

Comparison of the Physical and Chemical Properties of Briquette and Wood Charcoal in Khammouane Province, Lao PDR

การเปรียบเทียบคุณสมบัติทางกายภาพและเคมีของถ่านจี้เลื้อยอัดแท่งและถ่านไม้ที่แขวงคำม่วน
สาธารณรัฐประชาธิปไตยประชาชนลาว

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Abstract

The economy of Lao Peoples Democratic Republic (PDR) has been expanding with substantial dependence on natural resources. Forests are continuously depleted to meet industrial demands for wood and furniture. In Khammouane Province where many wood processing industries are located, one of the problems from wood processing industries is the pollution of the near environment through saw dust disposal. On the other hand, the entire communities who live in this area use wood charcoal as a main source of fuel. An alternative to saw dust dumping will therefore be its conversion to briquette charcoal. However, the suitability of the wood charcoal for cooking has not been fully determined. This research seeks to determine this suitability by comparing the physical and chemical characteristics of briquette and wood charcoal. Six samples of wood charcoal from different tree species namely *Cratogeomys cochinchinense*, *Pterocarpus marcocapus*, *Pinus merkusii*, *Sindora siamensis*, *Ketepeleeria davidiana* and *Pettophorum dasylachis* and one sample of briquette charcoal were obtained and taken to the laboratory to determine the physical property (gross calorific value) and the chemical properties (moisture, volatile, ash and fixed carbon content). Results show that briquette charcoal is a quality charcoal in terms of high gross calorific value and high fixed carbon with 7,595 cal/g and 78.68%. Conversely, it had low moisture and ash content of 1.88% and 3.79%, respectively, comparing with the other wood charcoals. Results from this research leave the conclusion that briquette charcoal is an alternative source of fuel for consumption. Therefore the government of Khammouane province should encourage and increase the investment in briquette charcoal production to subsidize fuel consumption. In addition, enormous quantity of sawdust utilized also reduces environmental impacts from saw dust dumping.

Keywords: Lao PDR / Khammouan province / briquette charcoal / sawdust / alternative fuel

บทคัดย่อ

เศรษฐกิจของประเทศสาธารณรัฐประชาธิปไตยประชาชนลาวได้ขยายตัวอย่างต่อเนื่องและการขยายตัวของเศรษฐกิจจะขึ้นอยู่กับการใช้ทรัพยากรทางธรรมชาติ ไม้ในประเทศได้ถูกใช้ไปเพื่อสนองความต้องการของอุตสาหกรรมไม้และเฟอร์นิเจอร์ไม้ ในแขวงคำม่วนซึ่งเป็นเมืองที่มีอุตสาหกรรมที่เกี่ยวกับการผลิตไม้อยู่เป็น

คำสำคัญ : สปป.ลาว / แขวงคำม่วน / ถ่านขี้เลื่อยอัดแท่ง / ขี้เลื่อย / เชื้อเพลิงทางเลือก

1. Introduction

Khammouane province is one province located in the central of Laos (DPIK, 2003). The economy in this province is based mainly on natural resources from the forest and most people solely depend on agriculture for their livelihood. Presently, the Khammouane forest occupies about 47 percent of the total land area. On the other hand, industrial has covered 30% of GDP of the province, especially the commercial logging and wood products (DAFK, 2003) that belong to 13 wood processing factories and 20 saw mills. Annually, the government issues quotas approximately 50,000 m³ of timber for factories to produce different products. These products include parquet, wood floor, wood wall, furniture and lumber (DICK, 2006). According to STEAK (2006) concerned that enormous quantity of saw dust is produced from timber processing with approximately 200 metric tonnes per day in Khammuoane but only a little part of sawdust is used every day in the chipboard production and as fuel for charcoal production. Consequently, enormous sawdust is still deposited in the landfill and causes environmental problems such as the wood processing factories get rid of the sawdust by open burning. This causes serious problems as the burning activity releases a lot of particulate matters and gases into the atmosphere causing air pollution. In addition, disposal sawdust into landfills creates another problem to water drainage system. This problem is worse during the rainy season. The storm water carries saw dust into drainage pipes thus blocking the regular flow of water. Beside that, it also flows to rice fields which was piled for long time and transformed in form sediment and sludge in rice fields.

Approximately 90 percent of Khammouane population utilizes fuel wood as energy including wood charcoal and firewood for cooking, heating, lighting particularly in rural households and a minority of urban dwellers. In 2006, wood residues and sawdust were monthly produced roughly 35 and 15 percent, respectively within 13 wood processing factories and 20 saw mill factories in Khammouane province (DICK, 2006). Approximately 70 percent of wood residues are used as fuel in the combustions of steam boilers of wood processing factories, and remaining 30 percent of it is used as wood charcoal by some charcoal vendors living around those areas (STEAK, 2006). In addition, wood charcoal production is extremely famous for local communities which stay along Road number 13 from Sebangfay, Thakek to Hinboun district of Khammouane province.

Sawdust is a by-product, and emphasis should be placed on product planning and development. If it is not used, it may be disposed as waste and making it economically worthless. Looked at positively, it is a valuable concentration of new resources waiting for utilization. If these wood wastes are converted into a new product and properly marketed, it will considerably encourage the total profitability of the forest. Presently, there is an only one briquette charcoal factory name EP Energy Company that has the maximum ability of briquette charcoal production of 60 tones per month but the real situation is only 33 tones per month obtained monthly (DICK 2008). Causes of less do not belonged to material as sawdust but it belongs to domestic briquette charcoal consumers or domestic market requirement, domestic consumers do really not understand about the quality of briquette charcoal definitely.

Therefore, the suitability of using briquette charcoal from sawdust comparing with wood charcoal is considerable. The main objective of this research was to analyze the physical and chemical properties of utilized product as briquette and wood charcoal in Khammouane province.

2. Material and Methods

2.1 Collection of charcoal samples

The samples of charcoal were collected during November 27 to December 05, 2008 in Khammouane province. One sample of briquette charcoal was collected at AP Energy Company (Briquette charcoal production factory), and six wood charcoals produced from different tree species namely *Cratoxylum cochinchinense*, *Pettophorum dasylochis*, *Pterocarpus marcocapus*, *Pinus merkusii*, *Sindora siamensis* and *Ketepeleeria davidiana* were collected. The first two wood charcoals were produced from indigenous trees of specifiable wood charcoal production (MAF, 2008) while the others were wood charcoal produced from residue woods of commercial timber around wood processing factories.

2.2 Charcoal properties

The experiment of this research conducted physical and chemical properties of briquette and wood charcoal. For analysis of gross calorific value was determined for physical property while moisture content, volatile matter, ash content and fixed carbon were analyzed for chemical properties.

2.3.1 Physical property

Gross calorific value of charcoal was carried out in the Laboratory at the Faculty of Engineering, Mahidol University, Nakonpathom, Thailand. One briquette and six wood charcoal specimens were analyzed by an adiabatic oxygen bomb calorimeter of Parr 1563 and Parr 1261 oxygen bomb, which were used following the Parr instruction manual according to ASTM D-5865-95 (1996). The charcoal specimens were milled with 0.7-0.9 gram of each as pellets then placed in a capsule and combusted in the oxygen bomb. The gross calorific value produced after combustion of sample was recorded and converted into calories per gram.

2.3.2 Chemical properties

Chemical properties of this experiment includes moisture content, volatile matter and ash content were determined by using the chemical analysis of wood charcoal in accordance with ASTM D-1762-84 (1996). On the other hand, fixed carbon content was computed by following the equation of Anon (1987). The chemical properties of charcoal were conducted in the Laboratory at the Faculty of Environment and Resource Studies, Mahidol University, Nakonpathom, Thailand.

The moisture content was determined as loss in weight in a drying oven at 105 °C. The same specimen was used for volatile matter and ash content determination.

The Volatile matter was determined as loss of weight at 950°C by preheating the specimen in the muffle furnace for two minutes at 300°C then heating for three minutes at 500°C, finally for six minutes at 950°C in covered crucible of specimen by lid. Volatile matter was calculated as a proportion of oven-dry weight of charcoal specimen.

The ash content was determined as the residue after burning of specimen to constant weight at 750°C for six hours in uncovered crucible of specimen. Ash content was computed as a proportion the residue to the oven-dry weight of charcoal.

3. Results and Discussion

Table 1 showed the results of the experiment of physical and chemical properties of briquette and wood charcoal. Briquette charcoal had a moisture content of 1.88%, a volatile matter of 15.65%, an ash content of 3.79%, a fixed carbon of 78.68% and a gross calorific value of 7,595 cal/g, and charcoal of wood species had moisture contents, volatile matters, ash content, fixed carbon and gross calorific value ranged between 0.76% and 3.17 %, 19.43% and 37.59%, 1.15% and 3.47%, 58.33% and 73.92% and 7,068cal/g and 8,246cal/g, respectively.

Table 1 Mean values of moisture content, volatile matter, ash content, fixed carbon, and gross calorific value of briquette charcoal and charcoal of wood species.

| No | Description | MC (%) | VM (%) | AC (%) | FC (%) | GCV (cal/g) |
|----|----------------------------------|--------|--------|--------|--------|-------------|
| 1 | <i>Cratoxylum cochinchinense</i> | 2.81 | 24.68 | 2.59 | 69.92 | 7,222 |
| 2 | <i>Pettothorum dasylochis</i> | 2.85 | 37.59 | 1.23 | 58.33 | 7,269 |
| 3 | <i>Pterocarpus marcocarpus</i> | 2.66 | 32.45 | 1.65 | 63.24 | 7,727 |
| 4 | <i>Pinus merkusii</i> | 2.07 | 23.31 | 1.38 | 73.24 | 8,246 |
| 5 | <i>Sindora siamensis</i> | 3.17 | 19.43 | 3.47 | 73.92 | 7,607 |
| 6 | <i>Keteleeria davidiana</i> | 0.76 | 36.86 | 1.15 | 61.23 | 7,068 |
| 7 | Briquette charcoal | 1.88 | 15.65 | 3.79 | 78.68 | 7,595 |

Moisture Content – MC

Volatile Matter – VM

Ash Content – AC

Fixed Carbon – FC

Gross Calorific Value – GCV

3.1 Moisture content

Moisture content of the charcoal produced from *Keteleeria davidiana* was the lowest with the value of moisture content of 0.76%, while the highest value of moisture content was 3.17%, which was the charcoal produced from *Sindora siamensis*, as for moisture contents of charcoal produced from *Pinus*

merkusii, *Pterocarpus marcocapus*, *Cratoxylum cochinchinense*, *Pettophorum dasylachis* were 2.07%, 2.66%, 2.81% and 2.85%, respectively and moisture content of briquette charcoal was 1.88% as shown in figure 1.

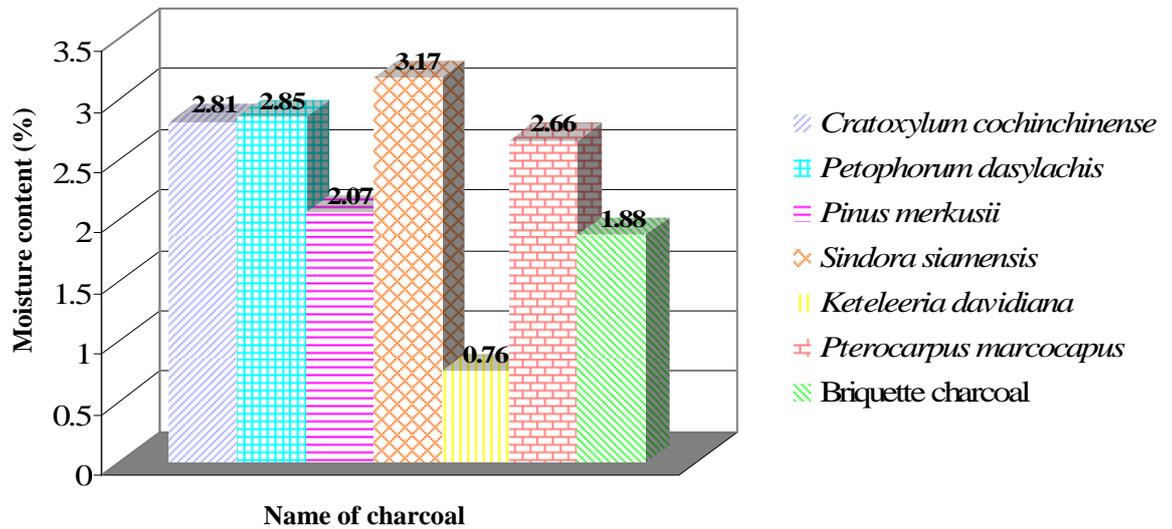


Figure 1 Moisture contents of briquette and wood charcoals.

Moisture contents of the charcoal also differed significantly between charcoal produced from different wood species and briquette charcoal as shown in figure 1. The high moisture content gives the result of low calorific value (FAO, 1985). It seems true where a briquette charcoal had lower moisture content of 1.88% and had the higher gross calorific value of 7,595 cal/g. If briquette charcoal containing high of moisture content will lead to the swelling and the disintegration of the briquette charcoal (Singh, 2004). Normally, the fresh charcoal from an opened kiln contains a very little moisture content, which is usually less than 1% but it can absorb the moisture content from the humidity of air itself rapidly with time, a gain of moisture even without any rain wetting and even the charcoal in well burned situation can take the moisture content about 5 to 10% (FAO, 1987). The quality specification of charcoal usually limits the moisture content between 5 to 15% (FAO, 1985) while the good quality of charcoal should have the moisture content is 10% maximum. On the other hand, there is some evidence concerned that charcoal with high moisture content at 10% or more than 10% tends to shatter when heated in the blast furnace (FAO, 1987). According to FAO (1985) concerned that the value of moisture content of the charcoal produced from mixed tropical hardwood was 5.4% while moisture contents of charcoal in this experiment ranged 0.76% to 3.17%, which falls within the desirable criteria by FAO (1987).

There is one reason of lower moisture contents of the charcoal produced from different wood species and briquette charcoal from this experiment, because the whole of each sample was collected at opened kilns, where was ready for packing, then fresh charcoal was filled into plastic bags that charcoal is

unabsorbable of the humidity of the air itself. Plastic bags were afresh opened when conducting of the experiment. Therefore, it is quite difficult for the charcoal to absorb the humidity from the air. Thus this reason tends to be one reason of less values of moisture content in briquette and wood charcoal.

3.2 Volatile matter

Volatile matters in wood charcoal of *Keteleeria davidiana* and *Petophorum dasylochis* were not significantly different with 36.86% and 37.59%, respectively, while volatile matters of the charcoal produced from *Pinus merkusii* and *Cratoxylum cochinchinense* were not also different at 23.31% and 24.68%. The lowest volatile matter was 15.65%, which achieved from briquette charcoal. The proportions of volatile matter in the charcoal of other wood species as *Sindora siamensis* and *Pterocarpus marcocapus* was definitely different with 19.43% and 32.45%, respectively as shown in figure 2.

Volatile matter in charcoal can vary from a high value of 40% or more down to 5% or less than 5% (FAO, 1985). Good quality charcoal should have volatile matter range from 20 to 25% (FAO, 1987). The charcoal of *Petophorum dasylochis* had the highest volatile matter with 37.59% compared with the charcoal of *Keteleeria davidiana* with 36.86%, while volatile matters of the charcoal produced from *Pinus merkusil* and *Cratoxylum cochinchinens* were similar, which fall within the desirable criteria by FAO (1987). On the other hand, FAO (1985) concerned that the value of volatile matter of the charcoal produced from mixed tropical hardwood ranged from 17.1% and 23.6%. In this experiment, the lowest volatile matter of briquette charcoal was 15.65%. Otherwise, it is very difficult to ignite in the blast furnace due to interviews of briquette charcoal consumers in Khammouane province.

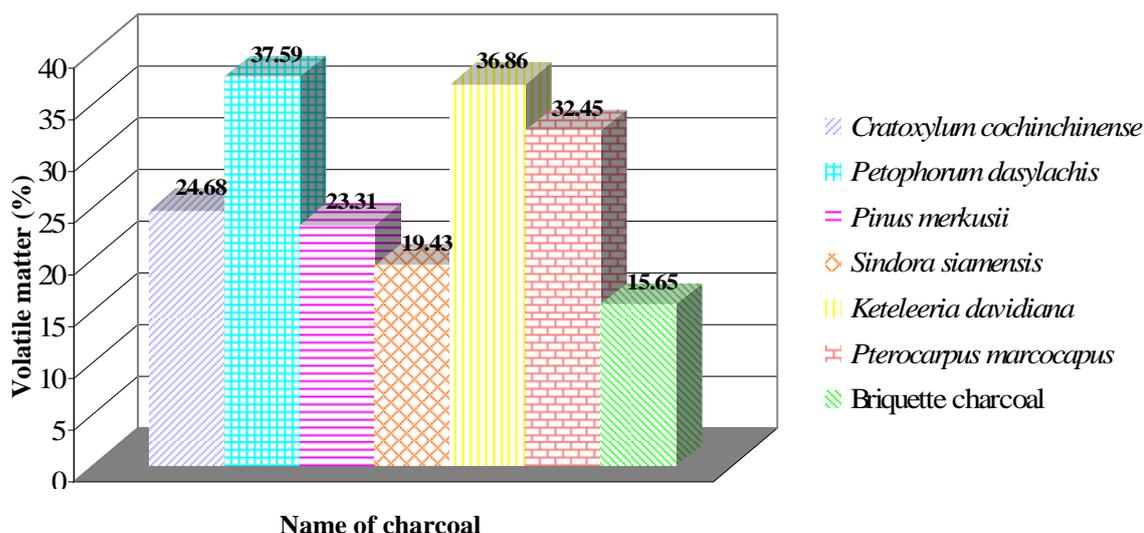


Figure 2 Volatile matters of briquette and wood charcoals.

Charcoal produced at high temperature will have lower value of volatile matter than charcoal produced at low temperature. In addition, the high value of volatile charcoal tends to be stronger, heavier, harder and easier for the ignition than low volatile charcoal. Therefore, high volatile charcoal is easier to ignite but may burn with smoky flame while low volatile charcoal is difficult to ignite and burns with less smoke. Consequently, high volatile charcoal is preferable for domestic charcoals (Erlinda and Dionco-Adetayo, 2001) that use in any purposes such as barbecue, cooking and heating, while other utilizations as metal manufacture and chemical purification prefer low volatile charcoal (EI-Juhany et al, 2003)

3.3 Ash content

Briquette charcoal had 3.79% of ash content, which was significantly different from the charcoal of different wood species. The proportion of ash content in *Keteleeria davidiana*, *Petophorum dasylachis*, *Pinus merkusii* and *Pterocarpus marcocapus* produced charcoal had only 1.15%, 1.23%, 1.38% and 1.65%, respectively, which is lower than those of other wood charcoals from *Cratoxylum cochinchinense* and *Sindora siamensis* with 2.59% and 3.47%, respectively as shown in figure 3.

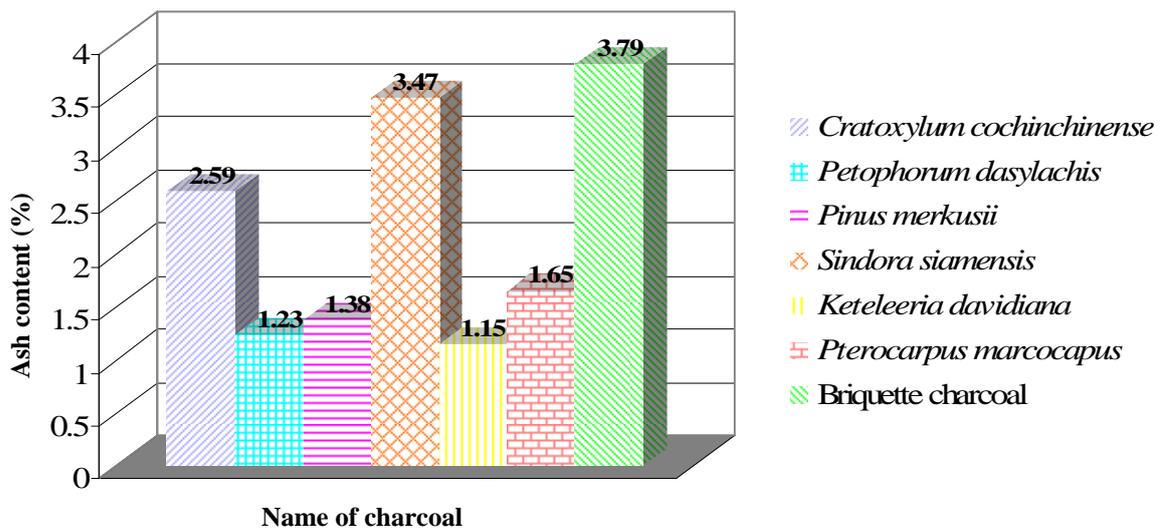


Figure 3.3 Ash contents of briquette and wood charcoals.

The ash content of charcoal ranged from 0.5 to 5% or more than 5% that depending on the wood species (FAO, 1985). According to FAO (1987) concerned that the good quality charcoal should have typically the ash content ranged from 3 to 4%. FAO (1985) identified that the ash content of the charcoal produced from mixed tropical hardwood ranged from 1.2% to 8.9%, it was further more explained that fine charcoal as briquette charcoal may have high ash content. In the process of charcoal production if material less than 4 mm is screened out and remains only the plus 4mm for charcoal produced may have an ash content of approximately 5 to 10%. Therefore, the result of ash content of briquette charcoal in this research seems true. However, briquette charcoal still contains the highest ash

content comparing to other wood charcoals within this investigation. Briquette charcoal consumers concerned that briquette charcoal had enormous quantity of ash that observed during finished combustion of briquette charcoal compared generally to wood charcoal.

3.4 Fixed carbon

Fixed carbon in the briquette charcoal was 78.68%, which was the greatest proportion comparing to the charcoal produced from different wood species. The charcoal produced from *Pinus merkusii*, *Sindora siamensis* were not significantly different of fixed carbon while charcoals from *Keteleeria davidiana*, *Pterocarpus marcocapus* and *Cratoxylum cochinchinense* had 61.23%, 63.24% and 69.92%, respectively, and the lowest value of fixed carbon was 58.33%, which was the charcoal produced from *Petophorum dasylachis* as shown in figure 4.

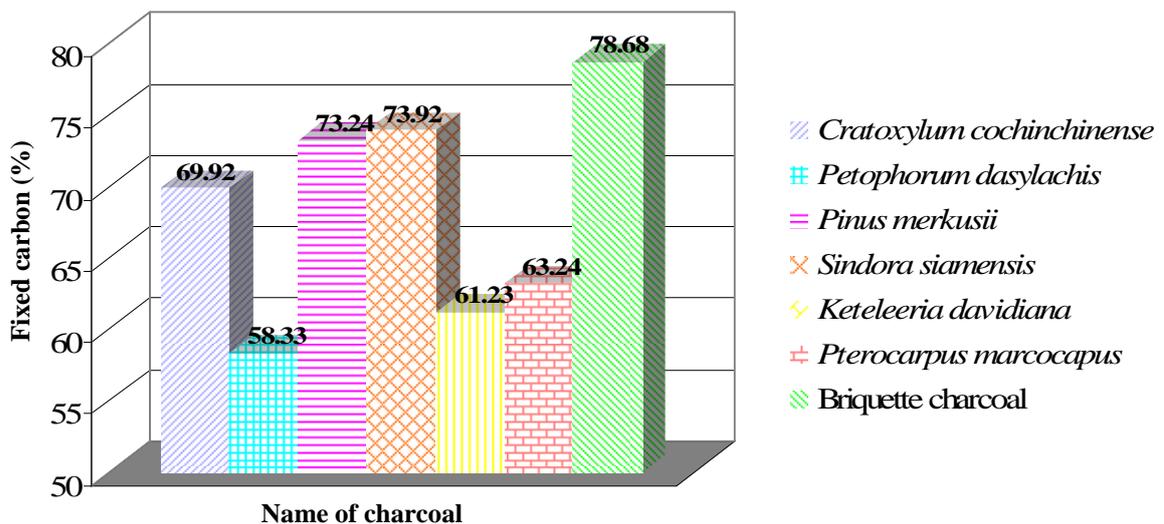


Figure 4 Fixed carbons of briquette and wood charcoals.

The fixed carbon of charcoal ranges from a low of approximately 50% to a high of around 95% (FAO, 1985). Thus the charcoal contains mainly of carbon. FAO (1985) recommended that the charcoal produced from mixed tropical hardwood had fixed carbon ranged 68.6% and 69.8% if compared to the charcoal produced from *Keteleeria davidiana*, *Pterocarpus marcocapus* and *Petophorum dasylachis* had only 61.23%, 63.24% and 58.33%, respectively. The charcoal for domestic use is recommended that it should contain 80.5% of fixed carbon, while the industrial charcoal is recommended to have 86.7% of fixed carbon (FORPRIDECOM, 1979). On the other hand, the quality smokeless domestic wood charcoal has been specified to consist 75% of fixed carbon or more than this (Ugnay, 1983), while the industrial wood charcoal has been specified to contain not less than 85% of fixed carbon (Erlinda and Dionco-Adetayo, 2001). According to Hindi (1994) recommended that the proportion of fixed carbon can be controlled through maximum temperature and its residence time during the

carbonization process, which it seems true with the research of Erlinda and Dionco-Adetayo, (2001) explained that the charcoal produced from high temperature will be higher in fixed carbon than the charcoal produced at lower temperature. In addition, the charcoal has the high volatile matter is lower in fixed carbon, which low fixed carbon tends to be harder, heavier, stronger and easier to ignite than high fixed carbon charcoal. In the real experience of wood charcoal consumers in this region explained that the whole of wood charcoals from this research were easier to ignite but the first two charcoal made from *Cratogeomys cochinchinense* and *Petophorum dasylachis* were quite heavier, stronger and long burning and the significant one was not sparking while other wood charcoals was more shattered, and further explained that the cause of sparking might belong to the kind of wood charcoal produced from different wood species. On the other hand, briquette charcoal consumers and the manager of its product mentioned that briquette charcoal was heavier, stronger, long burning and heating, and not shattered but it tended to be difficult to ignite comparing to the whole of wood charcoal that it seems true with the real value of volatile matter and fixed carbon discussed above.

3.5 Gross calorific value

Significant differences of the gross calorific value were found between charcoals. Briquette charcoal had the gross calorific value at 7,595 cal/g, while charcoal produced from *Pterocarpus marcocapus* and *Sindora siamensis* had similar value but charcoal produced from *Pinus merkusii* contained the highest value of 8,246 cal/g and the lowest value of gross calorific value was 7,068 cal/g from *Keteleeria davidiana*, as for charcoals from *Cratogeomys cochinchinense* and *Petophorum dasylachis* were 7,222 cal/g and 7,269 cal/g of gross calorific value, respectively as shown in figure 5.

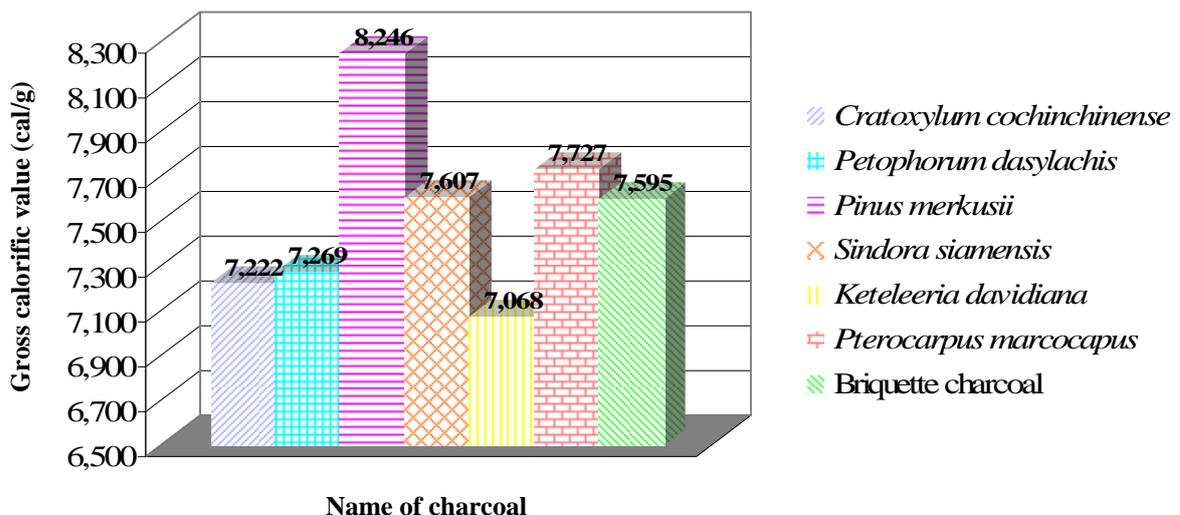


Figure 5 Gross calorific values of briquette and wood charcoals.

Briquette charcoal had the higher gross calorific value comparing to the charcoal produced from *Petophorum dasylachis*, *Cratogeomys cochinchinense* and *Keteleeria davidiana*, while the highest gross

calorific value was 8,246 cal/g of *Pinus merkusii* charcoal, it is higher than gross calorific value of charcoal made from *Dimorphandra conjugate* (Dakama) and *Licania majuscula* (Kautaballi) with 7,165 cal/g and 7,743 cal/g, respectively but less than the charcoal from *Eperua calcata* (Wallaba) with 8,500 cal/g in Guyana (FAO, 1985). Significant differences of gross calorific value of the charcoal produce among different wood species may due to the different age of wood species that use for material of charcoal production. In addition, the difference of the environmental conditions as using the different temperature in carbonization process also one factor influence the significantly different in gross calorific value (Erlinda and Dionco-Adetayo, 2001), especially briquette charcoal, the use of modern machine in the compression process of briquette charcoal production as Screw Pressed Machine with 30 HP leads to achieve the good quality of briquette charcoal, due to the recommendation of the manager of Briquette Charcoal Factory in Khammouane province.

However, charcoal of *Pinus merkusii* had the highest gross calorific value but it was too sparking when combusting in blast furnace or cooking stove and also had the short burning compared to other wood charcoals and briquette charcoal, even briquette charcoal had higher value of gross calorific value comparing to other wood charcoal. Conversely, it was still less than gross calorific value of charcoal of *Pinus merkusii* but it had the long heat energy for combustion and also no sparking that were significant issues of charcoal consumption requirement and marketability, due to recommendations of charcoal consumers.

4. Conclusion

Briquette charcoal was a quality charcoal in terms of high gross calorific value and fixed carbon with 7,595 cal/g and 78.68%. Conversely, it had low volatile charcoal, low moisture and ash content of 15.65%, 1.88% and 3.79%, respectively, compared to the other wood charcoals that had gross calorific value ranged between 7,068 to 8,246cal/g, fixed carbon of 58.33 to 73.92%, volatile matter of 19.53 to 37.59%, ash content of 1.15 to 3.47% and moisture content ranged between 0.76 to 3.17%. Charcoal produced from *Cratogeomys cochinchinense* and *Petophorum dasylachis* were quality charcoals compared to other wood charcoals. Those of both charcoal generally made from indigenous wood species in Production and Community forest around villages, which have been accepted in the marketability for long time while other wood charcoals made from wood residues of *Pterocarpus marcopapus*, *Pinus merkusii*, *Sindora siamensis* and *Keteleeria davidiana* in wood processing factories, even though those of four wood charcoals have likely good quality properties but in term of sparking tends to easily unaccepted by consumers in this region, however these kinds of charcoal still fairly used in many households due to cheaper price compared to *Cratogeomys cochinchinense* and *Petophorum dasylachis* charcoal . On the other hand, Briquette charcoal was heavier, stronger, long burning and long heat energy but no sparking, with lower value of volatile matter tended to be difficult to ignite.

However, with the good charcoal properties comparing with other wood charcoals, briquette charcoal should definitely be an alternative source of fuel for consumption in Khammouane province.

5. Recommendation

The government should encourage and increase the investment in briquette charcoal production to subsidize fuel consumption, and give intensive policies for the investors who invest with briquette charcoal production. The technical feasibility of producing high grade quality of briquette charcoal should indentify, particularly the outcome of high quality of briquette charcoal supply sufficiently in domestic market, In addition, enormous quantity of sawdust utilized also reduces environmental impacts from saw dust dumping.

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