AZOLLA AND DUCKWEED PYROLYSIS PROCESS TO BECOME ENVIRONMENTALLY FRIENDLY FUEL

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Abstrak

Pirolisis merupakan proses konversi termokimia yang dilakukan untuk mengubah biomassa secara efisien, seperti azolla dan duckweed dalam menghasilkan bahan bakar yang ramah lingkungan. Penelitian ini bertujuan untuk membandingkan hasil proses pirolisis limbah azolla dengan duckweed menjadi bahan bakar. Penelitian ini menggunakan reaktor pirolisis untuk menghasilkan produk bahan bakar yang produk utamanya seperti syngas, bio-oil, dan arang karbon yang ramah lingkungan. Dari penelitian ini, didapatkan bahwa azolla hanya menghasilkan minyak 0,6%. Hal ini 2,07% lebih rendah dari duckweed, sehingga duckweed merupakan bahan baku yang potensial untuk bio-oil. Disisi lain, azolla mampu menghasilkan bahan bakar syn-gas lebih banyak daripada duckweed dibuktikan dengan penyalaan azolla lebih lama daripada duckweed.

Kata kunci*: azolla, duckweed, minyak pirolisis, pirolisis*

Abstract

Pyrolysis is a thermochemical conversion process carried out to efficiently convert biomass, such as azolla and duckweed, to produce environmentally friendly fuels. This study aims to compare the results of the pyrolysis process of azolla waste with duckweed into fuel. This study uses a pyrolysis reactor to produce fuel products whose main products are syngas, bio-oil, and environmentally friendly carbon charcoal. From this study, it was found that azolla only produces 0.6% oil. This is 2.07% lower than duckweed, so duckweed is a potential raw material for bio-oil. On the other hand, azolla is able to produce more syn-gas fuel than duckweed, as evidenced by the longer ignition of azolla than duckweed.

Keywords*: azzola, biofuel, duckweed, pyrolysis*

INTRODUCTION

Global warming due to excessive use of fossil fuels, and decreasing fossil fuel reserves have sparked global interest in finding alternative, renewable, sustainable, cost-effective and environmentally friendly energy sources [1]. Biofuels are an excellent alternative to replace fossil fuels, because they can be produced in large quantities, the supply of renewable biomass is abundant, and they emit less greenhouse gas emissions.

Biomass is a renewable and sustainable energy source as an alternative for biofuel production. The pyrolysis process is a technology used to convert biomass into biofuel and produce solid, liquid, and gas products. The examples of potential biomass raw materials for biofuel production are azolla and duckweed.

Azolla and duckweed are chosen in this study because Azolla has a high growth rate and can capture heavy metal and organic pollutants, while duckweed has the ability to reproduce quickly with nutrients from waste water, adapt quickly and has low costs.

Azolla is a microalgae found in wetlands such as rice fields, rivers, lakes or ponds. Symbiotic cyanobacterium helps azolla grow by fixing nitrogen. This nitrogen provides the necessary nutrients for natural fertilizer for sustainable agriculture [2]. Azolla is suitable for capturing heavy metal and organic pollutants, as well as for bioremediation. Lipids, pH, ash, microalgae components, and carbohydrates (starch, cellulose, and cellulose) are the main constituents of Azolla even though it does not contain lignin [2].

The chemical composition of Azole makes it suitable for biofuel production. Some methods of biofuel production from hydrothermal liquefaction of azole include: transesterification, pyrolysis, torrefaction, and yeast isolation. Transesterification can be done to convert monoglycerides (MG), fatty acids (FA), diglycerides (DG), and triglycerides (TG) into fatty acid methyl esters (FAMEs) which are used as biodiesel materials. Duckweed (Lemna minor) is a small aquatic plant that grows freely floating on the surface of the water, and it is the smallest flowering plant (angiosperm) in the world. This plant is an attractive candidate for biofuel feedstock because it exhibits many desirable properties such as rapid reproduction, strong adaptability and low cost [3]. Under suitable growing conditions, duckweed mass can double in 24 hours, producing 20 tons of dry biomass per hectare per year [3]. During growth, duckweed can obtain nutrients from wastewater without requiring additional energy. Duckweed biomass can be converted into crude bio-oil through pyrolysis [4] and thermolysis [5]. Given the high water content of duckweed after harvesting, hydrothermal liquefaction (HTL) is the preferred approach used to convert wet aquatic biomass directly into bio-oil, avoiding the energy-intensive drying process. During the HTL process carried out at high temperatures (250-380 °C) and pressures (4.1-22.1 MPa), duckweed is converted into crude bio-oil with high energy density (>30 MJ/kg) [6].

Azolla and duckweed are weeds that are easily found in waters throughout Indonesia. The results of the study showed that azolla and duckweed can be processed through the pyrolysis process to produce bio-oil. Bio-oil produced from azolla and duckweed contains water and organic compounds, similar to the components of petroleum that are usually produced from the petroleum processing process. Research related to pyrolysis to produce energy has been widely conducted, such as research on the potential of the pyrolysis process in the waste processing sector [7, 8], modeling and optimization of pyrolysis reactors [9], production of liquid fuel and carbon charcoal from fish waste using the pyrolysis process [10], discussing the characteristics of pyrolysis production of fast-growing aquatic biomass - duckweed [11, 12], experiments on pyrolysis as a clean coal technology [13], and discussing the analytical characteristics of products obtained from slow pyrolysis of Calophyllum inophyllum [14]. Further research shows that the composition of compounds in biofuel produced from azole and duckweed, such as carboxylic acids, amides, and phenolic compounds, is different and higher in azole compared to duckweed [15].

This process is known to be environmentally friendly because it produces lower emissions compared to direct combustion of biomass materials. And the products produced from biomass pyrolysis can be used as an alternative to fossil fuels, thereby reducing dependence on non-renewable energy.

The concept of pyrolysis testing is to change biomass raw materials by heating the reactor with the help of heat from coal combustion in the furnace, to produce three types of products, namely: pyrolysis oil (biofuel), carbon charcoal, and synthesis gas (syn-gas).

Azolla and duckweed have high biomass content, including lignocellulose, protein, and other organic components[12]. This content makes both potential raw materials for pyrolysis, although the chemical composition of both can also affect the pyrolysis results.

The purpose of this study was to compare the results of pyrolysis of azolla vegetable waste with duckweed into environmentally friendly fuels whose main products are syngas, bio-oil, and carbon charcoal.

RESEARCH METHOD

This research was conducted in several stages, namely raw material preparation, fuel preparation, production of syngas, bio-oil and carbon charcoal from raw materials with pyrolysis, combustion test and retrieval of pyrolysis products. The equipment used is as described in Figure 1 below.

Description:

1. Combustion chamber,
2. Pyrolysis,
3. Cyclone separator combustion chamber,
4. Cyclone separator pyrolysis,
5. Blower,
6. Arduino Mega 2560 module with 0.5% error
7. Thermocouple combustion chamber 1, with an accuracy of -270 °C to 1260 °C and an error of ± 0.75% or equivalent to ± 2.2 °C,
8. Thermocouple combustion chamber 2,
9. Thermocouple pyrolysis 1,
10. Thermocouple pyrolysis 2.

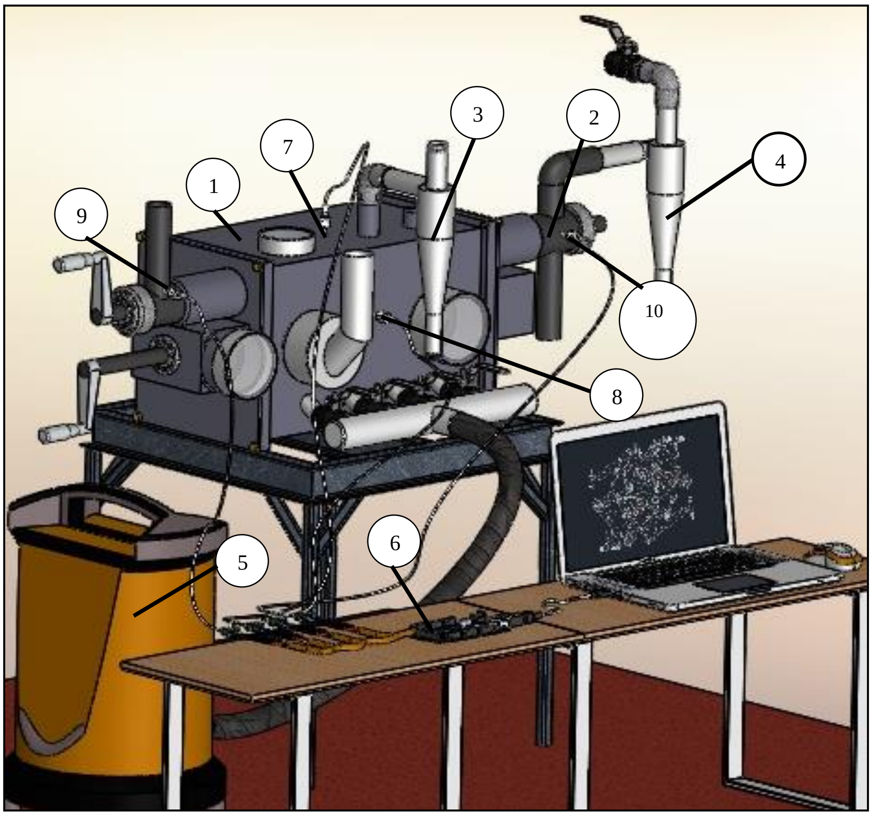

Figure 1. Pyrolysis System Test Scheme

a. Azolla b. Duckweed

Figure 2. Biomass raw materials

The stages of the testing process carried out are:

1. Preparation of raw materials

   The raw materials in this pyrolysis system are azolla and duckweed.

2. Preparation of Measuring Instruments

   The measuring instruments and auxiliary measuring components used in the pyrolysis process are Type K Thermocouple, Arduino Mega 2560

Module, MAX6675, Yisun Digital Scales. All measuring instruments and auxiliary components have known accuracy and error specifications, and are calibrated before use.

3. Testing Process
   a) Raw materials of azolla and duckweed waste weighing 150 grams each are inserted into a pyrolysis reactor tube equipped with two type K thermocouples at both ends of the pyrolysis tube.
   b) Coal briquettes are inserted into the combustion chamber equipped with two type K thermocouples on the middle side of the combustion chamber until half of the combustion chamber is filled.
   c) Combustion begins by burning coal briquettes using a torch until the coal briquettes ignite, then the air supply from the blower is installed by opening the valve to the fully open position.
   d) After the fire has grown and spread, all valves are opened halfway. The temperature in the combustion chamber that was monitored had reached 300 °C, the temperature was maintained for 30 minutes with a temperature range of 400 °C - 600 °C by adjusting the coal briquettes and the air source entering the combustion chamber.
   e) After going through a holding time (holding time/length of heating at high temperatures) for 30 minutes, open the syn-gas valve then perform a syn-gas flame test. Record the time from the appearance of the flame to the extinguishing. Weigh and record the bio-fuel and char (carbon/ charcoal) produced.

RESULTS AND DISCUSSION

The results of the pyrolysis process of azole and duckweed into environmentally friendly fuels are seen from several aspects, namely bio-fuel, charcoal (char), and syn-gas, and there are also unprocessed materials. Table 1 below shows a comparison of the pyrolysis results between azole and duckweed.

Table 1. Result - Pyrolysis of Azole and Duckweed

No.	**Raw Material**	**Mass (g)**	**Temp (ºC)**	**Results of The Pyrolysis**			
				Biofuel (g)	Char (g)	Unprocessed Material (g)	Ignition Syn-gas (second)
1	Azolla	150	480	0,9	52,6	65,1	739
2	Duckweed	150	400	4	38,4	59,3	126

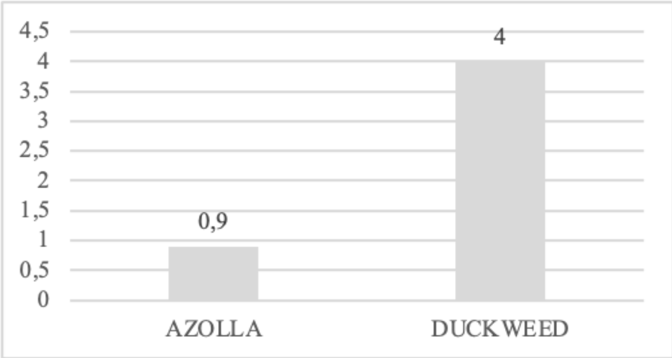

Figure 3. Comparison of the mass of biofuel products from pyrolysis

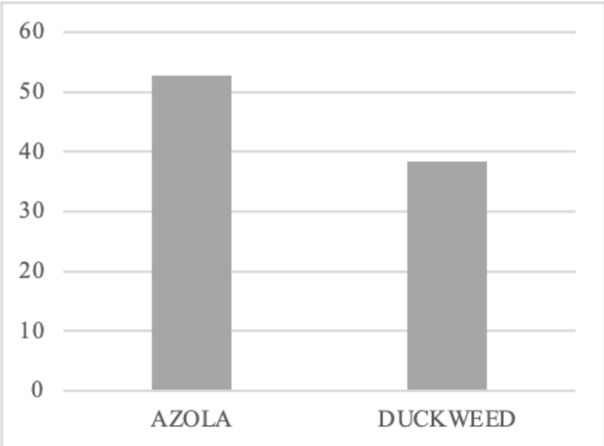

Figure 4. Comparison of char from pyrolysis results

The comparison of the mass of biofuel from azole and duckweed pyrolysis is shown in Figure 3. The biofuel produced from azole pyrolysis looks less than duckweed, but all the biofuel produced has the potential to be further processed into liquid fuel that can be used in diesel engines. This biofuel needs to be purified to remove acidic compounds, water, and tar.

Figure 4 shows the char produced from azole and duckweed pyrolysis. The char product of azole pyrolysis is 52.6 grams, which is 14.2 grams higher than duckweed which is only 38.4 grams. Char can be used as solid fuel, as a base material for activated carbon, or as biochar to improve the quality of agricultural soil.

The product results from the testing process have proven that syn-gas can be a gas fuel with an ignition time of more than 12.3 minutes using azole raw materials as the feed material, although in the ignition process the fire still looks very small. This is due to several factors, namely:

1. Raw material density factor (size)
2. Temperature factor in the heat source furnace, and pyrolysis reactor
3. The time factor to get a temperature of 300 °C in the furnace/combustion chamber is very long, so the total heating time in the azole test is longer than the duckweed test.

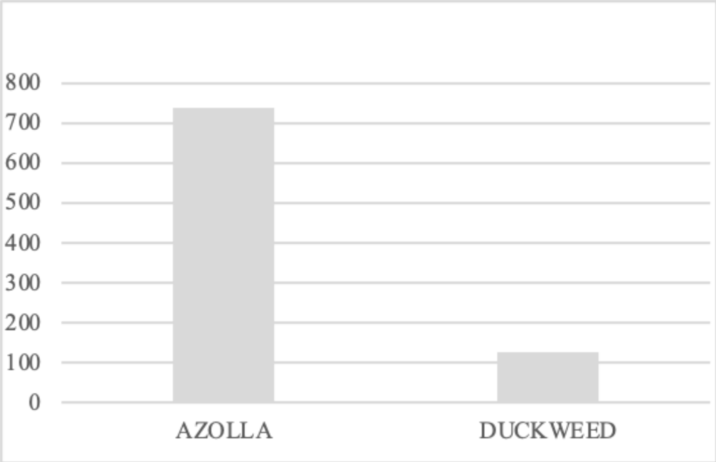

Figure 5. Comparison of Syn-Gas Product Ignition Times

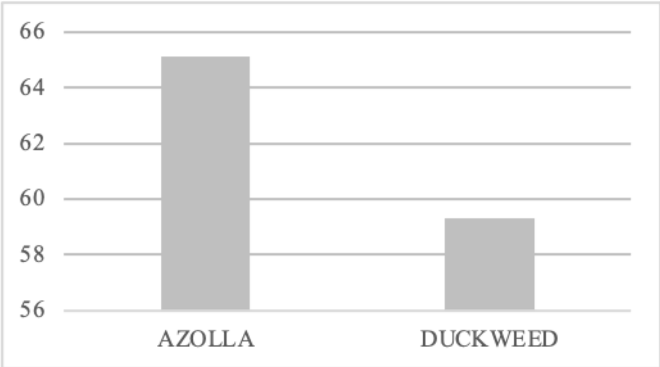

Figure 6. Comparison of Unprocessed Materials

Based on the pyrolysis results, it can be concluded that azole and duckweed pyrolysis have their respective advantages. The mass of biofuel produced from azole is lower than duckweed, this shows that duckweed is superior in producing biofuel than azole. Azolla has a very high protein content (around 20-30% of dry weight), so azole tends to be superior in producing syn-gas, with better quality due to its high protein content, while duckweed is more efficient in producing biofuel due to its higher lignin and cellulose content.

Pyrolysis of biomass such as azole and duckweed is an efficient process in converting raw materials into usable energy. However, this efficiency is highly dependent on process parameters such as temperature, pyrolysis time, and heating rate. The choice between the two for pyrolysis will depend on the final purpose of using the resulting product as well as the availability and sustainability of the biomass resources.

The efficiency of biomass pyrolysis in converting raw materials into usable energy depends on the yield of desired products—biochar, bio-oil, or syngas—based on operating conditions. Azolla and duckweed are aquatic plants with high growth rates and biomass productivity, making them promising feedstocks. Their composition (high volatile content, low lignin) supports efficient thermal decomposition, leading to good energy conversion[16, 17].

1. *Temperature:* Determines product distribution. Lower temperatures (300–500°C) favor biochar, while higher temperatures (500–700°C) increase bio-oil and gas yield.
2. *Pyrolysis Time:* Affects decomposition extent. Short residence times enhance bio-oil production, whereas longer times increase gas yields.
3. *Heating Rate:* Fast pyrolysis (high heating rate) maximizes bio-oil, while slow pyrolysis (low heating rate) produces more biochar.

If the goal is bio-oil production, duckweed (higher carbohydrate content) may be more suitable. If biochar for soil amendment is needed, Azolla (higher nitrogen content) could be preferable[18]. Duckweed grows rapidly in wastewater, aiding bioremediation. Azolla is nitrogen-fixing and supports soil fertility, enhancing its sustainability.

CONCLUSION

A comprehensive comparison between the pyrolysis results of azole and duckweed raw materials has been carried out. Azolla produces an oil yield of 0.6% which is 2.07% lower than duckweed, so duckweed is a potential raw material for bio-oil. Meanwhile, azole produces more syn-gas fuel than duckweed as shown by the ignition of azole 10 minutes longer than duckweed.

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