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Performance of intensive vannamei (*Litopenaeus vannamei*) culture at low salinity

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ABSTRACT

Intensive aquaculture systems that are not managed properly often cause problems that disrupt the balance of the environment so that shrimp are susceptible to disease. One of the aquaculture innovations that have been developed to minimize disease impact is shrimp farming with low salinity. This study aims to determine the performance of intensive *Litopenaeus vannamei* shrimp culture with low salinity. This study used quantitative descriptive analysis with a purposive sampling technique in three ponds for three maintenance cycles. The result of the study on three cycles of vannamei shrimp culture with low salinity overall found that productivity ranged from 2.35 to 3.69 kg/m². ADG values in aquaculture ponds ranged from 0.26 – 0.36 g/day. The survival rate ranged from 61% to 98%, and the feed conversion ratio ranged from 1.01 to 1.62. The survival rate tends to increase, and FCR value tends to decrease in 3 cycles of cultivation. Water quality including temperature, dissolved oxygen, pH, phosphate, ammonia, and TOM indicate the optimal range based on water quality standards for intensive vannamei shrimp culture (SNI 01-7246-2006). At the same time, nitrite and alkalinity exceed the SNI standard but this nitrite and alkalinity level could still be tolerated by vannamei shrimp during the rearing period. Overall, water quality during the rearing period can still support the growth of vannamei shrimp. The above result showed that vannamei shrimp culture at low salinity (6-8 mg L^{-1}) has the potential to be developed.

Introduction

Vannamei shrimp is one of the leading fishery commodities which was introduced in 2001 to revive the shrimp business in Indonesia and diversify fishery commodities (Hendarajat *et al*., 2007; Nababan *et al*., 2015; Sahabudin *et al*., 2020). The high demand for vannamei shrimp both at home and abroad encourages farmers to cultivate shrimp intensively with high stocking densities (Bagus, 2021; Cahyanurani and Dowansiba, 2022; Hidayat *et al*., 2019).

Intensive cultivation systems with limited environmental conditions, high stocking density, overfeeding problems and inappropriate water quality management can disrupt the environmental balance so that shrimp become susceptible to disease (Zafar *et al*., 2015; Widodo *et al*., 2021). One of the cultivation innovations that have been developed to reduce the rate of disease spread is through a low salinity cultivation system (Ariadi *et al*., 2019; Panakorn, 2012). Under low salinity conditions, the total number of Vibrio in *L. vannamei* culture was successfully controlled (Suantika *et al.,* 2018). Pathogenic Vibrio is one of the main pathogens affecting *L. vannamei* aquaculture, and estimates of the total number of Vibrio present in the culture can be used as an important indicator of the impact on the culture's health (Bauer *et al.,* 2018; Pena *et al.,* 2001). Schofield *et al.* (2021) demonstrated the ability *Vibrio parahaemolyticus* AHPND to cause disease in *P. vannamei* at different salinities and showed higher survivability in lower salinity. *V. parahaemolyticus* is a halophilic bacterium reproducing more efficiently in environments with high salinities. The increased bacterial density led to the production of a greater amount of pirAB toxin at higher salinities than lower salinities.

Estrada-Perez *et al.* (2020) also analyzed *L. vannamei* production when exposed to acute hepatopancreatic necrosis disease (AHPND) in seven production cycles from shrimp farms in Mexico from 2013 to 2016. The correlation analysis

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significantly shows that during those years, mortality by disease is more severe when water salinity is high and productivity low.

Vannamei shrimp are euryhaline because they have a wide tolerance to salinity ranging from 2 – 40 ppt (Scabra *et al.,* 2021). The ability of vannamei shrimp to adapt to a wide salinity range allows farmers to develop this commodity in inland water or low salinity media (Maghfiroh *et al*., 2019; Tahe and Nawang, 2012).

Shrimp cultivation with low salinity has been widely practiced in many areas around the world (Roy *et al*., 2010). In Indonesia, intensive vannamei shrimp cultivation with low salinity can be found in Lampung, Purworejo, Tuban, Lamongan, and Probolinggo areas (Ariadi *et al*., 2019). The salinity used in low salinity shrimp culture is less than 10 g L^{-1} (Boyd and Thunjai, 2003).

Shrimp cultivation at low salinity has several advantages, including minimizing the impact of disease, decreasing the level of toxicity of toxic gases in ponds, and can suppress the growth of pathogens (bacteria, viruses), which are the main causes of failure of shrimp culture (Samocha *et al*., 2004; Supono, 2019; Valencia-Castañeda *et al*., 2019). The prospect of developing low-salinity shrimp culture is very good in the future from an ecological and economic perspective (Ariadi *et al*., 2019).

The previous study of low salinity shrimp culture has been reported to evaluate the growth performance, change in immunological and physiological under low salinity exposure with different stocking densities (Samocha *et al.,* 2004; Li *et al.,* 2015; Esparza-Leal *et al.,* 2010; Esparza-Leal *et al.,* 2018). However, all the studies conducted only showed the performance of low salinity vannamei shrimp culture in one cycle (a certain time period of rearing).

The success in the production of vannamei shrimp is seen through the successful performance of its aquaculture performance. To assess the success of shrimp farming with low salinity, it is necessary to study the performance of shrimp culture with low salinity in several cycles. Therefore, this study aims to determine the performance of intensive vannamei shrimp culture with low salinity in several cycles.

Materials and Methods

Location and time of research

This research was conducted from March 2021 to January 2022 in pond CV. Vanname 79, Kraksaan, Probolinggo. Ponds in CV. Vanname 79 has a salinity ranging from 6 – 8 g L^{-1}. The type of research used is descriptive quantitative with purposive sampling technique. Data were collected in 3 circular ponds with an area of 530 – 615 m^2, namely plots A, B and C for 3 maintenance cycles with a stocking density of 179 – 279 shrimp/m^2. According to Arifin *et al.* (2005) vannamei cultivation with intensive technology has high stocking ranges from 100-300 shrimp/m^2.

Culture system description

The pond construction used in this study used a circular pond construction with a geomembrane layer and a wire mess height of 1.5 m. Cultivation activities begin with the preparation of cultivation containers, namely the process of drying the round pond for 1 to 2 weeks with the help of sunlight and sterilization using a disinfectant (Rizky *et al*., 2022).

The water medium used is bore well water. The borehole water is then flown into the pond and sterilized with 1.5 ppm $CuSO_4$ for 1 week, followed by the administration of 2 ppm disinfectant. After 30 minutes then followed by the administration of 60% chlorine at 30 ppm and aeration for 24 hours. Furthermore, liming with $CaCO_3$ at 20 ppm and pond water aerated until there is a change in water color as an indicator of plankton growth so that it can be stocked (Mustofa *et al.,* 2012).

To maintain the dissolved oxygen level, a windmill and turbine aerator are used to distribute water in each pond (Cahyanurani & Hariri, 2021). During maintenance, dissolved oxygen levels were maintained at 4.5 ppm. The fry used in this cultivation are those that have been certified SPF (specific pathogen free) or are free from the WSSV, IMNV, or TSV viruses, which have been through the PCR test. The stocking of fry is done in the afternoon. The stocked fry, namely PL-9 with a length of 7.6-8 mm, had an active movement and moved against the current. The fry were acclimatized before stocking (Rizky *et al*., 2022).

Feed management during rearing uses the method of blind feeding and anco feeding program (Cahyanurani & Hariri, 2021). The feed is artificial and comes in powder, crumble, and pellet forms, with feeding adjusted to the opening of the shrimp's mouth. The feeding frequency at the time of initial stocking - DOC 30, which is 4 times, then at DOC 31 - harvesting, the feed is given 7 times. The feeding mechanism is done manually. The addition of vitamin C and vitamin B complex is added through feed as much as 5 g/kg of feed with a frequency of 2 times a day.

Water quality management is carried out through regular daily water changes of 15 – 18% with a maintained water height of 1.2 m, administration of probiotics containing nitrifying bacteria and

Lactobacillus, and to maintain the stability of phytoplankton given 30 ppm dolomite and 1 ppm sodium silicate every week (Mustofa *et al.,* 2012). Water quality monitoring is carried out regularly, either directly or through laboratory analysts covering physical and chemical parameters to maintain stable culture media water quality. Growth monitoring was carried out through sampling activities to determine the average weight of shrimp, daily weight gain rate, shrimp biomass and monitoring of shrimp health conditions.

Research parameters

Parameters tested to see the performance of vannamei shrimp culture with low salinity include:

a. Average Daily Growth (ADG)

Average Daily Growth (ADG) is the average daily weight gain of shrimp in a certain period of time so that it can be used to determine the growth rate of shrimp. Average Daily Growth (ADG) can be calculated by the following formula (Haliman and Adijaya, 2005).

$$ADG = \frac{current\ ABW - previous\ ABW}{sampling\ time\ interval}$$

Description:
ABW = average weight of shrimp from sampling

b. Productivity

Productivity in shrimp farming, calculated using the formula (Dewi, 2019):

$$Productivity = \frac{Biomass}{land\ area}$$

Description:
Biomass = final shrimp weight (kg)

c. Feed Conversion Ratio (FCR)

The calculation of feed conversion is carried out using the formula (Supono and Wardiyanto, 2008) as follows:

$$FCR = \frac{F}{Biomass}$$

Description:
FCR = Feed Conversion Ratio
F = Amount of cumulative feed end of harvest (kg)
Biomass = final shrimp (kg)

d. Survival Rate (SR)

Measurement of survival rate can be done using the formula according to Haliman and Adiwijaya (2005), the formula for calculating survival rate (SR) is as follows:

$$SR = \frac{Nt}{No} \times 100\%$$

Description:
SR = Survival Rate (%)
Nt = Number of shrimp at harvest
No = Number of initial stocking of shrimp

Water quality parameters

Water quality measurements included temperature, DO, salinity, pH, ammonia, nitrite, phosphate, Total Organic Matter (TOM) and alkalinity. Water quality measurements such as pH, Dissolved Oxygen (DO), temperature and salinity were carried out in situ (at the study site), while measurements of ammonia, nitrite, phosphate, TOM and alkalinity were carried out by taking water samples. Sampling of pond water was carried out using a sample bottle. Water samples were taken at a depth of 50 cm or in the water column. Furthermore, the water samples were analyzed at the PT. Indonesia Evergreen Agriculture, Paiton, East Java.

Data analysis

The data collected includes productivity, average daily growth, feed conversion ratio and survival rate were displayed in histogram graphic. Water quality data was displayed in tabular form. All of data collected described descriptively.

Result

Observations on the performance of vannamei shrimp culture at low salinity based on productivity, average daily growth, feed conversion ratio, and survival rate can be seen in Figure 1.

The productivity of vannamei shrimp culture salinity in 3 ponds for 3 maintenance cycles ranged from 2.35 to 3.69 kg/m^2. Productivity tends to increase in 3 cycles of cultivation, except in pond B where productivity tends to decrease compared to the first cycle. Average daily growth (ADG) in aquaculture ponds ranges from 0.26 – 0.36 g/day. ADG values in pond A tend to be decrease for 3 cycles, while ADG in pond B and C ranged from 0.29 – 0.3 g/day and 0.26-0.28 g/day, respectively. The survival rate in 3 cultivation ponds for 3 maintenance cycles ranged from 61 – 98%, overall survival rate for 3 maintenance cycles tended to increase in each cycle, except for pond A which had decreased in the second cycle. The feed conversion ratio ranges from 1.01 to 1.62. The overall FCR value in 3 cultivation ponds for 3 cycles decreased in each cycle, except for pond A, the highest FCR value was recorded in the second cycle.

Water quality parameters for 3 maintenance cycles including temperature, dissolved oxygen, pH, phosphate, ammonia and TOM showed the optimal range for vannamei shrimp culture based on water quality standards for intensive vannamei shrimp culture (SNI 01-7246-2006). Meanwhile, the value of nitrite and alkalinity based on measurements exceeds the optimal standard (Table 1).

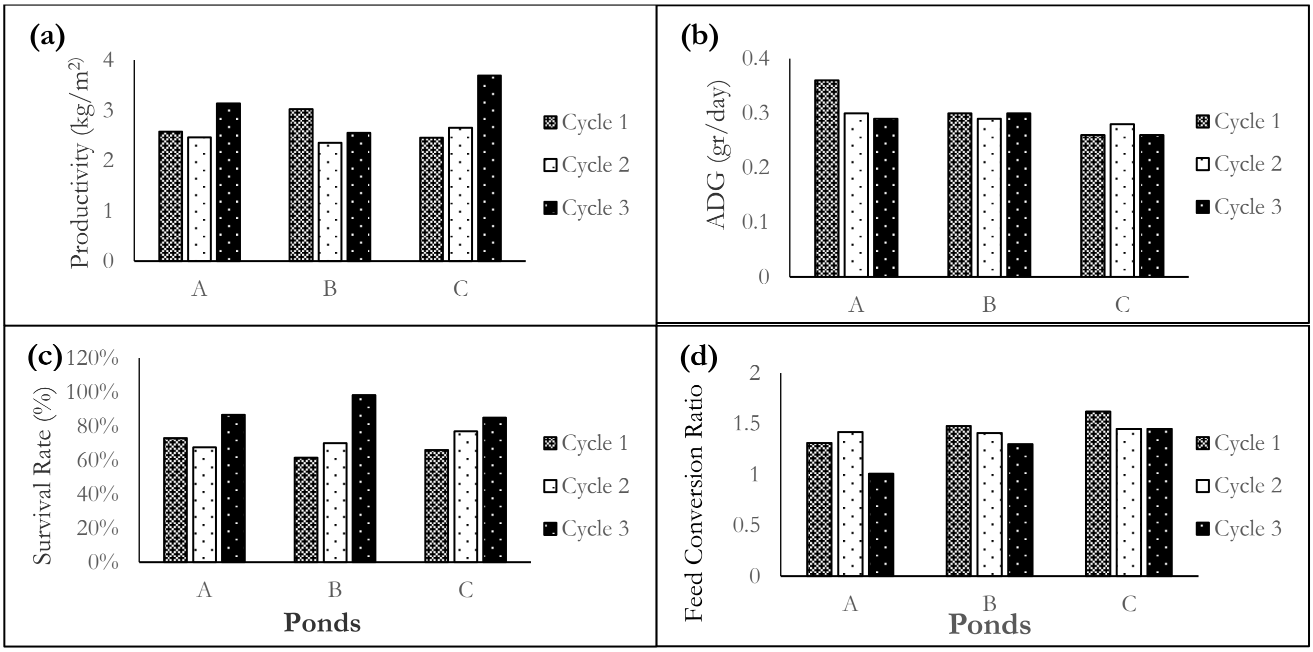

Figure 1. Performance of vannamei shrimp culture at low salinity in ponds A, B and C for 3 cycles. maintenance; (a) productivity; (b) average daily growth (adg); (c) survival rate; (d) feed conversion ratio.

Table 1. Water quality parameters in low salinity vannamei shrimp culture for 3 maintenance cycles.

Water Quality Parameters	Unit	Maintenance Cycles*			Optimal Level (SNI 01-7246-2006)
		1	2	3	
Temperature	°C	27,4 - 27,6	27,4 - 27,7	27,3 - 27,6	28,5 - 31,5
Dissolved Oxygen	mg L^{-1}	5,9 - 6,2	6,5 - 6,7	6,5 - 6,6	min. 3,5
Salinity	g L^{-1}	7-8	7-8	7-8	15 - 25
pH	-	7,92 - 8,08	8,09 - 8,12	8 - 8,1	7,5 - 8,5
Ammonia	mg L^{-1}	0,005	0,001 - 0,016	0,002 - 0,009	max. 0.01
Nitrite	mg L^{-1}	0,125 - 0,175	0,014 - 0,17	0,08 - 0,12	min. 0,01
PO_4	mg L^{-1}	0,659 - 0,687	0,838 - 0,914	1,1 - 1,2	min. 0,1
TOM	mg L^{-1}	12,64 - 17,7	10,11 - 11,38	11,4 - 12	max. 55
Total alkalinity	mg L^{-1}	284 - 292	306 - 313	305 - 310	100 - 150

*Note: Water quality data in each cycle is the range of water quality data measured in ponds A, B and C

Figure 2. Shrimp affected by White Feces Disease (WFD).

Discussion

Productivity is one of the determining factors for increasing the production of cultivation activities (Dewi, 2019). In this study, productivity that can be achieved in low salinity vannamei shrimp culture reached more than 2.35 kg/m². Supono (2019) reported that vannamei shrimp culture with low salinity (4 ppt) has a productivity of 1 kg/m², a stocking density of 70 shrimp/m² in a pond area of 2,000 m². Esparza-Leal *et al.* (2009) reported the productivity of *L. vannamei* with low salinity (0.52-0.88 ppt), stocking density of 200 shrimp/m² in a pond area of 3.14 m² was 1.08 – 1.19 kg/m². Meanwhile, Cahyanurani and Hariri (2021) reported the productivity of intensive shrimp ponds with higher salinity (11-14 ppt), stocking density of 235 shrimp/m² in a pond area of 907 m² was 2.36 – 2.4 kg/m². According to Rizky *et al.* (2021), intensive culture system with higher salinity, stocking density of 142 - 159 shrimp/m² in a pond area of 1.116 – 2.500 m² was 1,58 – 2,12 kg/m². This present result

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confirms reports that *L. vannamei* cultivated in low salinity can support production equal to that reported with higher salinity water. The high productivity is thought to be influenced by several factors, such as optimal water quality management through daily water changes, optimal stocking for both the number of stockings and the stocking procedure. According to (Lailiyah *et al*., 2018), pond productivity is influenced by the number of stockings, maintenance age, harvest tonnage and final average shrimp weight. High productivity is also supported by environmental quality, environmental management and the application of good cultivation technology (Maarif and Somamiharja, 2000).

Average daily Growth (ADG) for 3 maintenance cycles is above 0.26 g/day. According to (Lailiyah *et al*., 2018), ADG values to be achieved in cultivation when they are in the range of 0.2 - 0.23 g/day. These results show a higher value when compared to the research of Rahman *et al.* (2016) at 15 ppt salinity of 0.07 g/day and research by Lusiana *et al.* (2021) reported ADG values in intensive ponds with salinity above 28 ppt, namely 0.18 and 0.19 g/day. The ADG value which was quite high during the study was thought to be due to the low salinity during rearing which supported more optimal shrimp growth. According to (Rahman *et al*., 2016), the lower the salinity, the better the growth of shrimp. This is due to the low salinity treatment shrimp, more energy is used for the growth process than the osmoregulation process. This is inversely proportional to shrimp reared at high salinity.

Survival rate is an important monitoring in aquaculture because it serves as a guideline or reference for how many shrimp live at the end of their maintenance period (Renitasari *et al*., 2021). Survival rate in 3 cultivation ponds for 3 maintenance cycles ranged from 61 – 98%, overall survival rate for 3 maintenance cycles tended to increase in each cycle. Esparza-Leal *et al.* (2009) reported that low-salinity shrimp culture with a rearing period of 84 days had an SR of 76.35 – 79.55%. According to Anita *et al.* (2017), with salinity 10 ppt obtained an SR of 88.3% with an optimal SR of 100% at a salinity of 17.5 ppt. Different results reported by Aziz (2010), vannamei shrimp rearing at low salinity (10 ppt, 5 ppt, and 0 ppt) still did not show optimum growth and survival rates, the optimum result of SR was found in higher salinity (30 ppt) reached 77%. Furthermore, according to Febriania *et al.* (2018), shrimp rearing with a salinity of 10 ppt with a stocking density of 150-200 fish/m^2 has an SR ranging from 70.83 - 92.31%. Based on observations, the SR in the first cycle ranged from 61-73%, the second cycle was ranged from 67-77% and the third cycle was ranged from 86-98%. When compared with other studies with higher salinity, the survival rate in this study with lower salinity (6-8 gL^{-1}) was able to show a fairly good SR value. Overall, the survival rate in low salinity cultivation in the first cycle had moderate performance, while in the second and third cycles, the performance was improving. According to Widigdo (2013), the survival rate is categorized as good if the SR value is > 70%, for the medium category SR is 50-60%, and in the low category the SR value is <50%. Renitasari *et al*., (2021) reported that the survival rate of shrimp farming reached more than 86%, including the high category.

The low SR in the first cycle was because the shrimp were exposed to WFD disease during the rearing period, thus causing higher shrimp mortality. Shrimp that are attacked by WFD have the characteristics of white dirt floating on the surface of the water and decreased appetite drastically, white hepatopancreas, this condition will continue and cause the shrimp to become porous if handled and shrimp growth slows down or no growth at all (Figure 2). White Feces Disease is caused by poor water quality, this disease causes a decrease in shrimp appetite so that it has an impact on the slow growth of vannamei shrimp and if left unchecked has the potential to cause death in vannamei shrimp culture (Febrianti, 2019).

Feed conversion ratio (FCR) is related to the efficiency of feed absorption by shrimp, where a lower FCR value indicates that the feed provided is more efficient in supporting shrimp growth (Rizky *et al*., 2022). Based on the results of the study, the FCR value of shrimp decreased in each cycle. The FCR value of vannamei shrimp at low salinity ranged from 1.01 to 1.62 with an average FCR of 1.3 ± 0,16. Samocha *et al.* (2004) reported that the production of vannamei shrimp with low salinity at high and low stocking densities had FCR values ranging from 2.11 to 2.75. Meanwhile, Esparza-Leal *et al.* (2009) reported that the FCR value in low salinity shrimp culture ranged from 1.35 to 1.58. These results indicate that the FCR value in this study is better. According to Witoko *et al.* (2018), in general, the FCR of shrimp cultured in ponds ranges from 1.3 – 1.7.

One of the successes in cultivation is determined by the quality of the media water which has a large enough influence on the growth of organisms that live in water (Ariadi *et al*., 2021; Witoko *et al*., 2018). The water quality observed during low-salinity vannamei shrimp culture included temperature, dissolved oxygen, salinity, Ph, ammonia, nitrite, PO_4, TOM and alkalinity. In general, the water quality parameter values obtained are still within the standard limits of shrimp maintenance. The values of temperature, dissolved oxygen, pH, phosphate, ammonia, and TOM indicate the optimal range for vannamei shrimp culture based on water quality standards for intensive vannamei shrimp culture (SNI 01-7246-2006). Meanwhile, the value of nitrite and alkalinity based on measurements exceeds the optimal standard. Nitrite levels during the rearing period ranged from 0.014 – 0.175 mg L^{-1}, this nitrate level exceeded the maximum SNI level, which was 0.01 mg L^{-1}, but this nitrite level could still be tolerated by vannamei shrimp during the rearing period. According to Rahmawati (2019), an increase in concentration of 1 – 5 mg L^{-1} in 15 mg L^{-1} salinity environment can reduce productivity including survival rate, absolute weight growth, and growth in length and weight. Nkuba *et al.* (2021) reported that concentrations of more than 1 mg L^{-1} ammonia and nitrite could affect the prevalence of parasitic infections in shrimp ponds. So that the level of nitrite during maintenance which is still below 1 mg L^{-1} is still relatively safe for shrimp growth.

Alkalinity is the amount of carbonate, bicarbonate, and hydroxide contained in water. Alkalinity is an important key in water because of its ability to maintain a low pH level and water alkalinity is a poor buffer against changes in pH (Suwoyo, 2017). Alkalinity during the rearing period ranged from 284 - 313 mg L^{-1}, this level of alkalinity can still be tolerated by vannamei shrimp. According to Sitanggang and Amanda (2019), a good alkalinity level for shrimp rearing is >20 mg L^{-1} and not more than 500 mg L^{-1}.

Conclusion

Vannamei shrimp culture at low salinity (6-8 mg L^{-1}) has the potential to be developed. Research on 3 cycles of vannamei shrimp culture with low salinity overall showed the productivity for 3 cycles of maintenance ranged from 2.35 to 3.69 kg/m^2. ADG values in aquaculture ponds ranged from 0.26 – 0.36 g/day. The survival rate in 3 cultivation ponds for 3 maintenance cycles ranged from 61 – 98% and feed conversion ratio from 1.01 – 1.62. Water quality including temperature, dissolved oxygen, pH, phosphate, ammonia, and TOM indicate the optimal range for vannamei shrimp culture based on water quality standards for intensive vannamei shrimp culture (SNI 01-7246-2006), while nitrite and alkalinity exceed the SNI standard but this nitrite and alkalinity level could still be tolerated by vannamei shrimp during the rearing period. Overall, water quality during the rearing period can still support the growth of vannamei shrimp.

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