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# Feasibility Analysis of Producing Bio-char from Rice Husks in Vietnam

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***Abstract:*** *The biomass pyrolysis has been a way to generate a bio-char, including rice husk. In Vietnam, the rice husk has covered more than 10% of total biomass, and been a potential alternative energy source in the context of fossil fuel sources in running out. Our study of rice husk pyrolysis has been acted in two separate reactors, a muffle furnace and a macro-TG, under nitrogen surroundings. The peak temperatures were at 873 K and 1173 K, and the heating rates were at 293 K.min$^{-1}$ and 2073 K.min$^{-1}$. The achieved results have provided more data and technical analysis of the feasibility of bio-char generation from rice husk in Vietnam. The perfect conditions to get the best bio-char have found at peak temperature of 873 K and heating rate of 293 K.min$^{-1}$ with Te Do rice husk from Red River Delta.*
***Keywords:*** *Biomass, bio-char, pyrolysis, rice husk, Vietnam*

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## I. Introduction

Due to the increase in annual energy demand and the exhaustion of fossil fuels, biomass has been considered as one of potential alternative energy sources in the future [1, 2, 3, 4]. Biomass come from the organic materials, and its products have forms of gas, liquid, or/and solid under biochemical and thermo-chemical mechanisms [5, 6, 7].

The pyrolysis is one of thermo-chemical processes for converting biomass into energy products like biochar, bio-oil or HC compounds in gas [5, 6, 8]. Depending on operating conditions of temperature, heating rate, residence time and pressure, the pyrolysis process could take place in slow, fast or hydrolysis [9, 10, 11]. The morphology of the output products has been influenced of the chemical and physical structure, particle size, ratios of lignocellulosic constituents of feedstocks [9, 10]. In biomass pyrolysis, a biochar would be more reactive and more much porosity under high pressure, or the particle size could influence the heat transfer and the carbon deposition, or the heating rate would affect to the volatile matter composition and the biochar structure [12, 13, 14]. Due to the unique physicochemical properties, biochar has been used in energy and chemical applications, including the use as a fuel in electricity production [9, 11, 15, 16].

In Vietnam, there are many sources of renewable energy with good potential for exploitation such as small hydropower, wind energy, biomass, urban waste, and solar energy [17, 18, 19]. But the main concern of renewable energy in Vietnam currently has been bio-energy, and biomass has been considered as a potential alternative energy source in the future [19, 20]. Vietnam has about 84 million tons of biomass each year with over 9 million tons of rice waste [21, 22, 23]. However, producing bio-char hereby still has been quite new and its applications in energy were not much [24]. Our study has focused on the rice husk sources in Vietnam due to its huge potential and low moisture content [9, 21, 22]. The achieved results would provide more database of making biochar from rice husk and contribute a view for the future development of biomass pyrolysis in Vietnam.

## II. Materials And Methods

### 2.1. Materials

Rice husks have got from some regions in Vietnam, as Red River Delta, Mekong River Delta, etc. The raw rice husks were harvested at the same time, and removed any doped objects. The sample length was between 5 and 7 mm, and 2 to 3 times larger than their width.

### 2.2. Experimental system and sample preparation

The experimental system included a reactor of macro-TG (see Fig. 1) and a furnace of Nabertherm LT 24/12/P330 (see Fig. 2).

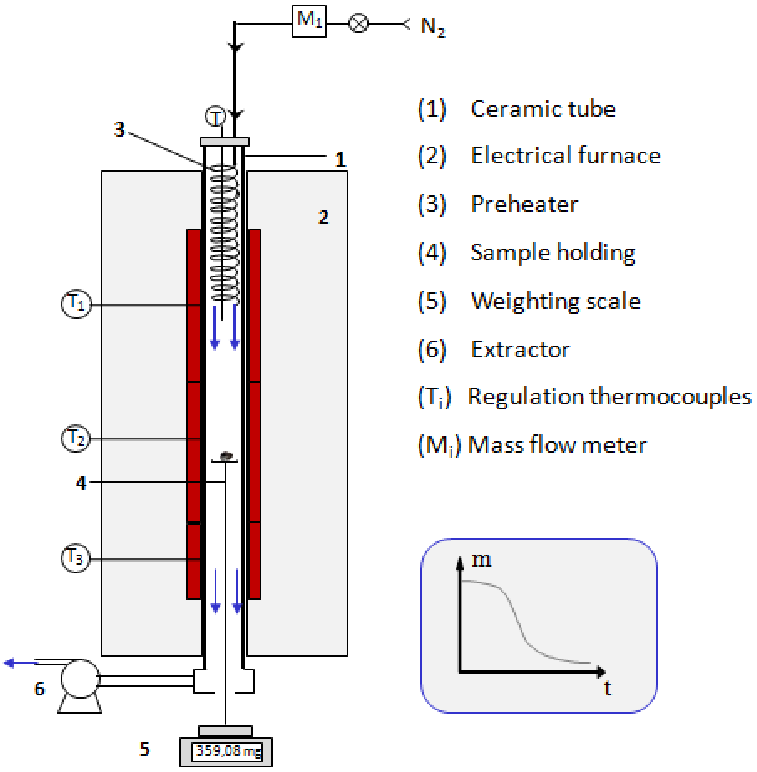



**Figure 1**: Macro-TG Reactor

The length of macro-TG was 1.11 m and its diameter was 0.75 m. The reactor could electrically heat up to 1323 K. Before injecting into reactor, the nitrogen ($N_2$) was crossed a pre-heater to catch the temperature of reactor with the average flow of 5 Nl/min.

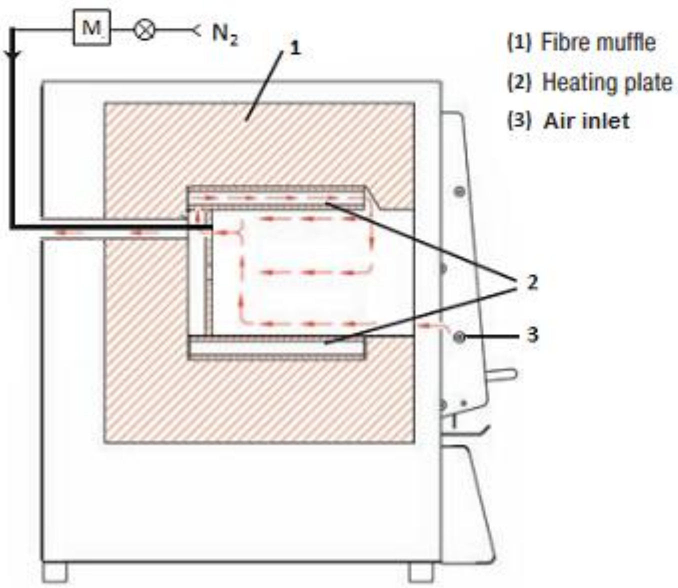



**Figure 2:** Nabertherm Furnace

The furnace of Nabertherm LT 24/12/P330 had a volume of 24 l and was controlled by P330 program. The furnace could electrically heat to a maximum temperature of 1473 K. And the nitrogen ($N_2$) was injected into a furnace with average flow rate of 1.87 Nl/min.

**2.3. Description of the Experiments**

2.3.1. Determining the composition of raw and char samples

The moisture, volatile matter, and ash were determined in laboratory and followed the standards in CEN /TC-281 (2005), and the fixed carbon was found out by difference.

For raw rice husk, they were done by standards of AFNOR XP CEN/TS 14774-3/14775, XP CEN/TS 15148/14774/14918, and for its char, they were AFNOR NF EN 1860-2 and XP CEN/TS 14918.

The samples were crushed into a particle of 1 mm or less and mixed well before analysis. All experiments were carried out step by step by standards and done at least 2 times to check repeatability with a maximum acceptable deviation of about ±5%.

2.3.2. Making bio-char from rice husk

The bio-char was produced at various heating rates and final temperatures under nitrogen medium. After that, the char yield (η) was determined by (1):

$$\eta = \frac{m_{char}}{m_{raw}} \times 100\% \quad (1)$$

where: $m_{char}$, $m_{raw}$ - mass of bio-char and raw rice husk in grams, respectively.

By Nabertherm furnace: The raw material was put into a gas-tight steel box inserted inside the furnace. The nitrogen ($N_2$) was injected into this box at average flow of 1.87 Nl/min. And then, the sample in a steel box was initially heated to 873 K (or 1173 K) in 30 minutes (or 45 minutes), and maintained at this temperature in 45 minutes. Before taken out and weighed, the char was cooled to the room temperature.

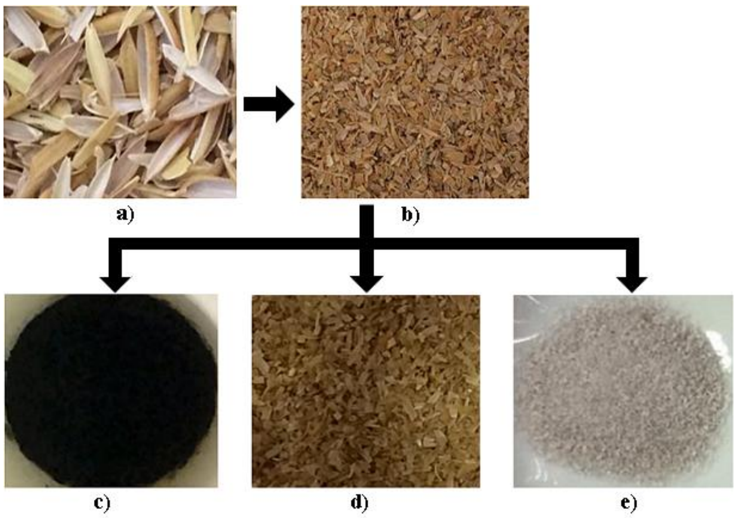
By macro-TG: The raw material was placed in a grid crucible on a fixed bed, and under an inert medium with average flow of 5 Nl/min. And then, the sample was heated to 1173 K in 30 seconds, and maintained at this temperature in 45 minutes. The charcoal was cooled to the room temperature before taken out and weighed.

## III. Results And Discussions

**3.1. Proximate Analysis**

The moisture (M), volatile matter (VM), ash (A), fixed carbon (FC), and high heating value (HHV) has been important compositions to determine the characteristic of fuels. The moisture would be used to assess the energy cost for drying a fuel, the ash was to determine the amount of ash treated before using fuel, the volatile matter was to evaluate the combustion characteristics of a fuel, and the fixed carbon was to represent the carbon content in a fuel.

The experimental samples in each step after grinding, drying, and burning were showed in Fig. 3 below. And the compositions of samples after proximate analysis were listed in Table 1.




a) Raw RH, b) Grinded RH, c) RH char, d) Dried RH, e) RH ash

**Figure 3:** Experimental Samples of Rice Husk (RH) before and after Proximate Analysis

**Table 1:** Results of Proximate Analysis of Raw Rice Husks

| RH name | M% | $VM_{db}$% | $A_{db}$% | $FC_{db}$% | HHV(MJ/kg) |
|---|---|---|---|---|---|
| Bac Thom (Red River Delta) | 8.7 | 65.1 | 15.5 | 19.4 | 15.3 |
| B.C (Red River Delta) | 9.7 | 67.6 | 13.3 | 19.1 | 15.6 |
| Te Do (Red River Delta) | 10.0 | 64.6 | 16.4 | 19.0 | 15.1 |
| Ha Noi (Red River Delta) | 11.3 | 69.3 | 12.8 | 17.8 | 15.6 |
| Khang Dan (Red River Delta) | 12.3 | 66.1 | 14.5 | 19.4 | 15.2 |
| Nang Hoa (Mekong River Delta) | 10.6 | 66.3 | 13.3 | 20.4 | 15.6 |
| Can Tho (Mekong River Delta) | 11.2 | 66.5 | 13.7 | 19.8 | 15.4 |
| Thau Dau (Red River lowlands) | 10.2 | 65.2 | 17.3 | 17.6 | 14.8 |
| Thien Uu (North Central coast) | 12.5 | 65.0 | 15.8 | 19.2 | 14.6 |

(**Note:** M - Moisture (as received), VM - Volatile matter, A - Ash, FC - Fixed carbon, HHV - higher heating value, db - dry basis)

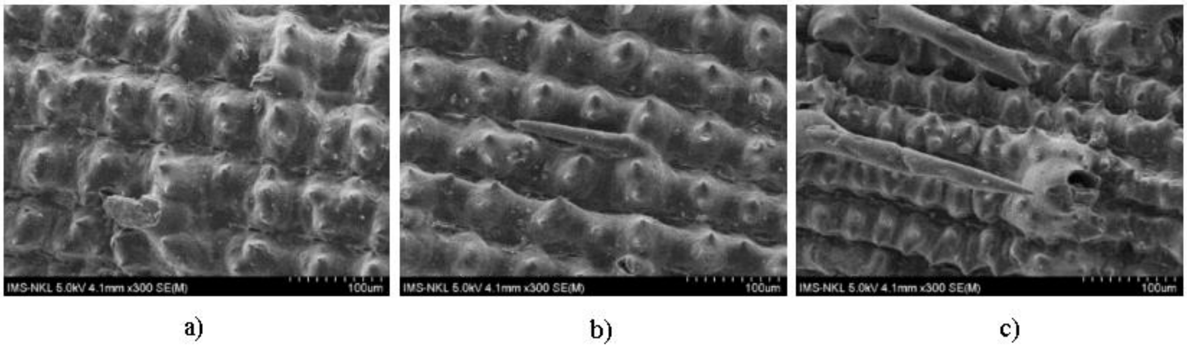
Experimental results showed that all rice husks have got the high heating value of round 15 MJ/kg, and their moisture was in range from 9% to 13%. The largest HHV was rice husks of Te Do, B.C and Nang Hoa, and the moisture of 10% or less was rice husks of Te Do, B.C, and Bac Thom. Almost of rice husks have the fixed carbon content of above 19%, including Te Do, B.C, Nang Hoa and so on.

It seemed that the moisture content of rice husks in Vietnam was quite high in comparison with the average value of others on the world [9, 25, 26]. However, the potential for making bio-char from rice husk in Vietnam has been very big due to its annual huge production. And the exploitability in generating energy of rice husks from Red River Delta was better than that from other regions.

### 3.2. Producing biochar

With the high fixed carbon of 19%, high heating value of over 15 MJ/kg and moisture content of 10%, Te Do rice husk was chosen to produce charcoal in next step. The experiment was done under nitrogen atmosphere at the heating rate of 293 K.min$^{-1}$ and 2073 K.min$^{-1}$, and the final temperature of 873 K and 1173 K, respectively. Te Do rice husk particles before and after pyrolysis was showed in Fig. 4, and Fig. 5 displayed the SEM images of sample surface at different conditions, including 873 K, 293 K.min$^{-1}$; 1173 K, 293 K.min$^{-1}$; and 1193 K, 2073 K.min$^{-1}$.


**Figure 4:** Samples of Rice Husk (RH) before (a) and after (b) Pyrolysis




a) 873 K, 293 K.min$^{-1}$; b) 1173 K, 293 K.min$^{-1}$; c) 1173 K, 2073 K.min$^{-1}$

**Figure 5:** SEM Images of Testing Biochars

Results shown that the shrinkage of rice husk was significant after pyrolysis, about 50%, but its surface was not undergone secondary cracking due to the small and homogeneous particles [27]. The decomposition of charcoal at 873 K and 1173 K was incomplete, and only serrated peaks were formed. As the heating rate increased to 2073 $K.min^{-1}$, many cracks and pores were formed due to the sudden and continuous change of experimental temperature [28, 29].

**Table 2.** Results of Proximate Analysis of Rice Husk Biochars

| Final temp., °C | Heating rate, $^oC.min^{-1}$ | Yield, % | $VM_{db}$% | $A_{db}$% | $FC_{db}$% | HHV (MJ/kg) |
|---|---|---|---|---|---|---|
| 873 | 273 | 35.1 | 3.3 | 39.8 | 56.9 | 19.6 |
| 1173 | 293 | 33.7 | 1.4 | 39.6 | 59.0 | 19.3 |
| 1173 | 2073 | 29.7 | 1.9 | 46.5 | 51.6 | 16.3 |

(**Note:** VM - Volatile matter, A - Ash, FC - Fixed carbon, HHV - higher heating value, db - dry basis)

Results shown that the char yield was the highest at 873 K and 293 K.min-1, but the fixed carbon at 873 K was lower than that at 1173 K with same heating rate, and the lowest was with 2073 K.min-1 at 1173 K. The results totally agreed with the theoretical basis and experimental studies of biomass pyrolysis [9, 10, 13, 14]. Finally, the char quality and yield of Te Do rice husk were relatively good in comparison with that of the others in the world [28, 29].

## IV. Conclusions

The strong points of biomass energy are towards sustainability and low cost, and biomass pyrolysis has been an essential need in the present and future. Rice husk is one of the potential biomass sources, and rice husk pyrolysis has being developed strongly on the world and considered deeply by Vietnam government and private organizations. Preliminary experiments showed the characteristics of some popular rice husks in Vietnam, and their behaviors during pyrolysis. The peak temperature of 873 K and heating rate of 293 $K.min^{-1}$ has been good options to make bio-char by Te Do rice husk. And the rice husks from Red River Delta have been more feasible than that from the others. These experimental results would facilitate the development of the biomass pyrolysis in making bio-char in Vietnam.

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