

## **Energy Characteristic Comparing of Briquette Fuel from Leaf Litter and Firewood for Forest Fire Solution in Northern of Thailand**

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### **ABSTARCT**

In Northern of Thailand there has been affected of forest fire in every year resulting in air pollution and smog covering the area. This study was aimed at finding of energy characteristic of briquette fuel from leaf litter by comparing with firewood. Leaf litters from forest in Northern Thailand was taken to produce the briquette fuel. Leaf litter is the main material made briquette fuel by removing from forest. The energy characteristic of briquette fuel was determined in the proximate analyzed by moisture of 14.58%, ash of 6.43%, volatile matter of 66.34%, and fixed carbon of 12.65% with its net calorific value of 15.03 MJ/kg. The ultimate analyzed data was carbon of 50.01%, hydrogen of 5.82%, nitrogen of 1.63%, total sulphur of 0.13% and oxygen of 34.89%. Firewood was determined in proximate analysis by moisture of 15%, ash of 1.5%, volatile matter of 65.20%, and fixed carbon of 18.4% with its net calorific value of 16.74 MJ/kg. The ultimate analyzed data was carbon of 55.8%, hydrogen of 6%, nitrogen of 0.3%, total sulphur of 0.01% and oxygen of 36.2%. The efficiency of community stove by briquette fuel and firewood are 11.62% and 18.47%, respectively.

From the study, the result of briquette fuel from leaf litter can be replaced firewood for rural energy consumer in daily life. However, the briquette fuel needs the cylindrical biomass stove for high efficiency. Because the cylindrical biomass stove was designed to support the solid biomass fuel.

**Keywords:** Briquette fuel, Forest fire, Renewable energy,

### **INTRODUCTION**

The forest in Thailand has two types i.e. evergreen and deciduous. It can be categorized by number of sub-types presented in different geographical locations for example tropical rainforest, dry evergreen forest, hill evergreen forest, coniferous forest, peat swamp and mangrove forest, beach forest, mixed deciduous forest, deciduous dipterocarp forest, and savanna forest. Most of

forest in Northern of Thailand is mixed of deciduous and deciduous dipterocarp forest. (Emmanoch, 2015). During fire seasons, there was an impact of air pollution from forest fires annually. Population health and transportation were impacted of mistake by smoke hanging in the atmosphere. Forest degradation from forest fire was made by people who are living around the forest. Open air fires are the cheapest way to preparation of planning area on upper farming land used and easier for hunts wild animals. Forest fire was come from lose control of fire (Ongprasert, 2012). From the satellite Landsat 5 TM image report on year 2007 comparing with image reports on year 2010, it was found that the burned area in Chiang Rai province occurring from January to April. The percentage of burning area in Chiang rai province on 2007 and 2010 were 37.46% and 37.86% (Sirimongkonlertkun, 2014). According to the burning experiments, the fire spread rate was 0.51–2.55 m/min by multiple nonlinear regression analyses of slope terrain, fuel load, and moisture content of fuels. Accurately predict the fire spread rate at a confidence level of 25–88% (Junpen et al. 2013). The impact of biomass burning aerosols in Asia by radiative was estimated ranging from 1.9 to 0.4 Wm<sup>2</sup> at the top of atmosphere and 0.5 to 12.0 Wm<sup>2</sup> at surface (Weng et al. 2007). About the use of fuel in dry dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary was 4,004 kg/ha, which consisted of leaves 1,244 kg/ha, twigs 1,163 kg/ha, grass 807 kg/ha and ground wood 794 kg/ha. The maximum value of biomass was recorded in February (5,693kg/ha) while the minimum value recorded in July (2,300 kg/ha) (Akaakara et al, 2003). Litter productions in Mae Hong Son province on fire season was 2,856 kg/ha (January-April) with the highest production in March at 4,058 kg/ha. (Phobdhamjarernjai et al, 2013).

In rural areas the biomass has been used for direct combustion for supporting their life. Biomass utilization was most common method for the area caused population in the area poor efficiency and unknown of alternative technics for community (Islam et al, 2013). Household energy consumption has depended on family incomes (Ashby and Pitts, 2011; Miah et al, 2010). From geography of Northern Thailand to many of tribal household were stayed on the hill and used firewood for cooking in daily life, twice a day with firewood consumption of 90 kilogram/month (3 kg/day) (Sutthathron et al, 2013). Briquette fuel is an alternative fuel, which can replace firewood and reduce forest fire by moving litter from the forest. Briquette fuel is compressed into small pellets or briquettes (Ogwu et al, 2014). The characteristic of briquette fuel were showed by proximate and ultimate analysis thus ascertaining the optimum biomass composition for use as composite domestic fuel (Adekunle et al, 2015). A good physical properties of the briquettes have high efficient and potentially viable as a replacement for firewood in household (Said et al, 2013). The cylindrical biomass stove used with briquette fuel gives high efficiency in thermal energy and is betters than normal stove (Jodnok et al, 2011). Briquette fuel can replace the firewood for protecting forest destroy from forest fire by moving litter production for briquette material. Briquette fuel were replacement firewood in daily life. This study is to determine the energy characteristic and pollutant emitted of briquette fuel from litter productions testing.

## 2. Materials and Methods

### 2.1 The oven-dry testing

The mix of litter productions from dipterocarp forest was collected every month in Mae Hong Son province for moisture and biomass in the forest finding. The moisture removal process for biomass quantities from forest with ecology metrology by setting temperature of hot air oven 103 °C and baked litter productions for 72 h. Litter was weighed before and after bake for moisture loss. Moisture content was determined by weight data calculated for wet basis. The percentage of moisture in the analyzed sample, M, can be calculated as follows: (ASTM D 4442-92)

$$M = \left[ \frac{W-B}{W} \right] \times 100 \quad (1)$$

where:

W = weight of specimen used, (gram).

B = weight of specimen after heating in moisture test,  
(gram).



Fig 1. Leaf litter

### 2.2 Briquette fuel production process

Litter was squeezed by hand for making a small size and soaked by putting it in a container and pour water flood. The litter was mixed with 5% of cassava mucilage by weight.

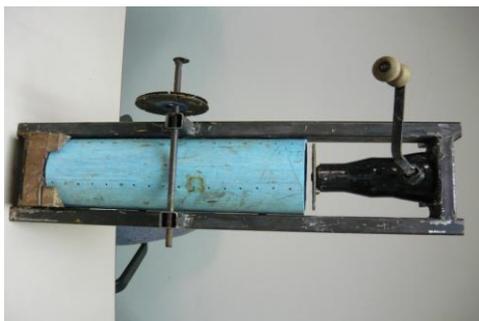


Fig 2. Fuel manual pressure machine



Fig 3. Briquette Fuel

After litter productions and binder was mixed, the material is fed into the fuel Manual Pressure Machine (MPM). The machine was built to operate the strength of one-ton pressure by jack. The machine had 10.5 cm. diameter and 35.6 cm. length of PVC pipe. The process of briquettes fuel making was taken 300 grams of material in to pipe by inserting separate sheet for other cubes. This machine can produce four fuel cubes for one time process. Tack the briquette fuel productions to measure, to weigh and record. Then it is kept sun-dried for 3 days and take the dried briquette fuel to measure and to weight it again. (Fig 2-3). (Thoongsap, 2009.).

## 2.3 Determination of Proximate and ultimate analysis

### 2.3.1 Proximate analysis

Briquette fuel and firewood were tested for the energy characteristic by proximate analysis. The analyzed method was followed the American Standard of Testing Material (ASTM) method. Proximate analysis was presented the percentage of Fixed Carbon (FC), Volatiles Matter (VM), Ash (A), and Moisture Content (MC) by weighs. The total of fixed carbon and volatile matter were inflammable matter thus directly contributing to the heating value of fuels. Fixed carbon characteristic was showed heat generating during burning indicate. Volatile matter indicated of ignition was showed on high level. Ash content data is used in the design of the furnace about combustion volume, furnace grate, and pollution control equipment.

Moisture content analysis was followed from litter productions moisture content analysis (ASTM D3302-02a, 1996).

Ash content analysis was burned crucible at 900 °C for 10 minutes and cool down. One grams of sample was treated to crucible by burned at 500 °C and 750 °C for hours. The sample was weighed after burned and data is used to calculate for ash content by formula below (ASTM D7582-10, 1996).

$$A = \left[ \frac{F-G}{W} \right] \times 100 \quad (2)$$

Where :

F = weight of crucible and ash residue, (gram).

G = weight of empty crucible, (gram).

Volatile matter content analysis was burned crucible at 600 °C for 10 minutes and leave for cool down. One grams of sample was treated to crucible by burned at 950 °C for 7 minutes and cool down. The sample was weighed after burned and data is used to calculate for volatile matter by formula below (ASTM D7582-10, 1996)

$$VM = \left[ \frac{B-C}{W} \right] \times 100 \quad (3)$$

where:

C = weight of specimen after heating in volatile matter test, (gram).

The volatile matter determinate to separated portion of sample from the analysis sample bottle, and then calculate volatile matter as follows: (ASTM D7582-10, 1996)

$$D = \frac{W-C}{W} \times 100 \quad (4)$$

Fixed carbon analysis was taken sum of moisture content, ash and volatile matter minus from one hundred (ASTM D7582-10, 1996)

$$FC = 100 - (A + M + VM) \quad (5)$$

### 2.3.2 Ultimate analysis

The chemical elements estimations were determined details of biomass, namely percentage of carbon, hydrogen, oxygen, nitrogen and sulphur. These properties were determined in accordance with ASTM analytical methods (Jenkins et al, 1998).

Instrumental determination of carbon, hydrogen and nitrogen in laboratory samples of briquette fuel was followed on (ASTM D5373-02, 1996). Carbon, hydrogen, and nitrogen elements were determined concurrently in a single instrumental procedure. The testing method provides for the conversion of the subject elements of oxygen stream in their entirety to carbon dioxide, water vapor and nitrogen oxides. Carbon dioxide and water vapor were determined by infrared detection at precise wavelengths on an aliquot of the combustion gases by halides and sulfur oxides removal. Nitrogen was

determined by thermal conductivity on a second aliquot additionally treated to reduce all nitrogen oxides to nitrogen and removed residual oxygen, carbon dioxide and water vapor.

Sulphur analysis was used high-temperature combustion and infrared absorption by following on (ASTM D4239-10, 1996). Method summary was tested specimen of heat in a tubular furnace with stream of oxygen to sulfur dioxide. Gas stream was contained of the sulfur dioxide passed through a cell to measure at a precise wavelength by an infrared absorption detector.

### 2.3.3 Calorific value analysis

Heating value analysis was determined of the gross calorific of briquette fuel by adiabatic bomb calorimeter in SI unit. (ASTM 5865-10, 1996). The sample was weighed and burn under the controlled conditions by the oxygen bomb calorimeter. The higher heating value was calculated from the temperature rise to the water in the calorimeter vessel and the effective heat capacity of the system. Corrections were made for the heat released by the ignition of the fuse and the thermo chemical reactions forming nitric and sulfuric acids.



Fig 4. The cylindrical biomass stove (Jodnok et al, 2011).

### 2.4 Efficiency of stove testing

The test of efficiency of stove testing by briquette fuel and firewood. This experiment used community stove supplied by ministry of energy (DEDE), (Jodnok et al, 2011). The process was worked on 500 grams of briquette fuel prepared per sampling and a 1,000 gram of water pouring in 20 cm. diameter container. The water temperature was recorded by thermometer installed in container and set up to middle of container without touching the container. Gasoline is used as a starter by pouring down in the sampling at 50

cm<sup>3</sup>. Bring the container on the stove when the fire was ignited. Temperature is recorded every 3 minute. For the relative data observed a characteristic of smoke, ash, flame ignition, ambient temperature and humidity by recording during the trial. Efficiency is calculated in the formula below (Jindaruksa et al, 2005).

$$\eta = \frac{[m_{w,1} \times c_{p,w} (T_{w,b} - T_{w,i})] + [m_{w,2} \times h_{fg}]}{m_{fuel} \times LHV} \quad (6)$$

Where

- $\eta$  = Efficiency
- $m$  = Mass of water (kg)
- $m_{w,2}$  = Mass of evaporation water (kg)
- $C_{p,w}$  = specific heat capacity of water (KJ/kg) K
- $h_{fg}$  = Latent heat of evaporation for water (KJ/kg)
- $T_{w,B}$  = Boiling temperature of the water (°C)
- $T_{w,i}$  = room temperature of the water (°C)
- $m_{fuel}$  = Mass of fuel (kg)
- $q$  = Heating value of fuel (KJ/kg)

### 3. Results

#### 3.1 Moisture content of leaf litter

From the study site locate on Huay Poo LingThe, Tha Pong Deang and Ban Pha Bong were different altitude and forest type. The moisture content in biomass indicates the efficiency combustion because of quantity of moisture content in fuel affects the ignition. The quantity of moisture high was transferred of heat into fuel more difficult than low moisture content. Moisture content influences for heating value, combustion control and fuel pricing (Nystrom et al, 2004). The result of moisture content from dipterocarp forest in Mae Hong Son province was 33.36% in average a year, whereas the moisture content of biomass during December to April was in low range at 14.57% – 23.87%. The leaf litter from these periods is good for material supply to fuel briquette because of low moisture content. During May – November, it was high percentage of moisture needing a time to make the leaves dried. (Table 1.)

**Table 1** Percentage of litter moisture content from dipterocarb forest

DESCRIPTION	Huay Poo Ling	Tha Pong Deang	Ban Pha Bong	Average	S.E. (+/-)
	(% by weight)				
January	14.60	15.12	14.00	14.57	0.32
February	25.20	19.93	24.63	23.25	1.67
March	27.22	17.87	13.03	19.37	4.16
April	26.25	17.89	13.96	19.37	3.62
May	29.94	59.08	37.21	42.08	8.76
June - July	49.09	64.07	67.47	60.21	5.65
August- October	53.52	75.71	67.11	65.45	6.46
November	51.81	28.59	15.71	32.04	10.56
December	34.86	25.76	10.98	23.87	6.96
Year Average	<b>34.72</b>	<b>36.00</b>	<b>29.35</b>	<b>33.36</b>	

### 3.2 The physical properties of briquette fuel

The physical property of briquette fuel after compressing is diameter 0.10 m, height of 0.03 m, mass 0.143 kg, volume 0.00023 m<sup>3</sup>, density 594.74 kg/m<sup>3</sup>, with dark brown color and rough texture. The briquette fuel after dried was diameter 0.11 m, height 0.045 m, mass 0.08 kg, volume 0.00047 m<sup>3</sup>, density 168.42 kg/m<sup>3</sup>, with brown color and rough texture (table 2.).

**Table 2** Physical properties of briquette fuel from leaf litter.

Parameters	Value	
	Wet	Dried
Height of briquette (m)	0.03	0.04
Diameter of briquette (m)	0.10	0.11
Mass of briquette (kg)	0.14	0.08
Volume(m <sup>3</sup> )	0.00023	0.00047
Density(kg/m <sup>3</sup> )	595.74	168.42
Color	Dark Brown	Brown
Texture	Rough	Rough

### 3.3 Proximate analysis

The energy characteristic of briquette fuel was showed on proximate analyzed data. By the results were moisture of 14.58%, ash of 6.43%, volatile matter of 66.34%, and fixed carbon of 12.65% with its net calorific value of 15.03 MJ/kg. A comparison of the energy characteristic of briquette fuel and fire wood for the possible adoption was found the characteristic of fire

wood in proximate analyzed at volatile matter 65.2%, fixed carbon 18.4% ash 1.5% and Net calorific value 16.72 MJ/kg (Table 2).

**Table 3** Energy characteristic of briquette fuel and firewood

Parameter	Briquette fuel	firewood
Moisture (%)	14.58	15.00
Ash (%)	6.43	1.50
Volatile Matter (%)	66.34	65.20
Fixed Carbon (%)	12.65	18.40
Net Calorific Value (MJ/kg)	15.03	16.72

The moisture content of the both fuel was similar because period of these is same, insignificant moisture in ambient including leaf litter and fire wood are plants too. The moisture content of briquette fuel and firewood was 14.50% and 15.00%, respectively. The pyrolysis process is the thermal decomposition of biomass occurring in the absence of oxygen. Moisture content directly affected to the pyrolysis process. A percentage of moisture content should be at 10% or less than that cause made a good efficiency of briquette fuel.

Ash content of briquette fuel is higher than that of firewood. Ash is a byproduct of fuel combustion, which contains several mineral matters such as carbon, silica, alumina, iron oxide and sulfur. In ash, there had unburned carbon mixing in it and the carbon is a major index to determine an efficiency of material combustion for the fuel. Ash or unburned carbon indicates of combustion efficiency in a burning process. A high volume of ash indicates poor combustion efficiency. It was found that ash from briquette fuel (6.43%) is more than that from firewood (1.50%).

Volatile matter is byproduct given of fuel in the form of gas or vapor. Volatile matter was determined by definite prescribed methods for property of fuel. In combustion process, volatile matter is a substances apart of moisture content given off as gas and vapor during combustion. Volatile matter of briquette fuel was 66.34% and firewood 65.20%.

Fixed Carbon is the measure of a substance that can be burned or solid combustible material. It is used to calculate the efficiency of the combustion engine. Fixed carbon was 12.65% in briquette fuel and 18.40% in firewood.

Heating value or calorific value is an amount of heat that is emitted per unit of weight when fuel was burned. The analysis has led to the burning of fuel in Bomb Calorimeter and the temperature of the water rises. Fuel with calorific value and high ash content is low efficiency. The heating values of the briquette fuel and firewood are 15.03MJ/kg and 16.72 MJ/kg, respectively.

### 3.4 Ultimate analysis

Ultimate analysis was analyzed for the proportion of main element i.e. carbon, hydrogen, nitrogen, and oxygen. The sulphur and chlorine are a

little element inside of material. The impact of these elements were released to atmosphere when getting burned. Impact of air pollutant releases from briquette fuel was affected to family member with health problem. Nitrogen element in the fuel can be emitted in the form of nitrous oxide ( $N_2O$ ), nitrogen oxides ( $NO_x$ ), ammonia ( $NH_3$ ), particulate nitrogen were impacted to living organisms and the ecosystem. Acid rain and smog was effected from sulphur element burning in the form of sulphur dioxide. The result of ultimate analysis from briquette fuel was at carbon of 50.01%, hydrogen of 5.82%, nitrogen of 1.63%, total sulphur of 0.13% and oxygen of 34.89%. While the firewood data analyzed was carbon of 55.08 %, hydrogen of 6 %, nitrogen of 0.30 %, and total sulphur of 0.01% and oxygen of 36.20% (Table 3).

**Table 4** Ultimate result of briquette fuel and firewood

Parameter	Briquette fuel (%)	Firewood (%)
Carbon*	50.01	55.80
Hydrogen*	5.82	6.00
Nitrogen*	1.63	0.30
Total Sulphur**	0.13	0.01
Oxygen (plus error)	34.89	36.20

\* ASTM D5373-08, \*\* ASTM D4239-12

### 3.4 Efficiency of community stove

From the result, it was found that information of briquette fuel and firewood do not give significant difference of efficiency for community stove. Because of this study method was work on gasification system by thermochemical conversion process. The process was used air controller to controlling the air flow into stove causes incomplete combustion. The reaction of briquette fuel with community stove was made producer gas than firewood. Therefore, energy efficiency is same firewood. Briquette fuel can replaced firewood when burn in community stove because the energy characteristic is similar. Briquette fuel can be a new channel for energy consumer on their daily life and indirectly effected to reduce deforestation for firewood. The complete combustion can be achieved by a good excess air, lower moisture content and high efficiency. Percentage of fuel efficiency was indicated of characteristic burning. Efficiency of briquette fuel was showed in combustion efficiencies when burned in community stove. It was founded that the efficiency of briquette fuel is 9.43% and firewood is 15.42%. (Fig 5.)

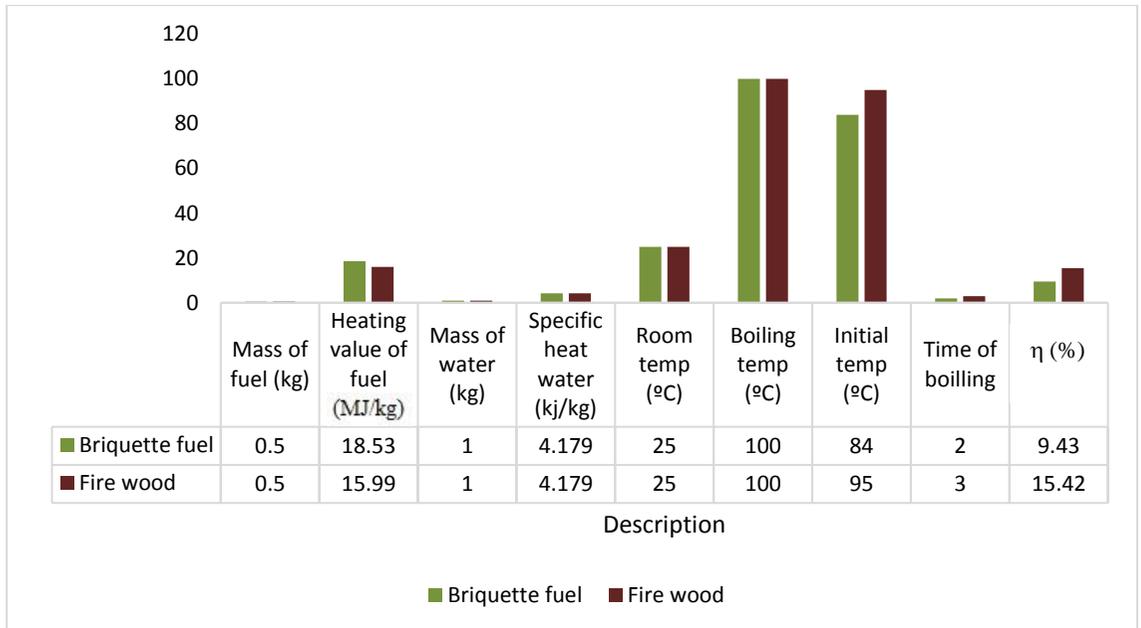


Fig 5. Community stove efficiency from fuel briquette and firewood

Characteristic of fuel results by eye observation was showed a good ignition with starter, ash in the form of dust, smoky and soot, with strong flame. Firewood was showed ash is lumpy, smoke and flame is same as briquette fuel. The time of boiling water to 100 °C of briquette fuel and firewood was 7.20 minutes, and 6.35 minutes, respectively. However, the study taken a normal stove for efficiency finding briquette fuel should be haven't got long time like community stove. (Table 5)

Table 5. Fuel characteristics resulting from observation

Description	Ignition	Ash	Smoke	Flame	Time to 100 °C (min)
Dry leaves + MPM	Good	Dust	Smoky, soot	strong	7.20
Fire wood	Good	Lumpy	Smoky, soot	strong	6.35

## Conclusion and Discussion

A study of Energy Characteristic Comparing of Briquette Fuel from Leaf Litter and Firewood for Forest Fire Solution in Northern of Thailand was studied. The energy characteristic and efficiency of briquette fuel is similar to that of firewood when work with community stove.

1. Leaf litter from dipterocarp forest is a source of forest fire fuel. The litter releases pollutes to the environment by direct burning. However, it can be converted to a solid briquette fuel for consumer in rural communities and firewood replacement.

2. Briquette fuel was showed 66.34% of volatile matter, which is good for ignited in combustion process. High percentage of volatile matter also during combustion will release producer gas to the combustion zone. It's best for gasification system in community stove. Because the efficiency of briquette fuel is higher than that of firewood.

3. The calorific value from briquette fuel was 15.03 MJ/kg, which is closed to firewood of 16.74 MJ/kg when burned in community stove. Briquette fuel is good for used in household cooking and small scale industrial application.

4. The environmental impact, briquette fuel would be friendly due to the low nitrogen (1.63%) and sulphur (0.13%).

Northern Thailand was impacted from forest fire every year and forest fire impacts to air pollution and health hazards with population. Briquette fuel production helps withdrawal leaf litter out of the forest and reduces fuel from forest because leaves deposition in the forest in large quantity will to increase the risk of forest fire. From the study, result briquette fuel from leaf litter can be replaced firewood to energy consumer in population daily life. The impacts of emission release from briquette fuel do not increase to an effect more than firewood.

## 5. Acknowledgement

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