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Analysis of water and sediment quality in Pacific whiteleg shrimp (*Litopenaeus vannamei*) culture on different sediment redox potential values

Analisis kualitas air dan sedimen pada budidaya udang vaname (*Litopenaeus vannamei*) dengan redok potensial sedimen yang berbeda

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ABSTRACT

Water quality, soil, health, and growth observations are important for the pacific white leg shrimp culture. The correlation among these parameters is necessary for further determination and analysis. This study aimed to investigate the correlation among the various parameters of water quality, soil quality, technical coefficient of shrimp culture, and shrimp health parameters in shrimp culture activities with different sediment redox potential values. This study was conducted with different sediment redox potential values, namely 69.33 ± 14.5 mV, 151.00 ± 8.89 mV, and 210.00 ± 17.32 mV with four replications. The 25 shrimps with an average weight of 1.37 ± 0.04 g and a stocking density of 144 shrimp/m2 were used in the study for 30 days. During the study, the parameters included water quality, health, and growth parameters. The water quality parameters did not show significant differences among treatments, except pH and dissolved oxygen values. At a low redox potential, the pH value tended to be higher, while the dissolved oxygen value was higher, following the higher redox potential value. The water quality parameters were correlated to the conductivity and TDS levels based on the principal component analysis (PCA) and clusters analysis. Meanwhile, the soil quality parameters were correlated to the total P, total Fe, total Mn, and total S contents. The shrimp growth and health parameters did not meet the requirements for PCA analysis.

ABSTRAK

Pengamatan parameter kualitas air, tanah, kesehatan dan pertumbuhan merupakan hal yang penting untuk dilakukan dalam budidaya udang vaname. Keterkaitan antar parameter tersebut perlu untuk diketahui dan dianalisis lebih lanjut. Penelitian ini bertujuan untuk melihat keterkaitan antara berbagai parameter kualitas air, kualitas tanah, koefisien teknis budidaya dan parameter kesehatan udang dalam kegiatan budidaya udang dengan nilai sedimen redok potensial yang berbeda. Penelitian ini dilakukan dengan perbedaan nilai sedimen redok potensial yaitu 69,33 ± 14,5 mV, 151,00 ± 8,89 mV, dan 210,00 ± 17,32 mV dengan empat ulangan. Udang sebanyak 25 ekor dengan bobot rata rata 1,37 ± 0,04 g dan padat tebar 144 ekor/m2 digunakan dalam penelitian selama 30 hari. Selama penelitian parameter yang diamati meliputi parameter kualitas air, kesehatan dan pertumbuhan. Parameter kualitas air tidak menunjukkan perbedaaan nyata antar perlakuan kecuali nilai pH dan oksigen terlarut. Pada nilai redok potensial yang rendah nilai pH air cenderung lebih tinggi sedangkan pada nilai redok potensial yang lebih tinggi nilai oksigen terlarut lebih tinggi. Parameter kualtias air yang menunjukkan keterkaitan berdasarkan analisis komponen utama (PCA) dan klaster adalah konduktivitas dan TDS sedangkan parameter kualitas tanah yang saling berkaitan adalah total P, total Fe, total Mn dan total S. Adapun parameter pertumbuhan dan kesehatan udang tidak memenuhi syarat untuk diuji lanjut dengan PCA.

Kata kunci: kualitas air, PCA, redok potensial, sedimen, udang putih.

INTRODUCTION

Monitoring is important as a successful key in shrimp culture activities (Xiao *et al*., 2017; Mohanty *et al*., 2018; Zainuddin *et al*., 2019; Rozario & Devarajan, 2021). Monitoring contains shrimp growth, shrimp health, water quality (Encinas *et al*., 2017; Zainuddin *et al*., 2019), and pond sediments based on the redox potential, total P, total S, total Mn, and other mineral contents (Wiyoto *et al*., 2016; Widigdo *et al*., 2018). In addition to water quality parameters, the sediment conditions are important parameters to observe (Hidayati *et al*., 2021; Saraswathy *et al*., 2019; Zeng *et al*., 2021), as shrimps are benthic organisms (Zhang *et al.*, 2019) that are abundant on the pond base. Monitoring can be performed daily or periodically at a certain time following the shrimp culture condition (Ariadi *et al*., 2019; Silva *et al*., 2021). The water quality parameter monitoring is performed daily, such as dissolved oxygen (Mohanty *et al*., 2018; Ariadi *et al*., 2019; Rozario & Devarajan, 2021), pH (Ariadi *et al*., 2019; Zainuddin *et al*., 2019), temperature (Mohanty *et al*., 2018) (Zainuddin *et al*., 2019), and salinity (Mohanty *et al*., 2018; Ariadi *et al*., 2019); while parameters that can be measured weekly contain total ammonia-nitrogen (TAN) (Ariadi *et al*., 2019), nitrite (Ariadi *et al*., 2019; Silva et al., 2021), and parameters observed among 7-10 days contain shrimp growth and health conditions (Tong *et al*., 2020).

The monitoring results from various parameters are used to determine the technical actions performed in the field (Hukom *et al*., 2020). For example, the dissolved oxygen monitoring is used as a basic for determining the addition of paddle wheel aerators in the pond, besides the shrimp biomass level in the pond. The paddle wheel aerators requirement for culture activities in the pond is about 28.1-50 hp/ha or 234-476 kg shrimp/hp (Boyd & McNevin, 2021). Moreover, dissolved oxygen affects the FCR value and shrimp health condition (Xiao *et al*., 2017). Also, the pH value monitoring is used as a basic for determining the total lime addition in the pond (Akazawa & Eguchi, 2017). The observation data can be analyzed for anticipatory actions on the alterations that may occur in the pond, either water quality or shrimp health that can affect the shrimp growth.

Various observation parameters in shrimp culture are all correlated each other. Based on this condition, correlation among the observed parameters are necessary to evaluate for further parameter analysis. Various parameter analyses can be performed using the multivariate analysis, such as principal component analysis (PCA) and cluster analysis (Juárez-Rosales *et al*., 2020; Silva *et al*., 2021). These analyses can simplify the available data by minimizing the information loss and presenting the correlated important data (Wiyoto & Effendi, 2018; Silva *et al*., 2021). Furthermore, these analyses are utilized to determine the correlation among numbers of parameters without losing all required information. Therefore, this study aimed to investigate the correlation among water quality, soil quality, technical coefficient, and shrimp health parameters in the shrimp culture activities on different sediment redox potential values.

MATERIALS AND METHODS

Animal samples

The certified specific-pathogen free Pacific whiteleg shrimp *L. vannamei* post-larvae (PL-10) were obtained from the shrimp hatchery in Anyer, Banten, Indonesia and reared for a month to reach 1.37 ± 0.04 g size. The shrimp samples used in this study had complete organs, bright color, and were unmolted.

Container preparations and experimental design

The rounded plastic containers at 47 cm diameter and 80 L volume were used for the experiment, as the container base was coated with a soil at 5 cm depth and different redox potential values. The sediment was originated from the pond soil in Karawang, West Java, Indonesia and land soil was from the aquaculture laboratory of College of Vocational Studies location. The treatments included pond soil (A), pond soil and land soil combination (1:1 ratio) (B), and land soil (C). These treatments also had different redox potential values (Table 1). The containers were filled with 80 L water and aerated at 5 L/minute, as the aeration point was set at 5 cm above the sediment. The water preparation was performed for a week, and the 25 shrimps (144 shrimps/m^2) at an average weight of 1.37 ± 0.04 g were stocked in each treatment container with four replications and reared for 30 days. Shrimps were fed with 35% protein-feed at 4-6% of the shrimp biomass four times per day. Meanwhile, the water was exchanged at 10% per week.

Parameters

The parameters observed during the experimental period included water quality, shrimp growth, and shrimp health parameters. The water quality parameters that were observed daily contained pH, dissolved oxygen (DO), salinity, temperature, redox potential, total dissolved solid (TDS), and conductivity by a *HORIBA U-50 series Multi-parameter water quality checker* device. Meanwhile, the water quality parameters that were observed on the final experimental period contained total ammonia-nitrogen (TAN), nitrite (NO_2), nitrate (NO_3), and alkalinity based on APHA of 2005 (Beutler *et al.*, 2014).

The shrimp growth parameters included average shrimp weight (ABW) and final biomass (Wiyoto *et al.*, 2017), while health parameters included lysozyme activity (Novriadi *et al.*, 2021), total hemocyte count (THC) (Wiyoto *et al.*, 2017), hemocyte differentials, phenoloxydase (PO) (Wang & Chen, 2005), superoxyde dismutase (SOD) (Campa-Córdova *et al.*, 2002), and respiratory burst (RB) (Song & Hsieh, 1994). The shrimp growth was recorded through a weekly sampling by measuring five shrimps randomly from each replication treatment. The weekly shrimp weight data were used to determine the total feed used. The health sampling was performed on the final experiment period by taking four shrimp samples from each treatment. The hemolymph sample was taken from shrimp with a 1 mL syringe on the fifth pereiopod base. The hemolymph samples obtained were observed and analyzed in the laboratory.

Data analysis

Data were analyzed using ANOVA for water quality parameters. Data that fulfilled the statistical criteria for significant difference were continuously tested using the Duncan's test. The principal component analysis and cluster analysis from various parameter data contained sediment quality, water quality, shrimp health, and shrimp growth parameters. The principal component analysis was continued for parameters that fulfilled the criteria based on the correlative matrix. These statistical analyses were all performed using *SPSS 20.0* software.

RESULTS AND DISCUSSIONS

Results

Water quality parameters

The pH (Figure 1) and dissolved oxygen (Figure 2) values were different among treatments ($P<0.05$), while other water quality parameters were insignificantly different (Table 2). The pH value on pond soil and land soil combination

Table 1. The redox potential value from different sediment treatments for shrimp rearing.

Treatment	Redox potential (mV)
Pond soil (A)	69.33 ± 14.57^{c}
Land soil + pond soil (B)	151.00 ± 8.89^{b}
Land soil (C)	210.00 ± 17.32^{a}

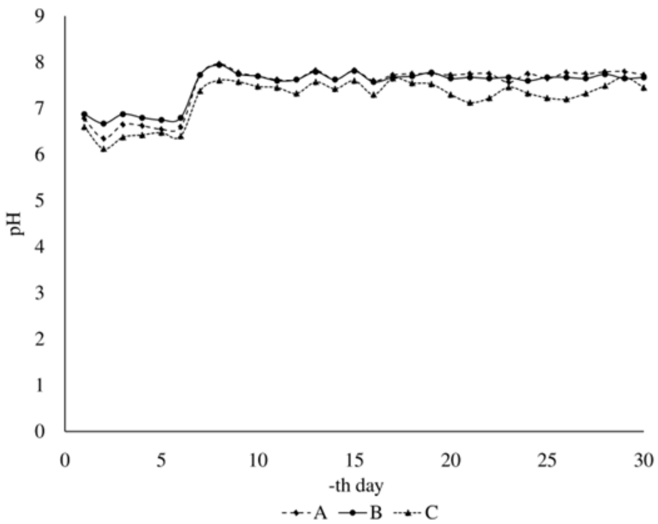

Figure 1. pH value of Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

treatment (B) was higher than the pH value on the C treatment, but showing an insignificant difference value on the A treatment. Different pH values were also influenced by the measurement time (P=0.00), but there was no interaction between the treatments and measurement time. The pH value on the B treatment was among 6.6 8.

The dissolved oxygen level on the C treatment was higher than the A treatment, but showing an insignificant difference on the B treatment (P=0.00). The dissolved oxygen value was influenced by the measurement time, but there was no interaction between the treatments and measurement time. The dissolved oxygen value on the C treatment was among 4.1-8.6 mg/L.

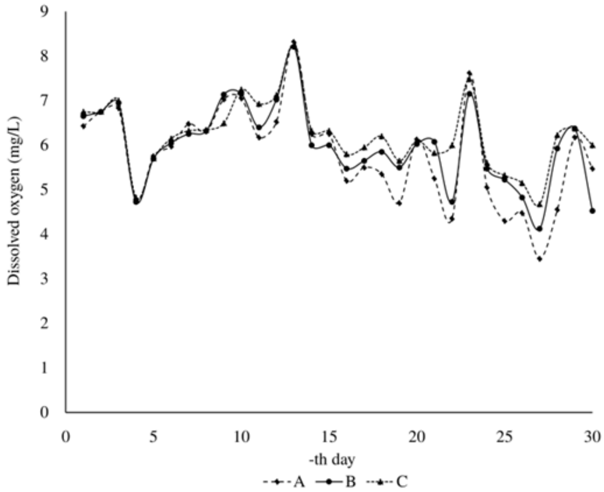

Figure 2. Dissolved oxygen (DO) value of Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

Table 2. The water quality of Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

Treatment	Salinity (g/L)	Temperature (ºC)	Water redox potential (mV)	TDS (mg/L)	Conductivity (μS)
A	25.86 ± 1.87^{a}	29.52 ± 0.80^{a}	112.52 ± 27.60^{a}	25.43 ± 0.87^{a}	41.68 ± 0.86^{a}
B	24.73 ± 1.50^{a}	29.78 ± 0.63^{a}	107.99 ± 7.97^{a}	24.65 ± 0.77^{a}	40.58 ± 0.39^{a}
C	25.38 ± 0.95^{a}	29.40 ± 0.78^{a}	113 ± 10.27^{a}	23.55 ± 1.10^{a}	38.61 ± 2.06^{a}

Table 3. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) of Bartlett's Test and Anti-image Correlation values of total dissolved soild (TDS), conductivity, total P, total Fe, total Mn, and total S on the Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.708
Bartlett's Test of Sphericity	Approx. Chi-Square	137.867
	df	15
	Sig.	.000

Anti-image Matrices

		TDS	Conductivity	P	Fe	Mn	S
	TDS	.504^{a}	-.998	-.245	.214	-.187	.088
Anti-image Correlation Conductivity	-.998	.514^{a}	.226	-.189	.179	-.104	-.104
P	-.245	.226	.746^{a}	-.827	.391	-.209	-.209
Fe	.214	-.189	-.827	.704^{a}	-.705	.045	.045
Mn	-.187	.179	.391	-.705	.753^{a}	-.501	-.501
S	.088	-.104	-.209	.045	-.501	.900^{a}	.900a

Principal component analysis

Based on the analysis results, not all parameters were qualified for the principal component analysis test. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) of Bartlett's Test value (Table 3) showed that only several parameters were qualified for a further test with the KMO value of 0.708 (>0.5) and P value = 0.000 (<0.05). The anti-image correlation showed variables that obtained the Measures of Sampling Adequacy (MSA) above 0.5 were total dissolved solid (TDS), conductivity, total P, total Fe, total Mn, and total S. Based on this condition, the six parameters could be analyzed further.

The principal component analysis results obtained two factors. The matrix component presented six variables distributed on the two factors formed. The correlation between the TDS variable and Factor 1 was weak due to below 0.5, which could also be found on the conductivity variable condition. Therefore, the TDS and conductivity parameters were included in the second factor. The first factor contained total P, total Fe, total Mn, and total S (Table 4) with a strong correlaton in the component. All variables formed in the factors had a strong correlation of 0.918-0.988.

The division of two components can be identified clearly form the plot components formed presented in Figure 3, where the conductivity and TDS position form their own group as well as total Mn, total Fe, total P, and total S. based on the various variables observed, two factors were obtained, namely: 1) Factor 1: total P, total Fe, total Mn, and total S, which can be named as redox potential factor; 2) Factor 2: Conductivity and TDS. The horizontal and vertical axis are the water or soil quality parameters transformed

Table 4. Matrix component of total dissolved soild (TDS), conductivity, total P, total Fe, total Mn, and total S on the Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

	Component	
Parameter	1	2
TDS	-.380	.925
Conductivity	-.396	.918
P	.971	.186
Fe	.988	.128
Mn	.977	.170
S	.953	.255

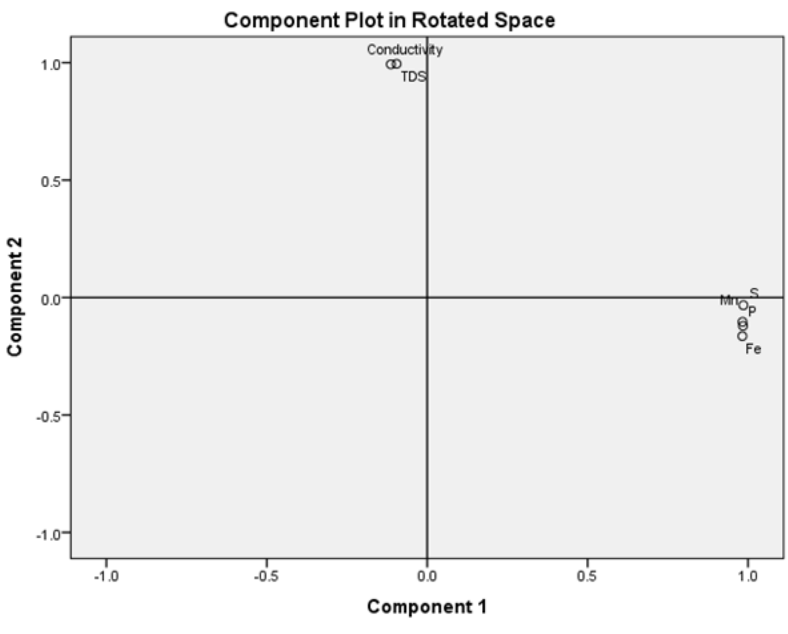

Figure 3. The plot components of conductivity, total dissolved solid (TDS), total P, total Mn, total Fe, and total S on the Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

after the principal component analysis (PCA) application correlated to the first and second components respectively. These two components are the greatest components from all parameters in affecting the culture activities for 30 days. Components closed to the axis center (x = 0, y = 0) are less relevant than components far from the axis point on the shrimp rearing activity effect. The closed parameters had more correlation effect. Conductivity and TDS had a closer correlation, as well as for total Mn, total P, total S, and total Fe. This condition may become useful

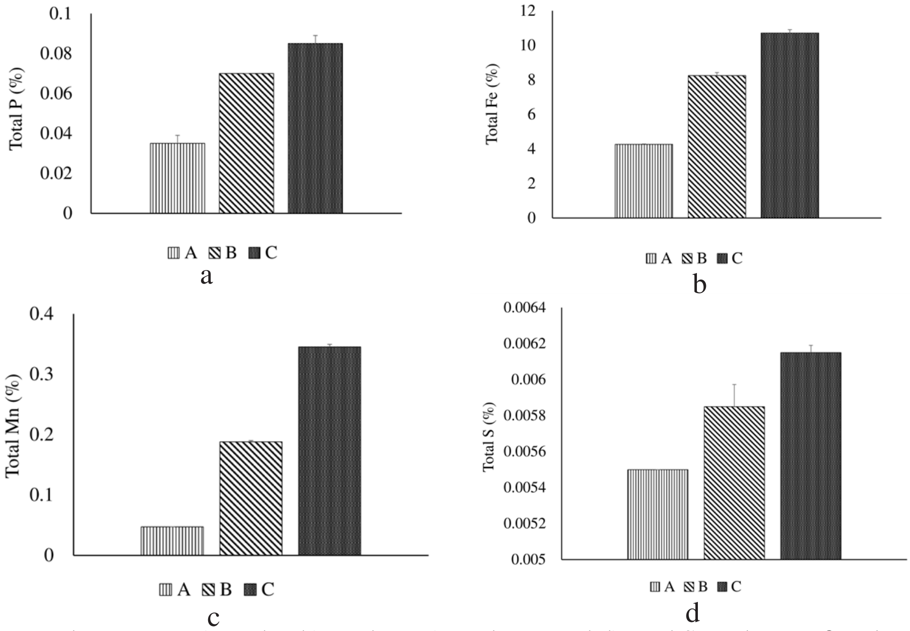

Figure 4. Soil mineral contents: a) total P, b) total Fe, c) total Mn, and d) total S on the Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

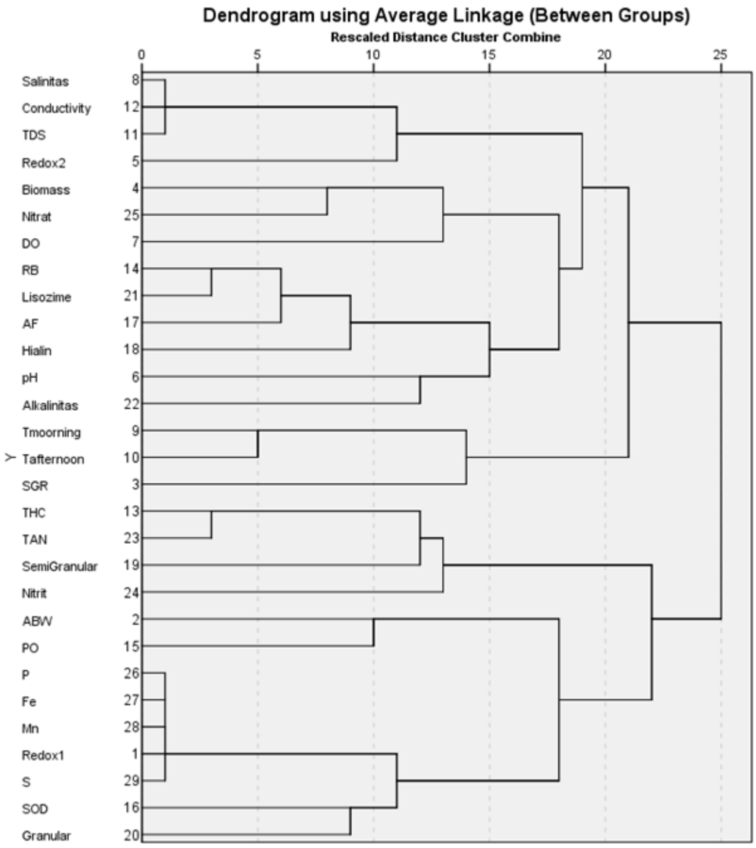

Figure 5. The cluster analysis dendogram for water quality, health, growth, and sediment quality variables on the Pacific whiteleg shrimp *L. vannamei* rearing media for 30 days with different sediment redox potential values based on pond soil (A), pond soil and land soil combination (B), and land soil (C) treatment conditions.

to identify the parameters affected shrimp rearing under different sediment redox potential values.

The total P, total Fe, total Mn, and total S increased along with more positive value of soil redox potential. The highest composition value was obtained from the total Fe that increased gradually along with the increased redox potential value, respectively (Figure 4).

Cluster analysis

The cluster analysis was performed in all observed parameters. The cluster analysis results emphasized the principal component analysis formed. Figure 5 presents that salinity, conductivity, and TDS parameters have a similarity by forming a cluster, as well as the parameter group of total P, total Fe, total Mn, total S, and redox potential value.

Discussions

Water quality parameters, such as pH and dissolved oxygen, are several key parameters in the culture activities. The pH values of the study results were in a normal range. The pH value for shrimp culture should be among 6.5-9.5, which should fluctuate daily at 0.55 (Carbajal-Hernández *et al*., 2012). The pH value change in the water can be caused by the sediment condition (Saraswathy *et al*., 2019). Several sediment quality parameters that influences the water pH value is sediment redox potential (Wiyoto *et al*., 2016), sediment pH value, and organic matter contents. A higher soil pH value in the pond soil and dry soil combination was thought due to reactions between two soil types that affected the water pH value. The stable pH value tendency without reduction during the shrimp rearing period was thought due to weekly water exchange. This condition was different from the shrimp rearing in general, whereas the pH value tended to decrease during the rearing period (Wei *et al*., 2021).

Dissolved oxygen is main parameter in aquatic organism production, whereas good oxygen supply condition will assure the cultured organism health (Cao *et al*., 2020). The dissolved oxygen in the water can be affected by the pond sediment condition such as redox potential value, as negative redox potential results in a lower dissolved oxygen due to dissolved oxygen use by sediment (Wiyoto *et al*., 2016). Water quality, shrimp health, and shrimp production parameters were processed to describe the correlation among the measured variables, however several parameters were unable for further test. The main component grouping from the water quality factor can be performed by identifying the matrix component coefficient values of the formed factors. The matrix component coefficient above 0.6 means that the variables included can explain the factors formed (Cao *et al*., 2020). The closed correlation among salinity, conductivity, and TDS presented on the principal component analysis and hierarchial analysis can become a reference in measuring the water quality of shrimp culture media. Conductivity and TDS can be used to describe the salinity level as both parameters are related in a formula TDS = k.EC at 25 ºC (Rusydi, 2018). The total dissolved solid describes the available anorganic salt and little amount of organic matters, while conductivity measures the water capability in conducting an electric current (Rusydi, 2018). Parameters that affected the redox potential were also obtained clearly from total P, total Fe, total Mn, and total S. These parameter dynamics were closely correlated with the soil redox potential measured (Wiyoto *et al*., 2016).

CONCLUSIONS

The pH and dissolved oxygen values were affected by the measuring time, whereas the lower sediment redox potential value, the higher water pH value, while the higher redox potential value, the higher dissolved oxygen level. The related water quality parameters, such as total P, total Fe, total Mn, and total S, were closely correlated with the soil redox potential value.

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