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The Preliminary Study Of Two-Stage Pyrolysis Durian Shell To Biochar

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Abstract**–** *Pyrolysis technology is a thermochemical process that can be used to produce useful products from biomass, such as biochar, bio-oil and combustible pyrolysis gases. Durian is a significant economic fruit in Thailand that continuous increase in durian consumption has led to a massive amount of waste from processing is durian shell. This research focuses on the production of biochar from durian shell using a two-stage pyrolysis process. The primary aim is to manage two types of waste: durian shell and flue gases, at a temperature of 500°C with various time (1-5 hours). The biochar was characterized by SEM, FTIR, XRF, BET analysis, and its high carbon content determined by proximate analysis. The result found that after heating durian shells turned into black color which 70.51% carbon, heating value is 6,385.32 Kcal/kg. Moreover, surface area, pore volume, and pore size of 74.20 m^2/g, 0.13 cc/g, and 0.005 mm., respectively. The results from this research can encourage developing different approaches towards making use of food waste (durian shell) and flue gases to Value-added materials (biochar) by two-stage pyrolysis process.*
Keywords**–***Bio char, durian shell, excess heat, food waste, pyrolysis.*

I. INTRODUCTION

Thailand is renowned as one of the world's largest producers and consumers of durian, a significant economic fruit that generates substantial income for both farmers and the country. However, the continuous increase in durian consumption has led to a massive amount of waste from processing and consumption is durian shell. Durian shell account for over 60-70% of the total weight of the fruit. Currently, most durian husks are disposed of through landfilling or burning, which contributes to environmental problems such as increased waste, unpleasant odors, and greenhouse gas emissions. Considering Thailand's increasing durian production, which reached over 1.76 million tons in 2023 (data from the Office of Agricultural Economics) [1-2], this means approximately 1 million tons of durian husks need to be managed annually. Even though, durian husks are often considered waste, they actually possess significant potential and several advantages that can be harnessed. First, Durian husks are rich in numerous beneficial compounds, including cellulose, hemicellulose, and lignin, which are primary components of fiber. They also contain flavonoids, carotenoids, and polyphenols, known for their antioxidant properties, as well as various beneficial minerals. Second, given their massive quantity, durian husks can be used as a biomass fuel for electricity or heat generation. This can be achieved through processes like palletisation or biogas production, which helps reduce reliance on fossil fuels and mitigate environmental issues associated with open burning. Moreover, durian shell has potential for value-added product processing such as activated carbon and biochar its high adsorption properties, it can be used in wastewater treatment, odor removal, or as a component in various industries.

Biochar is a charcoal-like substance produced from biomass (like agricultural residues, wood branches, or organic waste) through a process called pyrolysis. This is a high-temperature thermal decomposition process that occurs in the absence or limited supply of oxygen. This process results in a black, highly porous, and carbon-rich material with a stable structure that doesn't easily decompose. Biochar's unique properties give it a wide range of benefits, especially in agriculture. Biochar can improve soil properties, enhancing its water retention and nutrient-holding capacity, leading to better plant growth, reduced need for chemical fertilizers, and increased agricultural yields. Furthermore, biochar plays a significant role in carbon sequestration in the soil, which helps reduce the amount of carbon dioxide in the atmosphere, a primary cause of climate change. Beyond its agricultural benefits, biochar can be applied in other areas, such as water and air purification, as a component in construction materials, and in bioenergy production. With its diverse and environmentally friendly properties, biochar is a crucial innovation in promoting sustainable development and efficient resource management.

Pyrolysis is one of the most important processes continuously studied and developed for biomass conversion which is a thermochemical process that involves the decomposition of organic matter in biomass under conditions of no or extremely limited oxygen. There are three types of pyrolysis: slow, rapid and flash. Each method of pyrolysis produces different compounds with unique compositions [3-4]. This process yields three main products bio-oil: A dark liquid containing a variety of organic compounds. It can be used as fuel or as a raw material for chemical production, biochar is a solid material primarily composed of carbon. It can be used as a soil amendment, an adsorbent, or a solid fuel. In addition, syngas (or pyrolysis gas) is a gas mixture containing hydrogen, carbon monoxide, methane, and other gases. It can be used for electricity generation or as a fuel. The ability of pyrolysis to transform biomass into a diverse range of value-added products makes it a highly attractive technology, offering both environmental friendliness and economic potential. However, controlling the conditions and variables within the pyrolysis process such as temperature, reaction time, and biomass type significantly impacts the type and quantity of products obtained. Therefore, understanding these mechanisms and factors is crucial for maximizing the process's efficiency and yield.

This research aims to preliminary study the feasibility of producing biochar from durian shell using a two-step continuous pyrolysis process.

II. Experimental

A. Biochar production

Durian shell was sourced from Rayong province, Thailand. It was subsequently dried at 105 °C. After drying, Durian shell was converted into biochar using a two-stage pyrolysis process. The pyrolyzer consisted of two connected stainless-steel closed chambers, linked by a stainless-steel pipe. An LPG was used to heat at the first chamber to 500 °C for 1-5 hours. Subsequently, excess heat from the first chamber were directed into the second chamber to heat up the durian shell within it into biochar via pyrolysis at 500 °C for 1-5 hours.

B. Biochar characterization

After heating, durian shells turned into black color. surface morphology, pore size, pore volume, elemental compositions, and crystalline phases of biochar were investigated by X-ray diffractometer (XRD), X-ray fluorescence (XRF), Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM) and energy dispersive x-ray spectrometry (EDX), respectively. Moreover, the moisture content, ash content, fixed carbon content, volatile matter, and calorific value of biochar were analysed using proximate and ultimate analysis methods.

III. RESULTS AND DISCUSSIONS

The study on the efficiency of biochar production from durian shell using a two-stage pyrolysis process revealed that when the first chamber, containing durian shell, was heated by LPG at 500 °C and excess heat from the first chamber were directed into the second chamber to heat up the durian shell within it into biochar via pyrolysis at 500 °C for 1-5 hours. The result found that durian shells turned into black color after completely pyrolyzed for 3 hours (fig.1). The moisture content, ash content, fixed carbon content, and volatile matter of biochar were shown in table1. It was indicated that durian shell can be used to produce high-quality biochar, exhibiting low moisture content (4.26%), ash content (17%), and volatile organic matter (26.38%). Additionally, it exhibits a high fixed carbon content of 50%, which is considered excellent for biochar.

TABLE I PROXIMATE ANALYSIS OF BIOCHAR FROM DURIAN SHELL

Proximate Analysis	As received
Moisture, %	4.262
Volatile matter, %	26.385
Fixed carbon, %	51.501
Ash, %	17.852
Total	100

Fig.1 biochar from durian shell

BET analysis of the durian shell biochar revealed the following properties: pore volume of 0.14 cm^3/g, average pore size of 5.23 nm, specific surface area of 74.50 m^2/g, and iodine adsorption of 111.83 mg/g, respectively. This indicates that the biochar derived from durian shell falls into the macro-pore category (Macro-pores: > 50 nm). The beneficial properties of macro-pores contribute to improved soil aeration, better water drainage (reducing waterlogging and soil compaction), and provide a suitable habitat for larger microorganisms and plant roots.

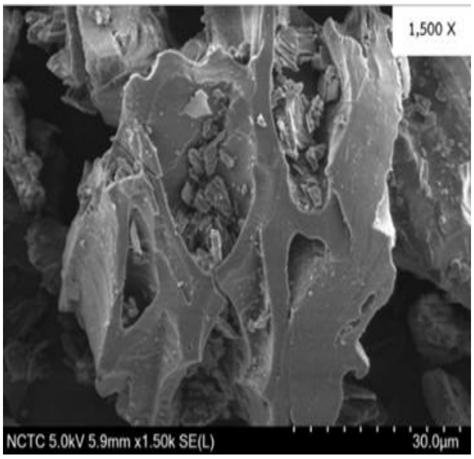

Fig. 2 SEM analysis of biochar from durian shell

SEM analysis (fig.2) showed the distribution of pore on all biochar fractures with similar apparent BET analysis. XRD results (fig.3) showed phase formation of carbon in biochar, which could form both amorphous and semicrystalline phases. While oxygen could be composed in other elements in biomass through many forms of mineralogical compositions such as $CaCO_3$ (Calcite), K_2SO_3 (Potassium sulfite), MgSiO3 (Clinoenstatite), and Sanidine (K(AlSi3O8)). That is consistent with the results of the chemical composition analysis by XRF which showed that the oxide components are as shown in Table2. Moreover, the alkali lignin phase appears in biochar at 500 °C. The $CaCO_3$ and $Ca_3(PO_4)_2$ phases could decompose at low pyrolysis temperature.

TABLE2 THE OXIDE COMPONENTS OF DURIAN SHELL BIOCHAR

Oxide	Component (%)
Potassium Oxide (K2O)	22.50
Calcium Oxide (CaO)	3.47
Phosphorus Oxide (P2O5)	3.35
Magnesium Oxide (MgO)	1.88
Silicon Oxide (SiO2)	1.22
Sulfur Oxide (SO3)	1.09

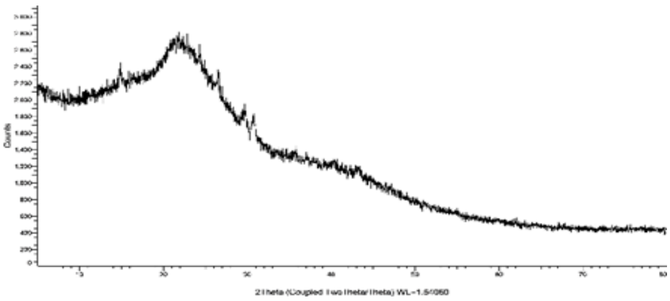

Fig. 3 XRD results of biochar

IV. CONCLUSION

A two-stage pyrolysis process can produce high-quality biochar from durian peels, with simultaneous biochar production in both chambers. This represents an advancement in continuous two-stage pyrolysis systems and reuses excess heat from the system, saving energy and reducing the production time for biochar in the second chamber. Furthermore, producing biochar from durian peels is a value-added way to repurpose food waste. Therefore, utilizing a two-stage pyrolysis process for durian peel biochar production offers an effective approach to waste management and promotes a low-carbon society.

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