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Research Article
Correlation of Major Mineral Properties in Brackish Water Ponds Environment and Pacific White Shrimp *Litopenaues vannamei* Survival, Growth and Production

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Abstract

Background and Objective: The physiological status of crustacean is significantly affected not only by concentration of major minerals in water environment but also by their concentration ratios. The objective of this research was to analyze the effect of major mineral concentrations and their ratios on the production performance of Pacific white shrimp *Litopenaeus vannamei*. **Materials and Methods:** Seven commercial grow out ponds were evaluated. All ponds were filled up with coastal water diluted with fresh water from nearby creek or a river with salinities of 18.0-28.8 g L^{-1}. All ponds were stocked with Specific Pathogen Free (SPF) Post Larvae 10 (PL10) at densities of 65-128 PLs m^{-2}. Shrimp were fed with commercial feed 3-5 times a day and the shrimp growth was monitored weekly. Water samples were collected from all ponds at 1-2 weeks prior to harvest for major minerals (Cl, Na, Mg, SO_4, Ca and K) analyses. **Results:** The results revealed that the variation of water salinities between 18.0-28.8 led to variation in major minerals concentration and their ratios. These ratios were also different to that of standard seawater at the same water salinities. Concentration of Mg in all ponds within those salinity ranges were markedly higher than that of standard diluted seawater at the same salinity and it varied from 1,858.0-5,958.2 mg L^{-1}. In contrast, concentration of Na and K in all ponds were markedly lower than those of standard seawater diluted to corresponding salinity and varied from 1,386.2-5,626.9 mg L^{-1} for Na and from 123.4-248.7 mg L^{-1} for K, respectively. The specific growth rate (SGR) was significantly influenced ($p<0.05$) by Na and K ions, while survival rate (SR) was significantly influenced by Mg ion and Na/K ratio. **Conclusion:** The Na and K ions were crucial for the growth, while Mg ions and Na/K ratio were crucial for survival of *L. vannamei*. These results implied that the concentrations of K, Na and Mg and their ratios were the most important factors than actual water salinity for efficient production of *L. vannamei* aquaculture.

Key words: Mineral properties, brackish water, pacific white shrimp, *Litopenaeus vannamei*, production

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pacific white shrimp *Litopenaeus vannamei* has been widely cultured worldwide. In Indonesia since it officially introduced[1] in 2002, this shrimp has dominated the production of Indonesian shrimp aquaculture. This species is mostly cultured in coastal areas, which receive water directly from the open sea. The sea water is frequently mixed with freshwater from ground or surface waters. Therefore the salinity of ponds water varies greatly from as low as 5 g L^{-1} up to 35 g L^{-1} depending on the site and quality of the freshwater[2]. In order to optimize shrimp culture production in various salinity, it is necessary to assess the impact of variability in ionic contents and their ratios in water[3,4].

The ideal ratio of major minerals in saline water would be closed to those of sea water even at the different salinities. The ratios are crucial to meet the physio-biological requirement of marine shrimp[3]. Although water salinity is in a favorable level for shrimp, imbalances major ions might negatively affect the growth and survival of shrimp[3,5]. The Pacific white shrimp *L. vannamei* has been successfully cultured in inland low saline water (<10 ppt) in Thailand but the growth performance and survival rates are in sub-optimal when the shrimp is cultured in low saline in the USA, China and Equador[6]. These differences were recognized by Boyd *et al.*[6] and in their analysis it revealed that success story of culturing marine shrimp in low saline ponds water in Thailand related to proportionalities of mineral composition in ponds water to sea water, while in other countries were generally lacking some minerals. The influences of salinity and mineral content in the culture media to growth performance and survival rate of marine shrimp has then been of interest and attracted many researcher with difference perspectives[7-12] Maica *et al.*[7] have studied the effects of salinity on performance and body composition of white shrimp juvenile in laboratory scale of 163 L tanks. They concluded that the increase in salinity from 4-32 g L^{-1} resulted positively effects on the growth and survival rate of *L. vannamei* when it is reared in super-intensive system without water exchange. Roy *et al.*[8] have reviewed paper works regarding low salinity aquaculture with *L. vannamei* which were focused on short-term bioassays with post-larvae or 4-10 weeks growth trials juvenile shrimp. They described that low salinity well water (<10 g L^{-1}) are generally deficient in K, Mg and sulfate and it have significant influenced the survival and growth, where higher K and Mg resulted better growth and survival. In other study Chitra *et al.*[9] suggested that to correct the imbalances of a particular mineral (Ca, K, Mg and Na) in low saline ponds, application of individual mineral salt may be better than mineral mixture. According to Roy and Davis[10], modification of the rearing medium with potassium and magnesium fertilizer is more effective than dietary modification technique to improve the growth, survival rate and osmoregulation in marine shrimp reared in low saline water.

Aruna and Felix[11] reported that the magnesium-calcium concentration need to be maintained at a ratio of 3:1 for the better survival and growth rate of *L. vannamei* when cultured in low saline water of <9.0 g L^{-1}. Davis *et al.*[12] described that Ca, K and Mg are the most important ions for shrimp survival. They further suggest when the Ca:K ratio in water is high, additional of K is needed to improve the survival rate of *L. vannamei*. Mortality associated with the ionic composition have also been observed in low salinity inland shrimp culture in Alabama USA[3]. The best survival and growth performance of *L. vannamei* was recognized when Na:K ratio of the water close to 28:1, which is the ratio found in natural seawater[13].

Although the significant role of the major mineral in water and their ratio to the growth and survival rate of shrimp have been published, such studies in the field and commercial scale production are limited. As mentioned above almost study in the similar topics are carried out in low saline water (<10 g L^{-1}) and in laboratory scale. Studies and publications on the relationship between major minerals proportion and survival rate as well as growth and production of *L. vannamei* reared in brackish water with higher salinity of 15-<30 g L^{-1} are limited up to now. In this context, the present study aimed to elucidate the relation between the variation of mineral properties in brackish water ponds (salinity varied from 15-<30 g L^{-1}) and the production performance of *L. vannamei* in commercial grow out ponds.

MATERIALS AND METHODS

Brackish water ponds: The present study was conducted in 7 brackish water ponds over a grow out cycle in April-August 2017. Among seven ponds, 4 ponds of each 3,600 m^2 (B5, B6, C5 and C6) were located in the north coast of Pandeglang district, province of Banten, Indonesia. The ponds were supplied with coastal water diluted naturally with creeks fresh water having salinity of 22-29 g L^{-1}. Two ponds of each 1,200 m^2 (K1 and K2) were located in the north coast of Cirebon district, province of West Java, Indonesia. These two ponds were supplied with coastal water with salinity of 20-23 g L^{-1}. Another pond of 5,000 m^2 (G14) was located in the north coast of Karawang district, province of West Java, Indonesia. This pond was supplied with coastal water mixed with river water at a salinity of 18.0 g L^{-1}. The bottom of all ponds were covered with hard density polyethylene (HDPE) plastic line except pond G14. All ponds were stocked with specific pathogen free (SPF) shrimp stadium post larvae 10 (PL10) at a density of 125-128 organism m^{-2} except one pond (G14) was stocked at a density of 65 organism m^{-2}.

Shrimp culture was carried out based on the Standard Operation Procedure (SOP) described by Widigdo[14]. Briefly, each pond was equipped with one Horse Power (HP) of electrical paddle wheel aerator for every 23,000 PLs stocked. Shrimp were fed with a commercial pellet 3-5 times a day. The feeding rate was based on the weekly growth and ages. During the first 30 days of culture, new water was added to ponds to replace water lost due to evapotranspiration, while on the 31st days onward, water exchange of 5-7% was implemented daily. Lime material such as $CaCO_3$, Ca $(OH)_2$ or dolomite were applied for all ponds to maintain water quality, and alkalinity and pH stabilities.

Water quality and minerals measurement: Water quality parameters such as pH, temperature and dissolved oxygen (DO) were measured daily at 05:00 and 14:00, using pH meter (EUTECH pHTestr10, Singapore), DO meter (YSI, Type 550A, USA). Salinity was measured once a day at 14.00 using a Master Refractometer (ATAGO Japan). Water samples were collected from all ponds at 1-2 weeks prior harvesting, stored at 4°C until further analyses, in the Laboratory of Aquatic Productivity and Environment, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor, West Java, Indonesia. Major minerals Cl, Na, SO_4 and K were analyzed by following the standard protocol recommended by Clescerl *et al.*[15], while Ca and Mg were performed based on the Indonesian National Standard[16,17] (Table 1).

Survival and growth rates of shrimp: Shrimps body weight was monitored weekly starting from 34th days of culture up to the harvest time. The shrimp was harvested after 110-120 days culture (DOC 110-120), productivity (kg ha^{-1}) was calculated by weighing of all harvested shrimp while survival rate (SR) and specific growth rate (SGR) were estimated by using the following formula[18]:

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

$$SGR = \left[\sqrt[t]{\frac{Wt}{Wo}} - 1 \right] \times 100\%$$

Table 1: Water quality analysis methods used in this study

Water quality parameters	Method of analysis
Calcium (Ca)	SNI06-6989,13-2004
Magnesium (Mg)	SNI 06-6989,12-2004
Sodium (Na)	APHA, ed 22, 2012, 3111-B
Potassium (K)	APHA, ed 22, 2012, 3111-B
Sulphate (SO_4)	APHA, ed. 22, 2012, 4500-SO4-E
Chloride (Cl)	APHA, ed 22, 2012, 4500-Cl-B
Salinity	Refractometer

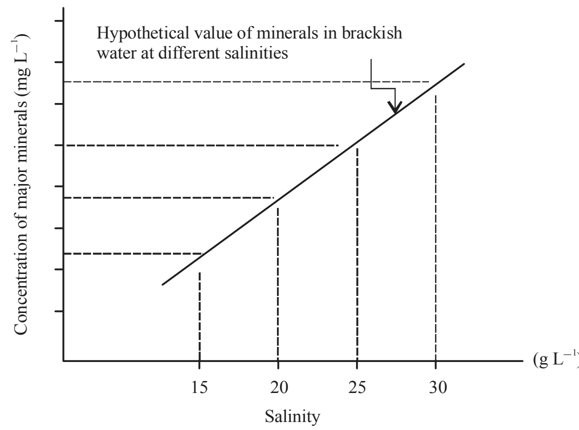

Fig. 1: Standard graphic (values) of mineral concentration of major ions in various salinities in diluted normal sea water with distilled water

where, Nt and No are total shrimps population at time t and 0, while Wt and Wo are mean body weights at time t and 0.

Data analysis: The deviation of each mineral concentration at a certain salinity between ponds water and diluted seawater was determined by using the method described by Boyd and Thunjai[6]. The primary assumption in the analyses was the natural sea water has a certain proportion of major ions chloride (Cl), sodium (Na), sulfate (SO_4), magnesium (Mg), calcium (Ca) and potassium (K) which is the most appropriate for marine shrimp culture. In this regard, it was hypothesized that in order to provide sufficient mineral concentration in water for marine shrimp culture at any salinity, especially at lower salinity than natural seawater, the mineral composition should be proportionally comparable to that of normal seawater. For further analysis, the mineral composition of normal seawater as described by Anderson[19] was used as a standard, where the major mineral content were Cl 19,345, Na 10,752, SO_4 2,701, Mg 1,295, Ca 416 and K 390 mg L^{-1}. Hence a "standard graphic" (Fig. 1) was made by plotting the concentration of each major ion in normal seawater versus decrease in sea water salinity as a hypothetical sample of normal seawater that was progressively diluted with distilled water[6]. The relationship between the major minerals concentration and salinity is a linear relationship (Fig. 1). The deviation magnitude of major ions proportions in studied ponds water from those at standard graphic, might suggest some major mineral is at adequate or inadequate concentration. To simplify this comparison visually, major ions measured in each pond water was then plotted at standard graphic . Data points above or under the line represent ionic concentration greater or less than those of diluted seawater at the same salinity.

The effect of mineral composition on growth and survival rate was analyzed by using Person's Correlation Program SPSS 20.0. To describe the relation model of this effect, multiple linear regression of Steel and Torrey[20] was used as follow:

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_m X_m + \varepsilon$$

where, Y is dependent variable, X_1 ....X_m are independent variables while ε represent the random error.

The appropriate mineral composition in water for pacific white shrimp culture was then descriptively analyzed by comparing it and making correlation to the production performance in each pond.

RESULTS

Water quality, major minerals concentration and their ratios: The average value of pH in the morning in all ponds showed a similar pH level and slightly increase in the afternoon (Table 2). The similar pattern and level was also indicated by dissolved oxygen (DO) in the morning and the afternoon. Temperatures were slightly increased from the morning to the afternoon as the increase in the sunlight intensity.

The results of the water analyses revealed that the ponds water salinities varied among the pond water. The total concentration of major minerals were lower in all studied pond compared to standard seawater, even though some individual minerals were higher. The deviation of major minerals concentration in each pond from the standard graphic were visualized in Fig. 2-4.

Chloride and SO_4 concentrations in all ponds demonstrated similar deviation pattern to standard graphic. Ponds (K1, K2, B5 and B6) demonstrated higher concentration of Cl but other ponds (G14, C5 and C6) demonstrated lower Cl concentration than those in standard seawater, even though the deviation magnitudes were considerably narrow (Fig. 2a). Sulphate concentrations in pond B5, B6, C5 and C6 were slightly higher than those in standard seawater as presented in the standard graphic. In contrast the sulphate concentrations were markedly lower in pondsG14, K1 and K2 (Fig. 2b). It was recognized that lowest concentration for both Cl and SO_4 were found in pond G14.

Concentration of Ca in pond K1, K2, C5 and C6 were very close to the standard seawater, while those in ponds B5 and B6 were markedly much higher than that of standard seawater but remarkable lowest concentration was found in pond G14 (Fig. 3a).

Concentration of Mg in all ponds water were markedly higher than that in standard seawater and the most remarkable high concentration were found in pond K1, K2 C5 and C6 while the low concentration was found in pond G14 (Fig. 3b). In contrast, concentrations of Na and K in all ponds water were markedly lower than those in standard seawater and pond G14 was remarkable the lowest concentration for both Na and K (Fig. 4a, b).

The Na/K ratio in all ponds water were lower than those in standard seawater (Fig. 4a, b), even though the deviations were considered to be narrow especially in pond B5 and B6. The mineral ratios for Ca/K at all ponds were higher than those in standard seawater and remarkable higher were found in pond B5 and B6 which were more than 6 folds. Higher mineral ratio in ponds water than that in standard seawater was also found for Mg/Ca ratio. In this regard however, Mg/Ca ratio in pond B5 and B6 showed much closer to standard seawater compared to other ponds which were 3-7 folds higher. In the case of Mg/K ratio, all ponds indicated, much higher (5-11 folds), compared to that in standard seawater.

Table 2: Average values of pH, dissolved oxygen (DO), temperature and salinity of ponds water during the study period

Parameters	K1	K2	C5	B5	B6	G14
pH m	7.77±0.26	7.71±0.33	7.54±0.21	7.70±0.33	7.72±0.33	7.84±0.19
pH af	8.12±0.30	8.10±0.34	7.89±0.36	8.08±0.35	8.10±0.35	8.11±0.25
DO m (mg L^{-1})	4.31±0.45	4.92±4.62	4.42±0.49	4.64±3.04	4.45±0.53	4.33±0.42
DO af (mg L^{-1})	6.25±1.06	7.04±1.44	6.87±0.98	6.68±1.41	7.14±1.36	6.16±0.77
Temperatur m (°C)	27.23±1.32	28.68±0.90	28.47±0.76	28.27±3.14	28.68±1.01	28.90±1.16
Temperatur af (°C)	28.45±1.03	30.31±1.13	31.19±8.42	29.90±3.03	30.20±1.15	29.64±1.24
Salinity (g L^{-1})	20.01±3.43	23.07±4.61	28.22±1.75	22.74±2.74	22.30±3.51	18.07±1.68

m: Morning, af: Afternoon

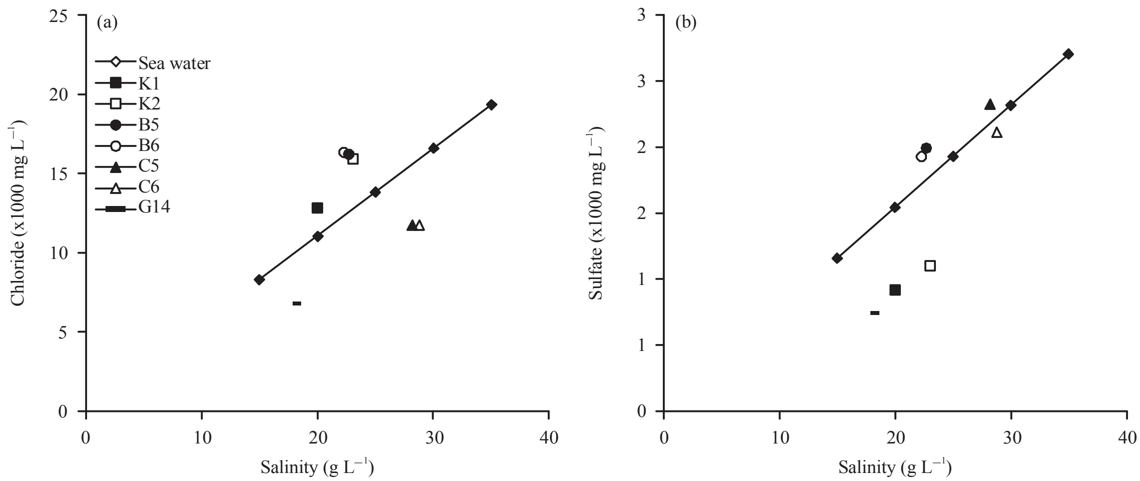

Fig. 2(a-b): Concentration of (a) Chloride and (b) Sulphate vs. standard graphic of those in normal seawater which hypothetically diluted with distilled water

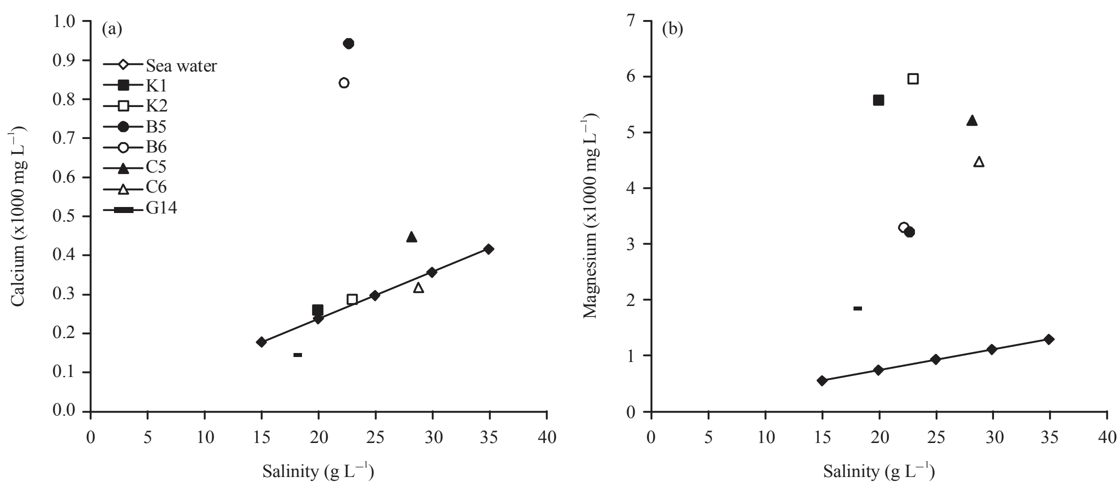

Fig. 3(a-b): Concentration of (a) Calcium and (b) Magnesium vs. standard graphic of those in normal seawater which hypothetically diluted with distilled water

Table 3: Specific growth rate (SGR), survival rate (SR) and production of *L. vannamei* reared in different water salinity

	Salinities (g L^{-1})						
	K1	K2	B5	B6	C5	C6	G14
Parameters	20.0	23.0	22.7	22.3	28.2	28.8	18.0
Fry stocked (pcs)	94,690	111,400	460,000	423,000	451,440	451,440	325,000
Area (m^{-2})	841	960	3,600	3,300	3,600	3,600	5,000
Density (pcs m^{-2})	113	116	128	128	125	125	65
DOC (days)	129	129	133	133	120	120	110
Initial weight (g)	2.53	2.64	2.73	2.52	1.93	2.41	2.52
Harvested MBW (g)	36.14	31.41	35.09	42.02	30.21	32.2	25.08
Biomass (kg)	2,511.30	2,667.30	9,629.41	9855.50	9,609.00	8,858.09	5,127.23
Survival Rate (%)	73.38	76.23	66.25	61.82	74.70	68.32	62.90
SGR (%)	3.04	2.84	3.02	3.29	2.96	2.92	3.06
Productivity (kg ha^{-1})	29,861	27,784	26,748	29,865	26,692	24,606	10,254

Major mineral-growth rate, survival rate and production relationships: Initial mean body weight of shrimp in all ponds as described in Table 3 were measured at day of culture (DOC) 34 and it varied from 1.93-2.73 g. The shrimp in all ponds

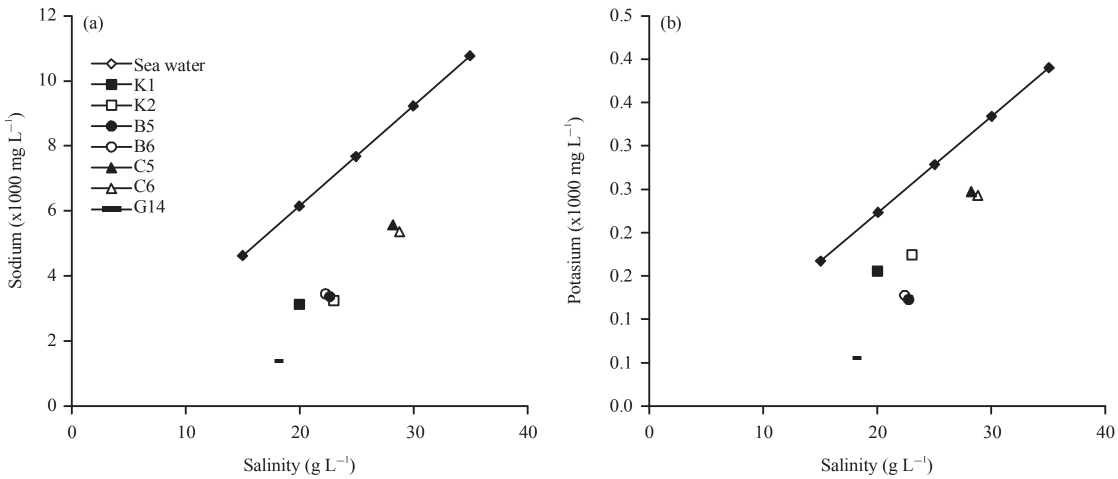

Fig. 4(a-b): Concentration of (a) Sodium and (b) Potassium vs. standard graphic of those in normal seawater which hypothetically diluted with distilled water

grew but exhibited difference specific growth rate (SGR). Statistical analysis using Pearson's Correlation Program SPSS 20.0 revealed that SGR was significantly ($p<0.05$) influenced by Na and K concentration in ponds water with coefficient correlation of 0.851 and 0.907 for Na and K, respectively. The regression model for this correlation is as follow:

$$Y = 0.48+0.01\ X_1-0.023\ X_2$$

Where:

Y = SGR
X_1 = Na
X_2 = K

Salinity and major minerals composition in all studied ponds have generally delivered 2 groups of SGR achievement. First group consist of ponds B5, B6, K1 and G14 with high SGR of above 3.0 and another group consist of ponds C5, C6 and K2 with SGR lower than 3.0 (Table 3). The highest SGR was reached in pond B6 (Table 3) where the concentration of Na and K in this pond were 3,447.8 and 129.3 mg L^{-1}, respectively (Table 3). The higher and lower Na and K concentrations resulted slower shrimp growth. High SGR resulted high mean body weight (MBW) of 35-42 g pcs^{-1} (pond B5, K1, B6) at harvesting day (DOC 120), while lower SGR have resulted lower MBW of 30-32 g pcs^{-1}. It has to be noted that pond G14 was an exceptional, even though it has the lowest stocking density of 65 PL m^{-2}, the shrimp was harvested earlier due to white spot syndrome virus (WSSV) outbreak. Hence, low MBW of 25.08 g was obtained from this pond. High SGR (in pond B5, B6 and K1) resulted better performance of shrimp growth comparing to other ponds as indicated in Fig. 5.

During the culture period, different salinities and mineral composition in pond water also resulted different survival rate (Table 3). Using the same statistical analysis method indicated that survival rate (SR) was significantly ($p<0.05$) influenced by Mg concentration and Na/K ratio with coefficient correlations of 0.925 and -0.847 for Mg concentration and Na/K ratio, respectively. The regression model for this correlation is as follow:

$$Y = 252.9570.03\ X_1-7.72\ X_2$$

Where:

Y = SR
X_1 = Mg
X_2 = Na/K

Salinity and major minerals composition in all studied ponds have also delivered 2 groups of SR achievement. First group consisted of ponds C5, K1 and K2 which have resulted high SR of 73-76% and another group consisted of ponds B5, B6, C6 and G14 which have resulted lower SR of 61-68% (Table 3). Highest SR were found in Pond K2, where Mg concentration was the highest, 5,958.2 mg L^{-1}. The lower Mg concentration caused the lower SR. The lowest SR was found in pond G14, the pond with lowest Mg concentration of 1,858.0 mg L^{-1} among the other 6 ponds. It should be also noted however that pond G14 with half shrimp stocking density of other ponds (65 PL m^{-2}), unfortunately were infected by white spot syndrome virus (WSSV) caused higher mortality (Table 3). Ponds productivity determined by combination of SGR and SR, both were compensating to each other. Low SR in pond B6 (61.82%) was compensated by high SGR to reach high productivity of 28,865 kg ha^{-1}

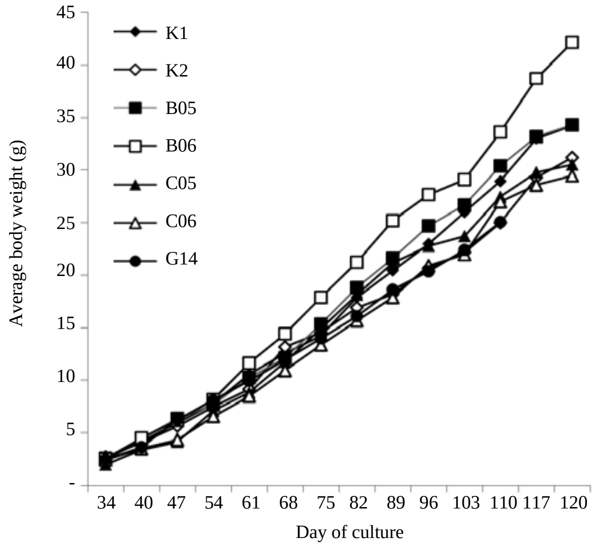

Fig. 5: Growth performance of *L. vannamei* reared in different water salinity and mineral proportion

while high SR in pond K2 (76.23%) reached lower productivity of 27,784 kg ha^{-1} as it had lower SGR of only 2.84.

DISCUSSION

Protocols of shrimp culture implemented in this study resulted ideal water quality parameters of DO, pH, temperature and salinity. According to Boyd *et al.*[3], the optimal DO for shrimp culture should be >4.0 ppm, while pH and temperature should be 7.5-8.5 and 26-32°C, respectively. The *L. vannamei* is able to survive in the water salinity ranging from 1-40 g L^{-1} but the most appropriate water salinities ranges[3] from 15-30 g L^{-1}. The variation of major minerals in this study were in corresponding to the previous study reported by Boyd and Tunjai[6], where various water salinity resulted different composition of major minerals of Na, Cl, Mg, SO_4, Ca and K.

The mineral composition in pondswater influences the physiology processes of shrimp[8,6]. Previous study revealed that water salinities at lower than 10 g L^{-1} could lead to different concentration and proportion of major minerals[6,21,22]. This present study found that water salinities of 18.0-28.8 g L^{-1} led to different concentration and proportion of major minerals with some remarkable notes. Low water salinity was usually deficiency in K, Mg and SO_4 comparing to those in diluted seawater at the same salinity level[8,21]. In contrast, this study found that higher water salinity was deficiency in K and Na, while SO_4 availability tended to be lower at lower salinity. On the other hand, the concentration of Mg was found much higher than that at standard seawater at the same salinity. This mineral exhibited a tendency to be higher at higher salinity. The variation of these major minerals concentrations occurred in all brackish water pond at the same salinity depend on the mineral concentration in the surface or ground water for seawater dilution[3,23]. Mineral compositions of water in pond are also influenced by mineral application to maintain water quality[3].

Roy *et al.*[9] described that the deficiency of K, Mg and sulfate in low saline water (<10 g L^{-1}) give negative impacts on the growth and survival of *L. vannamei*. The present study revealed that the growth rate of the shrimp was significantly influenced by Na and K concentrations when the shrimp was reared in water salinities of 20-29 g L^{-1}. When the concentration of Na in pond water was lower than that in natural seawater at the same salinity, the optimum concentration of Na seemed to be in the range of 3,360-3 and 447 mg L^{-1} indicating by the high SGR of 3.02-3.29. Ion K also gave identical role where the optimum concentration of this mineral in all water salinities seemed to be 123.4-129.3 mg L^{-1} to obtain the high SGR.

Roy *et al.*[8] also reported that SR was significantly influenced by Mg concentration. Higher Mg concentration resulted higher survival rate when shrimp were reared in low salinity of <10 g L^{-1}. This present study indicated that the SR was influenced not only by Mg but also by Na/K ratio. Optimum concentration of Mg seemed to be 174.2 mg L^{-1} indicating by maximum SR of 76.2% occurred at this Mg concentration. Furthermore Roy *et al.*[7] suggested that the Na/K ratio should be closed to the ratio in standard seawater, which is 27.6, to obtain a high SR when shrimp are reared in low water salinity of <10 mg L^{-1}. Interestingly, the present study indicated the high SRs of 73-76.2% (K1, K2, C5) were achieved in low Na/K ratio of 18.7-22.6 rather than 27.6. Meanwhile higher Na/K ratio of 26.7-27.2 (B5, B6) which were much closer to the ratio in normal seawater, resulted lower SR[24] of 61-66%. Zhu *et al.*[25] have reported that the optimum Na/K ratio for SR is 85.2 when *L. vannamei* is reared in artificial seawater with salinity of 30 g L^{-1}. This study revealed that lower deviation of K concentration gave more positive effect to the SR than that of Na/K ratio and Na concentration at salinity of 18-29 g L^{-1} (Fig. 4).

Even though the major minerals in the studied ponds water were not at ideal concentrations and ratios, shrimp production from these ponds were comparatively higher than the production previously reported. Widigdo[1] has reported the productivity of 11,722-19,016 kg ha^{-1} are reached when *L. vannamei* reared in brackish water at water salinities of 26.0-29.0 g L^{-1} in Lampung, Sumatra, Indonesia. The shrimp production might be improved by applying fertilizers to obtain the balance of major mineral concentrations in marine water Boyd and Thunjai[6].

CONCLUSION

The Na and K ions are significantly affect the specific growth rate (SGR) of *L. vannamei*, while Mg ions and Na/K ratio are crucial major mineral for the survival of the shrimp. This study proved that the optimum K concentration for *L. vannamei* growth ranges from 123.4-129.3 mg L^{-1}. It is the first report of field study establishing the crucial role of Na, K, Mg concentrations as well as the Na/K ratio for survival, growth and production of *L. vannamei*.

SIGNIFICANCE STATEMENTS

The present study has established understanding on the important role of major mineral in the shrimp aquaculture. In the term of salinity, shrimp aquaculture technology should be developed by considering the composition and ratio of major mineral in water rather than single salinity level. These chemical water environment properties significantly affect the survival, growth and production of shrimp culture. These results would assist the shrimp aquaculture industry to manage water quality for the better shrimp production.

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