Developing environmentally friendly fuel from rice straw and biodegradable household waste: Towards sustainable development

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Abstract

This research aims to develop environmentally friendly fuels from locally abundant raw materials in Go Cong city, including agricultural by-products and garden waste. These components contribute significantly to environmental degradation, especially air quality. Go Cong city is a region with a long history of rice cultivation, achieving high yields in Tien Giang Province, averaging about 98.5 tons per day. The number of households that have signed waste collection contracts in the district is 33,629 out of 36,520, with a rate over 92%. Depending on the season of the year, the form of handling agricultural by-products will be different, but most are treated by direct burning, including rural waste. Therefore, it is necessary to find a new direction to exploit the full potential of these two by-products. This research will initially prepare environmentally friendly fuel from the above two by-product sources, thereby evaluating the quality of the fuel and considering this as a type of biochar with great potential. This research component will focus on rice production byproducts such as straw and garden waste components such as grass, leaves, and dry twigs. Fuel samples were researched and prepared under temperature conditions from 400^{o}C to 600^{o}C over a period of time from 2h to 4h, resulting in a calorific value of 4150-4530 cal/g, moisture from 7.4-14.6%, and ash level of 22.8-32.7%, volatile matter content from 17.1-19.5%, fixed carbon content from 37.2-47.6%. The quality of fuel produced ensures that it meets basic fuel burning needs in life or for small-scale production, reducing the use of traditional fuels that are gradually running out such as coal and oil, and is considered a type of biochar. The results of this research contribute to creating a new direction in solving the above problems, contributing to minimizing negative impacts on the environment while promoting sustainable agriculture.

Key words: friendly fuel, agricultural by-product, garden waste, biochar.

I. Introduction

Go Cong City is a long-standing and highly productive rice growing area of Tien Giang province, averaging about 9,000 tons/year. Equivalent to the amount of waste produced by agricultural by-products of straw is about 10,000 tons/year (Astan e ARD, Hajilo M., 2017). In addition, the volume of household waste in the city is estimated at about 100 tons/day. In recent years, farmers have begun to utilize rice straw as an additional resource to increase their income, including using rice straw to grow mushrooms, raise cows, or sell it to others. In each season of the year, the forms of handling agricultural by-product s will be different. Typically, in the Winter-Spring and Summer-Autumn seasons, the most common method is to use straw t o grow mushrooms, sell straw or use it for other production purposes (accounting for 93.2%). In the Fall-Winter season, the rate of burning straw and burying it in the field is quite high. Converting biomass from plants into energy is also known as biomass energy. The development of biomass energy helps reduce the use of fossil fuels, solve environmental pollution pro blems, improve waste treatment efficiency, but also helps create additional sources of income for farmers through the use of biomass energy. Use available agricultural materials and garden waste (Glaser B, 2007)

II. Materials and Methods

1. Experimental materials

In this study, research materials will include agricultural byproducts of rice production, which are straw, and garden wast e, which are leaves, grass, and dry twigs.

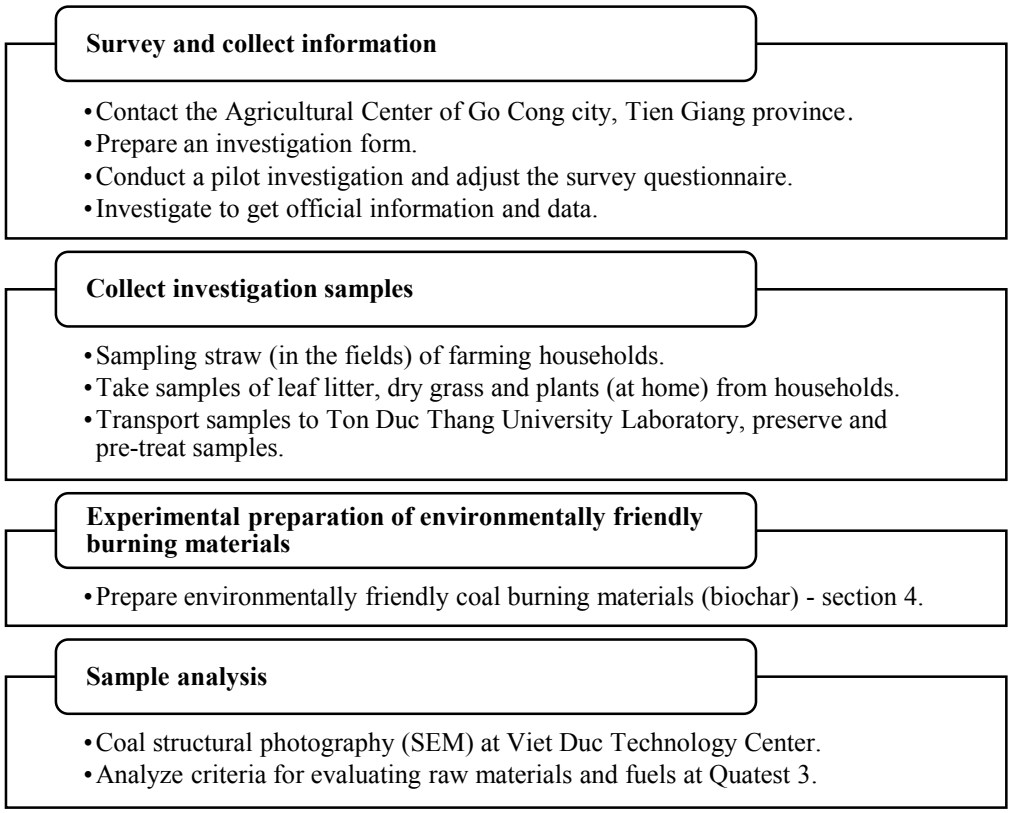
The ingredients in straw contain about 37.4% Lignocellulose, 44.9% Hemicellulose, 4.9% Lihin and high silica ash conte nt from 9-14%. Among them, the agent Lignocellulose causes straw to be difficult to biodegrade. The process of burning straw produces CO2, CO and water vapor, while the decomposed protein is converted into gasses such as NO_2, NO_3, SO_2... The act of burning straw causes environmental pollution, dust appears. Nano dust from the process of burning straw ha s the ability to penetrate deep into the respiratory system, affecting both individual and cellular health, while increasing the amount of GHG released into the atmosphere. In addition, smoke from straw is often pungent, stimulating reactions such as coughing, sneezing, phlegm, and a feeling of suffocation, causing discomfort to the human respiratory system (Lehmann J et al., 2006).

With the characteristics of being a region in the Mekong Delta and the condition of being a new rural area, households in Go Cong city have a relatively large garden area. The amount of dried/fresh leaves, branches and fresh grass when pruning is often not considered as a type of household waste, so most of it is not combined with household waste for transport com panies to collect and process. This amount of trash will usually be collected and burned by people. This leads to environme ntal pollution in rural areas, causing discomfort and affecting the health of people living in the area. When burned, dry/fres h leaves, twigs and grass will produce large amounts of CO, CO2, NOx, SO2, fine dust PM2.5,... causing serious air pollut ion. In addition, burning leaves and grass can easily break out into fires, causing property damage and affecting the ecosyst em. Leaves and dry grass components usually have a low calorific value of 17.5 - 19 MJ/kg, so when used as fuel, pay att ention to the humidity and calorific parameters to avoid ash when burned.

2. Data analysis

Through survey results, in Go Cong city there is a total of 3,704.9 hectares of rice growing land with 12,945 farming hou seholds producing more than 9,000 tons of rice/year. According to previous studies, the straw/rice ratio ranges from 0.91 - 1. 31 depending on rice variety and production method (S. Abrishamkesh et al., 201), (A. Nigussie et al., 2012). Thereby, it is estimated that the amount of straw generated in the area ranges from 8,000 - 12,000 tons of straw/year. Besides, because it i s a rural area, the amount of garden waste in households is also very large. Therefore, these are two rich sources of raw mate rials for research.

The database analysis in this study is based on the following process:



3. Survey and collect research samples

The survey research scale took place in Go Cong city, Tien Giang province. The survey will focus on information related to the rice production process, forms of post-production straw by-products and dry leaves, grass, and twigs. In surveys, choosing how many sample units to conduct a survey is also an issue that must be calculated very carefully and scientifically. To calculate the number of survey samples, the author applied the Slovin formula (1960):

$$n = \frac{N}{1 + N \times e^2}$$

n: Number of sample members to be determined for survey research

N: The total number of samples

e: The desired level of accuracy

Applying calculations to reality in Go Cong City with N = 12,945 (total number of rice growing households in the area), e = 0.1 (sampling error not more than 10% and confidence level of 90%).

$$n = \frac{12{,}945}{1 + 12{,}945 \times 0{,}1^2} = 99 \text{ (forms)} \approx 100 \text{ (forms)}$$

The process of collecting samples for research will be carried out during direct surveys in the area. The process of collecting straw samples is as follows:

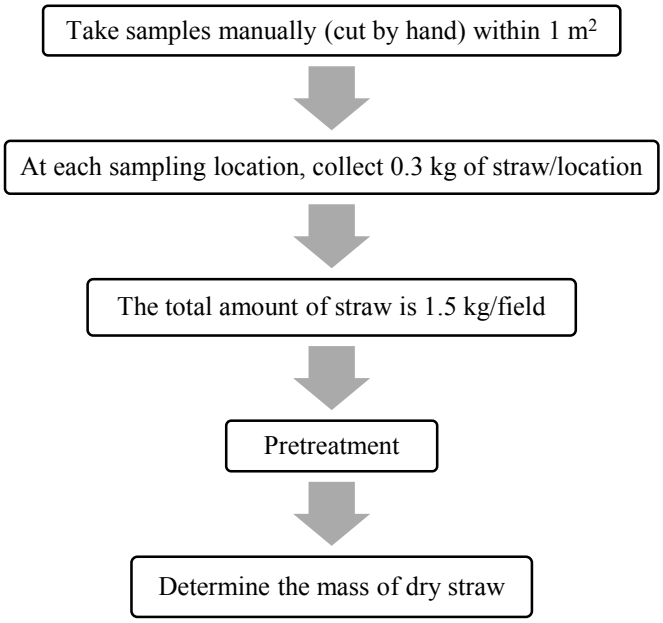


Figure 2. Straw sampling process

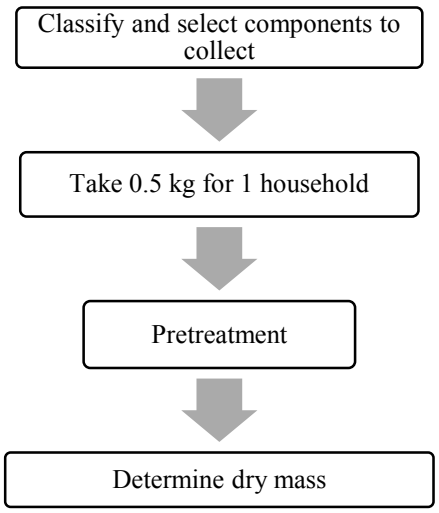


Figure 1. Garden waste sampling process

4. Experimental model

The fuel preparation process includes 04 steps:

Step 1: Pretreatment of raw materials: Straw and dry leaves, grass, and twigs will be crushed to a size of 2-3 cm. Wash and dry the sample at 105^{o}C for 2 hours.

Step 2: Charcoal the material: The sample after pretreatment will be calcined in anaerobic conditions at temperatures from 400^{o}C to 600^{o}C with time intervals from 2 hours to 4 hours.

Step 3: After calcination, the sample is ground finely and binder is added.

Step 4: Compress the sample and drain naturally.

Figure 3. Fuel preparation process

After the basic preparation process at the laboratory, the raw fuel is sent to a pellet production facility to add binder additi ves and form fuel pellets.

Figure 4. Environmentally friendly fuel

5. Results of survey

With 12,945 rice farming households in the area, through calculations, the number of samples needed to be surveyed is 100 random households throughout the area. The survey objective is to obtain information on ways to handle straw by-pro ducts and dry leaf, grass, and tree branch components of farmers in the area.

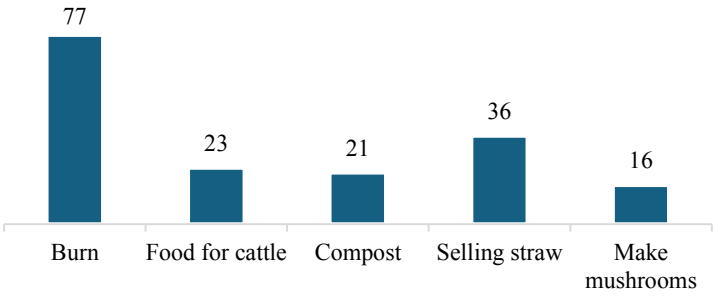


Figure 5. Main forms of processing (Unit: household)

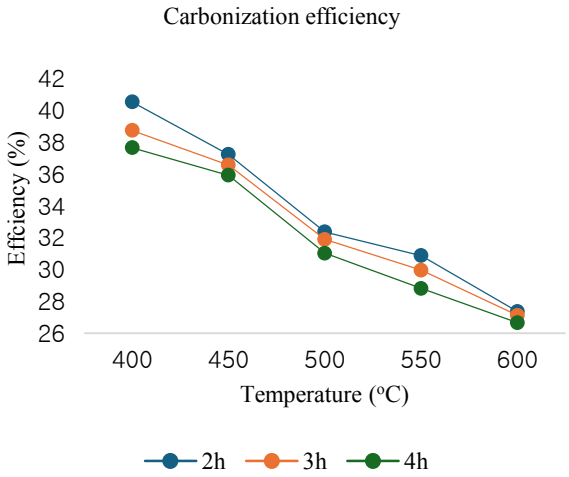
A farm household during the survey will have many different forms of treatment. The results show that the majority of households treat straw by-products and dry grass, leaves, and twigs by burning them, with 77/100 households. The volume of straw and dry grass, leaves, and twigs used for other purposes is lower and accounts for a small proportion of a household's generated volume, only about 10-20%.

6. Results of sample analysis

The results of elemental analysis of collected samples including straw, leaves, and dried grass and plants showed that there were 41.8% carbon, 4.6% hydrogen, 36.6% oxygen, 0.7% nitrogen, 0.08% sulfur, 15.9% ash, moisture about 14.7% and calorific value about 16.28 MJ/kg.

7. Results of the research process

After heating the sample in anaerobic conditions from 400°C to 600°C for 2h to 4h, fuel carbonization efficiency gradually decreases with temperature and time with the lowest being 26.67% at 600°C in 4 hours and the highest being 40.53% at 400°C in 2 hours.

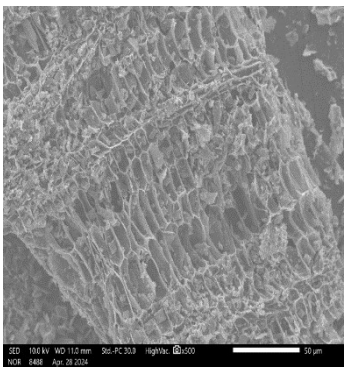


At the same time, after the preparation process, the fuel sample had moisture analysis results from 7.4-14.6%, ash content from 22.8-32.7%, volatile matter content from 17.1-19.5%, carbon content fixed from 37.2-47.6% and calorific value reached from 4150-4530 cal/g. From the analysis results, it can be assessed that the prepared sample can completely be made into an environmentally friendly fuel. With abundant raw material resources in Go Cong city, purchasing, transportation and production costs will be reduced, estimated at $0.3-0.35 for 1kg of fuel production.

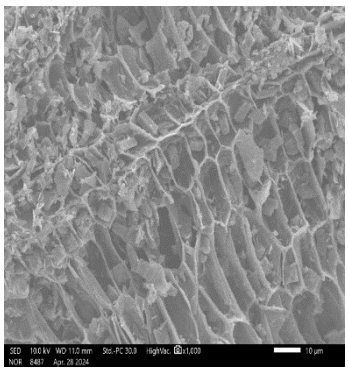
Table 1. Main parameters evaluate fuel quality through analysis under different research conditions

No.	Sample			Total humidity	Ash content	Volatile matter content	Fixed carbon content	Total calorific value
	Temperature	Time	Test method	ISO 18134-1:2015	BS EN ISO 18122	ISO 18123:2015	ISO 17225-1:2021	ISO 18125:2017
1	400°C	2h		14.6	22.8	19.5	43.1	4530
2	400°C	3h		13.2	23.5	19.1	44.2	4500
3	400°C	4h		11.7	24.3	18.8	45.2	4490
4	450°C	2h		13.8	24.6	19	42.6	4500
5	450°C	3h		11.5	25.1	18.6	44.8	4470
6	450°C	4h		10.4	25.9	18.4	45.3	4390
7	500°C	2h		12.6	25.2	18.3	43.9	4310
8	500°C	3h		10.8	25.9	17.8	45.5	4280
9	500°C	4h		8.9	26.8	17.6	46.7	4240
10	550°C	2h		11.2	27.2	17.9	43.7	4320
11	550°C	3h		9.0	28.1	17.5	45.4	4270
12	550°C	4h		8.2	29.5	17.3	45.0	4220
13	600°C	2h		10.8	29.2	17.4	42.6	4240
14	600°C	3h		8.1	30.8	17.2	43.9	4180
15	600°C	4h		7.4	32.7	17.1	42.8	4150

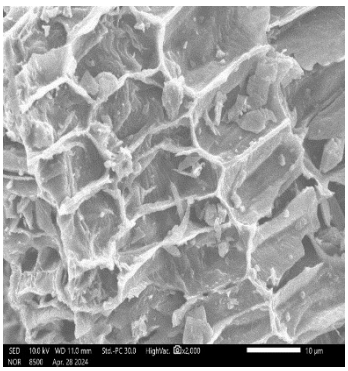
The analysis results are also supplemented with images showing the structure of the fuel after the research and prepara tion process. Images of the fuel surface structure were observed using a field emission scanning electron microscope (SEM) with magnifications of 500, 1000 and 2000 times using a field emission tube at high voltage. 10kV and working distance W D11mm.



Magnification (x500). Bar = 50 µm



Magnification (x1000). Bar = 10 µm



Magnification (x2000). Bar = 10 µm

Figure 6. Images of the fuel surface structure

III. Conclusions

The research has been carried out as a premise and experiment for the production of environmentally friendly fuel from agricultural by-products, specifically straw and garden waste components (in this research project, including leaves, grass and dry twigs). Research results have shown that the efficiency of creating biochar from straw and garden waste is relatively high from 26.67-40.53% with a calorific value of 4150-4530 cal/g. There by proving its suitability as an environmentally fr iendly fuel to replace depleting fossil fuels, while also helping to solve the problem of agricultural by-products and garden waste born in Go Cong city, Tien Giang province, improving environmental quality and aiming for sustainable agriculture.

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