INVESTIGATION ON ENERGY EXTRACTION AND CHARACTERIZATION WITH VALUE ADDED PRODUCT FROM BIOMASS

BY

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A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering)

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ABSTRACT

Energy demand around the world has been increasing rapidly especially in the developing countries. Considering global issues of sustainable energy and reduction in greenhouse gases, renewable energy is getting increased attention as a probable alternative source of energy. There are nine general sources of energy on earth; these are geothermal, nuclear, fossil, solar, biomass, wind, wave, hydro and tidal energies. Biomass resources are often locally available and conversion into secondary energy carriers is feasible with lower capital investments. Rice husk has a great potential to be used as a source of renewable biomass energy, some value-added material like activated carbon and electrically conducting carbon can be extracted. The major portion of rice husk is consumed by burning in traditional rice parboiling boilers, and some portion is used for making briquette fuel. Thermal energy production by burning rice husk is rather poor. The other use of rice husk is the briquette production. But the briquette production system is very much electricity intensive. The other use of rice husk is value added product preparation from rice husk such as activated carbon and conducting carbon. Furthermore, before going to the application of rice husk, it is needed to go for detailed analysis of different properties such as physical and thermo-chemical analysis of rice husk from different varieties. Based on the above limited information and scope of research of this study was conducted to develop an easy to use and easily transported product that can be accessible to the communities. The main objective of this study is to investigate the suitability of rice husk for achieving maximum energy extraction and for conversion into activated carbon with the particular application to adsorbing colour and dyes from aqueous solutions. The analysis includes moisture content, bulk density, proximate analysis, elemental analysis, calorific values and thermo-gravimetric properties. This study reports that the moisture content in all samples investigated is suitable to serve as feedstock for thermal conversion technologies. Activated carbon is produced from rice husk by using zinc chloride and phosphoric acid as activating agents. The adsorption capacity of rice husk activated carbon varies with different types of the husks. Thus use of rice husk biomass can create enormous opportunity for energy production and value-added product preparation in addition to clean energy production and bio-material preparation for both industrial and daily life use.

ملخص البحث

الطلب على الطاقة في جميع أنحاء العالم يتزايد بسرعة خاصة في البلدان النامية. النظر في القضايا العالمية للطاقة المستدامة والحد من غازات الاحتباس الحراري، والطاقة المتجددة هو الحصول على المزيد من الاهتمام كمصدر بديل محتمل للطاقة. هناك تسعة مصادر عامة للطاقة في العالم. هذه هي الطاقة الحرارية الأرضية والطاقة النووية والوقود الأحفوري والطاقة الشمسية والكتلة الحيوية، وطاقة الرياح، موجة، والطاقة المائية والطاقة المد والجزر. وغالبا ما تكون موارد الكتلة الحيوية المتوفرة محليا وتحويلها إلى شركات الطاقة الثانوية غير مجدية مع استثمارات رأس المال أقل. قشر الأرز لديه إمكانات كبيرة لاستخدامها كمصدر للطاقة الكتلة الحيوية المتجددة، وبعض المواد ذات القيمة المضافة مثل الكربون المنشط وإجراء كهربائيا الكربون يمكن استخراجها. ويستهلك الجزء الأكبر من قشر الأرز عن طريق حرق في الأرز سلق المراجل التقليدية، ويستخدم بعض جزء لصنع وقود فحم حجري في بنغلاديش. إنتاج الطاقة الحرارية عن طريق حرق قشر الأرز ضعيف نوعا ما. استخدام آخر من قشر الأرز هو انتاج فحم حجري. ولكن نظام انتاج فحم حجري هو الكثير جدا من الكهرباء المكثف. استخدام آخر من قشر الأرز والقيمة المضافة إعداد المنتج من قشر الأرز مثل الكربون المنشط وإجراء الكربون. وعلاوة على ذلك، قبل الذهاب إلى تطبيق قشر الأرز، هناك حاجة للذهاب لتحليل مفصل لخصائص مختلفة مثل التحليل الفيزيائي والحرارية والكيميائية وقشر الأرز من أصناف مختلفة. وبناء على المعلومات المحدودة المذكورة أعلاه ونطاق الأبحاث أجريت هذه الدراسة إلى تطوير وسيلة سهلة الاستخدام وسهولة نقل المنتجات التي يمكن أن تكون في متناول المجتمعات المحلية. الهدف الرئيسي من هذه الدراسة هو دراسة مدى ملاءمة قشر الأرز لمن قشر الأرز لتحقيق أقصى قدر من استخراج الطاقة وتحويلها إلى الكربون المنشط مع تطبيق معين إلى التكثيف اللون والأصباغ من المحاليل المائية. ويشمل تحليل محتوى الرطوبة وكثافتها، والتحليل المباشر، تحليل العناصر والقيم الحرارية و الخصائص الحرارية الجاذبية. تقدم هذه الدراسة أن محتوى الرطوبة في جميع العينات التحقيق هو مناسب لتكون بمثابة المادة الخام للتقنيات التحويل الحراري. يتم إنتاج الكربون المنشط من قشر الأرز باستخدام كلوريد الزنك وحامض الفوسفوريك وكلاء تفعيل. قدرة الامتصاص من قشر الأرز الكربون المنشط يختلف مع أنواع مختلفة من قشور. وسوف يكون حاضرا في العمل في المستقبل. وبالتالي استخدام الأرز قشر الكتلة الحيوية يمكن أن تخلق فرصة هائلة لإنتاج الطاقة وإعداد المنتجات ذات القيمة المضافة، بالإضافة إلى تنظيف إنتاج الطاقة وإعداد الحيوية المادي للاستخدام الصناعي والحياة اليومية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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“This thesis is dedicated to my wife”

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Ǻ	Armstrong
BCR	Benefit Cost Ratio
BCSIR	Bangladesh Council for Scientific & Industrial Research
BDT	Bangladesh Taka
BRRI	Bangladesh Rice Research Institute
DTA	Differential Thermal Analysis
DTG	Differential Thermo-Gravimetric
ETP	Effluent Treatment Plant
GTZ	German Technical Cooperation
H	Hour
H_3PO_4	Phosphoric acid
HCl	Hydrochloric acid
kg	Kilogram
kJ	Kilo joule
kW	Kilo watt
kWh	Kilo watt hour
L	Liter
LHV	Lower heating value
M	Mole
MB	Methylene blue
ppm	Parts per million
mW	Mega watt
mWh	Megawatt hour
NaOH	Sodium hydroxide
nm	Nanometer
NPV	Net Present Value
pJ	Pita joule
RHC	Rice Husk Char
rpm	Revolution per minute
SEM	Scanning Electron Microscopy
Tcf	Trillion cubic feet
TGA	Thermo-Gravimetric Analysis
UV/vis.	Ultra Violet visible
XRD	X-ray diffraction
XRF	X-ray fluorescence
$ZnCl_2$	Zinc chloride
RH	Rice Husk

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

The global energy market is dependent on the fossil fuels viz. coal, oil, and natural gas as sources of thermal energy. Formation of fossil fuels in the earth takes millions of years. The reserves of fossil fuels are finite and subject to depletion as they are consumed. "The only natural, renewable carbon resource known that is large enough to be used as a substitute for fossil fuels is biomass" (Klass, D. L, 2004). The sources of biomass are all water- and land-based organisms, vegetation, and trees, or virgin biomass, and all dead and waste biomass such as municipal solid waste (MSW), bio-solids (sewage), animal wastes (manures), forestry and agricultural residues, and certain types of industrial wastes. The biomass is renewable in the sense that it is regenerated within short rotation of time what is used as energy resource unlike the fossil fuel deposits. The size of global carbon sink (standing terrestrial biomass carbon used as an energy resource) is approximately 100 times the global energy consumption annually (Klass, D. L, 2004). Living plants capture the solar energy by fixing the carbon in its tissue via photosynthesis with the help of chlorophyll. The source of carbon fixed in the plant tissue is the carbon dioxide (CO_2) in atmosphere. The photosynthesis process converts atmospheric CO_2 to carbohydrate (glucose, starch, cellulose etc). The process of photosynthesis in the growth of biomass is expressed by the following equation 1.1 and shown in Fig 1.1:

$$CO_2 + H_2O + light + chlorophyll \rightarrow (CH_2O) + O_2 \qquad (1.1)$$

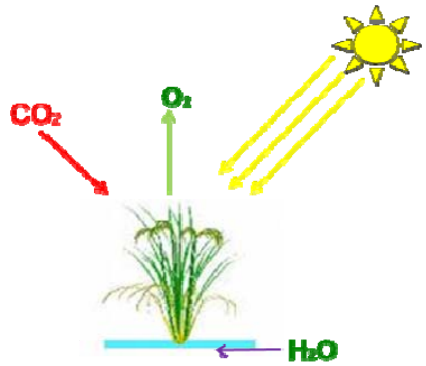

Figure 1.1 Process of biomass growth via photosynthesis

The product of photosynthesis process is called biomass. Carbohydrate, represented by the building block (CH_2O), is the primary organic product. For each gram mole of carbon fixed, about 470 kJ (112 kcal) is absorbed (Eltayeb, A . Y , 1994). When biomass is burnt it produces CO_2 into atmosphere and releases 393.8 kJ of energy due to burning of each gram mole of carbon. The released CO_2 from combustion of biomass is renewed during the next growing season of the plants. The key step of energy released by biomass is expressed by equations 1.2 and 1.3. Combustion of each gram of carbon releases about 393.8 kJ of heat energy. Biomass comprises lignin, cellulose, and hemicellulose. Cellulose and hemicelluloses has a heating value of 17.5 MJ/kg whereas, lignin contains a heating value of 25 MJ/kg (Klass, D. L, 2004). The heating value of different composition of biomass is shown in Table 1.1. A comparison of heating values of different fuel with biomass is shown in Table 1.2 (Quaak, P., Knoef, H., & Stassen, H. E., 1999). Biomass contains lower heating value compared to fossil fuel. However, it is renewable and readily available around the world.

$$(CH_2O) + O_2 \longrightarrow CO_2 + H_2O \qquad (1.2)$$

$$C + O_2 \longrightarrow CO_2 \text{ (393.8 kJ/gram mole C)} \qquad (1.3)$$

Table 1.1 Heating value of biomass components (Klass, D. L, 2004)

Component	Carbon content (wt%)	HHV (MJ/kg)
Monosaccharide	40.00	15.6
Disaccharides	42.00	16.7
Polysaccharides	44.00	17.5
Crude proteins	53.00	24.0
Lignin	63.00	25.1
Lipids	76.00-77.00	39.8
Terpenes	88.00	45.2
Crude carbohydrates	41.00-44.00	16.7-17.7
Crude fibres	47.00-50.00	18.8-19.8
Crude triglycerides	74.00-78.00	36.5-40.0

Table 1.2 Heating value of different fuel (Tariq, Reupke, & Sarwar, 1994)

Name	HHV (MJ/kg)	LHV (MJ/kg)
Coal	34.10	33.30
CO	10.90	10.90
Methane	55.50	50.10
Natural gas	42.50	38.10
Propane	50.30	46.30
Gasoline	46.70	42.50
Diesel	45.90	43.00
Hydrogen	141.90	120.10
Rice Husk	19.00	14.00
Wood	17.00-22.00	8.40-17.00

The husk is the coating for the seeds of the raw rice paddy in Fig. 1.2 (Olivier, P. A, 2004). To protect the seed during the growing season, the husk is made of hard materials, including lignin and opaline silica. The husk is mostly indigestible to humans. During the milling process, the husk is removed from the grain as a by-product to make the rice edible. The chemical components of rice husk are cellulose (44.83%), hemicelluloses (35.3%) and lignin (19.87%) (Maiti, S., 2007).

Figure 1.2 Photograph of raw rice grain covered by husk (Olivier, P. A, 2004).

The rice husk is one of the most abundant renewable agriculture-based fuel materials in the world that can be collected feasibly. It is lignocellulosic biomass, and a property is that it can be heated up and burnt to release energy. When rice husk is burnt to extract energy, it consumes oxygen from air and releases CO_2 as the end product to the atmosphere. The produced CO_2 can be captured by the rice plant again with the help of sun light and chlorophyll and it sends back the oxygen to the air during next growing season (Fig 1.1, Equation 1.1). Therefore rice husk is renewable comprising a closed carbon cycle (Fig. 1.7).