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EFFECT OF TEMPERATURE AND RESIDENCE TIME ON PYROLYSIS OF RICE HUSK PELLET

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Abstract: *Biomass, mainly agricultural residues, is found widely available in Vietnam for energy services. For these ends, it is normally upgraded by thermo-chemical or biological conversions before being use as clean and efficient fuels. In this work, a pyrolysis of rice husk pellet was performed by mean of an electrical oven. Three final temperature values were selected i.e 400^{0}C, 600^{0}C, and 800^{0}C. For each selected value of pyrolysis temperature, three levels of residence time for pyrolysis process were set as 0, 60 and 120 minutes, respectively. Some properties of the final product from the pyrolysis process i.e volatile, ash content, fixed-carbon and higher heating value (HHV) were measured. The experimental results have shown that in the current range of experimental work, charcoal products could get the highest fixed-carbon content at the pyrolysis temperature of 600^{0}C and with the residence time of 120 minutes.*

Key words: *Pyrolysis, rice husk pellet, biomass, charcoal.*

NOMENCLATURE:

A - ash content, %
M – moisture content, %
FC – fix carbon content, %
V – volatile mater content, %
HHV – higher heating value, MJ/kg
T_f – final temperature of pyrolysis, ^oC
t – resident time, minute

I. INTRODUCTION

Vietnam is a long-standing agricultural country with approximately 175 million tons of raw materials for the production of biomass energy. It will be equivalent to nearly 70 million tons of oil, twice the total oil and gas exploitation volume of the Vietnam Oil and Gas Group in 2016 [1]. The agricultural residues, especially rice husk- one importance biomass source, can be converted to useful energy by several methods, i.e. thermo-chemical or biological conversions. Among these methods, due to a high energy conversion efficiency and low carbon dioxide emission, gasification is a promising route for agricultural residue treatment. To enhance energy conversion efficiency, biomass is usually upgraded to a more advanced energy form before being gasified. Biomass pyrolysis to produce charcoal is one of the most popular options.

Biomass pyrolysis to produce charcoal is one of the most effective energy upgrading methods. In the agricultural countries as Vietnam, the capacities of rice products are very large, especially rice husk. Although biomass can be used directly as a primary energy resource, pyrolysis will help to create a more advanced form of energy. Charcoal, a product of pyrolysis, can be converted into a gas fuel by gasification. This enables biomass to be better applied in the industrial electric generation where fossil fuels have normally been used [2,3]. There are several works to apply such technology to provide thermal and / or electric energy [4,5]. In addition, the application of rice husk pellet appears attractive in Vietnam. This paper will present an experimental study on pyrolysis of the rice husk pellet to investigate the effect of the final temperature and the residence time on the quality of char products.

II. EXPERIMENTAL METHODOLOGY

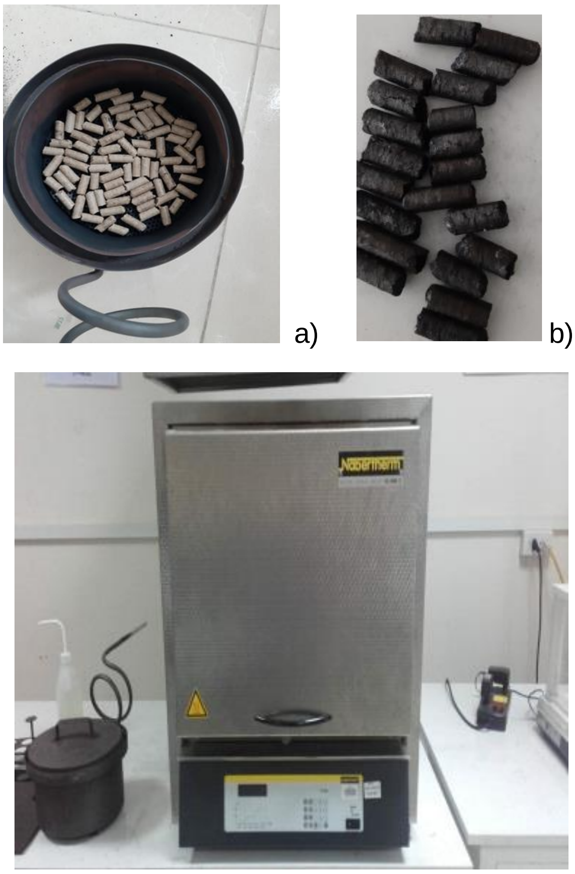
Materials selected for pyrolysis was rice husk pellet with the properties presented in Table 1.1:

Table 1: Rice husk pellet properties.

M (%)	*V (%)*	*FC (%)*	*A (%)*	*HHV, MJ/kg*
7.8	60.5	17.7	14.0	16.08

The rice husk pellets with 10 mm of diameter and 20 mm of length were placed in the steel box as shown in Fig. 1a. Total mass of these pellets for each experiment was 200 grams. Sand was used to fill the space between the cover and body of the steel box. The box was then put in an electrical furnace (see Fig. 1b) to start the pyrolysis process. Nitrogen flow with flow rate of 1.5 l/min was used during pyrolysis and char cooling periods. Experiment mode settings were consisted of final temperature and residence time. The heating rate was remained unchange of 3^0C/min for all experimental runs. The oven was first turned on so that the furnace temperature increased gradually until the pyrolysis temperature was reached. This value was kept for a certain period of time (i.e residence time) before the oven was turned off. The product of pyrolysis process is shown in Fig. 1c.

Pyrolysis conditions: Final temperatures were 400, 600, 800 ^{o}C, heating rate was 3 ^{o}C/mins, residence time: 0, 60, 120 mins. The pyrolysis system is shown in Fig.2.



a) b)

c)

Figure 1: a) Box of rice husk pellet; b) Electrical furnace c) Char product.

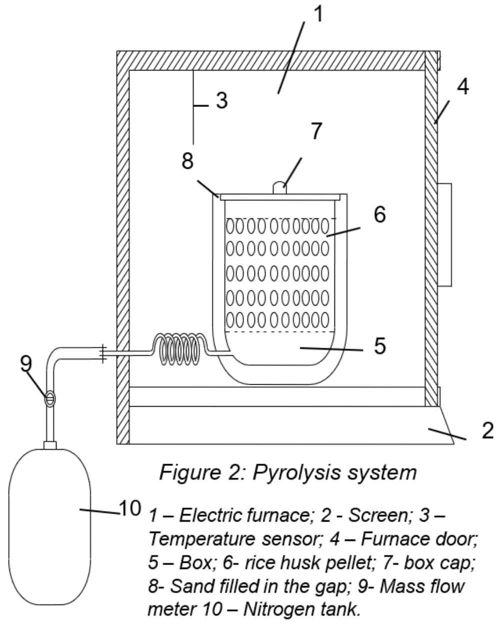


Figure 2: Pyrolysis system

III. EXPERIMENTAL RESULTS

The char properties are presented in table 2.

Table 2: Char properties

T_f °C	t min	V (%)	FC (%)	A (%)	HHV, MJ/kg	Yiel, %
400	0	22.8	47.6	29.6	20.41	42.6
	60	19.7	50.2	30.1	20.61	42.0
	120	17.3	52.2	30.5	20.97	40.3
600	0	6.8	57.9	35.3	20.95	36.7
	60	6.2	58.4	35.4	21.33	36.6
	120	4.4	58.8	36.8	21.49	35.7
800	0	4.9	58	37.1	20.85	35.2
	60	3.9	57.9	38.2	20.62	34.4
	120	3.1	57.6	39.3	20.50	34.2

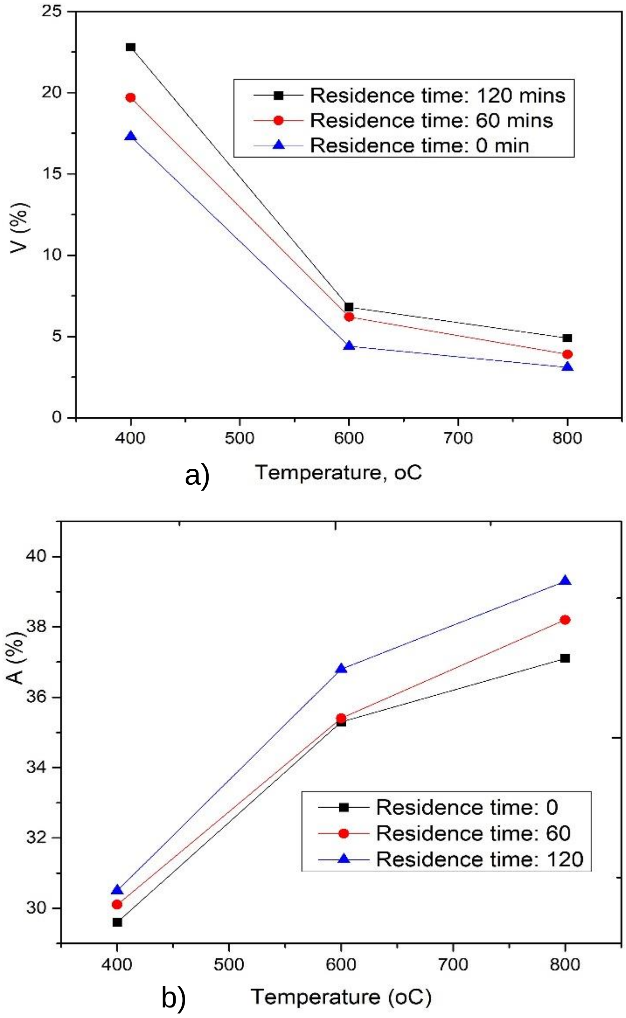


Figure 3: Effect of final temperature and residence time on the volatile meter (a) and ash (b) in char

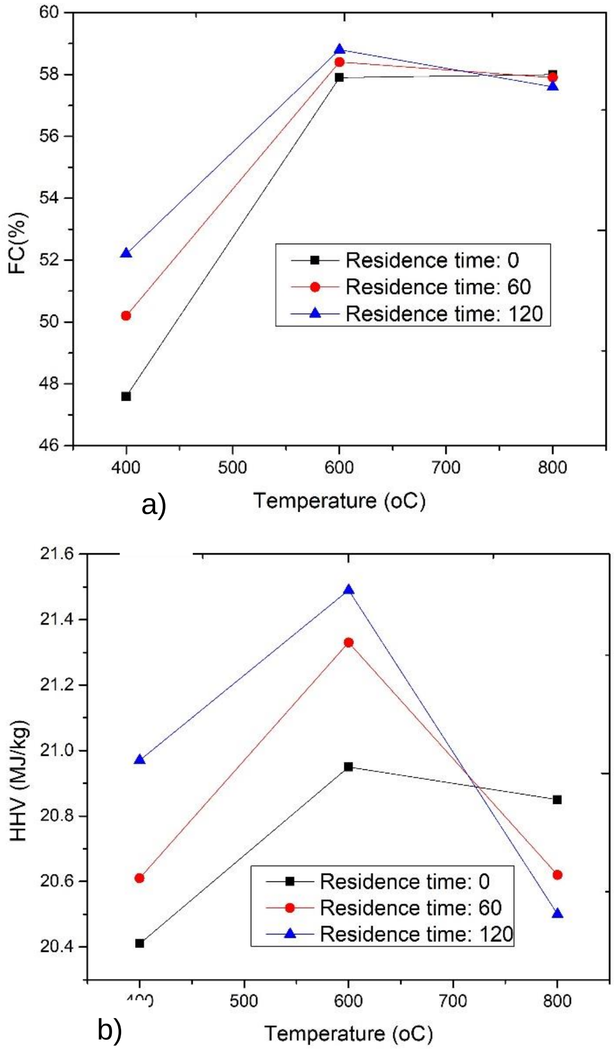


Figure 4: Effect of final temperature and residence time on FC content (a) and HHV (b).

Table 2 and Fig 3, 4 show that: when the final temperature rises from 400 °C to 800 °C and the residence time rises from 0 mins to 120 mins., FC content of char grows up very significantly. At 400 °C, if the residencs time increases from 0 to 120 mins, it makes FC content of char increases 9.7%, from 47.6% to 52.2%, meanwhile in the temperature range of 600 – 800 °C, the increase is slight and almost evenly. It can be explained as following: The volatile meter releases strongest around 400 °C in pyrolysis process [6], therefore the residences time is the important factor for both yiel and quality of char (FC content). Besides, due to the high volatile meter content of rice husk pellets (17.3 – 22.8%), the increase in residences time is an advantage point for volatile meter release strongly continuously. In contrast, in the range of 600 -800 °C, the rate of volatile meter escape decreased [6]. Furthermore, when the less volatile content in the pellet (6.8 – 0.8 %), the less effect of residences time on yiel and FC content. The experimental data also shows that the char reaches the highest FC content and HHV in the conditions: T_f = 600 °C and residence time of 120 mins, 5.8% and 21.49 MJ respectively. In 400 °C, when the residence time increases from 0 to 120 mins, FC content of char grows 47.6% to 52.2%, therefore the HHV of char goes up slightly. Meanwhile, by the pyrolysis temperature is 800 °C, the FC content tends to decrease slightly when the residence time extended. It also goes down compare to char of 600 °C, the most reduction with 120 mins residence time condition, reached 5%. This trend also mentioned in [7]: With high temperature pyrolysis, a small part of FC in biomass is converted into gas fuel. According to Anca Couce et al [8], the secondary reactions that occur during the formation of char above 750 °C can lead to the phenomenon that a part of FC is oxidized by the gases produced by previous primary pyrolysis reactions. Chen et al [9] and Fu et al [11] also confirmed that the char production of 900 °C pyrolysis can be decreased in the pore size and surface square, therefore it is not advantage for both gasification and combustion.

The previous research with rice husk in the same conditions [10] also dedicates that FC content tends to decrease when pyrolysis temperature is above 750°C. Figure 5 reveals that FC rate in rice husk pellet char is slightly higher than in rice husk when final temperature is below 600°C. It can be explained that the rice husks temperature profile will be more uniform and higher than rice husk pellets temperature due to the smaller particles and bulk density.

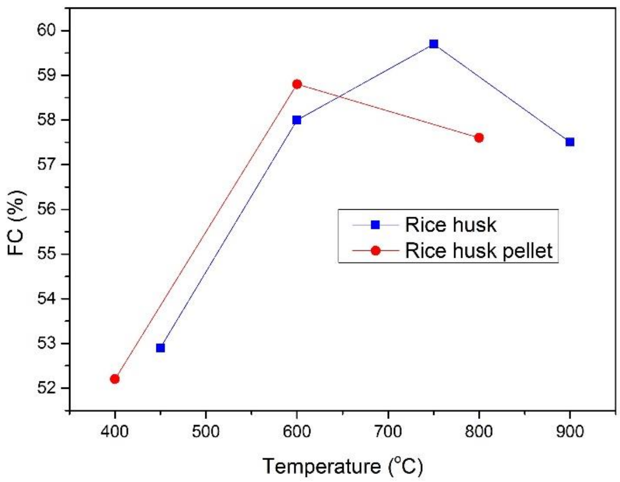


Figure 5. FC of rice husk char and rice husk pellets char. (Heating rate 3°C/min, residence time 120 mins.)

V. CONCLUSION

Temperature is the significant factor which effects on the rice husk pellet pyrolysis for char production. The result of pyrolysis study shows that in the range of expriment, the quality of char from the rice husk pellet reached the maximum value with pyrolysis conditions: the final temperature is 600 °C, the heating rate is 3 °C/mins, the residence time is 120 mins. Besides, for char production, the pyrolysis process should not go beyond 800°C as its FC content would be decreased.

REFERENCES

[1] Nguyen Thi Thu Ha. Overview report: Research on efficiency improvement of biomass gasification for heating industrial combustion chambers. Hanoi University of Science and Technology. (2018)

[2] Adams P.W.R and Manus M.C. Small-scale biomass gasification CHP utilization in industry: Energy and environmental evaluation. Sustainable Energy technologies and Assessments 6. (2014)

[3] Ajay Kumar, David D. Jones, Milford A. Hanna. Thermochemical Biomass Gasification: A Review of the current Status of the Technology. Energies. (2009).

[4] Sang Jun Yoon, Yung-Il Son, Yong-Ku Kim Jae-Goo Lee. Gasification and power generation c haracteristics of rice husk and rice husk pellet using a downdraft fixed-bed gasifier. Renewable Energy. (2011)

[5] C.T.Chang, M. Costa, M. Lavilletta, A. Macaluso, D. Piazzullo, L. Vanoli. Thermo-economic analyses of a Taiwanese combined CHP system fuel with syngas from rice husk gasification. Energy. (2018)

[6] P. Basu. Biomass Gasification and Pyrolysis Practical Design and Theory. Elsevier. (2010)

[7] Hoang-Luong Pham. Wood Energy Basics: A Technical Document, Regional Wood Energy Development Program of Food and Agriculture Organization. FAO/RWEDP, Bangkok, Thailand, (1999)

[8] Anca-Couce Andrés, Alba Dieguez- Alonso, Nico Zobel, Anka Berger, Norbert Kienzl and Frank Behrendt. Influence of heterogerous secondary reactions during slow pyrolysis on char oxidation reactivity of woody biomass. Energy&Fuel. (2017)

[9] Dengyu Chen, Yanjun Li, Kehui Cen, Min Luo, Hongyan Li and Bin Lu. Pyrolysis poly generation of poplar wood: Effect of heating rate and pyrolysis temperaturE. Bio resource Technology. (2016)

[10] Nguyen Thi Thu Ha, Pham Hoang Luong. Effect of temperature and heating rate in rice husk pyrolysis process for char coal production. Thermal Energy review. (2018)

[11] Peng Fu, Song Hu, Jun Xiang, Lushi Sun, Sheng Su and Jing Wang. Evaluation of the porous structure development of chars from pyrolysis of rice straw: Effect of pyrolysis temperature and heating rate. Journal of analytical and applied pyrolysis. (2012)

ẢNH HƯỞNG CỦA NHIỆT ĐỘ VÀ THỜI GIAN NHIỆT PHÂN ĐẾN CHẤT LƯỢNG NHIỆT PHÂN CỦA VIÊN NÉN TRẤU

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TÓM TẮT

Sinh khối, chủ yếu là phụ phẩm nông nghiệp, được sử dụng rộng rãi ở Việt Nam như một nguồn năng lượng năng lượng. Đối với mục tiêu cấp nhiệt, sinh khối thường được nâng cấp bằng cách chuyển đổi nhiệt hóa học hoặc sinh học trước khi được sử dụng làm nhiên liệu sạch và hiệu quả. Trong công trình này, quá trình nhiệt phân viên trấu được thực hiện bằng lò điện. Ba giá trị nhiệt độ cuối cùng được chọn là 400^{0}C, 600^{0}C và 800^{0}C. Đối với mỗi giá trị của nhiệt độ nhất định, 3 mức thời gian lưu trú cho quá trình nhiệt phân được đặt lần lượt là 0, 60 và 120 phút. Một số đặc tính của sản phẩm cuối cùng từ các quá trình nhiệt phân này, tức là chất bốc, hàm lượng tro, cacbon cố định và giá trị gia nhiệt cao (HHV) đã được xác định. Kết quả thí nghiệm cho thấy trong phạm vi thí nghiệm, sản phẩm than hoa đạt hàm lượng cacbon cố định cao nhất ở nhiệt độ 600^{0}C với thời gian nhiệt phân là 120 phút.