Potential of natural sunlight for microalgal cultivation in Yogyakarta

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Abstract. The study of microalgae is widely developed on a laboratory scale. The large-scale applications of microalgae such as large photo-bioreactors or commercial ponds are not well established due to some obstacles. The high cost of artificial lighting in microalgae cultivation is one of the obstacles. Markedly, the natural sunlight intensity is high every month for a whole year in Indonesia. This natural sunlight may serve as a low-cost lighting source for microalgae cultivation in a tropical country such as Indonesia. However, the basic knowledge of whether the natural sunlight in Indonesia is sufficient or not for microalgae cultivation is poorly understood. This study was performed to investigate whether sunlight in Indonesia, particularly in Yogyakarta, is sufficient or not for microalgae cultivation in the absence of artificial lighting. The sun lighting period data from January 2019 to June 2020 were collected from BMKG (Badan Meteorologi Klimatologi dan Geofisika) website. The sun lighting period data were converted into solar radiation data. The Liliefors test was performed to evaluate the distribution of the solar radiation data. To confirm whether the sun lighting in Yogyakarta is sufficient for microalgae cultivation or not, the parametric statistical test namely single sample T-test was used in this study. The Liliefors test showed that solar radiation in Yogyakarta (January 2019 to June 2020) was normally distributed. The calculated Liliefors value (0.14) was less than Liliefors table value (2.00). The T-test results revealed that the solar radiation in Yogyakarta is equal to or higher than the sufficient solar radiation (reference) for microalgae cultivation (795 kWh/m²). The calculated t value (0.65) was higher than the t table value (-1.74). When taken together, our findings suggest that natural sunlight in Yogyakarta is sufficient as a lighting source for microalgae cultivation.

1. Introduction

Microalgae potentially serve as a sustainable renewable energy source to supply the global energy demand [1]. In Indonesia, microalgae cultivation is poorly developed due to high-cost cultivation with low harvested biomass. Irradiation is one of the important factors that affect the microalgae production
cost [2]. Irradiation is defined as the lighting used by microalgae to perform photosynthesis. This process defines the cell proliferation as well as the biomass growth of microalgae.

A previous study reveals that the light and dark cycle of the lighting period affects microalgae proliferation. Utami et al. [3] use 4 treatments and 4 replications to get periods that are effective for microalgae production. The treatments are: A (24 hours in light and 0 hours in the dark), B (20 hours in light and 4 hours in the dark), C (18 hours in light and 6 hours in the dark), and D (12 hours in light and 12 hours in the dark) by using TL Lamp. The result is the high population of *Chlorella sp.* that was produced via treatment C with a density of 11,970,000 cells/mL. This finding suggests that artificial lighting needs specific control for light and dark cycles to get the optimum lighting for microalgae cultivation. Furthermore, artificial lighting also requires a high cost for infrastructure and electricity on the large scale of microalgae cultivation. Due to complexity and high cost, artificial lighting is likely ineffective to be applied on a large scale of microalgae cultivation. Finding a low-cost lighting source is important to reduce the microalgae cultivation cost. One study was performed using natural sun lighting for microalgae cultivation. The bioenergy façades can be perfectly integrated into cities by producing heat and biomass concomitantly that uses lighting of solar radiation (795 kWh/m²) in Hamburg, Germany [4]. This suggests the possibility of sun lighting as a low-cost lighting source for microalgae. Interestingly, Indonesia is a tropical country that has sunlight each month for a whole year. However, the concept and application of using sunlight for microalgae cultivation in Indonesia are poorly understood. In this study, we investigate the possibility that sunlight, particularly in Yogyakarta, is sufficient for microalgae cultivation.

2. Materials and method

2.1. Sunlight data

Sunlight period data were collected from BMKG (Badan Meteorologi Klimatologi dan Geofisika) website [5]. The data consist of the period of sunlight (how long the sunlight happens in a month). The solar radiation data were required for further analysis. By multiplying with 4.5 kWh/m², the sun lighting data were converted into solar radiation data [6]. The solar radiation data are also shown in figure 1, while the monthly sun lighting and solar radiation data are provided in table 1. It shows that every month has a high radiation.

![Solar Radiation Intensity (Yogyakarta)](image)

**Figure 1.** Monthly solar radiation intensity in Yogyakarta from January 2019 until June 2020.
Table 1. Sun lighting and solar radiation data.

| Month (2019-2020) | Sun Lighting (hour) | Solar Radiation (kWh/m²) |
|-------------------|---------------------|-------------------------|
| Jan               | 144.00              | 648.00                  |
| Feb               | 169.40              | 762.30                  |
| Mar               | 132.30              | 595.35                  |
| Apr               | 184.60              | 830.70                  |
| May               | 231.70              | 1042.65                 |
| June              | 178.70              | 804.15                  |
| July              | 213.60              | 961.20                  |
| Aug               | 237.80              | 1070.10                 |
| Sep               | 227.20              | 1022.40                 |
| Oct               | 253.30              | 1139.85                 |
| Nov               | 204.80              | 921.60                  |
| Dec               | 154.90              | 697.05                  |
| Jan               | 151.00              | 679.50                  |
| Feb               | 128.50              | 578.25                  |
| Mar               | 139.40              | 627.30                  |
| Apr               | 181.50              | 816.75                  |
| May               | 172.50              | 776.25                  |
| June              | 179.70              | 808.65                  |

2.2. Liliefors test
Statistical methods are based on various underlying assumptions. A common assumption is that a random variable is normally distributed. When this assumption is violated, interpretation and inference may not be reliable or valid. T-test compares group means and assumes that variables follow the normal probability distribution. One of the ways to test normality is Liliefors test [7].

Liliefors test could be done by several steps as follow [8]:
1. Deciding means ($\bar{x}$) and standard deviation (S)
2. Converting all of the data to Z value by Z estimation using equation 1:
   \[ Z = \frac{x-\bar{x}}{S} \]  
3. Calculating Z value to F(Zi) by Z distribution table.
4. Deciding Z value proportion to S(Zi) by looking up Z value position with the sum of data quantities.
5. Calculating $|F(Zi) - S(Zi)|$. Then, $L_{calculated}$ is the maximum value of it.
6. $L_{table}$ is a critical value from Liliefors table with a degree of freedom ($\alpha = 0.05$) and the sum of data ($n=18$).
7. Concluding by comparing $L_{calculated}$ and $L_{table}$ with criteria that $H_0$ will be accepted if $L_{calculated} < L_{table}$ (which means that the data have normality). $H_0$ will be refused if $L_{calculated} > L_{table}$ (which means that the data doesn’t have normality).

2.3. One sample-left tail T-test
William Seely Gosset, the first founder of the T-test, developed the T-test in 1915 [7]. This test has several functions:
1. As a tool to analyze one or two populations.
2. To compare two means to decide how significant the difference between them; one-sample t-test in particular is meant to compare the mean of the data with the mean from reference.
Grouping of t-test method was classified in figure 2.

![Diagram of T-test grouping]

**Figure 2.** Grouping of T-test.

This research used a one-sample t-test, with the equation (2) [9]:

$$ t = \frac{\bar{x} - \mu_0}{\delta/\sqrt{n}} $$

(2)

### 3. Result and discussion

#### 3.1. Liliefors test

All Liliefors test results of this study are provided in table 2.

| No | X      | Z      | F(Zi)  | S(Zi)  | |F(Zi)|-S(Zi)| |
|----|--------|--------|--------|--------|------|--------------------|
| 1  | 648.00 | -1.008 | 0.156  | 0.222  | 0.066 |
| 2  | 762.30 | -0.343 | 0.367  | 0.389  | 0.022 |
| 3  | 595.35 | -1.315 | 0.095  | 0.111  | 0.016 |
| 4  | 830.70 | 0.055  | 0.524  | 0.667  | 0.143 |
| 5  | 1042.65| 1.289  | 0.902  | 0.889  | 0.013 |
| 6  | 804.15 | -0.099 | 0.460  | 0.500  | 0.040 |
| 7  | 961.20 | 0.815  | 0.791  | 0.778  | 0.013 |
| 8  | 1070.10| 1.448  | 0.927  | 0.944  | 0.018 |
| 9  | 1022.40| 1.171  | 0.879  | 0.833  | 0.046 |
| 10 | 1139.85| 1.854  | 0.968  | 1.000  | 0.032 |
| 11 | 921.60 | 0.584  | 0.719  | 0.722  | 0.003 |
| 12 | 697.05 | -0.723 | 0.236  | 0.333  | 0.098 |
| 13 | 679.50 | -0.825 | 0.206  | 0.278  | 0.072 |
| 14 | 578.25 | -1.414 | 0.079  | 0.056  | 0.024 |
| 15 | 627.30 | -1.129 | 0.122  | 0.167  | 0.045 |
| 16 | 816.75 | -0.026 | 0.488  | 0.611  | 0.123 |
| 17 | 776.25 | -0.262 | 0.397  | 0.444  | 0.047 |
| 18 | 808.65 | -0.073 | 0.472  | 0.556  | 0.083 |

Mean ($\bar{X}$): 821.23  \(L_{\text{calculated}}\): 0.143

Standard Deviation (S): 171.817 \(L_{\text{table}}\): 0.200
The first hypothesis (H₀) is that the data have a normal distribution. Based on table 2, the L_calculated (0.143) is less than L_table (0.2). Therefore, H₀ is accepted. The data in this study have a normal distribution and represent the population.

3.2. One sample-left tail T-test
Normal distribution data has been proven by Liliefors test. Later, the T-test was applied to the solar radiation data. This research used one sample-left tail T-test and solar radiation of 795 kWh/m² as a mean reference. All of T-test results are provided in average: 821.23; standard deviation : 171.82; T_calculated : 0.65 and T_table : -1.74. T_table was taken from the T table with a degree of freedom (df)=17 (n-1) and degree of conviction (α)=0.05. The conclusion was made based on the graphic of the left tail T-test in figure 3. The red area is the rejected H₀ area. H₀ stated that “solar radiation value in Yogyakarta is the same or higher than the solar radiation reference.”. Based on figure 3, μ₀ is solar radiation reference and T_calculated is within the accepted H₀ area.

The accepted H₀ means that the solar radiation value in Yogyakarta is equal to or higher than the solar radiation reference. In detail, the mean value of solar radiation in Yogyakarta (821.23 kWh/m²) is equal to or higher than the solar radiation that is sufficient for microalgae cultivation in Hamburg (795 kWh/m²). Developing microalgae with natural sunlight is statistically possible to be performed in Yogyakarta. This condition could be met with the tropical climate in Indonesia, where the sun lighting will happen all year, though it decreases during rainy season.

![Figure 3](attachment:image)

**Figure 3.** One sample T test-left tail area has α 0.05 and degree of freedom 17.

4. Conclusion
Our findings suggest the possibility of microalgae cultivation using natural sunlight as a lighting source in Yogyakarta. The statistical analysis has shown that the data of solar radiation (natural sunlight) has normal distribution by Liliefors test. The result of one sample-left tail T-test showed that natural sunlight is sufficient for microalgae cultivation in Yogyakarta.
5. Reference

[1] Medipally S R, Yusoff F M D, Banerjee and Shariff M S 2014 Hindawi Publish. Corp. BioMed Res. Inter. 2015 13

[2] Norsker N H, Barbosa M J, Vermue M H and Wijffels R H 2011 Biotechnol. Adv. 29 24–27

[3] Utami N P, Yuniarti M S and Haetami K 2012 Jurnal Perikanan dan Kelautan 3 237-244

[4] Kerner M, Gebken T, Sundararao I, Hindersim S and Sauss D 2019 Energy & Buildings 184 65–71

[5] BMKG 2020 Data Online Pusat Database-BMKG accessed from https://dataonline.bmkg.go.id.

[6] Suyanto H 2016 Jurnal Ilmiah Energi dan Kelistrikan 8 114-118

[7] Park H M 2006 Univariate Analysis and Normality Test Using SAS, STATA and SPSS (The Trustees of Indiana University)

[8] Kismiantini 2011 Handout Rancangan Percobaan (Yogyakarta: Faculty of Mathematics and Science, State University of Yogyakarta)

[9] Field A 2009 Discovering Statistics Using SPSS Third Edition (London: SAGE Publication)

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