Cost Investigation on Green Fuel Production from Manila Grass Mixed with Crop Residues and GHG Emission Mitigation

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Abstract

Green fuel is a combination of methods to solve the problems related to production, transport, storage and use of biomass for household energy. This article discusses the study of green fuel production from manila grass mixed with crop residues, using cassava mucilage as a binder. The fuel is formed in the form of briquettes, which is compressed, easy to handle and takes little volume for storage. Experiments were carried out to determine heating value and other physico-chemical characteristics of the fuels. The results show that the 5 formulae of grass and cassava mucilage have heating values in the range 3,761.14 - 3,941.65 kcal/kg. The content of fixed carbon, volatile matter and ash were between 32.78 - 24.56%, 48.86 - 59.29% and 8.52 - 10.69% respectively. Fixed carbon and ash decreased when the proportion of cassava mucilage was increased. Concerning physical characteristics, it is found that mixing ratio between grass and cassava mucilage of 1:2 to 1:3 can make briquettes quite well. The cost increased when the proportion of cassava mucilage increased; the lowest was 15.58 baht/kg from ratio 1:1, the highest was 18.10 baht/kg from ratio 1:3.

The results of green fuel from grass mixed with crop residues (rice straw and sugar cane leaf) show that heating values of fuel were between 3,623.15 - 3,901.50 kcal/kg and increase when increasing the content of grass. Fixed carbon increased when increasing the content of grass. The content of fixed carbon was found to be between 22.99 - 25.12%, the highest was for ratio 80:20 of grass mixed with rice straw. The percentage of volatile matter decreased while increasing the content of grass. Volatile matter was found to be between 58.34 - 61.44%, the highest was for ratio 70:30 of grass mixed with rice straw. Ash was between 8.96 - 11.71%, increasing when the content of grass increase. The costs for grass mixed with rice straw of 80:20 at 3,849.95 kcal/kg, were between 17.25 baht/kg and decreased increasing the proportion of grass. The GHG emission mitigation is 1.5169 $kgCO_2$/kg. The costs for grass mixed with sugar cane leaf, at 3,901.50 kcal/kg were between 16.75 baht/kg, the lowest for ratio 80:20. The GHG emission mitigation is 1.5367 $kgCO_2$/kg.

Keywords: Green fuel, Manila grass, Bioenergy, Cost, GHG Mitigation

Introduction

Due to energy shortages and rise in oil price, people's cost of living is increasing. The survey of household energy use of Year 2005 from National Statistical Office, Ministry of Information and Communication Technologies found that the average revenue per household is 17,787 baht while the total expenses are 14,311 baht. The total energy cost is 1,434 baht per household, where 2.7% is spent for biomass in the form of wood charcoal and firewood as fuel, especially for cooking in households. The use of charcoal and wood fuel may affect the area of forest in Thailand. In the year 2003 the forest area was 167,590.98 square kilometers, representing 32.66% of the area of country. This is likely to decrease if the use of renewable energy from biomass from wood increases.

Manila grass is a species of mat-forming, perennial grass native to temperate coastal south-eastern Asia and northern Australasia. It forms extensive, velvety, green mats, spreading vigorously by stolons, or occasionally by rhizomes, once established. It prefers sandy soils where other grasses establish poorly. The stems are slender and prostrate, ranging from 5 - 25 cm in length. The leaves are alternate, produced at 1.5 - 3 cm intervals along the stem; they are slender, 2 - 10 cm long and 1 - 3 mm broad. The flowers are greenish, produced on erect racemes 6 - 35 mm long with a single 2 - 3.5 mm flower in each spikelet (Chaiyote et al., 2009)

Rice is the seed of a monocot plant Oryza sativa. As a cereal grain, it is the most important staple food for a large part of the world's human population, especially in East, South, Southeast Asia, the Middle East, Latin America, and the West Indies. It is the grain with the second highest worldwide production, after maize. Straw is a by-product of rice after harvest that makes up about half of the yield of cereal crops.

Sugar cane is any of six to thirty-seven species of tall perennial grasses of the genus Saccharum (family Poaceae, tribe Andropogoneae). Native to warm temperate to tropical regions of Asia, they have stout, jointed, fibrous stalks that are rich in sugar, and measure two to six meters (six to nineteen feet) tall. Sugarcane is harvested by manually and mechanically. Manual harvesting accounts for more than half of production, and is dominant in the developing world. In manual harvesting, the field is first set on fire. The fire burns dry leaves, and kills any lurking, venomous snakes, but also makes air pollution.

Manila grass is easily grown, and commonly used in sport stadiums and gardens. Much waste is produced when cutting, and this causes greenhouse gas if burned. In 1990 the Inter Governmental Panel on Climate Change (IPCC) requested for global responses to decline Greenhouse Gas (GHG) emissions by 2015. Two years after, international negotiations were formulated and then United Nations Framework Convention on Climate Change (UNFCCC) was established serving an objective of the atmospheric GHG reduction at the safe levels that would save us and prevent mankind from the dangerous anthropogenic interference by global warming (Keawkamthong, 2009). To use the manila grass waste, from many sport stadiums, golf court and gardens, to green fuel may help the country on GHG emission mitigation as well as create alternative choice on clean energy consumption.

Various types of biomass can be processed into green fuel, as an alternative energy replacing wood and charcoal. Normally agricultural waste has high moisture content and low density. The processing into green fuel improves its handling characteristics, increases the volumetric calorific values, reduces collection, transportation and storage cost and makes it available for variety of applications. The processing normally includes compaction into briquettes, to increase the density and make it easier to use. On the basis of compaction, the briquetting technologies can be divided into high pressure compaction, medium pressure compaction with a heating device and low pressure compaction using a binder (Mishra & Grover, 1996). Due to the advantages of green fuel, there have been experimental studies to make green fuel from various sources, for example, husk ashes, corn-cob, coconut shell (Sawadkit et al., 2008), rice husk-water hyacinth, bagasses-rice straw (Jamradloedluk et al., 2006), cotton plant peanut (Husain et al., 2002), rubber grass (Saejuo, 1985), palm fiber and shell (Wayne, 1999). From literature review, it can be concluded that different biomass materials require different conditions and processing.

Most of works focus on crop residue and forest waste densified fuel, either single material or pairs of materials blended together. This study investigated green fuel produced from manila grass blended with cassava mucilage as binding agent and mixed with crop residues (rice straw and sugar cane leaf). The effect of mixing ratio on physical characteristics, including the heating value, moisture content, fixed carbon, volatile matter and ash was investigated. For cost and GHG emission of fuel were investigated too.

The objectives of this paper is focus on the value added of manila grass, to find the ratios between manila grass and cassava mucilage giving the fuel the highest heating values and good fuel characteristics, e.g. hard briquettes which are easy to handle, at a low price. Another objective is to find the ratios between manila grass, cassava mucilage and different crop residues giving the fuel the highest heating values and good fuel characteristics, e.g. hard briquettes which are easy to handle, at a low price and to compare GHG emission from green fuel make from manila grass and the other conventional fuels.

Materials and Methods

Briquetting Procedure

The fuel in the study is based on manila grass, which was dry milled and sieved. All material was firstly sun dried for 7 hours (1 day) and milled into a particle size under 600μm. Thereafter, manila grass was mixed with cassava mucilage at different mixing ratios. The ratios between manila grass and binding agent were 1:1, 1:1.5, 1:2, 1:2.5 and 1:3. The mixture was formed into briquettes by a hydraulic machine, compressing the briquettes inside a tube with diameter 30 mm. The densified fuels obtained were sun dried and final moisture contents of the fuels were under 10%.

The best ratio of manila grass and binder was tested utterly, by adding some crop residues (rice straw or sugar cane leaves) to the mixture. The ratio between manila grass and crop residues were 50:50, 60:40, 70:30 and 80:20. The mixture was formed into briquettes and dried as described above.

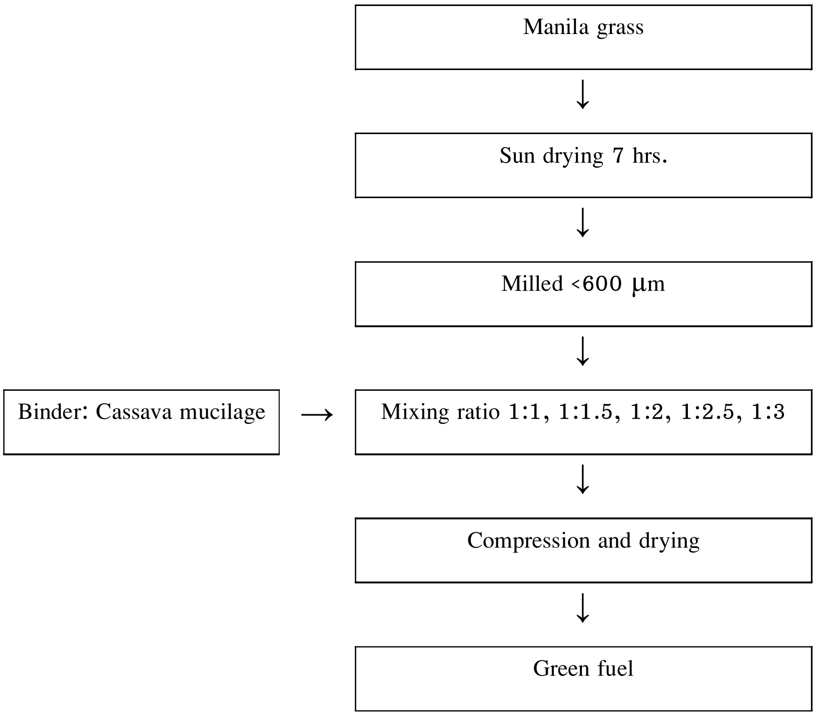

Figure 1. Briquetting procedure, manila grass and binder

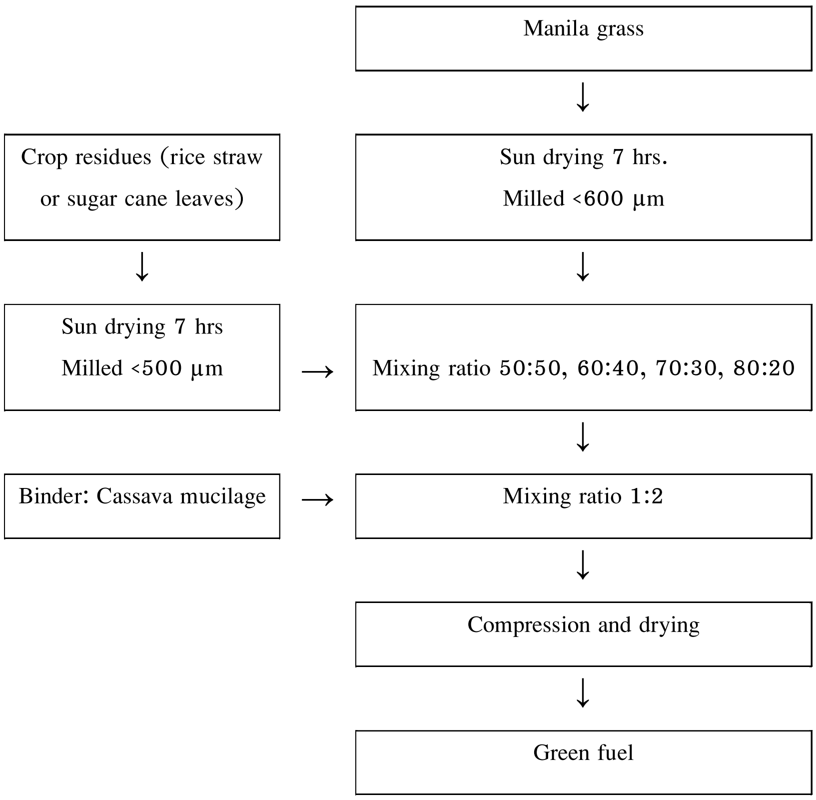

Figure 2. Briquetting procedure, manila grass, crop residues and binder

Heating Value test and Fuel Characteristics

Heating Value Test

Heating value is measured by burning a sample in a chamber filled with pressurized oxygen, in a container immersed in water. The heat from the reaction can be found from the temperature increase in the water. These measurements were done according to ASTM D 1989.

Fuel Characteristics

This study was concerned about fixed carbon, volatile matter, ash and moisture content. Moisture content was measured by the method from ASTM D 3173. The content of volatile matter was analyzed by standard method ASTM D 5832-95. The ash content was analyzed by standard method ASTM D 3174. Fixed carbon was analyzed by standard ASTM D 3172 in a volume element of a fixed carbon available from the following calculation:

Fixed carbon (%) = 100-% Moisture content-% Ash-% Volatile matter

Costs

Only the cost of cassava flour and electricity for milling, boiling the glue and compressing is considered. There machine has electricity capacity 2.206 kW, 1kW and 0.373 kW, respectively. Manila grass, rice straw and sugar cane leaves are agricultural wastes, and assumed to be free. 3 baht per kWh is used for calculating the cost of electricity, 480 g of cassava flour costs 12 baht. Other costs, like labor and equipment for processing and logistics are disregarded.

GHG emission mitigation

Make crop and collect Grasses per 1 sqm to find weight of grasses per year per sqm. Calculate energy from weight of grasses and electricity consumption (UNFCCC, 2010), after that a compare GHG emission from grasses and the other conventional fuel such as oil, coal, etc. from the following calculation:

GHG emission mitigation = Baseline Emission - (Project emission + leakage) GHG Emission

Results

Raw Material

Some material properties of manila grass as shows in Table 1.

Heating Value: Characteristics of Manila Grass and Binder

The variation of heating values of the fuels at different mixing ratios. Heating values of the fuels measured were 3,761.14 - 3,941.65 kcal/kg. The mixing ratio giving the highest heating value was 1:1, the lowest 1:3. From this is showed that increasing the amount of cassava mucilage makes the heating value decrease.

Fuel characteristics

Figure 3 shows the variation of fixed carbon, volatile matter, ash and moisture content of the fuels at different mixing ratios of grass and cassava mucilage. The ratio 1:1 gives the highest amount of fixed carbon, 32.78%: The fixed carbon content decreases with the increase in the content of cassava mucilage. Volatile matter was between 48.86 - 59.29% and increased when the content of cassava mucilage was increased, while the ash content decreased from 10.69% for ratio 1:1 to 8.52% for 1:3. Moisture content is in the range 7 - 7.6%.

Physical Characteristics: Comparison of Manila Grass and Binder

Figure 4 shows fuels with different mixing ratio of grass and cassava mucilage from 1:1 to 1:3 after sun drying. For the ratios 1:1 and 1:1.5 it can be seen that the material does not bound together tightly, especially for ratio 1:1. For mixing ratios from 1:2 to 1:3, the material binds together better than at the other ratios. It is worth mentioning that for mixing ratio 1:2.5 and 1:3, the briquette may have a problem of sticking to mould.

Cost of Manila Grass Mixed with Cassava Mucilage

Figure 5 represents the variation of cost of the fuels at different mixing ratios. Cost was between 15.58-18.10 baht/kg. The cheapest is ratio 1:1 was 15.8 baht/kg and the most expensive is ratio 1:3 was 18.10 baht/kg. Increasing the amount of cassava mucilage makes cost increase.

Table 1. Properties of raw materials

Material	Heating value [kcal/kg]	Volatile matter [%]	Ash [%]	Fixed carbon [%]	Moisture content [%db]
Manila grass	4,140.35	51.21	9.53	29.55	9.71
Rice straw	3,782.30	52.08	12	27.68	8.24
Sugar cane leaves	3,846.05	47.4	13.13	30.15	9.32

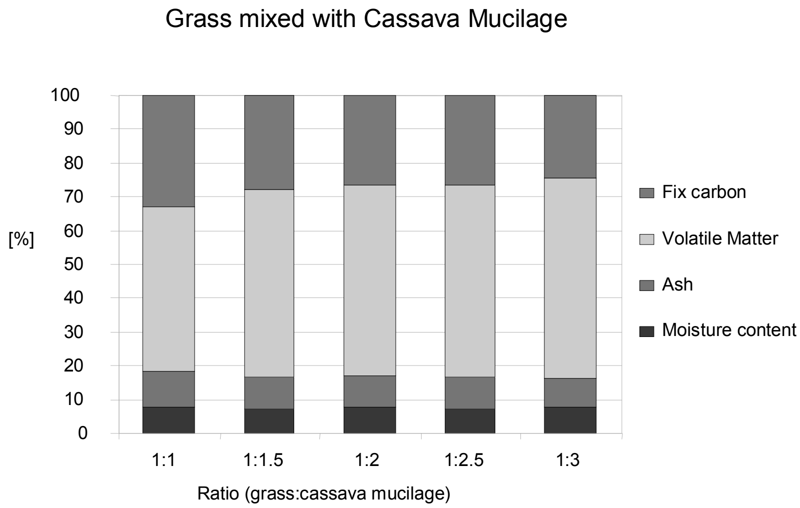

Figure 3. Variation in fuel characteristics with respect to ratio of grass and cassava mucilage.

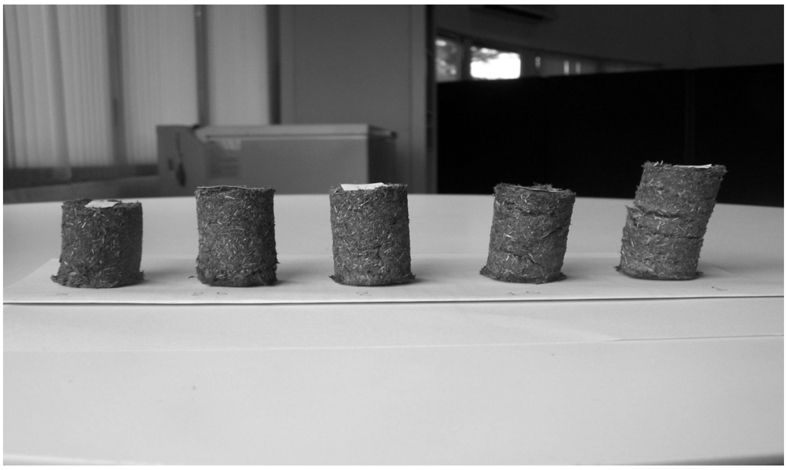

Figure 4. Physical characteristics of briquettes at different mixing ratios of grass and cassava mucilage

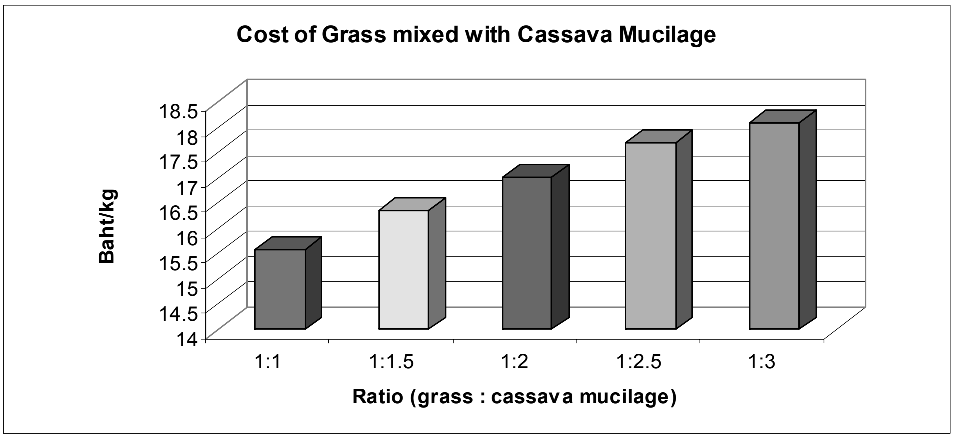

Figure 5. Relationship between cost and mixing ratios of grass and cassava mucilage

Heating Values Characteristics of Manila Grass Mixed with Crop Residues

The variation of heating values of the fuels at different mixing ratios between manila grass mixed with rice straw and binder at ratio 1:2 (grass and rice straw : cassava mucilage). Heating values of the fuels measured were 3,799.30-3,849.95 kcal/kg. The mixing ratio giving the highest heating value was 80:20 (grass: rice straw), the lowest 60:40 (grass: rice straw). From this, it is showed that increasing the amount of grass makes the heating value increase.

The variation of heating values of the fuels at different mixing ratios between manila grass mixed with sugar cane leaf and binder at ratio 1:2 (grass and sugar cane leaf : cassava mucilage). Heating values of the fuels measured were 3,771.50 - 3,901.50 kcal/kg. The mixing ratio giving the highest heating value was 80:20 (grass: sugar cane leaf), the lowest 70:30 (grass: sugar cane leaf). From this, it is showed that increasing the amount of grass makes the heating value increase.

Fuel Characteristics of Manila Grass Mixed with Crop Residues

Figure 6 represents the variation of fixed carbon, volatile matter, ash and moisture content of the fuels at different mixing ratios of grass mixed with rice straw and binder at ratio 1:2 (grass and rice straw: cassava mucilage). The ratio 80:20 gives the highest content of fixed carbon, 25.12%. The content of fixed carbon increases when increasing the content of grass. The content of volatile matter was between 58.34 - 61.44% and decreased when the content of grass increased, with lowest value for ratio 80:20. The ash content increases when increasing the content of grass, from 8.96% to 9.74%. Moisture content is in the range 6.61-7.78%

Figure 7 represents the variation of fixed carbon, volatile matter, ash and moisture content of the fuels at different mixing ratios of grass mixed with sugar cane leaf and binder at ratio 1:2 (grass and sugar cane leaf : cassava mucilage). The content of fixed carbon was between 23.11 - 24.56%, decreasing with the increase in amount of grass. Volatile matter was between 58.56 - 60.62%. The ash content increased while increasing the amount of grass from 9.56% for ratio 50:50 to 11.71% for 80:20. The moisture content is in the range 4.96 - 6.46%.

Cost of Manila Grass Mixed with Crop Residues

Figure 8 represents the variation of cost of the fuels at different mixing ratios between grass and rice straw. Costs were between 17.25 - 18.68 baht/kg. The cheapest ratio was 80:20 (grass: rice straw) at 17.25 baht/kg and the most expensive ratio, 50:50 (grass: rice straw) was 18.10 baht/kg. From this, it is shown that increasing the amount of grass makes cost decrease.

Figure 9 shows the variation of the cost of the fuels at different mixing ratios between grass and sugar cane leaf. Costs were between 16.75 - 17.50 baht/kg. The cheapest ratio, 80:20 (grass: sugar cane leaf), was 16.75 baht/kg and the most expensive ratio, 50:50 (grass: sugar cane leaf), was 17.50 baht/kg. From this, it is shown that increasing the amount of grass makes cost decrease.

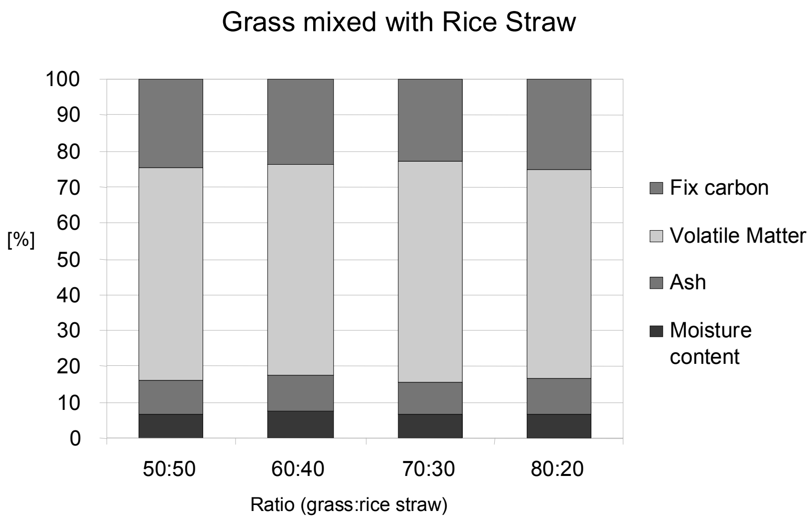

Figure 6. Variation in fuel characteristics with respect to mixing ratio of grass and rice straw.

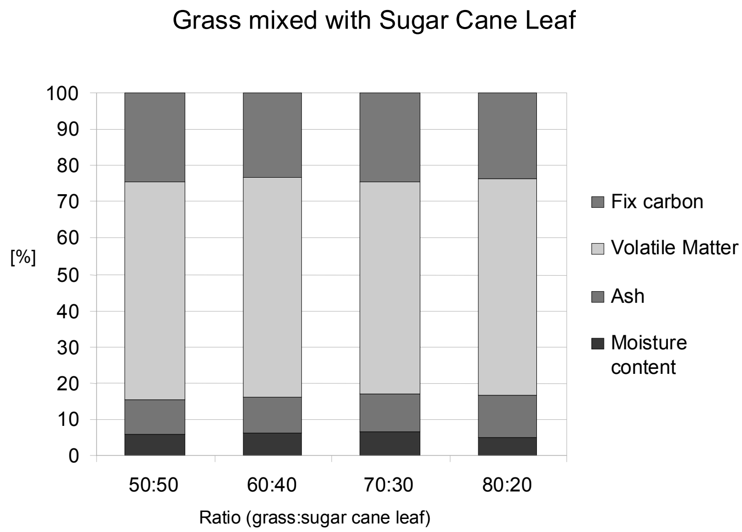

Figure 7. Variation in fuel characteristics with respect to mixing ratio of grass and sugar cane leaf.

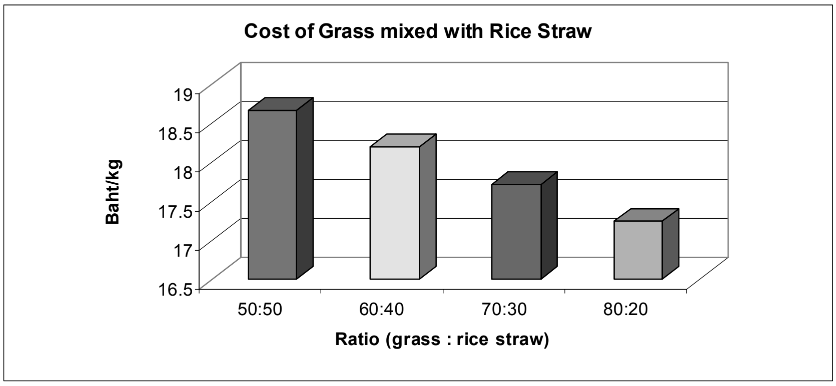

Figure 8. Relationship between cost and mixing ratios of grass and rice straw.

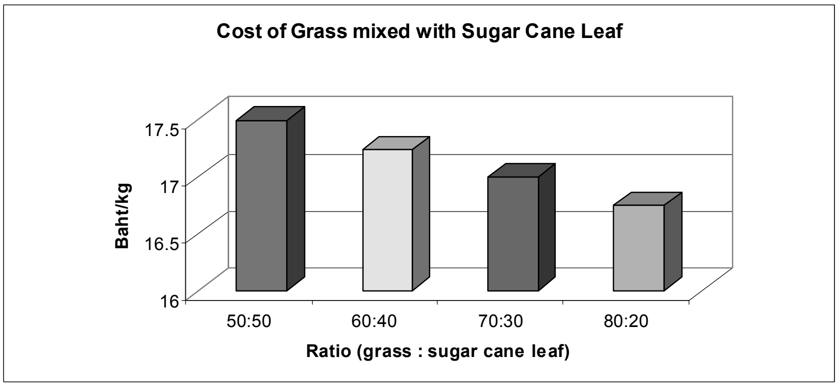

Figure 9. Relationship between cost and mixing ratios of grass and sugar cane leaf.

GHG Emission

Figure 10 represents the variation of GHG of the fuel at different source. GHG were between 0.0402 - 2.0179 kgCO_2eq per 21.018 MJ (from 1 sqm/year of manila grass). The fuel that makes lowest GHG was 0.0402 kgCO_2eq from manila grass and the highest from coal were 2.0179 kgCO_2eq. From this it is shows that manila grass give the lowest GHG when compare with the other fuel. Thus, the GHG emission mitigation of manila grass is 1.9777 kg CO_2/m_2 or 0.0941 kg CO_2/MJ. Lastly, the GHG emission mitigation for grass mixed with rice straw of 80:20 is 1.5169 kgCO_2/kg and grass mixed with sugar cane leaf is 1.5367 kgCO_2/kg.

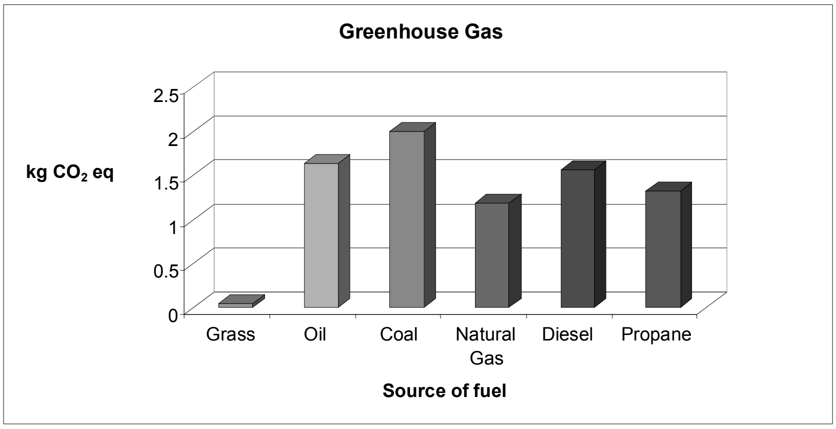

Figure 10. Relationship between GHG and source of fuel

Conclusion

This study has focused on green fuel produced from mixing the different proportions of manila grass, cassava mucilage and different crop residues. The effect of the mixing ratio of manila grass, cassava mucilage and different crop residues on heating values and good fuel characteristics at a low price was investigated. The mixing ratio was found to significantly affect heating values, contents of fixed carbon, volatile matter and ash, and cost. The heating values of the fuels (only grass) were in the range of 3,761.14 - 3,941.65 kcal/kg, comparing with bagasse: rattan chip 4,572.41 kcal/kg and water hyacinth 3,020.20 kcal/kg (Saetang, 1991) or saw dust: tapioca flour 4,726.48 kcal/kg durian skin: tapioca flour 4,220.24 kcal/kg (Sangrungrean, 2006) and cotton plant peanut 3,917 kcal/kg (Husain et al., 2002). For grass mixed with crop residues (rice straw and sugar cane leaf) and cassava mucilage at ratio 1:2 (grass and crop residues: cassava mucilage), heating values were found between 3,623.15 - 3,901.50 kcal/kg. The heating values increased while increasing the content of grass. The content of fixed carbon was in the range 22.99 - 25.12%, increasing with the increase in the content of grass.

The content of volatile matter decreased while increasing the amount of grass. The content of volatile matter was found to be between 58.34 - 61.44%, the highest at ratio 70:30 of grass mixed with rice straw. The ash content was between 8.96 - 11.71%, increasing with the increase in content of grass. The costs of mixing ratio from grass mixed with rice straw were between 17.25 - 18.68 baht/kg, lower when using more grass. For grass mixed with sugar cane leaf, the costs were between 16.75 - 17.50 baht/kg, and the lowest costs for ratio 80:20. Comparing with other green fuel (Chaiyote, 2009), at similar heating value, was found that eucalyptus wood, RDF, grass mixed with cassava rhizome, grass mixed with corncob, grass mixed with palm limb cost/kg were 54.60, 17.00, 16.63 and 17.00 baht, respectively. Increasing of electricity cost has higher significant effect to grass fuel cost than cassava flour costs as it is about 90% of total cost ratio. Less electricity consumption for milling, boiling the glue and compressing machine is needed to study as it can reduce the electricity cost and GHG emission for grass fuel too. The GHG emission factor for electricity is 0.5057 kgCO_2/kWh. The GHG emission mitigation for grass mixed with rice straw of 80:20 is 1.5169 kgCO_2/kg and grass mixed with sugar cane leaf is 1.5367 kgCO_2/kg.

The production process used is made for investigating physical and chemical characteristics of the briquettes, and is less suited for mass production. It is desirable to find a process not requiring the materials to be milled, as this is a major part of the electricity consumed, and thereby the costs. The machine for compressing should make briquettes in a continuous process, not by compressing the briquettes one by one. This would make the production more efficient, both in respect to work and energy consumption. The result of this study can be a guideline for the owner of sport stadium or garden who intends to save the world by not burn the waste grass that causes GHG. They can also get value added by making and selling green fuel.

This research is only primary; another study should be performed to improve the heating value and fuel characteristics, eg. by mixing with other crop-residue.

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