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การศึกษาฟางข้าวเพื่อเป็นพลังงานชีวมวลอัดเม็ด

Study on Rice Straw to be Bio-fuel Pellets

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บทคัดย่อ

องค์การอาหารและเกษตรแห่งสหประชาชาติรายงานว่าเมื่อปีพศ. 2551 ทั่วโลกมีการปลูกข้าวมากกว่า 40 ประเทศ และประเทศไทยมีปริมาณฟางข้าวมีมากกว่า 60 ล้านตันในแต่ละปี ตามปกติเกษตรกรจะใช้วิธีการเผาฟางข้าว ซึ่งทำให้เกิดกาซเรือนกระจก อาทิ แก๊สคาร์บอนไดออกไซด์(CO_2)ปลดปล่อยสู่บรรยากาศเป็นสาเหตุที่ทำให้เกิดภาวะโลกร้อน โครงการวิจัยนี้มีจุดประสงค์จะผลิตพลังงานราคาถูกจากฟางข้าว โดยศึกษาเมื่อปีพศ. 2552 ในเขตพื้นที่หนองจอก กรุงเทพมหานคร ฟางข้าวถูกนำมาผสมกับกากน้ำตาลและดินเหนียวในอัตราส่วน 80:10:10 อัดเป็นเม็ดขนาดเส้นผ่าศูนย์กลาง 1.54 เซนติเมตรและขนาดความสูงเท่ากับ 2 เซนติเมตร ทำการทดสอบค่าความร้อนภายใต้มาตรฐาน ASTM จากการทดสอบการแพร่กระจายของกาซคาร์บอนไดออกไซด์ พบว่าพลังงานอัดเม็ดจากฟางข้าวมีปริมาณแค่ครึ่งหนึ่งของการเผาฟางข้าวในพื้นที่เปิดโล่ง ราคาของพลังงานอัดเม็ดจากฟางข้าวมีราคาเท่ากับ 7 บาท เมื่อเปรียบเทียบกับการใช้กาซหุงต้ม(LPG) จะมีราคาเพียงครึ่งเดียว จึงเป็นพลังงานราคาถูกที่เหมาะกับครัวเรือนและภาคอุตสาหกรรม

Abstract

FAO reported in year 2008, world paddy production more than 40 countries and about 60 million tones of rice straw were produced in Thailand. For most farmers use an easy method for land clearing by straw burning in open area. Greenhouse gases such as carbon dioxide(CO_2) emissions from paddy field burning to atmosphere is causes of global warming problem. This project aimed to utilize agricultural waste from rice field to be cheap biomass energy was started in 2009 at Nhongjork area. The waste was mixed with molasses and kaolin in ratio of rice straw : molasses : kaolin as 80:10:10 by weights. A size of rice straw fuel pellet was 1.54 cm. diameter and 2 cm. height. The calorific value of the rice straw pellet was tested by using Gallekamp Autobomb instrument by ASTM(American Society of Testing and Materials) standard. The results of testing found : CO_2 emission from rice straw fuel pellets as half of burning in open area (by weight). Cost of energy for cooking by using Bio-fuel pellets only 7 Baht(0.25 US $) and half price by comparing with LPG. The useful of rice straw Bio-fuel pellet is one of a cheap biomass energy for household and small manufacturers.

คำสำคัญ **:** ฟางข้าว พลังงานอัดเม็ด ข้าว พลังงาน
Keywords **:** rice straw, fuel pellet, paddy, energy

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1. Introduction

Thailand is a major food producer in the world especially for rice production. There are 63 million tons rai (one rai = 0.34 acres) of cultivated area producing approximately 40 million tons of rice straw for each year [1]. Some of this waste is disposed in soil mainly by burning in the fields. The smoke from rice straw burning in open area that causes the environmental problems. The smoke diffusion can cause road accidents, fires and disasters. In addition, paddy fields in large area are a source of greenhouse gases emission such as carbon dioxide(CO_2), methane (CH_4) and nitrous oxide (N_xO). These gases affect on regional air quality and their contribution to global greenhouse effect[2]. Rice straw burning is a contributor, but other sources are more important on a regional basis. Concern has grown recently over the danger posed by small particles (less than 10 microns, PM<10 and more critically particles <2.5 microns)[3]. Rice straw and rice husk are used as renewable energy for household and offering much potential for energy generation and biomass to energy projects could create sustainable enterprises and reduce the quality of life for the rural area [4]. Straw fuels have proved to be extremely difficult to burn in most combustion furnaces, especially those design for power generation due to the rapid formation of deposits [5].

Summers studied about using rice straw for energy production and told that rice straw has a higher value about 16,000 MJ/Kg and meaning a potential fuel base of 1.8x1010 MJ in the rice growing region of California[6]. Chou et al. investigated the feasibility of preparing the biomass briquettes by the solid waste, such as rice straw and rice barn[7]. Biomass pellets are generally a superior fuel when compared to their raw feedstock. Not only are the pellets more energy dense, they are also easier to handle and use in automated feed systems. These advantages, when combined with the sustainable and ecologically sound properties of the fuel[8]. Global waste biomass energy capacity is about eight times the annual world consumption of energy from all sources. Therefore biomass represents a very large energy resource, in eastern Europe was used straw pellets in industrial more than 10 years and this low burning rate restricts the use of these pellets to small capacity applications such as stoves and domestic heating furnaces [9, 10].

The project of bio-fuel pellets made from rice straw aimed to reduce greenhouse gases such as carbon dioxide (CO_2) from rice straw in open areas burning. The first objective was to make rice straw fuel pellets as renewable energy. Utilization waste from paddy field are cover processing of rice straw fuel, costs and environmental benefits.

2. Material and Methods

Rice straw were collected from paddy field at Nhong-Jrok (the boundary of Bangkok Metropolitan, Thailand) area after major crop (growth season: May to October) in 2008. Over 90% of rice paddies during the high harvesting season are burned. Rice straw dried by the sun in open area. Tapioca starch and kaolin were added in ratio of rice straw : tapioca starch : kaolin (by weight) as 100:0:0 , 90:5:5, 80:10:10 70:15:15, 60:20:20 and 50:25:25 respectively. Compressed the bio-fuel pellets by using screw machine and a size of rice straw fuel pellet was 1.54 cm. diameter and 2 cm. height. A process diagram of rice straw fuel pellets as shown below:

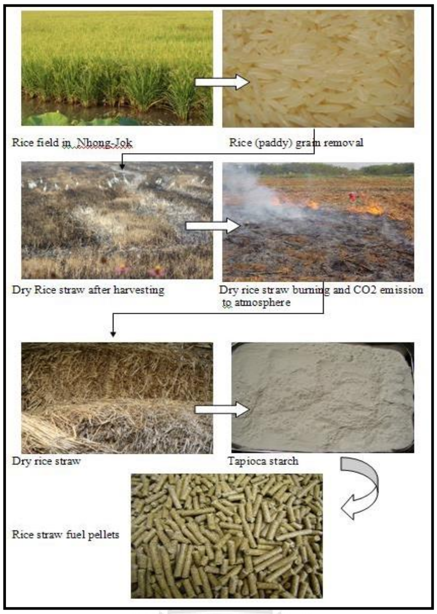

Fig. 1 Process diagram of rice straw fuel pellets

The characteristics of rice straw fuel pellets were tested as follows: water content , volatile components, ash, carbon, hydrogen, oxygen, nitrogen and sulfur under ASTM (American Testing Standard Materials) D.3173, D.3174 and D.4239. Gross calorific value was measured by using Gallekamp Autobomb Calorimeter Instrument following ASTM D.5685. Experimental data were analyzed by analysis of variance (ANOVA) and Duncan's New Multiple Range (DMRT) at significant 5%. The schematic diagram of statistical analysis as shown below:

T_1R_1	T_2R_1	T_3R_1	T_4R_1	T_5R_1	T_6R_1
T_1R_2	T_2R_2	T_3R_2	T_4R_2	T_5R_2	T_6R_2
T_1R_3	T_2R_3	T_3R_3	T_4R_3	T_5R_3	T_6R_3

T= Ratio of rice straw: tapioca starch: kaolin

T1 =100:0:0, T2 =90:5:5, T3 = 80:10:10, T4 = 70:15:15, T5 = 60:20:20 and T6=50:25:25

R= sample

R1 = sample1, R2 =sample3 and R3 = sample3

3. Results and Discussion

3.1 Physical characteristics

General physical characteristics of rice straw that taken from rice field at Nhong-jork area in Bangkok were tested in KMUTNB laboratory. The physical characteristics of rice straw were shown in table1.

Table 1 The physical characteristics of rice straw

Characteristics	% by weights of rice straw (one piece)
Moisture content	24.25
Ash	8.33
Fixed carbon	31.15
Bulk Density, kg/m^3	141

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3.2 Physical/Chemical properties of Bio-fuel pellets

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After Bio-fuel pellets dried in open area 7 days, all samples in 6 ratios of rice straw : tapioca : kaolin were selected the best sample from the experiment that was the sample in ratio of rice straw : tapioca : kaolin as 80:10:10. The represent sample was tested physical/chemical properties of biomass energy by ASTM conditions. The testing information showed in table 2.

Table 2 Physical/Chemical properties of Bio-fuel pellets

Physical/Chemical properties	Unit	100:0:0	90:5:5	80:10:10	70:15:15	60:20:20	50:25:25
Moisture content	%	17	20	16	17	21	22
Volatile components	%	85	88	84	87	90	93
Ash	%	12	15	17	25	27	26
Fixed carbon	%	31	37	35	34	34	30
Hydrogen	%	4.4	4.7	4.8	4.7	4.6	4.9
Oxygen	%	41	43	45	40	35	38
Nitrogen	%	0.56	0.44	0.51	0.43	0.38	0.33
Sulphur	%	0.18	0.15	0.15	0.19	0.23	0.29

Table 2. shows the results of proximate analyze was (Volatile components, Fixed Carbon and Ash) calculated on a dry and ash free(daf) basis. The ultimate analysis was tested the elements as carbon(C), hydrogen(H), Nitrogen(N), Oxygen(O) and Sulphur(S) by using Gas Chromatography technique. The results found that ratio of rice straw: tapioca: kaolin as 80:10:10 showed moisture content as 16% and compared with European Biomass Association suggested the moisture content of raw material before entering the pellet press must be 12-17% and it is not to exceed these values [11] . In addition, pellet should be stored in closed or room, silo, bunkers, plastics and airlight zip bags(dry conditions) and storage times should be minimized to prevent absorbing atmospheric moisture however, the bulk material supply is necessary[12] .

3.3 Heating value

The higher heating value is experimentally determined in a bomb calorimeter by concealing a stoichiometric mixture of fuel and oxidizer (e.g., two moles of hydrogen and one mole of oxygen) in a steel container at 25 °C is initiated by an ignition device and the combustion reactions completed. When hydrogen and oxygen react during combustion, water vapor emerges. Subsequently, the vessel and its content are cooled down to the original 25 °C and the higher heating value is determined as the heat released between identical initial and final temperatures[13] .

The CV (Calorific Value) of a substance is measured by burning it in a controlled environment. The resulting heat released by this combustion i.e. the net temperature rise, is proportional to the calorific value. In the adiabatic system the environment is controlled so that no energy is lost or gained. To achieve this state, the Calorimeter Vessel (bomb) and bucket are surrounded by a water jacket which is strictly temperature controlled by a system of circulators, heaters and coolers, so that it has the same temperature as the inner bucket. The Isothermal calorimeter measures the effect that the environment has on the bucket before and after the determination and corrects the result accordingly. This implies that the environment is stable during the determination. To achieve stability a large body of water surrounds the vessel and bucket assembly, which is thermally stable[14].

Heat of combustion was transferred to cooling water around Bomb calorimeter. Water temperature was measured by thermometer. Amount of heat transfer was calculated by equation (1).

$$Q = mc\,(T_1 - T_2) \qquad (1)$$

Where

Q = Fuel combustion heat

m = mass of water in Calorimeter

c = specific heat of water

T_1 = water temperature before combustion

T_2 = water temperature after combustion

Fuel thermal energy can be determined from equation (2).

$$\text{HHV} = \frac{(\Delta T \cdot w) - e}{g} \qquad (2)$$

Where

HHV = Combustion heat

ΔT = heat increasing temperature (°C)

w = 1,724.187 (cal/°C)

e = combustion heat correction factor = 2.3 (cal/cm) x combustion wire length (cm)

g = fuel sample weight (g)

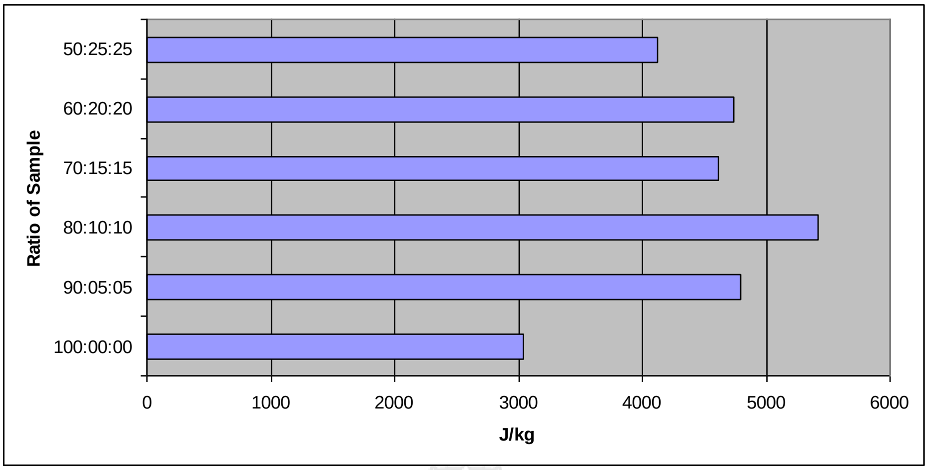

Fig. 2 Heating value of samples

Fig. 2 shows heating value of samples in 6 ratios of rice straw : tapioca : kaolin as 100:0:0 , 90:5:5, 80:10:10 70:15:15, 60:20:20 and 50:25:25. The experiment showed the maximum heating value testing by Bomb Calorimeter was about 5,413.71 J/kg from the ratio of rice straw : tapioca : kaolin as 80:10:10.

3.4 Determination of heat utilization efficiency

The thermal behavior of Bio-fuel pellets has been studied by measuring the rate of weight loss of the samples as a function of time and temperature. Combustion thermal energy could be measured by the time from initial until water boiling. The maximum average time for heat utilization efficiency was about 22 minutes from the ratio of rice straw mixture.

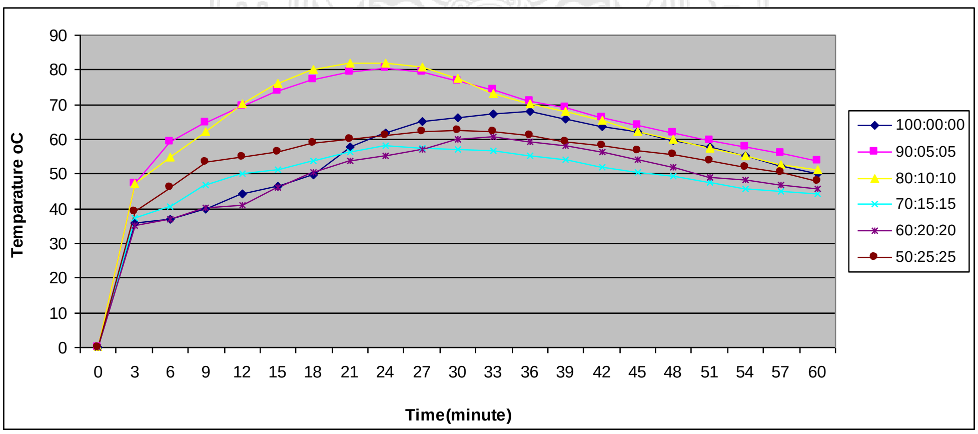

Fig.3 Heat utilization efficiency

Fig. 3 shows various ratios of combiner mixtures were analyzed for the best combination of mixtures. The ratio of rice straw: tapioca: kaolin as 80:10:10 was the best combiner. The highest temperature of Bio-fuel pellets at 22 minute of burning time as 81.24 °C. Percent of ash from burning in 60 minute as shown in Fig. 4.

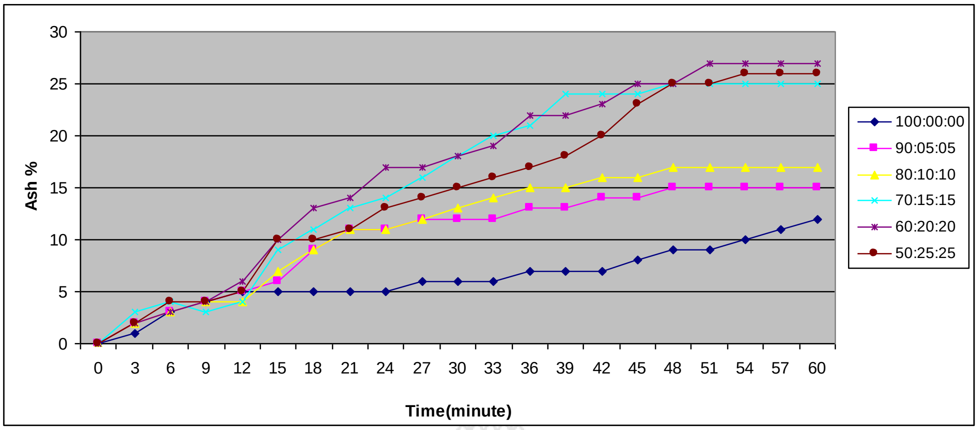

Fig. 4 Percent of ash from burning in 60 minute

Ash content was measured by % of Bio-fuel pellets burning depend on time of experiment in 60 minute. The lowest the ash content was the experiment at ratio of rice straw: tapioca: kaolin as 100:0:0 because this sample was no binder of tapioca or kaolin. Anyway, the less ash is produced from a residential pellet stove it gets more convenient for the consumer. From the experiment showed the ash content of 6 ratios of samples after 60 minute that 5 ratios of samples mixed with binder had higher ash content compared with wood pellet. Ash content in wood is usually less than 1%, while it can be very high in many agricultural residues. This is why wood pellets quality standards can't be reached when using agricultural residues as feedstock and another, specified quality standard for agricultural pellets needs to be introduced[15].

3.5 Testing rice straw fuel pellets for cooking purposes

Rice straw fuel pellets can be used for small industry and poor household in urban areas. The efficiency of rice straw fuel pellets tested by cooking in various food as shown below.

Fig. 5 Testing rice straw fuel pellets for cooking purposes

Time for egg boiling = 10 minute /1 kg. of rice straw fuel pellets using.
Time for rice cooking = 25 minute / 2.7 kg. of rice straw fuel pellets using.

The comparison of rice straw fuel pellets and LPG(Liquid Petroleum Gas):

1 kg. of rice straw fuel pellets = 5 Baht or 0.10 Euro(1 US$ = 30 Baht)
1 kg of LPG (Price list in Thailand during October 2008 to June 2009) = 25 Baht or 0.75 US$

The experiments showed the Bio-fuel pellets can be used as a fuel in household, whereas ash and volatile problems were not serious by using in open area. The detail of economic consideration and analysis of the experiment showed that environmental benefit by using waste from agriculture area and convert to be energy in household. The cost of equipment for making this solid energy not over than 1,500 Baht (50 US$).

4. Conclusion

The advantages of bio-mass fuel production are as follows: alternative energy for people both in the urban and rural areas , wastes reduction by agricultural wastes reuse and recycle, renewable energy from living organisms, alternative fuel market for low cost production about 2-3 Baht/piece for 15-25 minutes burning time and launched project for communities by self sufficiency economy. Moreover, these fuels can be developed for export to increase national incomes.

Open field burning emissions and rice straw fuel pellets have been tested in KMUTNB laboratory (pilot plant : wind speed at 10-15 km./ hour) . The results of testing found CO_2 emission from open field burning: rice straw fuel pellets burning as 1.743mg/ sq. m.: 0.975 mg./sq. m. respectively. The rise in energy costs as interlinked of food prices. The residues from agriculture area used to be renewable energy is the way to help people in developing country to use cheap energy and reduce growing plants for energy. That means food and energy security is the safety way of human being in the future.

The percentage of ash content measured from Bio-fuel pellets still higher than wood (1-2% of ash). In addition, ash content can originate from the biomass itself or from binder and often lead to high disposal costs resulting in a negative economic impact on biomass conversion systems. Ash content values may vary significantly from one biomass resource to another. In this energy conversion processes it is not only the amount of ash, but also its physical/chemical properties that should be considered.

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