Elemental compositions analysis of *Arthrospira platensis*-activated carbon blend using energy-dispersive X-Ray spectroscopy

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Abstract. The biomass combustion in the boiler furnace faces a common problem related to slagging and fouling. The slag deposits and fouling of boiler components have been significantly influenced by inorganic matter in biomass origin. Therefore, chemical composition greatly determines the potential of biomass as a fuel. This study was conducted to determine the chemical content of *Arthrospira platensis* (AP) microalgae, activated carbon (AC), and a mixture of AP and AC with a mass ratio of 10:1 (AP/AC:10/1) by using an Energy Dispersive X-Ray (EDX) spectroscopy. The results showed that the chemical content of AP microalgae was dominated by C and O elements by 63.25 and 27.99 (wt.%), respectively. It was also shown that activated carbon was dominated by C and O elements at 89.91 and 10.08 (wt.%), respectively. Moreover, the addition of AC to the AP led to a decrease in the percentage of O content and increased the percentage of C from 63.25 to 91.20 (wt.%). It is expected that adding AC can improve the performance of AP biomass during the thermal conversion process.

1. Introduction

Energy demand will be linear to an increase in population and industrial activity. Energy sources in Indonesia are dominated by coal for electricity supply and petroleum for transportation [1]. Fossil fuels are non-renewable energy sources, so they will run out due to intense use, concurrently with the pollution problem emitted by burning fossil fuels increasing SOx, CO, CO₂, and NOx compounds in the earth's atmosphere [2]. Thus, natural phenomena such as climate change and global warming are increasing. When no restrictions are made, they can cause the extinction of many species and complicate human life [3]. Renewable energy is predicted to be able to answer all problems of energy accessibility. It can be obtained from several sources, including biomass. Based on the Ministry of Energy and Mineral Resources data in 2019, biomass contributed 20% of the new and renewable energy sources for electricity generation. Its sources come from the organism and micro-organisms. Microalgae is a biomass source that is mass-produced potentially and classified as a third-generation biofuel with a much higher energy density than the previous generation of fuel [4] and relatively large bio-oil content [5].
One of the microalgae species is *Arthrospira platensis* (AP) from the phylum cyanobacteria. AP microalgae are widely cultivated since they have high nutritional value, rich in chemical content, and can be processed into biomass for various purposes [5].

The physicochemical properties are the primary references for proper furnace design to achieve efficient thermal conversion processes [6]. However, the chemical content of biomass is also an important parameter since it determines the amount of contained energy in the fuel. In addition, inorganic elements in the fuel affect the formation of slag deposits, ash, aerosols, and corrosion on boiler components during the thermal conversion process [7]. Therefore, researching the chemical constituents of microalgae is essential to know its potential as a fuel and as a basis for designing suitable reactors and proper handling of byproducts.

This work has analyzed the chemical elements of the AP, AC, and mixtures of AP/AC:10/1 (wt.%). All analyzes were performed using Energy Dispersive X-Ray (EDX) spectroscopy. These research results being fundamental data to serve a further consideration in the AP utilization as fuel feedstock and its conversion.

### 2. Materials and methods

#### 2.1. Materials preparation

The study was initiated by preparing samples of AP microalgae from the Center of Brackish Water Aquaculture (BPBAP) Situbondo Regency and of activated carbon from Sigma-Aldrich (CAS Number 7440-44-0). First, a 60 mesh size sieve filtered AP microalgae powder to have a uniform size. Then, mixing AP and AC microalgae powder with a mass ratio of 10:1 (AP/AC:10/1) was carried out with a magnetic stirrer for 30 minutes at 1200 rpm to obtain a homogeneous mixture.

#### 2.2. Methods

The test was carried out with a scanning electron microscope (SEM) instrument, FEI Inspect S50 equipment fitted out with the capability of X-ray microanalysis (AMETEK EDAX TSL). The sample was gold-coated to decrease the influence of surface-electron-charging, which might distort the image. EDX testing was performed three times for each sample in order to obtain valid results. The data from the three tests were processed so that the average value and standard error were known.

### 3. Results and discussion

The results of the EDX test for samples of AP, AC, and a mixture of AP/AC:10/1 were shown in Table 1, Table 2, and Table 3. The analyzed chemical elements were carbon (C), oxygen (O), sodium (Na), magnesium (Mg), phosphorus (P), sulfur (S), chlorine (Cl), and potassium (K). Table 1 showed the EDX test results on AP samples that are dominated by C and O. There were inorganic elements needed for microalgae growth. Besides, the presence of elements other than carbon and oxygen were assumed to originate from the AP microalgae habitat.

The results of the EDX test on AC shown in Table 2 indicated that there were only two elements, namely C and O. These results indicated that the activated carbon material had a high level of purity. Table 3 showed the results of the EDX test on the mixed sample AP/AC:10/1, showing that there were only two elements, namely C and O. The inorganic element content in the mixture was not detected, possibly because the very small amount was.

| Replications | Elemental compositions (wt.% | C    | O    | Na   | Mg   | P    | S    | Cl   | K    |
|--------------|------------------------------|------|------|------|------|------|------|------|------|
| Test 1       |                              | 64.20| 26.29| 1.83 | 0.53 | 1.09 | 1.15 | 3.54 | 1.38 |
| Test 2       |                              | 62.20| 30.02| 2.25 | 0.33 | 0.55 | 0.71 | 3.11 | 0.82 |
| Test 3       |                              | 63.35| 27.67| 1.84 | 0.88 | 0.00 | 1.04 | 3.61 | 1.61 |
| Mean         |                              | 63.25| 27.99| 1.97 | 0.58 | 0.54 | 0.96 | 3.42 | 1.27 |
| Standard error |                             | 0.57 | 1.08 | 0.13 | 0.16 | 0.31 | 0.13 | 0.15 | 0.23 |

Table 1. EDX test results of *Arthrospira platensis*
### Table 2. EDX test results of activated carbon

| Replications | Elemental compositions (wt.%): C, O, Na, Mg, P, S, Cl, K |
|--------------|--------------------------------------------------------|
| Test 1       | 87.66, 12.34, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Test 2       | 90.65, 9.35, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Test 3       | 91.44, 8.56, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Mean         | 89.91, 10.08, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00   |
| Standard error | 1.51, 1.15, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00 |

### Table 3. EDX test results for mixture of *Arthospira platensis* and activated carbon

| Replications | Elemental compositions (wt.%): C, O, Na, Mg, P, S, Cl, K |
|--------------|--------------------------------------------------------|
| Test 1       | 90.96, 9.04, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Test 2       | 91.33, 8.67, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Test 3       | 91.33, 8.67, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00     |
| Mean         | 91.20, 8.79, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00   |
| Standard error | 0.12, 0.12, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00 |

**Figure 1.** EDX spectrogram of AP sample

**Figure 2.** EDX spectrogram of AC sample
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Figure 3. EDX spectrogram of mixture of AP/AC:10/1

Figure 4. Elemental compositions comparison of AP, AC, and mixture of AP/AC:10/1

The carbon element (C) contributes to the production of calorific value, while for oxygen (O), especially in biomass, it functions as one of the supplies for the combustion reaction even though the oxygen content can reduce the higher heating value (HHV) [8–10]. The elements of chlorine (Cl) and sulfur (S) contained in AP can evaporate in the combustion process, which will bind to hydrogen (H) and form exhaust gases [11]. The content of elements other than C, O, and Cl in the sample contributed to the final product formation in combustion, namely ash.

Residues can be categorized based on their percentage, namely major ash-forming elements (>1%) and minor ones (1-0.1 %). If the combustion process is carried out in pure AP, the elements sodium (Na) and potassium (K) are classified as major ash-forming elements, while for minor elements, there are magnesium (Mg) and phosphorus (P). Chlorine content can lower the melting point of ash and cause corrosion. Potassium can cause corrosion, lower the melting temperature of ash, and can be used as fertilizer. Sodium causes corrosion and lowers the melting temperature of ash. Calcium causes an increase in the melting temperature of ash and can be used as fertilizer. Phosphorus produces ash which can be used as fertilizer [7,12,13].
The decrease in the percentage of O in the sample mixture AP/AC:10/1 was due to the nature of AC which was able to absorb elemental oxygen [14]. Likewise, AC can absorb elemental sulfur [15]. Thus, it was estimated that adding AC to AP could improve the performance of AP microalgae during the thermal conversion process.

4. Conclusion
The elemental composition in AP, AC, and AP/AC:10/1 mixture samples has been analyzed by EDX. The results showed that the AC could reduce the percentage of O in AP powder and increase the percentage of carbon elements by 91.2%, with a difference of 27.95%. Thus, based on the research results, it can be seen that activated carbon (AC) is possible to increase the performance of *Arthospira platensis* (AP) microalgae during thermal conversion.

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References
[1] Sugiyono A 2018 Outlook Energi Indonesia 2015-2035 : Prospek Energi Baru Terbarukan OUTLOOK ENERGI INDONESIA 2015-2035 : PROSPEK
[2] Phillips M C K, Cinderich A B, Burrell J L and Will R G 2015 The Effect of Climate Change on Natural Disasters : A College Student Perspective The Effect of Climate Change on Natural Disasters : A College Student Perspective
[3] Kweku D W, Bismark O and Maxwell A 2018 Greenhouse Effect : Greenhouse Gases and Their Impact on Global Warming Greenhouse Effect : Greenhouse Gases and Their Impact on Global Warming
[4] Dahiya A 2015 Bioenergy: biomass to biofuels
[5] Kim S 2015 Bioremediation of Heavy Metals by Microalgae [IN:] Handbook of marine microalgae biotechnology advances. Kim S-K. [ed.]
[6] Sukarni S 2018 Physical and Chemical Properties of Water Hyacinth ( Eichhornia crassipes ) as a Sustainable Physical and Chemical Properties of Water Hyacinth ( Eichhornia crassipes ) as a Sustainable Biofuel Feedstock
[7] van Loo S and Koppejan J 2008 The Handbook of Biomass Combustion and Co-firing (London: Earthscan)
[8] Obernberger I, Brunner T and Ba G 2006 Chemical properties of solid biofuels — significance and impact Biomass and Bioenergy 30 973–82
[9] Sukarni, Sudjito, Hamidi N, Yanuhar U and Wardana I N G 2015 Thermogravimetric kinetic analysis of Nannochloropsis oculata combustion in air atmosphere Front. Energy 9 125–33
[10] McKendry P 2002 Energy production from biomass (part 1): overview of biomass Bioresour. Technol. 83 37–46
[11] Sukarni, Sudjito, Hamidi N, Yanuhar U and Wardana I N G 2014 Potential and properties of marine microalgae Nannochloropsis oculata as biomass fuel feedstock Int. J. Energy Environ. Eng. 5 279–90
[12] Sumarli S, Upendra C, Bandhana S and Himawan K 2019 Physicochemical Characteristics of Corn Silk as Biomass Fuel Feedstock 515 1–5
[13] McKendry P 2002 Energy production from biomass (part 2): Conversion technologies Bioresour. Technol. 83 47–54
[14] Zhou Y, Wei L, Yang J, Sun Y and Zhou L 2005 Adsorption of Oxygen on Superactivated Carbon 1068–72
[15] Liu J, Gao S, Jiang X, Shen J and Zhang H 2014 NO emission characteristics of superfine pulverized coal combustion in the O2/CO2 atmosphere Energy Convers. Manag. 77 349–55