SHRIMP FARMING OF BLACK TIGER SHRIMP WITH ZERO WATER EXCHANGE MODEL USING MOLASSES AS CARBON SOURCES

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Abstrak

Penelitian bertujuan untuk: (1) mengevaluasi parameter kualitas air dan produksi udang windu pada tambak dengan model tanpa pergantian air dan menggunakan molases, dan (2) mengkaji keterkaitan antara parameter kualitas air dan produksi udang dengan tingkat perbandingan C:N melalui penggunaan molasses. Penelitian dilakukan di tambak udang windu Darwin, Australia selama dua siklus produksi dengan model tanpa pergantian air dan menggunakan molasses. Metode pengumpulan data yang digunakan adalah metode pengamatan lapang terhadap kualitas air (suhu, pH, kadar oksigen terlarut, ammonia, nitrite, nitrate dan kelimpahan jumlah bakteri heterotrofik). Analisis kualitas air dilakukan di laboratorium kualitas air pada Universitas Darwin Australia. Sedangkan data parameter produksi udang diperoleh dari perusahaan PT.Ardetex. Untuk melihat keterkaitan antara parameter kualitas air dan produksi udang dengan level perbandingan C:N maka studi ini menggunakan analisis regresi berganda. Studi menunjukkan bahwa: (1) kualitas air di tambak tanpa pergantian air menggunakan molasses masih mendukung kehidupan udang; (2) tingkat produks udang di tambak tanpa pergantian air menggunakan molasses tidak berbeda pada tambak dengan sistem pergantian air; (3) tingkat perbandingan C:N cenderung berkorelasi negatif dengan konsentrasi ammonia, nitrit, oksigen terlarut dan pH tetapi cenderung berkorelasi positif dengan kelimpahan bakteri heterotrofik; dan (4) pertumbuhan udang tidak berkorelasi dengan tingkat perbandingan C:N.

Kata kunci: *Budidaya udang windu, tanpa pergantian air, kualitas air, molasses, bakteri heterotrofik, perbandingan C: N*

1. Introduction

The main problem of developing conventional intensive shrimp farms is effluents which is detrimental to coastal environment due to it contains high concentration in suspended solid, dissolved organic, nutrient, pathogenic microorganisms and chemical residue. However it has the low concentration of dissolved oxygen (Allan and Maguire, 1987; Mitchell, 1987; Csavas, 1994 ; Smith 1996; Avnimelech, 1999; Troell *et al.*, 1999; Chamberlain, 2001)

In order to mitigate the detrimental impacts of shrimp effluent is develop shrimp farms with zero water exchange model. One obstacle of shrimp farms with zero water exchange system, however, is the accumulation of toxic nitrogen. The addition of organic carbon such as molasses through growing heterotrophic bacteria could be novel strategy within preventing the accumulation of inorganic nitrogen in shrimp farms with zero water exchange model. It has been previously proved that heterotrophic bacteria removed inorganic nitrogen in ponds with zero water exchange model through the addition of carbonaceous substrate into ponds (Wheeler and Kirchman, 1986; Fuhrman *et al.*, 1988; Avnimelech *et al.*, 1989; 1992; 1994; Avnimelech, 1998; 1999; Montoya *et al.*, 2002).

Further, carbon and nitrogen ratio obviously influenced heterotrophic bacteria in controlling inorganic nitrogen in aquaculture systems (Avnimelech *et al.*, 1992, 1994; Kochva *et al.*, 1994; Avnimelech, 1999), in experiments of Limnology and Oceanography (Kirchman *et al.*, 2000), and in Marine Ecology (Middleboe *et al.*, 1995). Goldman *et al.* (1987) found no inorganic nitrogen at organic substrate having C:N ratio level of higher than 10.0:1. Similarly, Tezuka (1990) reported that the amount of nitrogen regenerated increased with decrease C:N ratio level of organic substrates and there was no regenerated ammonia when C:N ratio level of organic substrate was more than 15.0:1.

Zero water exchange production strategy was successfully used to reduce effluents, increase biosecurity, and generate high yield of white shrimps *Litopenaeus vannamei* (Grillo *et al.*, 2000; Allen, 2001; McIntosh, 2001; Decamp *et al.*, 2007; Perez-Velazquez *et al.*, 2008). However, there have been no studies of shrimp farming for black tiger shrimp *Penaeus monodon* with Zero Water Exchange Model (ZWEM) using molasses as carbon source. The specific aim of work was to evaluate water quality and shrimp production variables in shrimp farming of black tiger shrimp (*Penaeus monodon*) with ZWEM using molasses.

2. Materials and Methods

2.1 Sites and general description of shrimp farming

Study was conducted in four earthen ponds located at Ardetex Company in Berry Springs about 65 km from Darwin, Australia. The size of each pond is about 2.5 ha (500 m long and 50 m wide and average depth of around 1.2 m). Each pond has central island and has its bottom sloped to a corner drain.

Pond preparation, water quality management and other culture techniques wre almost similarly managed for both crop one and two. The farm was operated with Zero Water Exchange Model (ZWEM) using molasses as carbonaceous substrate. Fresh water was pumped from the nearby creek to compensate evaporation and seepage loss. The loss was estimated around 5 % of total volume per week throughout the growth season. (Based on information from Ardetex Company).

After ponds had been tilled and limed with soda ash (Na_2CO_3) at rate of 0.1 ton ha^{-1} for crop one and with CaO_2 at the rate of 1.32 ton ha^{-1} for crop two (Boyd and Tucker, 1998), ponds were filled with brackish water (23.85 ± 1.27 ‰ for crop one and 25.97 ± 2.03 ‰ for crop two). In order to achieve sufficient standing crop of natural food for 15 days old larvae of shrimps in the pond, each pond was fertilized four weeks prior to stocking (Avnimelech, 1999).

Ponds were stocked with 15 day old larvae of black tiger shrimp, *Penaeus monodon* at around 35 shrimps m^{-2} for crop one and 40 shrimps m^{-2} for crop two (Allan and Manguire, 1992). Shrimps were not fed with exogenous food during the first 60-day of the culture period in crop one and 30-day culture period in crop two (Avnimelech *et al.*, 1992; 1994). Shrimps were then fed with several brands of commercially pellet (Ridley, Indonesia Suritani Company and Taiwan Product) twice a day during from day 60 to day 90 for crop one and from day 30 to day 90 for crop two. From day 90 until harvesting day shrimps were fed four times a day (Adam Body, the owner of shrimp farming, personal communication). The averages protein content of feed applied were around 38% while the averages of feed and molasses carbon content used in shrimp farming were 38.50% and 29.71%, respectively (Avnimelech, 1999).

Two months after stocking, ponds were supplied with paddle wheels with a capacity of 16 kw ha^{-1}. The paddle wheels were situated in opposing corners of ponds in such a way as to create a water current gyre (Boyd, 1998). Paddle wheels were turned on for 4-12 hour day^{-1} for the first three months and subsequently the operated period was increased to 12-20 hour day^{-1}(Adam Body, the owner of shrimp farming, personal communication). In addition to mixing and aerating the water, water velocities created by aerators effectively swept most of the pond bottom and deposited low specific gravity sludge particles to the corner of the pond, thus acting as the centre of sludge accumulation (Boyd, 1998)

Shrimps were harvested partly by a net trap and harvest started on around day 150. The total weight and size of shrimp were recorded by company to calculate the survival rate, production, and feed conversion ratio according to the methods described by Tookwinas and Songsangjinda (1999).

2.2 Water Quality Analyses

Study was conducted for two crops. Field study of crop one was carried out in four ponds while for crop two was conducted in three ponds. In order to obtain representative data for the whole of each pond, four locations were chosen as sites for the in-situ measurements and water collections for further chemical analysis (Boyd and Tucker, 1998). Three replicated measurements and water collection were performed in the morning between 9.00 and 10.00 am on weekly basis for first two months and fortnightly for the rest of culture period (Boyd, 1995).

Salinity, temperature, conductivity, pH and dissolved oxygen in water were measured in-situ using Horiba water quality checker with U-10 Model. Ammonia, nitrite and nitrate concentration in water were measured photometrically in laboratory of Charles Darwin University, Australia using the Palintest Photometer, which was based on indophenol method, diazotization method, and cadmium reduction/diazotization method for ammonia, nitrite and nitrate respectively. Orthophosphate and total alkalinity levels in water were determined photometrically using Palintest Photometer. The determination of total suspended solid concentration in water was conducted according to standard methods (APHA, 1989). Organic carbon concentration was measured by the use of oxidation with bichromate (Nelson and Sommers, 1982; Rayment and Higginson, 1992). Levels of viable heterotrophic bacteria were determined by counting the colonies which grew on plates of Tryptone.Soya Agar (TSA) with 10 % of NaCl (Johnsen *et al.*, 1993). Levels of bacteria were quoted in colony forming units per ml of water (CFU ml^{-1}) (Smith, 1998).

2.3 Determination of Feed C:N Ratio, Amount Of Average Daily Feed and Molasses

The amount of feed and molasses used in study was daily recorded from company in order to determine the level of average daily feed and molasses, subsequently feed C:N ratio level. The level of feed C:N ratio was calculated by dividing total input carbon with total input nitrogen used in shrimp cultures (Avnimelech *et al.*, 1989; 1992; 1994; Kochva *et al.*, 1994; Avnimelech, 1999). The main carbon source of shrimp culture was feed and molasses, while the main nitrogen source was feed.

2.4 Shrimp Growth And Survival Rate And Feed Conversion Ratio

Measurement of shrimp growth rate was carried out after day 45 of culture period. Every two weeks, the total body weight of shrimp (W) was measured each pond. Similarly, the number of shrimps surviving (N) in each pond was counted. Further, the amount of feed used in each pond (W_f) was recorded. The average body weight (W_a) were calculated by dividing W with N. The overall average values of survival rate (%), growth rate of shrimp (gram/day) and feed conversion ratios (FCR) were determined by the following equations below as used in common aquaculture studies (Balazs, 1973; Tseng *et al.*, 1998).

$$\text{Survival Rate (\%)} = \frac{(N_o - N_t)}{N_t} \times 100\%$$

$$\text{Growth Rate (gram/day)} = \frac{(W_{at} - W_{ao})}{t}$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{(\sum Wf)}{\Delta W}$$

Where N_o and N_t are the number of shrimps cultured in each pond at initial time (to) and t time. W_{ao} and W_{at} are the average body weight of shrimps at initial time (to) and t time, t is period time of raising shrimps, "Wf is the total amount of feed used in each pond, and "W is the increment of the total weight of shrimps in each pond for t time culture.

A random sample that was removed weekly from each pond with a seine and 30 shrimps were individually weighed to nearest 0.1 gram to determine the growth rate of shrimps in field study. Survival rate was measured using previous equation, however, the number of shrimps in each pond at harvest time (N_t) was counted by dividing total production each pond with average individual weight (Hopkins *et al.*, 1993; Tookwinas and Songsangjinda, 1999). Sub-samples of individual shrimp were weighted to determine average individual weight.

The amount of water used (liter) to produced one gram shrimp (water consumption rate) was determined by dividing the total water amount used in every shrimp culture during growing period (liter) with the shrimp production (gram) at the end of study.

2.5 Data Analysis

Data were analyzed using Statistical Version 6.1 software. Data were analyzed using multiple regression analysis to evaluate the relationships between one dependent variable and the independent variables (Steel and Torrie, 1980).

3. Results and Discussion

3.1 Daily C: N Ratio Levels

It is importantly noted that the average of daily C:N ratio levels describes the amount of molasses applied in ponds. The present study investigated that the averages of daily C: N ratio levels implemented in crop one and two were 7.31 and 8.56, respectively. These daily C:N ratio levels are still lower than implemented in removing effectively inorganic nitrogen in ponds studies by several authors (Avnimelech *et al.*, 1992; 1994; Avnimelech, 1999; McIntosh, 2000) as more detailed described in below.

3.2 *Water Quality Variables*

The concentrations of ammonia, nitrite and nitrate in overall culture period for both crops are shown in Table 1. It was observed that nitrite accumulated in each pond for two crops at the end of crop period (6.8097 mg L^{-1} in crop one and 5.3510 mg L^{-1} in crop two) while ammonia concentrations at the end of study in all ponds for both crops were around 0.000 mg L^{-1}.

This result is accordance with earlier report by Alcaraz *et al.*, 1999; Tacon *et al.*, 2002). There was a trend for negative correlation between ammonia concentrations with the levels of C:N ratio in each pond of ZWEM($P<0.05$). Likewise nitrite levels had a negative association with the levels of C:N ration in each pond of ZWEM for two crops. This result is consistent with previous investigation reported by several authors (Avnimelech *et al.*, 1992; 1994; Avnimelech, 1999).

As described in Table 2 that nitrite concentrations in each pond for two crops were higher compared to previous investigation by McIntosh (2000) who showed that nitrite concentration was low (below 0.05 mg L^{-1}) in ponds of *Lipopenaeus vannamei* shrimp treated with feed C:N ratio = 20.0:1. It could be caused by level of C:N ratio applied in each pond was still lower than 15.0. Earlier reports revealed that nitrogen was removed effectively from fish pond when level of feed C: N ratio was more than 15.0 (Avnimelech *et al.*, 1992; 1994; Hoch and Kirchman, 1995; Kochva *et al.*, 1994; Avnimelech, 1999; Montoya *et al.*, 2002). Likewise, Tezuka (1990) found that the ammonia was not found at organic substrate when the level of C: N ratio was above 15:1.

Table 1. Water quality parameters overall culture period in both crops for shrimp farming with ZWEM using molasses as a carbon source in Darwin, Australia

Crop	Water Quality Variables	Minimum	Maximum	Mean	Std.Dev
One	1. Ammonia (mg/litre)	0.0000	2.8800	0.4075	0.2347
	2 Nitrite (mg/litre)	0.0000	6.8097	2.5166	2.3997
	3. Nitrate (mg/litre)	0.0000	0.9790	0.2048	0.0501
	4. D.O (mg/litre)	2.15	9.50	4.43	1.61
	5. Carbon (mg/litre)	43.990	76.977	59.717	6.056
	6. pH	7.15	9.64	8.20	0.07
	7.Bacteria (CFU/ml)	3.34×10^4	8.42×10^9	3.92×10^9	2.06×10^9
	8. Temperature (°C)	22.0	32.6	27.8	2.7
	9.Salinity (‰)	20.40	33.60	27.88	2.61
Two	1. Ammonia (mg/litre)	0.0000	5.6099	1.4857	0.6585
	2 Nitrite (mg/litre)	0.0000	5.3510	2.1763	1.5898
	3. Nitrate (mg/litre)	0.0000	0.9520	0.2543	0.0586
	4. D.O (mg/litre)	2.39	9.03	4.32	1.62
	5. Carbon (mg/litre)	38.86.23	77.8370	57.6381	8.8872
	6. pH	7.06	8.56	7.86	0.04
	7.Bacteria (CFU/ml)	3.04×10^4	9.75×10^9	4.65×10^9	2.70×10^9
	8. Temperature (°C)	22.1	33.1	27.7	3.1
	9.Salinity (‰)	24.20	31.80	28.06	1.94

Table 2. Comparison of ammonia, nitrite and nitrate concentration in shrimp farming of black tiger shrimp with Zero Water Exchange Model (ZWEM) using molasses (present study) and in shrimp farming of white shrimp with Zero Water Exchange Model (ZWEM) by McIntosh (2000)

Water Quality Variables	Shrimp Farming of Black Tiger Shrimp with Zero Water Exchange Model (ZWEM) Using Molasses		Shrimp Farming of White Shrimp with Zero Water Exchange Model (ZWEM) by McIntosh (2000)
	Crop		
	One	Two	
1. Ammonia	0.4075 ± 0.2347	1.4857 ± 0.6585	0.0156 ± 0.0092
2. Nitrite	2.5166 ± 2.3997	2.1763 ± 1.5898	0.0234 ± 0.0035
3. Nitrate	0.2048 ±0.0501	0.2543 ±0.0586	0.1253 ± 0.0076

However, nitrite concentrations at the end of study (in crop one = 6.8097mg L^{-1} and crop two = 5.3510 mg L^{-1}) were lower compared to those obtained by Tacon *et al.* (2002) who observed that nitrite concentration reached a level of 20 mg L^{-1} by the end of experiment in white shrimp culture of ZWEM without using carbon resource. These results reveal that applying molasses in ZWEM had role in removing inorganic nitrogen even though the level of C:N ratio applied in ponds was lower than 15.0:1. In addition, it was reported earlier that zero water exchange ponds using carbon enable to control the accumulation of inorganic nitrogen through a balanced ratio of carbon to nitrogen of the feed (Avnimelech *et al.*, 1989; 1992; 1994; Avnimelech, 1998; 1999). Further Arnold *et al.* (2009) raised tiger shrimp *Penaeus monodon* in zero water exchange model using a daily carbon source (tapioca powder) to promote the microbial community and improve water quality. Similar finding also demonstrated that the addition of tapioca starch as carbon source in freshwater shrimp ponds reduced toxic inorganic nitrogenous compound in water (Asaduzzaman *et al.*, 2010).

Values of dissolved oxygen in shrimp farming with ZWEM tended to be negatively associated with levels of feed C:N ratio. The explanation for this result could be due to that increasing feed C:N ratio levels in ponds stimulated growth of bacteria that in turn required oxygen for their growth, subsequently, there was a decrease in dissolved oxygen concentrations with feed C:N ratio levels increased. This explanation can be supported by the results of present study in ZWEM that proved dissolved oxygen levels tended to have negative correlation with the total bacteria numbers increased. It has been observed previously that bacteria contributed as much as 77% of the total oxygen consumption in fishponds (Olah *et al.*, 1987). Similarly, Visscher and Duerr (1991) investigated that microbial population consumed at high level of dissolved oxygen in shrimp ponds.

It should be reported that the company had difficulty in increasing the level of C:N ratio in shrimp farming of ZWEM for two crops due to dissolved oxygen depletion. This indicated that shrimp ponds with ZWEM using molasses as a carbon source clearly required and augmented oxygen supply as been reported by several authors (e.g. Avnimelech *et al.*, 1989; 1994). Even though in all ponds were operated with paddle wheels with 16 kw ha^{-1} but it was insufficient to supply dissolved oxygen due to there was a large fraction of feed residues left and digested in shrimp ponds with ZWEM using molasses as carbon source. Further, aerating and agitating whole volume of the pond can be achieved by employing continual aeration in circular ponds (Avnimelech *et al.*, 1989; 1994). Earlier reports revealed that in order to achieve optimal growth of bacteria, continually mixing and aerating water in ponds with ZWEM are essentially required and oxygen supply should be 1.5 times higher in ponds ZWEM than pond with frequent water exchange (Avnimelech, 1998).

There was only slight accumulation of organic carbon compared to the amount of feed applied in ponds in all ponds for both crops. The explanation for this could be linked aerobic condition in ponds probably accelerated the rate of oxidation organic by heterotrophic bacteria which subsequently restricted the rate of carbon accumulation in shrimp ponds (Animelech *et al.*, 1992; Hariati *et al.*, 1998). Ponds located in warm climates can also be one factor inducing bacteria in oxidating water organic carbon, therefore the levels of organic carbon did not accumulate at high rates (Boyd and Teichert-Coddington, 1994; Munsiri *et al.*, 1996; Hariati *et al.*,1998; Sonnenholzner and Boyd, 2000).

In shrimp ponds, total bacteria numbers tended to have positive correlation with the levels of C:N ratio. It revealed clearly that bacteria required carbon from molasses in order to multiply their cells. Azam *et al.* (1983) well established that carbon, such as glucose was utilized by natural bacteria. It was previously observed that carbon is essential element for bacteria growth (O'Brien and deNoyelles, 1974; Visscher and Duerr, 1991). Further, the addition of glucose increased number of heterotrophic bacteria in water (Parsons *et al.*, 1981; Middleboe *et al.*, 1995). Likewise, some previous investigators (Avnimelech *et al.*, 1992; 1994; Kochva *et al.*, 1994; Avnimelech, 1999; Kuhn *et al.*, 2008; Johnson *et al.*, 2008; Kuhn *et al.*, 2009; Vasagam *et al.*, 2009) who found that numbers of heterotrophic bacteria increased in response to increasing levels of C:N ratio. Moriarty (1977) also pointed out that there was increased number of bacteria as the result of increasing carbon in food input of penaeid prawn culture. Further, It has been investigated that addition of carbon for maintaining a high C:N ratio improved production and economical in freshwater prawn ponds (Asaduzzaman *et al.*, 2009; 2010). Similar finding was reported by investigators (e.g. Neal *et al.*, 2010; Wasielesky *et al.*, 2006), who proved that white shrimp were successfully grown with bacterial flock in zero water exchange system.

The present study proved that the values of pH in each pond of ZWEM tended to be negatively correlated with the feed C:N ratio levels. This result caused by bacteria that composed organic matters can increase the level of water inorganic carbon (CO_2) and subsequently decrease the values of pH. This view is agreement with the report documented by (Boyd, 1995; Ritvo *et al.*, 1998) who observed that the pH usually declines as the redox potential declines as a result of microbial activity.

It was proved that the concentrations of total suspended solids in the present studies of shrimp farming with ZWEM increased progressively with raising period. This could be caused by the size of shrimp increased progressively with time. Larger shrimp have a greater abdominal surface area and walk faster which consequently have a greater impact on sediment disturbance and suspension than smaller shrimp (Ritvo *et al.*, 1997). Also increasing the operation hours of paddle wheels with culture period in ponds was likely to be one reason for the level of total suspended solids increased with growing time. Increasing the concentrations of total suspended solids with raising time also due to the accumulation of total suspended solids such as faces, uneaten food, bacterial biomass and microfauna (Malone *et al.*, 1993. Similar finding was reported by Decamp *et al.* (2003) who investigated that the concentration of total suspended solid increased with growing time and reached values up to 536.490 and 989 mg L^{-1} in zero water exchange culture systems of white shrimps (*Litopenaeus vannamei* (Boone)). Likewise, Hopkins *et al.* (1993) also investigated the increased level of total with growing period of the experiment.

3.3 Shrimp Production Variables and Water Consumption Rate

Table 3 presents shrimp production variables and water consumption rate in shrimp farming with zero water exchange model using molasses (present study) and in conventional shrimp farming without using molasses by previous authors. Interestingly, shrimp survival rates in crop one and two were 54.43 ± 22.63 and 64.06 ± 7.91 respectively even though the concentration of ammonia and nitrite was higher than safe level for *Penaeus monodon* in ponds. It was probably because the increase in nitrite and ammonia with experiment time was gradual and it might have allowed shrimps to acclimate to the environment. This contention is supported by previous studies (Allan and Manguire, 1992) which investigated that shrimp can acclimate to increase in ammonia gradually with growing time. Similarly, previous reports reveal that larval *Penaeus monodon* had a progressive increase in nitrite tolerance as it metamorphoses from the nupliar to postlarval stage (Chin and Chen, 1988). The studies with penaeid larvae also have shown that tolerance to acute toxic levels of ammonia increased with age (Jayasankar and Muthu, 1983; Chin and Chen, 1987).

Another reason of the shrimps survived at high ammonia level was probably due to the adverse effect of ammonia on aquatic organisms decreased with pH level decreased (Burkhalter and Kaya, 1977; Colt and Tchobanoglous, 1978; Boyd *et al.*, 1979). It also has been stated that the effect of any increase in ammonia in shrimp culture may be mitigated by decrease in pH which reduce the proportion of ammonia in the highly toxic un-ionized form (Allan and Manguire, 1991). Moreover, it should also be noted that one purpose of molasses application in ponds of ZWEM was to reduce pH which subsequently decreased toxicity of ammonia to shrimp (Adam Body, the owner of shrimp farming, personal communication).

The present study revealed that shrimp growth rates in all shrimp ponds with ZWEM for both crops did not have correlation with daily C:N ratio levels and the number of heterotrophic bacteria, was probably caused by the levels of daily C:N ratio implemented in all ponds for crop one and two were 7.31 and 8.56 respectively. These levels of daily C: N ratio were lower than implemented by McIntosh (2000) who has grown white shrimp successfully in ponds with zero water exchange model using grain-based pellet (18 % protein) with C: N ratio of 20.0:1. Several investigators (Avnimelech *et al.*, 1992; 1994; Avnimelech, 1999; Asaduzzaman *et al.*, 2010) also proved that the addition of carbonaceous material effectively removed inorganic nitrogen and produced single cell proteins in aquaculture system if available carbon sources have a C:N ratio of higher than 15.0:1.

Table 3 describes that shrimp growth rates in shrimp farming with ZWEM were lower compared to conventional shrimp farming with higher exchange rate (Briggs and Funge- Smith, 1994; Allan *et al.*, 1995), probably due to the higher concentration of ammonia and nitrite in water shrimp pond of ZWEM. However, generally, feed conversion ratio in ZWEM could be reasonably compared with the previous reports on *Penaeus monodon* shrimp farming with FCR = 2.3 ± 0.2 by Chen *et al.* (1989), with FCR = 3.8 ± 0.1 by Allan *et al.* (1995), and with FCR = 2.13 ± 0.53 by (Briggs and Funge-Smith, 1994). Furthermore, similarity in magnitude of production levels and feed conversion ratios in between shrimp farming with ZWEM and shrimp farming with conventional model reported by (Briggs and Funge-Smith, 1994) as shown in Table 3 implies that shrimp production level as well as feed conversion ratio were unaffected by water exchange (Allan and Manguire,

Table 3. The production variables of shrimp farming with ZWEM using molasses within each crop in Darwin, Australia compared with production variables in shrimp farming with conventional model without using molasses

Shrimp Production Variables	Shrimp Farming with Zero Water Exchange Model (ZWEM) Using Molasses		Report in Conventional Shrimp Cultures by Earlier Authors	
	Crop		Briggs and Funge-Smith (1994)[1]	Allan *et al.* (1995)[2]
	One	Two		
1. Stocking density (shrimp/m^{-2})	35.25 ± 4.57	42.66 ± 4.62	52.5 ± 11.5	15
2. Water exchange rate (% per day)	0	0	3.55 ± 1.37	14.3 ± 0.8
3. Culture period (days)	192.0 ± 5.59	210.33 ±2.08	118 ± 5	71
4. Survival rate (%)	54.43 ± 22.63	64.06 ± 7.91	40.6 ± 15.6	89.3 ± 1.8
5. Growth rate (gram/day)	0.113 ± 0.07	0.086 ± 0.04	0.159 ± 0.013	0.16± 0.02
6. Production level (ton/ha/crop)	4.15 ± 2.31	4.89 ± 0.55	4.36 ± 1.18	1.52 ± 0.06
7. Feed conversion ratio	2.82 ± 1.11	2.16 ± 0.03	2.13 ± 0.53	3.8 ± 0.1
8. Water consumption rate (liter of water/gram shrimp)	9.98 ± 5.90	6.10 ± 0.76	13.01 ± 3.65	8937 ± 2150

[1] Average of three ponds and three crops in intensive shrimp farming with conventional system for *Penaeus monodon* shrimp

[2] *Penaeus monodon* shrimp cultured in small tank

1993; Hopkins *et al*., 1996).

Although, waste discarded from ZWEM was not measured, but it should be importantly noted that shrimp farming of ZWEM discharged very little the total concentration of nutrient, solid, and oxygen demand to the source estuarine and oceanic water (receiving waters). Hopkins *et al*. (1993) revealed total weight of nutrients, solids and oxygen demand being added to receiving water from shrimp pond with zero water exchange was around four times higher compared from ponds with 25% day water exchange. In conventional intensive shrimp ponds, each tone of shrimp produced added 112.6 ± 34.9 kg nitrogen and 50.1 ± 12.0 kg phosphate to environment (Briggs and Funge-Smith, 1994). Furthermore, the practice of flushing water from shrimp ponds into water body is detrimental to coastal environment that is main problem in developing shrimp farming in the world as previously described above.

It was shown that water consumption rate in ZWEM for two crops is consistent with previous investigation by Hopkins *et al*. (1993) who revealed that water consumption rate in white shrimp culture with zero water exchange was six liter water per gram of shrimp. Further, the water consumption rate in ZWEM was lower than the estimated worldwide range of 39 – 199 liter water per gram shrimp (Hopkins and Villalon, 1992) and investigated by Briggs and Funge-Smith (1994). This result implies that raising shrimp in ZWEM had most efficiency of the water usage and lowest pump cost. Saving water and reducing pump cost should be considered as beneficial effect of growing shrimp in ZWEM using molasses.

4. Conclusions

The water quality of shrimp culture with zero water exchange model using molasses still met requirement of shrimp. The levels of feed C:N ratio tended to be negatively associated with the concentration of ammonia, nitrite, dissolved oxygen and pH but it tended to have positive correlation with the number of heterotrophic bacteria.

The shrimp growth rates in shrimp ponds with zero water exchange model did not have correlation with daily C:N ratio levels and the number of heterotrophic bacteria due to the level of C:N ratio implemented in ponds was less than 15:1. Further, there was no significant difference in shrimp production levels and feed conversion ratios between shrimp farming with zero water exchange model and shrimp farming with frequent water exchange model. Therefore, the shrimp farming with ZWEM is the most promising features of shrimp farming which can increase biosecurity, reduce water use for farmers and the release of waste into environment, subsequently, creates the shrimp farming industry along a path of greater sustainability and environmental compatibility.

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