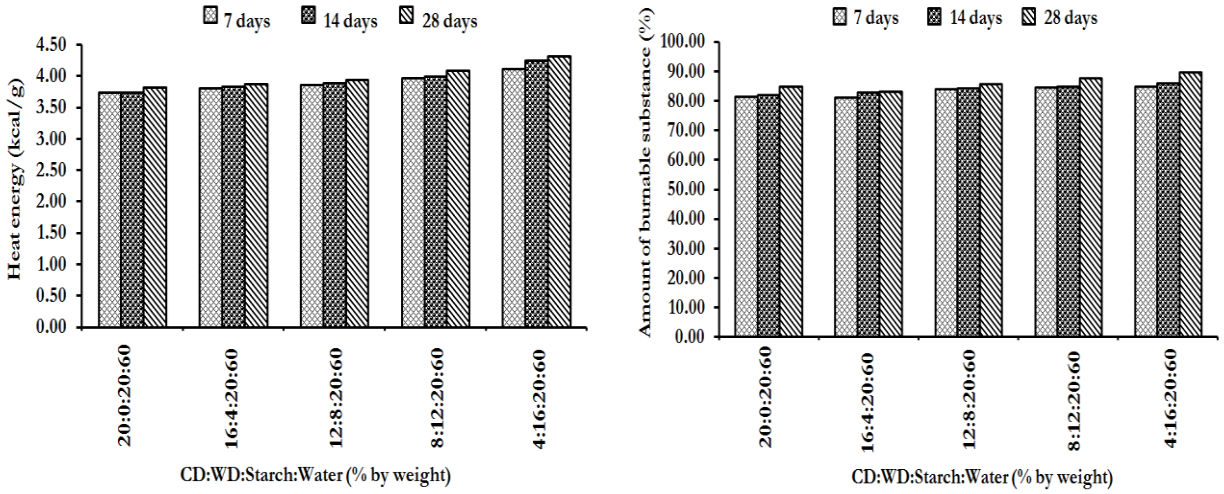
Materials	**Heat energy (kcal/kg)**	**Fixed carbon (% dry basis)**	**Ash content (%)**	**Moisture content (%)**	**Volatile matter (%)**
CD	3,567.50	16.65	7.35	5.63	70.37
WD	4,899.50	15.05	1.55	10.10	73.30
Starch	3,886.00	1.51	0.10	11.21	87.18
Standard of community	5,000.00	-	Not more than 10	Not more than 8	

For the results of heat performance tests, Fig. 5(a) showed the heat energy of briquette specimens, it found that briquette specimens made with 4:16:20:60 (% by weight) gave the highest heat energy. The heat energy decreased as the content of WD decreased. This was due to the WD had high heat energy. Figure 5(b) showed the amount of burnable substance in percentage. In addition, the briquette specimens made with 4:16:20:60 (% by weight) with 28 days keeping period gave the highest in percentage of burnable substance (89.74%). The percentage of burnable substance increased as time increased. This was due to moisture content of briquette decreased. Therefore, combustion efficiency was obtained. It was also found that this ratio specimen was also the highest increase rate found in burnable substance (5.6%). The percentage of burnable substance increased as the WD content increased. Figure 6(a) showed fixed carbon of briquette specimens. The briquette specimens made with ratio of 16:4:20:60 (% by weight) gave the highest fixed carbon among briquette specimens comprised with CD and WD. The amount of fixed carbon in each mixture of briquette specimens was not significantly different. It was in the range of 8.56% to 14.10%. It was further found that an increase in ratio of WD in mixture caused the amount of the fixed carbon in briquette specimens increased. This was due to the amount of fix carbon contained in WD material was high. In addition, CD material burnt at lower temperature and for longer time was that CD tends to have a much lower volatile matter content compared to WD. This caused the CD products to burn less vigorously and together with a higher carbon content which led to longer burning time.

Figure 6(b) showed ash content of briquette specimens. The briquette specimens of 4:16:20:60 (% by weight) with 28 days keeping period gave the lowest ash content among briquette specimens made with CD and WD (5.30%). The residual ash content was range from 1.70% to 5.30%. The ash content tended to increase as the amount of WD increased. Similarly, an increase in CD content also increased the ash content. This indicates a possible high interaction between CD and WD during combustion. However, the amount of ash generated from briquette specimens was lower than Thai Community Product Standard recommended.

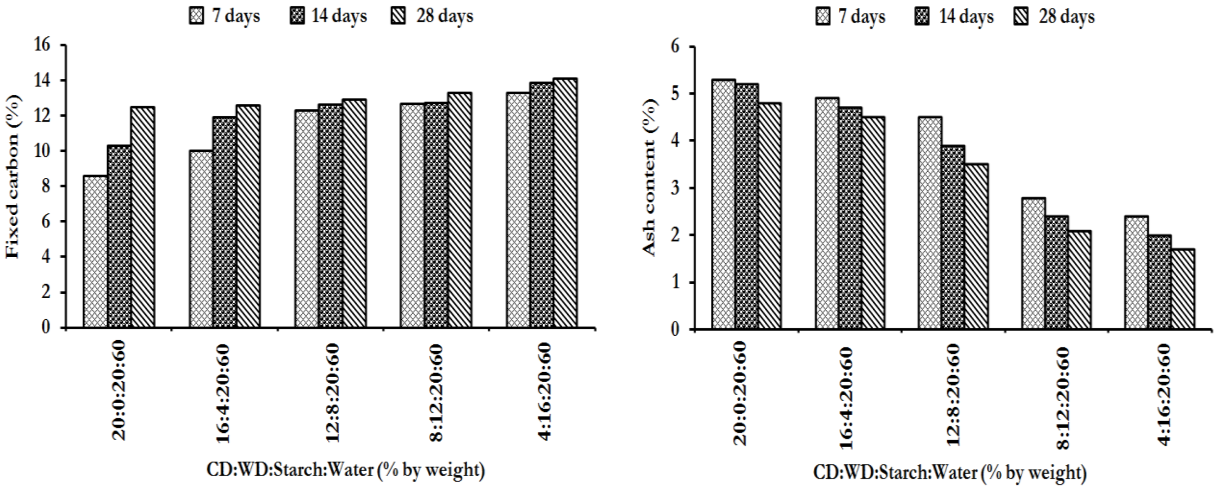
Figure 7(a) showed the change in moisture content of briquette specimens. The change in moisture increased as the content of WD increased. The lost in moisture content on the first 7 days was the highest. The lost in moisture decreased as time increased. The initial mass loss at low temperature was due to the evaporation of water adsorbed by the material when stored for a period of time after preparation. The mass loss at high temperature was due to the decomposition. It was further found that the briquette specimens of 4:16:20:60 (% by weight) with 7 days keeping period gave the highest moisture content. It was higher than the recommended range by 1.57% while the briquette made with ratio of 16:4:20:60 (% by weight) was the lowest in moisture content (10.84%) with keeping period of 28 days. The moisture of briquette decreased considerably with time. The moisture content of briquette reduced which was due to the rise in materials temperature during briquetting. A minimum change in moisture content due to briquetting was CD. In general, the compacted bio-material would have the moisture content between 7% to 14% [33]. However, the increase in WD content caused the moisture content of briquette specimens increased. It appeared that the moisture content of each ratio was not also significantly different. It was in the range of 10.84% to 11.57%. However, the moisture content was relatively high. All mixture ratios had higher moisture content than the requirement standard of communities (238/2547). This might due to the incompressibility of water, moisture trapped within the particles may prevent complete flattening and the release of natural binders from the particles. Addition, particle size is an important influencer of briquette moisture content. Generally, the finer the grind, the higher moisture content. Fine particles usually accept more moisture than large particles and, therefore, undergo a higher degree of conditioning [34].

Figure 7(b) showed the change in weight of briquette specimens. It observed that as the specimens made with ratio of 20:0:20:60 (% by weight) mixture exhibited a weight loss rate higher than that of briquette specimens mixed with WD mixture briquette specimens (22.8%). The change in weight decreased as the content CD decreased. Similar to change in moisture, the change in weight was greatly in the first 7 days. Then, the change in weight was gradually decreased.



(a) (b)

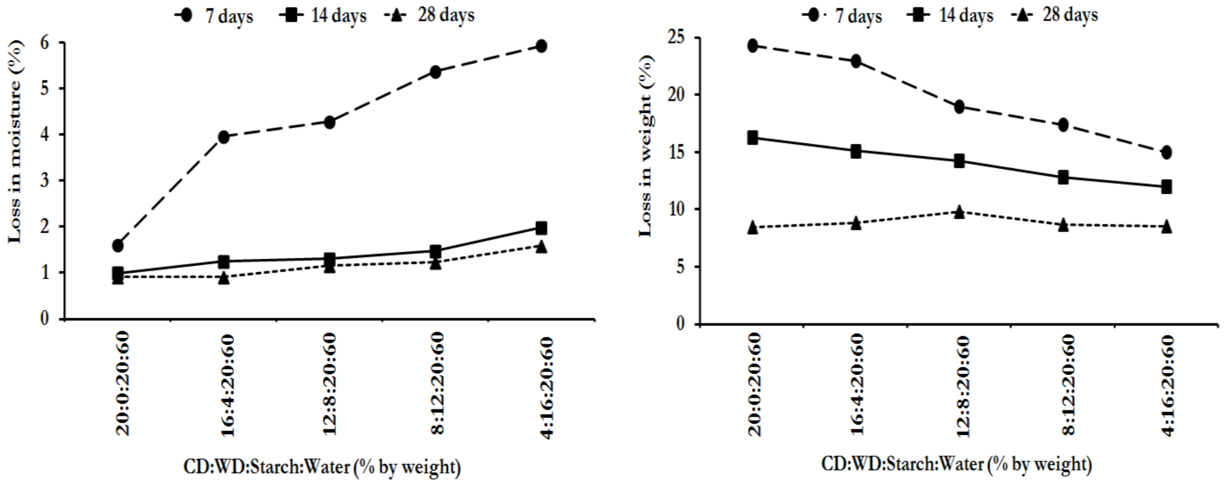
Fig.5. (a) Heat energy of briquette specimens; (b) Amount of burnable substance.



(a) (b)

Fig. 6. (a) Fixed carbon of briquette specimens; (b) Ash content of briquette specimens.

In Table 3 presented workability of fresh material test for produced briquette specimens. The workability of specimens determined the ease with which it can be mixed, placed, consolidated and finished to a homogeneous condition. It found that type of material, ratio of material and particle size of material affected to workability of fresh material. Similar results were found by Turner [35] and Vest [36]. It was further found that all fresh mixtures gave a true slump (see Table 3). There were subsided under own weight by the most of weight in center of base. The slump of mixtures was in the range of 0 to 3 mm (see Fig. 8(a)). This number indicated that the fresh mixture was very dry. The lower number of slump tests the drier of fresh mixture.



(a) (b)

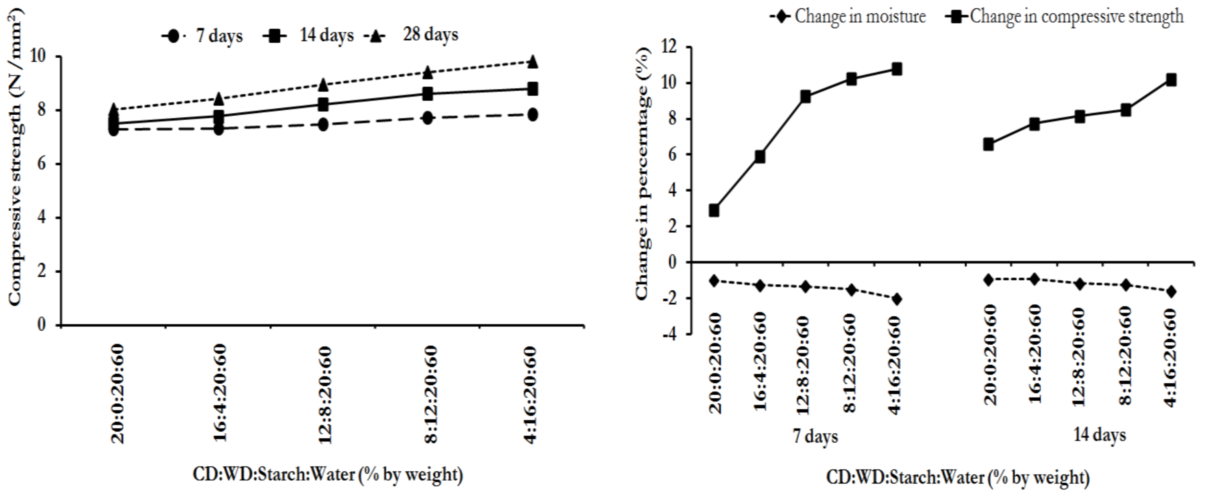
Fig. 7. (a) Loss in moisture content of briquette specimens; (b) Loss in weight of briquette specimens.

Table 3. Workability of fresh material test.

No.	Mixture (% by weight)	Characteristics of the mixture	Condition of slump	Slump (mm)
1	20:0:20:60	Dry	True	1
2	16:4:20:60	Dry	True	2
3	12:8:20:60	Dry	True	2
4	8:12:20:60	Dry	True	3
5	4:16:20:60	Dry	True	2
6	0:20:20:60	Dry	True	0

(a) (b)

Fig. 8. (a) Slump test of CD 100% and (b) Slump test of 8:12:20:60 (% by weight) mixture.



(a) (b)

Fig. 9. (a) The compressive strength of briquette specimens; (b) Relationship between moisture and strength.

Figure 9(a) represented the results of compressive strength test (7, 14 and 28 days). It found that the briquette specimens made with ratio of 4:16:20:60 (% by weight) was the highest compressive strength. It was further found that compressive strength increased as time increased. This might due to gelatinization of starch which occurred by two mechanisms: (i) hydration and swelling of starch granules and ultimately disruption of the crystalline structure due to the combined effect of temperature and moisture; and (ii) disruption of starch granules by shear friction as the feed mash expelled through the pellet die [37]. An increase amount of CD content caused the compressive strength of briquette decreased. This was due to CD fiber decreased the viscosity of the mixture and negatively affected the structural integrity of the briquette. Similar results were found by other researchers [38, 39]. However, an increase in WD content in mixture also reduced the ultimate compressive strength. It caused the coarse mixture was forced to leave the mixture matrix, forming some cavities in the briquette [40]. Furthermore, some of moisture content was evaporated with the releasing during keeping briquette specimens. It was found that briquette specimens made with WD 100% could not be formed or poorly formed. This was due to particle size of wood dust was too large. The adhesion of particle inside briquette specimen was not fully intact. Therefore, WD 100% mixture was not suitable for forming briquette fuel specimen.

Figure 9(b). The compressive of briquette increased as the moisture content decreased. It was further found that the loss in weight increased when CD material decreased. This might due to the CD particle was smaller than WD material. Therefore, the briquette specimen made with high ratio of CD material had smaller pores size which allowed lesser moisture to escape freely. However, a mixture of different particle sizes would gave optimum briquette specimens quality because the mixture of particles will make inter-particle bonding with nearly no inter-particle spaces [41]. Addition, during briquetting, CD was not able to absorb moisture in the pressing chamber so water remained on the surface of the materials, causing excess particle-to-particle lubrication. This condition caused the center of the briquette to extrude faster than the exterior which would reduce the briquette durability. Addition, this evaporation also brought about formation of new pores, reducing the strength of briquette. On the other hand, in order to obtain mechanically strong briquette. WD must be limited and CD material that acts as a binding agent by interaction with coarse particles should be used. It also appeared from the result that using CD as main mixture in making briquette fuel was not good combination. CD fiber can be classified as water-insoluble fibers which entangled and fold between particles or fibers [42]. Due to their resilience characteristics (e.g., stiffness and elasticity), fibers may not make good bonding between particles or fibers [43]. Also, presence of large amount of CD fibers in the briquette matrix may result in weak spots for fragmentation.

In Table 4 presented physical performance of briquette specimens. Physical performances of briquette were subjected to ignition temperature, ignition time, smoke temperature and duration of outage time test. Similar to compressive strength test, the briquette specimens were all kept for 28 days before it was subjected to tests. For ignition temperature result, it found that ignition temperature of briquette was in the range of 280 °C to 325 °C. The briquette specimen made with ratio of 20:0:20:60 (% by weight) had the lowest ignition temperature. The briquette specimen made with ratio of 16:4:20:60 (% by weight) gave the lowest ignition temperature among briquette specimens. The briquette specimens were also subjected to ignition time test. Each two grams of briquette specimen was ignited and the time required for the flame to ignite the briquette was recorded. For ignition times, it found that the briquette specimen made with ratio of 20:0:20:60 (% by weight) had the longest of ignition time which took 10:40 min/2g to ignite the briquette specimens.

Table 4. Physical performance of briquette specimens at 28 days age.

No.	Mixture (% by weight)	Ignition temperature (°C)	Ignition time (min/2g)	Smoke temperature (°C)	Duration of flame out time (min/2g)
1	20:0:20:60	280	10:40	275	6:30
2	16:4:20:60	305	9:50	295	6:20
3	12:8:20:60	310	9:40	305	6:10
4	8:12:20:60	320	9:20	315	6:10
5	4:16:20:60	325	9:10	325	6:00

For smoke temperature result, it observed that smoke temperature of briquette specimens were in the range of 275°C to 315°C. It found that smoke temperature decreased as CD content in briquette specimen decreased. However, the briquette specimen made with ratio of 4:16:20:60 (% by weight) had the lowest smoke temperature. The briquette specimens were also examined duration of flame out time which measured as time taken from the moment briquettes ignite until the complete burn out. Two grams of the composites briquettes were burned in charcoal stoves and the burning time was measured [44]. For duration of flame out time, it was found that briquette specimens were in the range of 6:00 to 6:30 min/2g. The briquette specimen mixed with ratio of 20:0:20:60 (% by weight) gave the longest duration of flame out time with 6 minutes and 30 seconds. A decrease in amount of CD tended to shorten the duration of flame out time. This might due to CD tends to have a much lower volatile mater content compared to wood. This causes the CD products to burn less vigorously and together with a higher carbon content [45]. Consequence, it leads to longer burning time.

Regarded to the production costs of fuel briquette made from CD and WD, Data received from the Thai Alliance Textile Company were used in estimating the cost of fuel briquette production (see Table 5). The average production rate was 22.8 kilogram per hour. An average weight of briquette specimen was 185g. The cost of raw material was the average transaction price per ton of CD, WD, starch and water which authors bought in between 2013-2014. Transport was carried out by own vehicle. Cost of electricity was estimated on the basis of historical data from the Thai textile companies. It found that the highest in the share was cost of electricity, raw material and labor respectively. However, the price factored the possibility of an additional grinding sawdust to a more fragmented faction. The fresh sawdust contained moisture content about 50%. This will affect their need for drying. The total materials cost of producing fuel briquette made from CD and WD was in the range of 0.99 to 1.06 baht per briquette. Table 6 showed comparison the cost of producing fuel briquette with various materials from other researchers. It found that the cost of producing the briquette specimen with ratio of 4:16:20:60 (%by weight) was 1,253.29 baht per ton. It was considerably cheaper than briquette made from straw, sawdust, cereal and oil-rape straw. However, the price paid for residues, if any, is very much a site-specific issue and must be regarded as an add-on unit cost relevant to a particular project. Even, if the residue is nominally free, it is common for a transport cost to be incurred in bringing the residue to the briquetting plant. In the case of units sited at the residue production point, other situations the transport cost may be a significant part of operational costs. In addition, transport costs may be added into general labor costs if fulltime drivers are employed. The labor costs of a briquetting plant are very dependent upon plant design; the scope of the operation, in particular whether there is any significant residue collection activity; the wage rates of the various categories of labor employed; and the extent to which the unit is integrated with a larger factory which can supply some labor needs on a part-time basis.

Table 5. The cost of raw materials in producing fuel briquette (baht per briquette).

Mixture (% by weight)	CD	WD	Starch	Water	Total
20:0:20:60	-	-	0.988	0.002166	0.99
16:4:20:60	-	0.01824	0.988	0.002166	1.00
12:8:20:60	-	0.03648	0.988	0.002166	1.02
8:12:20:60	-	0.05472	0.988	0.002166	1.04
4:16:20:60	-	0.07296	0.988	0.002166	1.06
0:20:20:60	-	-	0.988	0.002166	0.99

Table 6. The total average cost of producing fuel briquette (baht per ton).

Material	Raw materials	Labor	Transportation	Electricity	Total cost
Coffee[46]	32.68	98.44	535.01	98.63	832.28
Straw [46]	65.36	131.12	1173.90	163.81	2114.75
Sawdust [47]	1441.22	274.70	360.30	405.44	2481.67
Cereal and Oil-rape straw [47]	576.64	347.85	143.97	463.03	1531.49
CD and WD	396.88	313.61	7.39	697.65	1253.29

4. Conclusion

Though the use of cotton dust (CD) material as a source of fuel for substituting material may in the ray of acceptable for producing briquette fuel, as physical and mechanical properties of briquette specimen mixed with CD was concerned. The CD material could not be used as mainly fuel material in a mixture. The production of CD fuel briquette required low in moisture content (less than 11%), less ignition time, low ignition temperature and the longer duration of flame-out time. These could be accomplished by using combination of CD and wood dust (WD) in the ratio of 16:4:20:60 (% by weight). In this study, the CD material showed the best potential, not necessarily with the highest temperature but with the longest burning time. In order to maintain an optimum of heat energy value and the compressive strength which reflect its heat energy release and durability of briquette, it is recommended that 16% by weight of CD can only be added to a mixture. Therefore, it might be best not to use CD and WD material greater than 20% overall by weight. However, an increase in percentage less than 16% by weight of WD in mixture helped to formation of briquette specimen and decrease ignition time. As cassava starch used, a solution type binder, the strength of briquette was moderate. However, this strength increased with time of curing. Therefore, selection of binders mainly depended on cost and environmental friendliness. In order to have dense and solid briquettes, high moisture rates should be avoided. Otherwise, produced briquettes would swell and then break up to several pieces after taking them from the die. As a result, below 11% moisture level was found to be suitable according to the data. The briquette specimen made with ratio of 16:4:20:60 (% by weight) gave the highest compressive strength overall. On the basis of study conducted, the total cost of producing the ton of fuel briquettes from CD and WD was estimated at the level of 1,253.29 baht per ton. As it can be observed in Thailand seems to be an opportunity to increase profitability of Thais agriculture and reduce the land-fill cost of spinning-textile companies. Provided results of study may be a useful source of information in the management of companies involved in the production of agro biomass fuel briquettes.

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