REKAYASA
Journal of Science and Technology
https://journal.trunojoyo.ac.id/rekayasa

Rekayasa, 2021; 14(3): 340-347
ISSN: 0216-9495 (Print)
ISSN: 2502-5325 (Online)

Effects of Dietary Salt-Based Minerals and Phosphorus Supplements on Mean Body Weight, Survival Rate and Feed Conversion Ratio of White Shrimp Reared in Brackish Water

Nizar Amir[1*], Makhfud Efendy[2], Agriananta Fahmi Hidayat[3]
[1]Department of Mechanical Engineering, University of Trunojoyo Madura
[2]Department of Marine Science, University of Trunojoyo Madura
Jl. Raya Telang 02 Kamal Bangkalan Madura 69162 Jawa Timur
[3]Department of Agricultural Engineering, University of Mataram
Jl. Majapahit 62 Selaparang Kota Mataram 83115 Nusa Tenggara Barat 83115
*nizar.amir@trunojoyo.ac.id
DOI: https://doi.org/10.21107/rekayasa.v14i3.11808

ABSTRACT

This study aimed to examine the impact of dietary salt-based mineral and phosphorus supplements on mean body weight, survival rate, and feed conversion ratio of Litopenaeus vannamei (white shrimp) reared in brackish water. The experiment was performed randomized design with three replicates in each treatment used twelve 40 L rectangular polymethyl methacrylate containers reared 45 days. The four treatments in this study were based on the concentration of salt-based mineral and phosphorus supplements (control or 0 ppm, one ppm, two ppm, and three ppm) in dietary of white shrimp. The results showed that using salt-based mineral and phosphorus supplements in dietary of white shrimp positively impacts mean body weight, survival rate, and feed conversion ratio. Increasing the concentration of salt-based mineral and phosphorus supplements increased mean body weight and survival rate and reduced feed conversion ratio of white shrimp. The mean body weight, survival rate, and feed conversion ratio of white shrimp were achieved with three ppm of dietary salt-based mineral and phosphorus supplements reared 45 days was 5.98 gr, 88.57%, and 1.45, respectively.

***Key words** : salt, dietary supplements, litopenaeus vannamei, brackish water, white shrimp*

INTRODUCTION

The Litopenaeus Vannamei (white shrimp) is one of the most essential farmed shrimp species and has played a critical role in the world aquaculture business (Lee & Lee, 2018). In Addition, It is suitable for human health since it contains rich protein, Omega-3 Fatty Acids, a variety of minerals, and vitamins but is low in calories and fat (Larsen et al., 2011; Phadtare et al., 2021). White shrimp aquaculture has been rapidly developing in many regions of the world for decades, such as in China (Chang et al., 2020), Thailand (Sampantamit et al., 2020), India (Chellapandi, 2021), Vietnam (Nguyen et al., 2019), Indonesia (Azizah et al., 2020) and Brazil (Valenti et al., 2021). One of the reasons for the rapid development of white shrimp aquaculture is its tolerance of a wide range of salinity from 0.5 to 40 ppt (Gao et al., 2016).

Farmers in Indonesia have successfully reared white shrimp in brackish water as a solution to avoid disease and water quality degradation. (Supono, 2021). The farmers using brackish groundwater as water resources for supplying water to shrimp aquaculture. However, brackish water has low ionic composition caused low growth performance during reared white shrimp in brackish water (Suguna, 2020). Salt and phosphates are widely used in white shrimp culture in brackish water to improve performance (Faithong et al., 2006). Adding magnesium, calcium, potassium, sodium, chloride, sulfate, bicarbonates, and carbonates might be required to adjust the ionic water profile

Article History:
Received: August, 30th 2021; **Accepted**: November, 17th 2021
Rekayasa ISSN: 2502-5325 has been Accredited by Ristekdikti (Arjuna) Decree: No. 23/E/KPT/2019 August 8th, 2019 effective until 2023

Cite this as:
Amir, N., Efendy, M & Hidayat, A.F. (2021*). Effect of Dietary Salt Based Minerals and Phospourus Supplements on Mean Body Weight, Survival Rate and Food Conversion Ratio of White Shirmp Reared in Brackish Water*. Rekayasa 14 (3). 340-347.
doi: https://doi.org/10.21107/rekayasa.v14i3.1808.

when rearing a white shrimp on brackish water (Zacarias et al., 2019).

Potassium, calcium, sodium, and chloride play a crucial role in the osmoregulatory process of white shrimp (Valenzuela-Madrigal et al., 2017). Magnesium is important to improve the growth, survival, and osmoregulation of culturing white shrimp in brackish water (McGraw & Scarpa, 2003), while sodium carbonate and bicarbonate improve water quality (Furtado et al., 2011). In Indonesia, a white shrimp farming pond is frequently challenged to heavy rainfall and reduced salinity, even in a seawater pond. The additional mineral is required when the salinity tends to decrease. Zacarias et al. (2019) reported significant improvement in the survival rate of white shrimp reared in brackish waters by adding potassium and magnesium.

However, different potassium and magnesium concentrations do not improve the performance of white shrimp culture in low-salinity water. Magnesium is the essential mineral for dietary white shrimp reared in brackish water (K. M. Cheng et al., 2005). The survival rate was more than 80% for reared white shrimp in salinity water for eight weeks. 3,2 g and 1,6 g magnesium per 1 kg diet was the maximum value to achieve the highest weight gain and survival rate, respectively. Galkanda-Arachchige et al. (2021) examine the impact of varying magnesium levels in brackish water on white shrimp culture performance and product quality. After the six-week culture period, increased magnesium concentration significantly enhances the growth performance of white shrimp.

Nehru et al., (2018) investigate the effect of sodium, potassium, magnesium supplementation on growth and survival rate of white shrimp in brackish water. The study concluded that using additional mineral supplementation improved the growth and servival of white shrimp in brackish water. The highest growth performance when using dietary minerals supplementation of 3,92 g of potassium, while the highest survival rate achieved when using 10 g of potassium and 20 g of natrium. Another researcher discovered a solution to reduce the high cost of mineral supplementation by using a low-cost salt mixture (H. S. C. Galkanda-Arachchige et al., 2020). An agriculture grade of sodium chloride, magnesium chloride, magnesium sulphate, potassium oxide, calcium chloride, and sodium bicarbonate was mixed as source compounds to produce a salt mixture. The findings indicate that a low-cost salt mixture could be an effective method of reducing production costs in low-salinity white shrimp aquaculture. The on-farm evaluation of using a low-cost salt mixture was conducted at Greene Prairie Aquafarm in 800-L circular polypropylene tanks to confirm the laboratory investigation results (H. Galkanda-Arachchige et al., 2020). The result shows that a low-cost salt mixture can be implemented on-farm and is a great way to reduce production costs in white shrimp aquaculture.

In addition, phosphorus (P) is an essential dietary nutrient for white shrimp and improved the survival rate and weight gain (Truong et al., 2020). Lemos et al., (2021) examined performance of monocalcium phosphate, ammonium dihydrogen phosphate, and dicalcium phosphate in diets for white shrimp. When used additional inorganic phosphates were in diets of white shrimp improved survival rate above 90%. Most performance values showed ammonium dihydrogen phosphate diets greater than another inorganic phosphate. Due to the growth-related molting process, shrimp require an extra mineral such as phosphate.

The effects of feeding phosphorus and a calcium-phosphorus combination on the growth performances and tissue mineralization of white shrimp reared in low-salinity water were investigated by Kai Min Cheng et al., (2006). In conclusion, growth performance and tissue mineralization of white shrimp were significantly affected by dietary phosphorus in low-salinity water. The combination of calcium-phosphorus produced a better growth performance than single diets materials.

Finally, the effects of dietary minerals supplements have been well documented in phosphorus reared in brackish water. However, information on the effect of dietary salt-based minerals combined with phosphorus supplements on the performance of phosphorus reared in brackish water is limited. After the success of developing mineral-phosporous supplements by blending low-cost salt and phosporous materials, the objective of this study was to analyze the efficacy of the combination salt-based mineral combined with phosphorus supplements on the performance of white shrimp aquaculture. The effect of dietary salt-based minerals and phosphorus supplements will be evaluated on the mean body weight, survival rate, and feed conversion ratio of white shrimp reared in brackish water.

METHODS

Experimental design & culture conditions

The experiment was conducted in Salt Laboratory, University of Trunojoyo Madura, East Jawa, Indonesia. The excellent uniformity and robust postlarvae of Litopenaeus Vannamei (white shrimp) (PL20) used in the experiment had a mean weight of 0.025 g and were free of pathogens. A local commercial certified hatchery supplied the postlarvae of white shrimp. A 45-day experiment in a 40 L rectangular polymethyl methacrylate aquarium in density 63 shrimp/m^2 with a completely randomized experimental design was conducted (da Rocha Soares Neto et al., 2019).

Table 1**.** Chemical Composition of Feed Used in This Study

Chemical composition	Unit	Content
Ash	%	12
Crude fat	%	7
Crude fiber	%	3
Crude protein	%	36
Energy	Mj/kg	17
Fish oil	%	6
Moisture	%	11

Four treatments were developed in this experiment based on the concentration of salt-based mineral and phosphorus supplements (control or 0 ppm, one ppm, two ppm, and three ppm) in dietary of white shrimp, with three replicate tanks each. Shrimp were fed by commercial shrimp feed four times each day (7 am, 12 pm, 5 pm, and 10 pm), and the quantity is determined by the feed manufacturer's specifications. The commercial shrimp feed chemical composition used in this study was shown in Table 1. Each aquarium was supplied by an aerator driven by a 12-watt electrical motor and provide 3,75 L/min of air to keep optimum dissolved oxygen levels. Shrimp were weighed and counted every one week prior to analysis. Temperature, pH, and dissolved oxygen levels were monitored periodically, and maintenance at 28-30 ^oC, 7.8-8.2, and >7 mg/L, respectively. Salinity was maintained at approximately 15 - 20 ppt during the experiment, and adding clean brackish water was to replace the evaporation loss.

Table 2. The Composition of The Dietary Salt-Based Mineral and Phosphorus Supplement

Ingredients	Dry weight (%)
Calcium chloride	20
Magnesium chloride	15
Potassium chloride	10
Sodium chloride	15
Sodium bicarbonate	10
Calcium hydroxide	5
Magnesium sulfate	5
Sodium metasilicate	15
Mono ammonium phosphate	5

Dietary salt-based mineral and phosphorus supplements mixture

Dietary salt-based mineral and phosphorus supplement materials were obtained from local material suppliers and processed by our laboratory prior used this study. Calcium chloride, magnesium chloride, potassium chloride, sodium chloride, sodium bicarbonate, calcium hydroxide, magnesium sulfate, sodium metasilicate, and mono ammonium phosphate were used as source compounds. The detailed composition of the dietary supplements is given in Table 2.

Prior to use for the study, all materials were first ground to small particle size in a mechanical grinder and blew with a hot air blower to reduce the moisture content, as shown in Figure 1. After finish in the mechanical grinder section, all dry materials were mixed in a rotary batch mixer for 1 hour to ensure uniformity. Next, the dietary supplements material was carefully packed in grade polypropylene multiwall paper bag, as shown in Figure 2. After the production finish and before use in the experimental trial, dietary salt-based mineral and phosphorus supplements were carefully weighed and mixed thoroughly with shrimp feed base on the experimental concentration.

Data calculation

Shrimp were weighed and counted to determine mean body weight (MBW), survival rate (SR), and feed conversion ratio (FCR), determine to the formula (Huang et al., 2017).

MBW = (weight of total shrimp (g) / number of shrimp)

SR = (final number of live shrimp / initial number of shrimp x 100)
FCR = (feed shrimp consumed (g) / weight gain of shrimp (g))

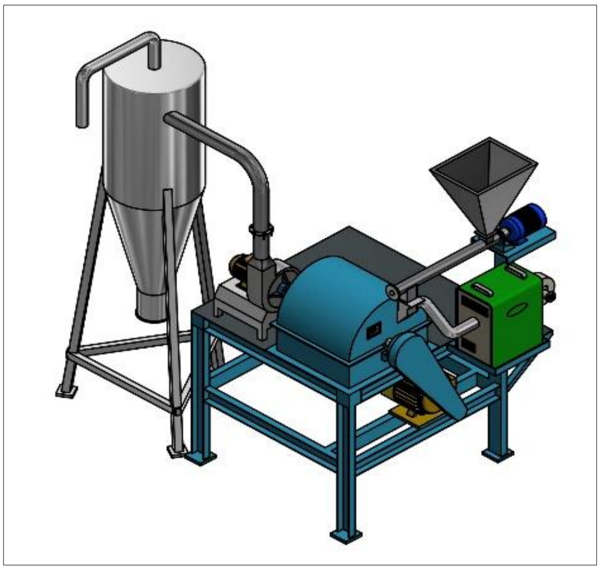

Figure 1. Mechanical Grinder with Hot Air Dryer Equipment for Salt-Based Mineral and Phosphorus Supplement Production

Figure 2. The Dietary Supplements used in The Present Study

RESULTS AND DISCUSSION

The mean body weight of white shrimp fed with dietary salt-based minerals and phosphorus supplements

After the 45-day experiment trial at brackish water, the mean body weight of white shrimp ranged from 5,398 g to 5,981 g, with positive differences between treatments. White shrimp after being reared for 45 days in brackish water, can be seen in Figure 3. The mean body weight presented in the present work was lower than other work (Huang et al., 2017; Jahan et al., 2018) but corresponds with this work (I. Patrick Saoud et al., 2007). This present work using clear water system lack availability of natural food like biofloc or plankton system. In biofloc and plankton systems supply other natural food apart from dietary feed and mineral supplements in the form of microalgae and bacteria (Ballester et al., 2010; Ray et al., 2010). The mean body weight of white shrimp was checked every week for different treatments and is presented in Figure 4. Increased dietary supplement concentration from 0 to 3 ppm causes an increase in mean body weight, from 5,398 g to 5,981 g. In brackish water, more mineral concentration and proper ionic ratio lead to needing more mineral supplementation to reduce osmotic stress and improve the growth performance (Saoud et al., 2003).

Figure 3. White Shrimp After Being Reared for 45 Days in Brackish Water

The survival rate of white shrimp fed with dietary salt-based minerals and phosphorus supplements

The survival rate of white shrimp in various experimental treatments reared in 45 days at brackish water is presented in figure 5. The survival rate increased from 68,57% to 88,57% at the 45 days when the dietary supplement was increased from 0 to 3 ppm. Increasing dietary supplements generated more mineral profiles and essential ions into the water, leading to higher shrimp growth and survival rate (Davis et al., 2005; Kumar et al., 2018; Valencia-Castañeda et al., 2017). Bicarbonate and phosphorus improved the mortality during the white shrimp molting stage, and then the survival rate was enhanced (Kai Min Cheng et al., 2006; Valenzuela-Madrigal et al., 2017).

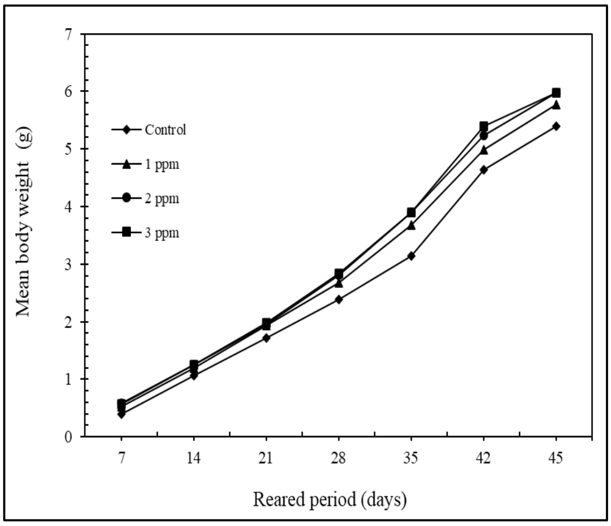

Figure 4. Weekly Observed Mean Body Weight of White Shrimp With Different Treatment Dietary Salt-Based Minerals And Phosphorus Supplements in Brackish Water

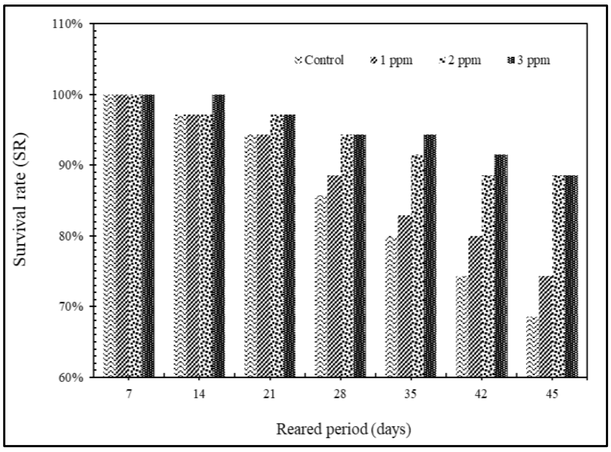

Figure 5. Weekly Observed Survival Rate of White Shrimp With Different Treatment Dietary Salt-Based Minerals And Phosphorus Supplements In Brackish Water

The feed conversion ratio of white shrimp fed with dietary salt-based minerals and phosphorus supplements

The feed conversion ratio in different experiments of white shrimp reared 45 days in brackish water was presented in figure 6. The range for feed conversion ratio observed at 45 days of experiment was found in between 1,45 (3 ppm) and 1,67 (0 ppm). Using 2 and 3 ppm of dietary supplement achieved the feed conversion ratio 1,42 and 1,45, respectively, as healthy shrimp (Tang et al., 2016). Increasing the dietary supplement improved the feed conversion ratio by enhancing white shrimp's metabolism (Liu et al., 2014). It indicates that shrimps well-digested feed given during the reared. Magnesium also plays a critical role in the metabolism of white shrimp (Roy et al., 2007).

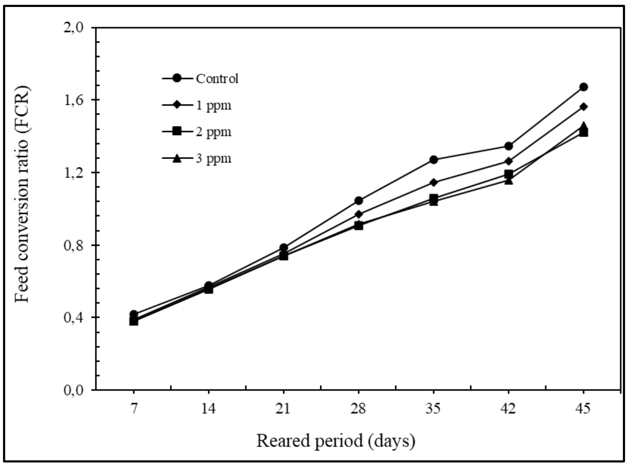

Figure 6. Weekly Observed Feed Conversion Ratio of White Shrimp With Different Treatment Dietary Salt-Based Minerals and Phosphorus Supplements in Brackish Water

CONCLUSION

In conclusion, the mean body weight, survival rate, and feed conversion ratio of white shrimp were significantly influenced by dietary salt-based minerals and phosphorus supplements reared in brackish water. Giving 2 - 3 ppm is the proper concentration to improve the quality of shrimp farming. However, application on-farm may be higher due to the complexity of white shrimp aquaculture. The combination of salt-based minerals and phosphorus is an appropriate mixture to support the growth of the white shrimp and improve water quality. This successful production of the dietary supplements was helping to stimulate the growth of the shrimp industry further in Indonesia and Southeast Asia.

REFERENCES

Azizah, F. F. N., Ishihara, H., Zabala, A., Sakai, Y., Suantika, G., & Yagi, N. (2020). Diverse perceptions on eco-certification for shrimp aquaculture in Indonesia. *Sustainability (Switzerland)*, *12*(22), 1–19. https://doi.org/10.3390/su12229387

Ballester, E. L. C., Abreu, P. C., Cavalli, R. O., Emerenciano, M., de Abreu, L., & Wasielesky, W. (2010). Effect of practical diets with different protein levels on the performance of Farfantepenaeus paulensis juveniles nursed in a zero exchange suspended microbial flocs intensive system. In *Aquaculture Nutrition* (Vol. 16, Issue 2, pp. 163–172). https://doi.org/10.1111/j.1365-2095.2009.00648.x

Chang, Z. Q., Neori, A., He, Y. Y., Li, J. T., Qiao, L., Preston, S. I., Liu, P., & Li, J. (2020). Development and current state of seawater shrimp farming, with an emphasis on integrated multi-trophic pond aquaculture farms, in China – a review. *Reviews in Aquaculture*, *12*(4), 2544–2558. https://doi.org/10.1111/raq.12457

Chellapandi, P. (2021). Development of top-dressing automation technology for sustainable shrimp aquaculture in India. *Discover Sustainability*, *2*(1). https://doi.org/10.1007/s43621-021-00036-9

Cheng, K. M., Hu, C. Q., Liu, Y. N., Zheng, S. X., & Qi, X. J. (2005). Dietary magnesium requirement and physiological responses of marine shrimp Litopenaeus vannamei reared in low salinity water. *Aquaculture Nutrition*, *11*(5), 385–393. https://doi.org/10.1111/j.1365-2095.2005.00364.x

Cheng, Kai Min, Hu, C. Q., Liu, Y. N., Zheng, S. X., & Qi, X. J. (2006). Effects of dietary calcium, phosphorus and calcium/phosphorus ratio on the growth and tissue mineralization of Litopenaeus vannamei reared in low-salinity water. *Aquaculture*, *251*(2–4), 472–483. https://doi.org/10.1016/j.aquaculture.2005.06.022

da Rocha Soares Neto, J., de Azevedo Silva Ribeiro, F., Gonçalves, A. A., & Coelho Emerenciano, M. G. (2019). Tilapia processing waste silage (TPWS): An alternative ingredient for Litopenaeus vannamei (Boone, 1931) diets in biofloc and clear-water systems. *Aquaculture and Fisheries*, *4*(5), 214–218. https://doi.org/10.1016/j.aaf.2019.04.005

Davis, D. A., Boyd, C. E., Rouse, D. B., & Saoud, I. P. (2005). Effects of potassium, magnesium and age on growth and survival of Litopenaeus vannamei post-larvae reared in inland low salinity well waters in West Alabama. *Journal of the World Aquaculture Society*, *36*(3), 416–419. https://doi.org/10.1111/j.1749-7345.2005.tb00346.x

Faithong, J., Raksakulthai, N., & Chaiyawat, M. (2006). Effect of phosphates and salt on yield and quality of cooked white shrimp (Penaeus vannamei). *Kasetsart Journal - Natural Science*, *40*(SUPPL.), 108–116.

Furtado, P. S., Poersch, L. H., & Wasielesky, W. (2011). Effect of calcium hydroxide, carbonate and sodium bicarbonate on water quality and zootechnical performance of shrimp Litopenaeus vannamei reared in bio-flocs technology (BFT) systems. In *Aquaculture* (Vol. 321, Issues 1–2, pp. 130–135). https://doi.org/10.1016/j.aquaculture.2011.08.034

Galkanda-Arachchige, H., Roy, L. A., Dahl, S., James, J., Kelly, A. M., & Allen Davis, D. (2020). Laboratory and on-farm evaluation of low-cost salt mixtures for use during salinity acclimation and the nursery phase of Pacific white shrimp (Litopenaeus vannamei). *Aquaculture Research*, *51*(8), 3460–3471. https://doi.org/10.1111/are.14681

Galkanda-Arachchige, H. S. C., Roy, L. A., & Davis, D. A. (2020). Evaluation of an alternative salt mixture to culture Pacific white shrimp (Litopenaeus vannamei) in inland aquaculture. *Aquaculture Research*, *51*(9), 3540–3550. https://doi.org/10.1111/are.14691

Galkanda-Arachchige, H. S. C., Roy, L. A., & Davis, D. A. (2021). The effects of magnesium concentration in low-salinity water on growth of Pacific white shrimp (Litopenaeus vannamei). *Aquaculture Research*, *52*(2), 589–597. https://doi.org/10.1111/are.14916

Gao, W., Tian, L., Huang, T., Yao, M., Hu, W., & Xu, Q. (2016). Effect of salinity on the growth performance, osmolarity and metabolism-related gene expression in white shrimp Litopenaeus vannamei. *Aquaculture Reports*, *4*, 125–129. https://doi.org/10.1016/j.aqrep.2016.09.001

Huang, F., Wang, L., Zhang, C. xiao, & Song, K. (2017). Replacement of fishmeal with soybean meal and mineral supplements in diets of

Litopenaeus vannamei reared in low-salinity water. In *Aquaculture* (Vol. 473, pp. 172–180). https://doi.org/10.1016/j.aquaculture.2017.02.011

Jahan, I., Reddy, A. K., Sudhagar, S. A., Harikrishna, V., Singh, S., Varghese, T., & Srivastava, P. P. (2018). The effect of fortification of potassium and magnesium in the diet and culture water on growth, survival and osmoregulation of pacific white shrimp, Litopenaeus vannamei reared in inland ground saline water. In *Turkish Journal of Fisheries and Aquatic Sciences* (Vol. 18, Issue 10, pp. 1235–1243). https://doi.org/10.4194/1303-2712-v18_10_10

Kumar, A., Reddy, A. K., Rani, A. M. B., Rathore, G., & Lakra, W. S. (2018). *Growth and digestive enzymatic activity of Litopenaeus vannamei raised in bio floc systems with different C / N ratios in ground saline water Growth and digestive enzymatic activity of Litopenaeus vannamei raised in bio floc systems with different C / N ratios in ground saline water*. *August*.

Larsen, R., Eilertsen, K. E., & Elvevoll, E. O. (2011). Health benefits of marine foods and ingredients. *Biotechnology Advances*, *29*(5), 508–518. https://doi.org/10.1016/j.biotechadv.2011.05.017

Lee, C., & Lee, K. J. (2018). Dietary protein requirement of Pacific white shrimp Litopenaeus vannamei in three different growth stages. *Fisheries and Aquatic Sciences*, *21*(1), 1–6. https://doi.org/10.1186/s41240-018-0105-0

Lemos, D., Coelho, R., Zwart, S., & Tacon, A. G. J. (2021). Performance and digestibility of inorganic phosphates in diets for juvenile shrimp (Litopenaeus vannamei): dicalcium phosphate, monocalcium phosphate, and monoammonium phosphate. *Aquaculture International*, *29*(2), 681–695. https://doi.org/10.1007/s10499-021-00651-3

Liu, H., Zhang, X., Tan, B., Lin, Y., Chi, S., Dong, X., & Yang, Q. (2014). Effect of dietary potassium on growth, nitrogen metabolism, osmoregulation and immunity of pacific white shrimp (Litopenaeus vannamei) reared in low salinity seawater. *Journal of Ocean University of China*, *13*(2), 311–320. https://doi.org/10.1007/s11802-014-2118-3

McGraw, W. J., & Scarpa, J. (2003). Minimum environmental potassium for survival of Pacific white shrimp Litopenaeus vannamei (Boone) in freshwater. *Journal of Shellfish Research*, *22*(1), 263–267.

Nehru, E., Chandrasekhara Rao, A., Pamanna, D., Priyadarshini, N., Anil Kumar, P., & Raveendra, M. (2018). Effect of Dietary Minerals Supplementation on Growth and Survival of Litopenaeus vannamei in Low Salinity Water. *International Journal of Current Microbiology and Applied Sciences*, *7*(03), 3040–3049. https://doi.org/10.20546/ijcmas.2018.703.353

Nguyen, T. A. T., Nguyen, K. A. T., & Jolly, C. (2019). Is super-intensification the solution to shrimp production and export sustainability? *Sustainability (Switzerland)*, *11*(19), 1–22. https://doi.org/10.3390/su11195277

Phadtare, I., Vaidya, H., Hawboldt, K., & Cheema, S. K. (2021). Shrimp oil extracted from shrimp processing by-product is a rich source of omega-3 fatty acids and astaxanthin-esters, and reveals potential anti-adipogenic effects in 3T3-L1 adipocytes. *Marine Drugs*, *19*(5). https://doi.org/10.3390/md19050259

Ray, A. J., Seaborn, G., Leffler, J. W., Wilde, S. B., Lawson, A., & Browdy, C. L. (2010). Characterization of microbial communities in minimal-exchange, intensive aquaculture systems and the effects of suspended solids management. *Aquaculture*, *310*(1–2), 130–138. https://doi.org/10.1016/j.aquaculture.2010.10.019

Roy, L. A., Davis, D. A., Saoud, I. P., & Henry, R. P. (2007). Effects of varying levels of aqueous potassium and magnesium on survival, growth, and respiration of the Pacific white shrimp, Litopenaeus vannamei, reared in low salinity waters. In *Aquaculture* (Vol. 262, Issues 2–4, pp. 461–469). https://doi.org/10.1016/j.aquaculture.2006.10.011

Sampantamit, T., Ho, L., Lachat, C., Sutummawong, N., Sorgeloos, P., & Goethals, P. (2020). Aquaculture production and its environmental sustainability in Thailand: Challenges and potential solutions. *Sustainability (Switzerland)*, *12*(5), 1–17. https://doi.org/10.3390/su12052010

Saoud, I. Patrick, Roy, L. A., & Davis, D. A. (2007). Chelated Potassium and Arginine

Supplementation in Diets of Pacific White Shrimp Reared in Low-Salinity Waters of West Alabama. *North American Journal of Aquaculture*, *69*(3), 265–270. https://doi.org/10.1577/a06-045.1

Saoud, Imad P., Davis, D. A., & Rouse, D. B. (2003). Suitability studies of inland well waters for Litopenaeus vannamei culture. *Aquaculture*, *217*(1–4), 373–383. https://doi.org/10.1016/S0044-8486(02)00418-0

Suguna, T. (2020). Application of Minerals in Low Saline Water Culture Systems of L. vannamei. *International Journal of Current Microbiology and Applied Sciences*, *9*(9), 516–521. https://doi.org/10.20546/ijcmas.2020.909.065

Supono. (2021). Current status of technical and economic analysis of inland shrimp culture in Lampung Province ,. *AACL Bioflux*, *14*(1), 218–226.

Tang, K. F. J., Han, J. E., Aranguren, L. F., White-Noble, B., Schmidt, M. M., Piamsomboon, P., Risdiana, E., & Hanggono, B. (2016). Dense populations of the microsporidian Enterocytozoon hepatopenaei (EHP) in feces of Penaeus vannamei exhibiting white feces syndrome and pathways of their transmission to healthy shrimp. *Journal of Invertebrate Pathology*, *140*, 1–7. https://doi.org/10.1016/j.jip.2016.08.004

Truong, H. H., Moss, A. F., Bourne, N. A., & Simon, C. J. (2020). Determining the importance of macro and trace dietary minerals on growth and nutrient retention in juvenile penaeus monodon. *Animals*, *10*(11), 1–25. https://doi.org/10.3390/ani10112086

Valencia-Castañeda, G., Millán-Almaraz, M. I., Fierro-Sañudo, J. F., Fregoso-López, M. G., & Páez-Osuna, F. (2017). Monitoring of inland waters for culturing shrimp Litopenaeus vannamei: application of a method based on survival and chemical composition. *Environmental Monitoring and Assessment*, *189*(8). https://doi.org/10.1007/s10661-017-6108-y

Valenti, W. C., Barros, H. P., Moraes-Valenti, P., Bueno, G. W., & Cavalli, R. O. (2021). Aquaculture in Brazil: past, present and future. *Aquaculture Reports*, *19*(July 2020), 100611. https://doi.org/10.1016/j.aqrep.2021.100611

Valenzuela-Madrigal, I. E., Valenzuela-Quiñónez, W., Esparza-Leal, H. M., Rodríguez-Quiroz, G., & Aragón-Noriega, E. A. (2017). Effects of ionic composition on growth and survival of white shrimp Litopenaeus vannamei culture at low-salinity well water. *Revista de Biologia Marina y Oceanografia*, *52*(1), 103–112. https://doi.org/10.4067/S0718-19572017000100008

Zacarias, S., Schveitzer, R., Arantes, R., Galasso, H., Pinheiro, I., Espirito Santo, C., & Vinatea, L. (2019). Effect of different concentrations of potassium and magnesium on performance of Litopenaeus vannamei postlarvae reared in low-salinity water and a biofloc system. *Journal of Applied Aquaculture*, *31*(1), 85–96. https://doi.org/10.1080/10454438.2018.1536009