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Dynamics of Physics and Chemistry of Vanamei Shrimp (*Litopenaeus vannamei*) Pond Water with Semi Biofloc System

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Abstract: Vannamei shrimp (*Litopenaeus vannamei*) is one of the leading commodities in Indonesian aquaculture. The cultivation potential that is developing at this time is with intensive technology. However, along with the development of intensive technology, it experienced problems, namely crop failure caused by a decrease in water quality. This study aims to examine the physical and chemical dynamics of vannamei shrimp pond water cultivated with a semi-biofloc system. This study used a survey method and was statistically analyzed using *Ms. Excel* and *Principal component analysis* (PCA). Physical and chemical parameters of water that are measured and observed include Temperature, Brightness, pH, Dissolved Oxygen, Salinity, *Carbon Dioxide* (CO_2), Total Organic Matter, Nitrate (NO_3), Phosphate (PO_4^-) and Ammonia (NH_3). The results showed that all the physical and chemical parameters of pond water experienced daily and weekly fluctuations during shrimp rearing. Average temperature fluctuations during the study ranged from 26.7 – 32.5 ^oC, brightness ranged from 26.5 – 85.0 cm, pH ranged from 7 – 8 tended to be normal, dissolved oxygen ranged from 5.8 – 8.8 mg/L, salinity ranged from 18.3 – 22.8, carbon dioxide (CO_2) average values during rearing were 0 mg/L, TOM ranged from 18.42 – 71.80 mg/l, nitrate 0.022 – 0.136 mg/l, phosphate 0.017 – 0.136 mg/L and ammonia ranging from 0.008 – 0.088 mg/l. While, the results of the PCA analysis show that dissolved oxygen and brightness significantly affect the life of the shrimp that are cultivated. So it can be concluded that the dynamics of the physics-chemistry of water measured during the study showed that dissolved oxygen and brightness fluctuated and affected aquaculture activities.

Keywords: Brightness; Dissolved oxygen; PCA; Shrimp; Water quality

Introduction

Vannamei shrimp (*Litopenaeus vannamei*) is one of the leading commodities in Indonesian aquaculture because it has advantages such as disease resistance, relatively fast growth, can be cultivated in a wide range of salinities and maintained with high stocking densities (Purnamasari et al., 2017). Therefore, the advantages possessed by vanamei shrimp cultivation in Indonesia are carried out with various cultivation systems. Starting from traditional cultivation systems to using super-intensive cultivation systems (Suwoyo et al., 2015). One of the cultivation systems widely applied in Indonesia is the intensive cultivation system since it can be applied with a high stocking density.

The application of an intensive cultivation system with a high stocking density will pollute the aquaculture ecosystem, namely the accumulation and increase of the waste load in the aquatic environment (Na nakorn et al., 2017). The presence of high stocking densities can cause the increase and buildup of waste because the higher the stocking, the more artificial feed the amount will increase, which is in line with the increasing age and size of shrimp and the period of shrimp rearing (Wulandari et al., 2015). The shrimp utilize not all of the artificial feed provided, but only about 25-30% TN (nutrient

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retention) and 10% TP (protein retention) and 30% TC (carbon retention) are retained in the shrimp meat (Syah et al., 2014).

The feed that the shrimp do not use will eventually add to the increase in the burden of aquaculture waste in the form of organic matter, nitrite (NO_2^-) and ammonia (NH_3). In addition, the increase in waste load also comes from remaining shrimp faeces (Pratiwi et al., 2020). The increase in waste in pond waters will affect pond ecosystems and pond waters' physical and chemical factors (Ariadi et al., 2020). Physico-chemical factors or overall water quality in the pond aquaculture environment are important factors for supporting the comfort, survival and growth of aquatic biota during the cycle of aquaculture activities (Carbajal-Hernández et al., 2013; Kane et al., 2015).

The condition of the physical-chemical factors in the aquaculture waters ecosystem indirectly has a positive or negative effect on the productivity of the shrimp cultivated at a certain concentration level (Zafar et al., 2016). Therefore, increasing shrimp productivity is carried out by implementing intensive cultivation with a semi-biofloc system. The semi-biofloc system is a cultivation system that combines the proper and controlled use of bacteria and phytoplankton in waters (Duru et al., 2013). The semi-biofloc system allows the physical and chemical parameters of pond waters to be better maintained because of the working system of heterotrophic bacteria that utilize organic matter to form flocs that can be consumed by shrimp (Suwoyo et al., 2015).

Based on this description, this study aimed to examine and study the physical and chemical dynamics of vannamei shrimp pond water cultivated with a semi-biofloc system.

Method

Location and Time of Research

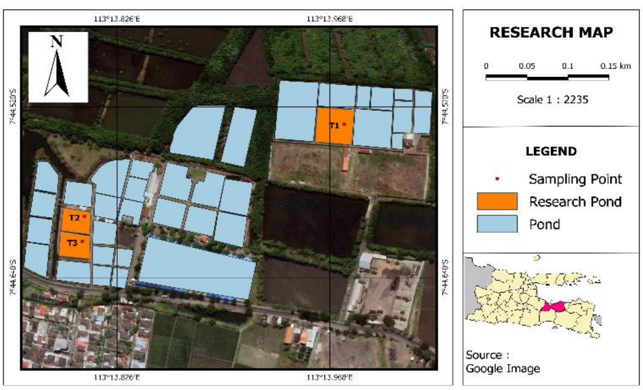

Figure 1. Research ponds location

This research was conducted in Intensive Shrimp Ponds, Brackishwater and Marine Fisheries Laboratory, Faculty of Fisheries and Marine Sciences, University of Brawijaya (Figure 1) located in Probolinggo City, East Java Province (7º44'32.0''LU 113º13'58,3''BT). This research was also carried out from January until April 2022. This research was conducted in intensive pond aquaculture in three plots with an area of 1600 m^2 with a stocking density of 160 shrimp/m^2.

Observed Material and Parameters

This research was conducted using a survey method, which was carried out to obtain primary and secondary data in the field. Pond water sampling was carried out during one cycle of vannamei shrimp cultivation to see the dynamics of the physics and chemistry of pond waters. The physical and chemical parameters measured and observed included Temperature, Brightness, pH, Dissolved Oxygen, Salinity, Carbon Dioxide (CO_2), Total Organic Matter, Nitrate (NO_3), Phosphate (PO_4^-) and Ammonia (NH_3).

Data Analysis

All data were statistically analyzed using Ms. Excel 2019 and Principal component analysis (PCA) to show variables that are more significant than ten physical and chemical parameters of water that affect the application of cultivation with a semi biofloc system.

Result and Discussion

Temperature

The observation of the temperature of vannamei shrimp pond water during maintenance can be seen in Figure 2 that fluctuations in the temperature every day on the three plots are relatively the same. The temperature in pond waters will experience daily fluctuations both morning and evening that can be caused by instability in weather conditions such as rain and the length of sunlight. Sunlight affects the ups and downs of water and water temperatures on the surface heat faster than the temperature in the water (Annisa et al., 2021).

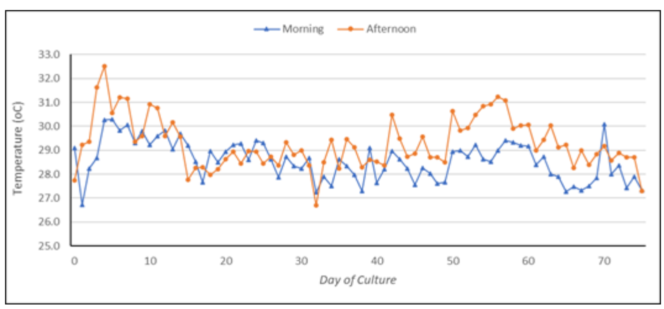

Figure 2. Temperature chart during maintenance

Based on the graph above, the highest temperature in the morning was 30.3 ^{0}C on the 4th day of maintenance and the lowest was 26.7 ^{0}C on the 1st day. While in the afternoon, the highest temperature was 32.5 ^{0}C on the 4th day and the lowest was 26.7 ^{0}C on the 32nd day of maintenance. Temperature is an essential factor affecting biota life's activities in waters such as growth, survival, reproduction, molting and metabolic activity. The average fluctuation of water temperatures from ponds during vannamei shrimp maintenance is optimal. The optimal pond temperature for vannamei shrimp maintenance ranges from 26-32 ^{0}C (Ariadi et al., 2021; Edhy et al., 2010).

Brightness

Observation of the Brightness of vannamei shrimp pond water during maintenance can be seen in Figure 3 that brightness fluctuations every day in the three ponds is relatively same. The brightness value of pond waters tends to be high because the brightness value at the beginning of maintenance tends to be higher and the brightness value every day in the morning and evening tends to fluctuate.

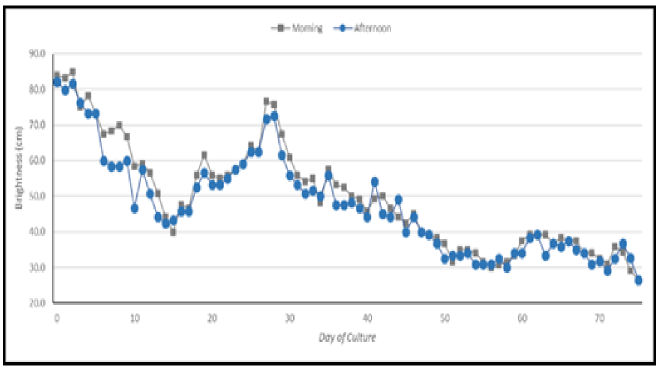

Figure 3. Brightness chart during maintenance

Based on the graph above, the highest brightness in the morning was 85.0 cm on the 2nd day of maintenance and the lowest was 26.5 cm on the 75th day. While in the afternoon, the highest brightness was 82.0 cm on the 1st day and the lowest was 29.2 cm on the 71st day of maintenance. In a culture system with an intensive system, brightness is affected by the accumulation of leftover feed given and the remains of shrimp metabolism in the form of feces that accumulate in the waters (Tangguda et al., 2018). In addition, if the brightness in pond waters is low, it will also affect oxygen levels in the pond and shrimp survival.

Brightness is also influenced by the presence of phytoplankton in pond waters, the higher the phytoplankton, the brightness of the pond waters will decrease (Aziz et al., 2015). In this case, brightness is a physical parameter related to primary productivity because it affects the process of photosynthesis in water (Rahman et al., 2016).

Power of Hydrogen (*pH*)

Based on the measurement results, the average pH value in the three ponds in the morning and evening was 7-8. The average pH value during the maintenance of vannamei shrimp is categorized as suitable for shrimp cultivation. The pH value of pond water suitable for maintaining vannamei shrimp ranges from 7-8.5 (Renitasari, 2022). The range of pH values in vannamei shrimp ponds during the maintenance period tends to be stable and does not fluctuate. If the pH value is less than 4.5 or more than 9.0, it will cause shrimp to become susceptible to disease and decreased appetite, which can cause shrimp to become porous (Renitasari et al., 2020).

Dissolved Oxygen (DO)

The observations of dissolved oxygen in vannamei shrimp pond water during rearing can be seen in Figure 4 that the daily fluctuations in dissolved oxygen in the three plots are relatively the same. The average value of low dissolved oxygen in the morning of the three ponds was 5.9 mg/l and the highest was 8.8 mg/l. While the lowest average value of dissolved oxygen in the afternoon was 5.8 mg/l and the highest was 8.7 mg/l. Dissolved oxygen is a water quality parameter that has an important role in metabolic processes and is a limiting factor for aquatic ecosystem life (Nurhasanah et al., 2021). Dissolved oxygen fluctuates daily, season, mixing and movement of water masses, the level of penetration of light that enters the waters, the process of photosynthesis and organic matter (Alhaq et al., 2021; Sastrawijaya, 2002).

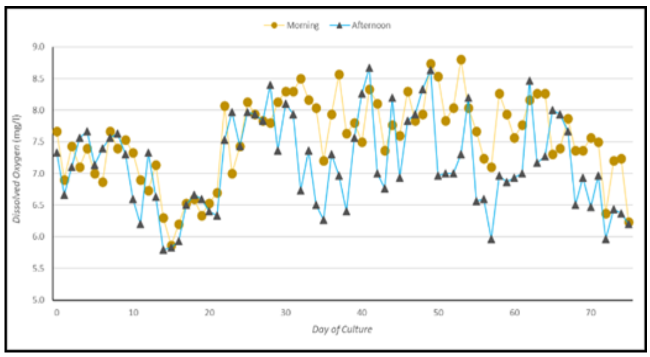

Figure 4. Dissolved oxygen chart during maintenance

The average value of dissolved oxygen in the three ponds is stable and still in the optimal range for vannamei shrimp maintenance. The dissolved oxygen value required in shrimp pond waters is > 3 mg/l. The optimum dissolved oxygen value in pond waters for normal shrimp growth ranges from 5-9 mg/l. The range of the average dissolved oxygen values in the morning in the three ponds tends to be higher than in the afternoon. It is because the photosynthesis process has started which produces O_2, which makes dissolved oxygen concentrations tend to be high (Renitasari et al., 2020).

Salinity

The observation of the salinity of vannamei shrimp pond water during maintenance can be seen in Figure 5 that fluctuations in the salinity every day on the three plots are relatively the same. Salinity is a water quality parameter that plays a role in the process of osmoregulation in shrimp. If the salinity in pond waters is in a hyperosmotic or hypoosmotic state, the growth and survival of the shrimp will be disrupted (Maghfiroh et al., 2019).

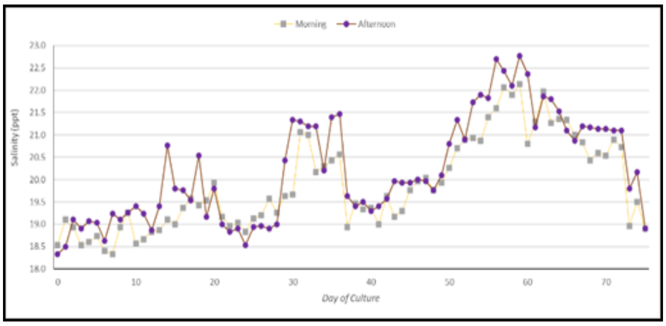

Figure 5. Salinity chart during maintenance

Based on the graph above, the highest salinity in the morning was 22.1 mg/l on the 59th day of maintenance and the lowest was 18.3 mg/l on the 21st day. While in the afternoon, the highest brightness was 82.0 cm on the 1st day, and the lowest was 29.2 cm on the 71st day of maintenance. The salinity range in the three ponds is still in the optimum range for vannamei shrimp maintenance. Vannamei shrimp can grow optimally in the salinity range of 15-25 ppt (Renitasari et al., 2020).

Salinity fluctuations in the morning and afternoon in the three ponds tend not to be too different. This is presumably because there was an evaporation process in pond waters and the influence of seasons, such as rainfall, at the time of measurement. The level of salinity in pond waters can be affected by the evaporation process, water circulation patterns in ponds, rainfall and river flows (Choeronawati et al., 2019).

Carbon Dioxide (CO_2)

Based on the measurement results during the cultivation cycle, the average value of carbon dioxide (CO_2) in the three ponds in the morning and afternoon is 0 mg/l. It is suspected that the CO_2 found in pond waters is free because the CO_2 found in waters is bound to water even though CO_2 has properties that readily dissolve in water (Barus, 2020).

In addition, the results of CO_2 measurements were 0 mg/l which could be due to photosynthetic process activities that had already begun. As long as the sun shines during the day, CO_2 is utilized by phytoplankton while pH and DO increase as a result of the photosynthetic process so that free CO_2 decreases. However, at night the respiration process dominates and CO_2 is released, and there is a decrease in pH and DO (Edi et al., 2021).

Carbon dioxide in pond waters can come from rainwater, atmospheric diffusion and the results of the respiration of aquatic biota, phytoplankton and the decomposition of organic matter by bacteria (Supono, 2015). The optimum CO_2 concentration for aquaculture activities such as shrimp is <5 mg/l and most aquatic animals can still survive at carbon dioxide concentrations of 20 – 60 mg/l. If the concentration of carbon dioxide > 60 mg/l will interfere with breathing and eventually cause death (Furtado et al., 2017).

Total Organic Matter (TOM)

The observation of total organic matter in vannamei shrimp pond water during rearing can be seen in Figure 6 that fluctuations in total organic matter every week in the three plots are relatively the same.

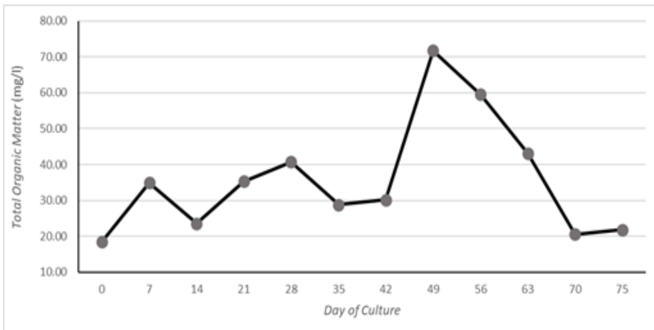

Figure 6. TOM chart during maintenance

Total organic matter is a collection of accumulated organic compounds that have undergone a decomposition process and describes the concentration of organic matter in waters in the form of dissolved, suspended and colloidal organic matter. Organic material in ponds comes from an uneaten feed, feces and dead plankton (Jefri et al., 2020).

The concentration of organic matter can increase with increasing shrimp cultivation time due to the accumulation of leftover feed and feces from the reared biota. The concentration of organic matter values in waters will be needed by biota in specific amounts. The maximum total organic matter concentration for growing vannamei shrimp is <90 mg/l (Edhy et al., 2010; Wafi et al., 2020). If the total organic matter value concentration exceeds the threshold, it will disrupt the metabolic activity of the shrimp and can also result in blooming (Edi et al., 2021).

Nitrate (NO_3)

The observation of nitrate in vannamei shrimp pond water during rearing can be seen in Figure 7 that fluctuations in nitrate every week in the three plots are relatively the same. The average value range of nitrate is 0.02 – 0.14 mg/L. The nitrate concentration is optimal for shrimp farming, while the nitrate concentration for vannamei shrimp farming ranges from 0.4 – 0.8 mg/L (Jumraeni et al., 2020).

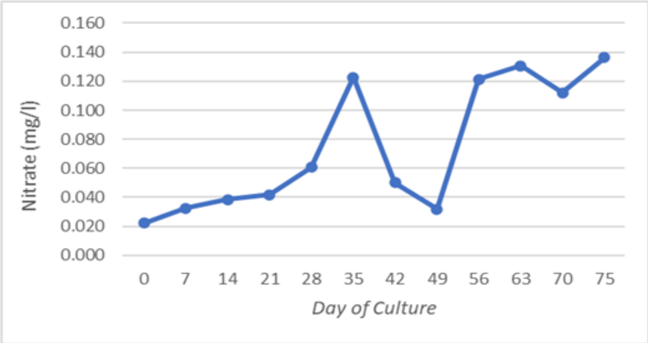

Figure 7. Nitrate chart during maintenance

Nitrate is the main form of nitrogen found in natural waters and including in the primary nutrient for algae growth. Nitrates are produced from the oxidation of nitrogen in water and are stable and very soluble in water. The presence of nitrate in pond waters is needed to stimulate the growth of plankton as a natural food for shrimp. During maintenance, nitrifying bacteria have worked optimally in oxidizing nitrite to nitrate (Putri et al., 2020). Nitrate in the water is formed from the nitrification process which oxidizes ammonia by bacteria to nitrite and nitrate. Then, nitrate will be utilized by phytoplankton and other aquatic plants. Bacteria and algae in the waters will utilize inorganic nitrogen which will be converted into protein and become nutrients for phytoplankton (Supono, 2018).

Phosphate (PO_4^-)

The observation of phosphate in vannamei shrimp pond water during rearing can be seen in Figure 8 that fluctuations in phosphate every week in the three plots are relatively the same. Phosphate concentration increased as the vannamei shrimp rearing time increased, where the highest phosphate concentration was in the last week of rearing, namely the 75th day, which was 0.14 mg/l, which was the last week of rearing. The phosphate concentration in this shrimp pond is still above the concentration for shrimp farming. The phosphate concentration for vannamei shrimp maintenance is <0.1 mg/L (SNI, 2006).

Phosphate can be a limiting factor in water, and phosphate is essential in forming proteins and metabolic activities. Phosphates consist of organic phosphates (sugar phosphates, nucleoproteins, phosphoproteins) and inorganic phosphates (orthophosphates and polyphosphates). Phosphate is used for the growth and development of microalgae cells, and energy transport reactions such as the formation of ADP and ATP compounds (Tsany et al., 2019).

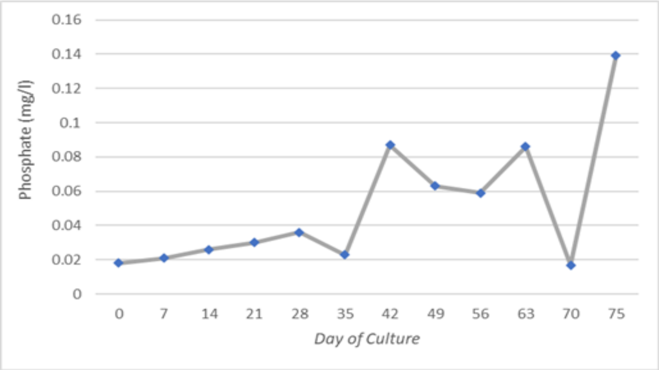

Figure 8. Phosphate chart during maintenance

Ammonia (NH_3)

The observation of ammonia in vannamei shrimp pond water during rearing can be seen in Figure 9 that fluctuations in ammonia every week in the three plots are relatively the same. Ammonia in waters comes from the decomposition of organic matter containing protein, such as feed. The highest ammonia concentration occurred on the 7th week of maintenance, on the 42nd day of, 0.088 mg/l. PERMEN-KP Number 75 of 2016 states that the value of the standard quality of ammonia intended for vannamei shrimp maintenance activities is ≤ 0.1 mg/l. The concentration of ammonia in this pond is below the quality standard for vannamei shrimp maintenance, this is due to the work of bacteria and phytoplankton in converting ammonia into nutrients for growth (Patnaik et al., 2006).

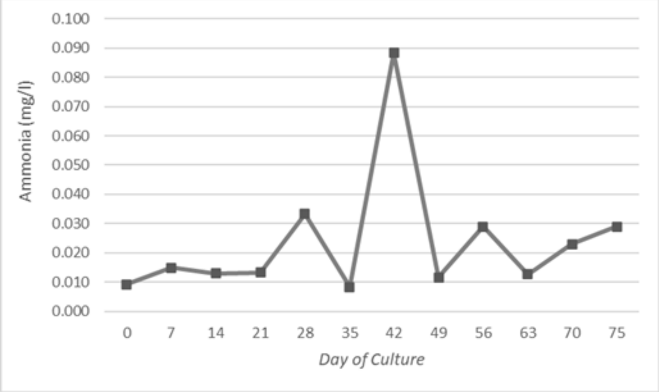

Figure 9. Ammonia chart during maintenance

Data Analysis

Based on the results of the PCA analysis, it can be seen in Figure 10 describes the relationship between the eight physical and chemical parameters of pond waters which were measured during the study, explained by factors 1 and 2 of 64.39%. The main factor (F1) represents about 44.28% of the data diversity with the main variables being Dissolved oxygen and brightness. There is a negative correlation between the main parameters, where an increase in Dissolved oxygen and Brightness results in a decrease in TOM, Phosphate, Ammonia, Nitrate, Salinity and Temperature levels. While, the second factor (F2) presents around 20.11% with the main variables being TOM, Phosphate and Ammonia. These three variables are negatively correlated, if there is an increase in levels of TOM, Phosphate and Ammonia, it will result in decreased levels of nitrate, salinity and temperature.

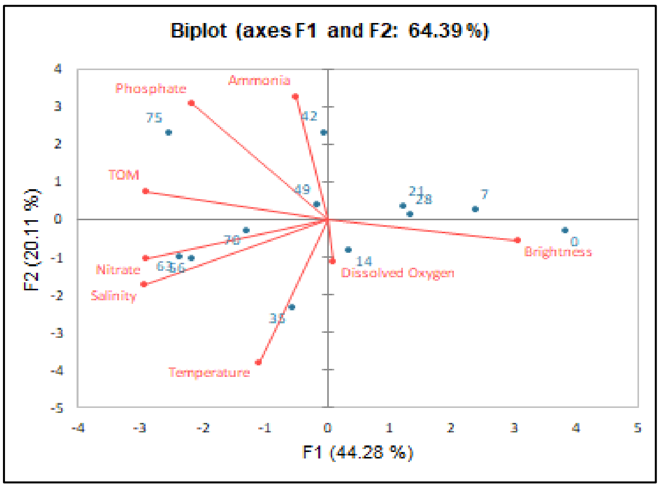

Figure 10. Graph of PCA analysis of pond water physics-chemistry characteristics

Based on Figure 10, the physical and chemical parameters of pond water with a semi-biofloc system significantly affect Dissolved oxygen and brightness. The water's dissolved oxygen concentration is sufficient, so the organic matter degradation process goes well (Takarina et al., 2017). Dissolved oxygen is one of the parameters that must be paid close attention to in an intensive aquaculture system with a biofloc or semi biofloc system because it avoids the accumulation of leftover packs and feces (Hargreaves, 2013). At the same time, the brightness concentration is an indicator that affects the productivity of aquaculture waters, where brightness affects the sunlight energy needed by microorganisms with chlorophyll for photosynthesis (Umami et al., 2018).

Conclusion

It can be concluded that the dynamics of the chemical physics of water measured during the research process experienced daily and weekly fluctuations. Based on the results of the PCA analysis, the most influential water Physic-chemical parameters are dissolved oxygen and the brightness of the pond waters.

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