Agriculture, Forestry and Fisheries
2022; 11(1): 1-7
http://www.sciencepublishinggroup.com/j/aff
doi: 10.11648/j.aff.20221101.11
ISSN: 2328-563X (Print); ISSN: 2328-5648 (Online)

Growth Performance of Scalloped Spiny Lobster *Panulirus homarus* (Linaeus) Fed Formulated Diet in Recirculating System

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To cite this article:

Minh Duy Mai, Luu Thi Tran. Growth Performance of Scalloped Spiny Lobster *Panulirus homarus* (Linaeus) Fed Formulated Diet in Recirculating System. *Agriculture, Forestry and Fisheries.* Vol. 11, No. 1, 2022, pp. 1-7. doi: 10.11648/j.aff.20221101.11

Received: December 16, 2021; **Accepted**: January 4, 2022; **Published**: January 12, 2022

Abstract: Lobster aquaculture industry in sea cage farming has used seafood as its food leading to challenges such as disease risk, environmental degradation and disaster. This paper presents growth, survival, sexual maturity and flesh quality of scalloped spiny lobsters from a two period culture in recirculating system. In the first period, a number of 2655 healthy juveniles acclimated with formulated diet at average body weight of 11.4-14.0 g were stocked at 36.88 individuals m^{-2} in three months. In the second period, a number of 2334 selected healthy juveniles at average body weight of 52.18-69.97 g were restocked at 13.5-14.1 individuals m^{-2}. The lobsters were fed formulated diet twice a day at a feeding rate of 2.2-1.6% of the body weight. The quality of biofilter based reused water was 28.4-29.8°C, pH: 7.6-8.0, salinity: 26.8-36.4 ppt, dissolved oxygen ≥ 5.2 mg L^{-1}, total ammonia nitrogen ≤ 0.82 mg L^{-1}, NO_2-N ≤ 0.5 mg L^{-1}, NO_3-N ≤ 4.3 mg L^{-1}, alkalinity: 96.4-132.4 mg L^{-1}. The body weight of lobsters increased following a polynomial (r^2 = 99.9%) and reached harvest size of 300 g after nine months and final size of 349.5 ± 9.9 g, survival of 81.5% and productivity of 4.51 ± 0.28 kg m^{-2} after thirteen months. The lobster performance was similar to those fed seafood in sea cage farming. The berried females were observed at a minimum carapace length of 3.5 cm from July to September. The cooked lobster flesh and its content of fat and highly unsaturated fatty acids were less reddish and half of the lobsters fed seafood in sea cage farming, respectively. The differences are likely due to a deficiency of astaxanthin content in the formulated feed and possibly a poor assimilation of lipid by the lobsters. The results are interesting in development of a land based farming of spiny lobsters.

Keywords: *Panulirus homarus*, Formulated Diet, Recirculating System

1. Introduction

Traditional culture of spiny lobsters in sea cages has developed three decades ago and become an important industry in Vietnam. This is only established and significant lobster aquaculture industry in the world currently producing around 1600 tonnes of premium grade lobsters, equivalent to USD 120 million in which scalloped lobster has represented 40% of producton just behind ornate lobster [1]. Although the Vietnam lobster farming industry is successful, it has experienced significant challenges from disease and environmental degradation [2]. The use of fresh seafood as lobster food which has seasonally unstable quality and potentially serious disease agents is a major contributing factor to poor condition of lobsters and increased susceptibility to disease. It was showed that feeding lobsters with seafood resulted in a markedly higher benthic carbon loading and release of disolved inorganic nitrogen when compared with artificial lobster feed [3]. Therefore, the elimination of the use of seafood would greatly reduce the environmental impacts of spiny lobster aquaculture. Formulated diet will provide a much cleaner and nutritionally complete diet, and increase disease resistance. Additionally, live lobster products from seafood based culture will face international trading barrier in the coming years. Thus, the development of formulated diet to replace seafood in spiny lobster farming is of interest. The

preleminary results in development of formulated diet [4, 5] showed a possibility to apply formulated pellets in scalloped spiny lobster farming. However, the lobsters fed these pellets had slower growth and lower survival compared to those of the lobsters fed seafood. Until now, the lobster sea cage farming in Vietnam has depended on seafood [6]. Therefore a suitable formulated diet to spiny lobsters is especially required. Another challenge to lobster farming in Vietnam should be the force majeure disaster for example flood and typhoon. In major lobster culture zones of Vietnam, the seasonal heavy rain every year has caused lobster dead in mass and the typhoon Damrey in 2017 destroyed completely lobster farming. Recirculating aquaculture system (RAS) expected to eleminate the impact of disaster has been commercially applied in European lobsters [7]. However, its application in scalloped spiny lobster has just achieved preliminary results because it was in short term pilot trials to understand water quality [8, 9], shelter [10], density [11] and formulated diet [5, 12, 13].

This paper is to present culture system, husbandry, water quality, and the performance and flesh quality of scalloped spiny lobsters fed formulated diet in RAS. The results are interesting in development of a land based farming of spiny lobsters.

2. Materials and Methods

2.1. Culture System and Influent Water Quality

RAS for experiment constituted of culture tanks; manhole, settlement tank, biofilter, water standard tank, heat controller, pumps, air supplier, ultraviolet light (UV) and skimmer (Figure 1). There were eight rectangular concrete tanks each had a 8 m length, 3 m width and 0.8 m depth (water depth of 0.6 m), and installed 16 aerators on the bottom. A vertical immerged netting was in the water column for lobsters to stay on. The round concrete settlement tank had a 5 m diameter and 1.4 m depth. The submerged bed biofilter (Figure 2) had three consecutive parts, each had a 2.6 m length, 1.4 m width and 1.4 m depth. The first part connecting to the settlement tank was filled of coarse gravels (15-30 mm size). For two remaining parts, each had an empty section (0.5 m length x 1.4 m width x 1.4 m depth) and a biological section. The biological section of the second and third part was filled of medium (10-15 mm) and fine (5-10 mm) gravels, respectively. The biofilter has been activated and in use for several years. The square standard tank had a side of 5 m was equipped by pumps (24 m^3 h^{-1}, Taiwan) and a heat controllers (200 m^3 capacity, Nha Trang University Vietnam). The pumps were connected to a UV (24 m^3 h^{-1}, Camix) followed by a skimmer (24 m^3 h^{-1}, Ltd SAEN Vietnam). Air suppliers (3 HP, Taiwan) were used to supply oxygen to culture tanks, empty sections of the biofilter and standard tank.

The clean seawater with salinity of 26-36 ppt, pH of 7.8-8.2 was treated first by chlorine 70% at 10 mg L^{-1} and three days later by thiosulphate to make sure no existence of free chlorine before supplying to the system. In RAS, the water from culture tanks was gathered in a manhole and settlement tank entering the biofilter before going to standard tank. Water from standard tank was pumped through a UV and skimmer before back to culture tanks. The water temperature in the standard tanks was stabilized by heat controller in range of 28-30°C.

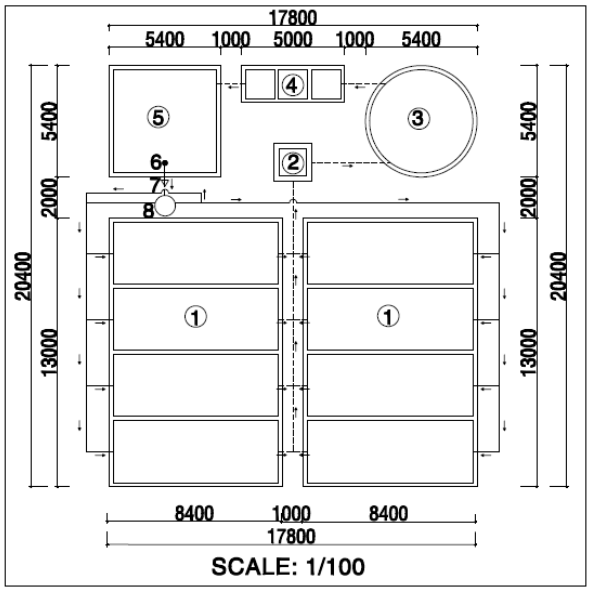

Figure 1. *Horizontal system plan for lobster culture. 1: culture tank; 2: manhole; 3: settlement tank; 4: biofilter; 5: standard tank; 6: pump; 7: UV; 8: skimmer.*

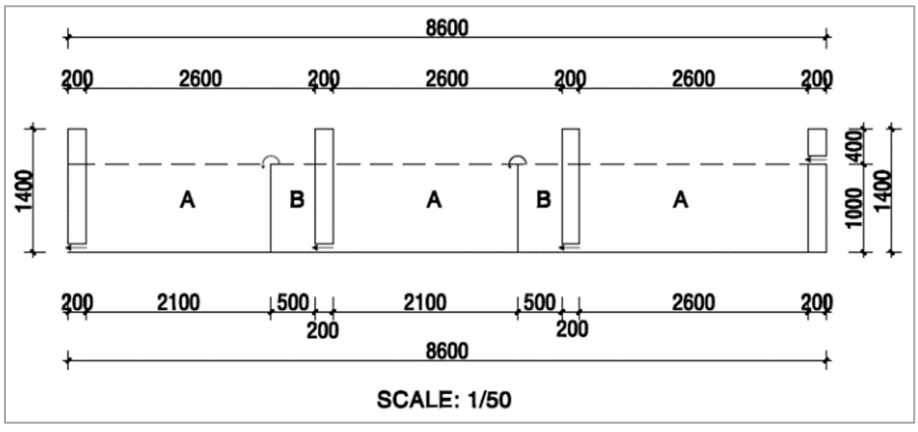

Figure 2. *Design of submerged bed biofilter. A: gravel filled section; B: empty section.*

2.2. Formulated Diet

Table 1. *Formulation and proximate compositionsof diet.*

No.	Ingredient	Percentage
1	Super fishmeal (67% of protein), KIHUSEA VN	71.71
2	Wheat flour, Vietnam	8.96
3	Squid liver powder, Vietnam	1.99
4	Wheat gluten (76% protein)	5.98
5	Fish oil, 98%, Vietnam	1.99
6	Lecithin, E322, Argentina	2.39
7	Megabic®, Bayer	0.50
8	Biomos® Altech	0.50
9	Grownmix®shrimp, Bayer	1.99
10	Gelatin, progel mexicana S. A. de C. V. Mexico	1.99
11	Nustic®, Bayer	1.99
	Total	100
1	Cholesterol (g 100 g^{-1})	0.33
2	HUFA (g 100 g^{-1})	1.67
3	Carbohydrate (g 100 g^{-1})	12.41
4	Ash (g 100 g^{-1})	19.25
5	Protein (g 100 g^{-1})	49.63
6	Lipid (g 100 g^{-1})	11.94
7	Dry matter (g100 g^{-1})	95.23
8	Astaxanthin (mg kg^{-1})	0.1

Formulation and biochemical composition of diet were given in Table 1. All flour materials were mixed and ground to 0.8 mm. The flour mixture was added liquids, mixed thoroughly and added clean fresh water to have a dough. The dough was then pushed through a breaker plate to have noodles of 8 mm in diameters by extruder. The noodles were steamed in 5-7 minutes before being pushed through a breaker plate to gain final pellets of 2-4 mm in diameter and 2-3 cm in length by extruder. The final pellets were dried in 65-70°C for 90 minutes and being packed in 5 kg plastic bags. The proximate compositions and the relative methods carried out by Upscience, Vietnam branch were cholesterol: ISO 12228-1: 2014 (VF), highly unsaturated fatty acids (HUFA): ISO 12966-2: 2017 (CH035), ash: GE001 (Ref. AOAC 942.05) (V), carbohydrate: calculation, dry matter: EC 152/2009, protein: TCVN 8134: 2009 / ISO 937: 1978 (V), lipid: hydrolysis-extraction, dry matter: EC 152/2009, astaxanthin: HPLC.

2.3. Lobster Juveniles and Stocking

The scalloped spiny lobster juveniles collected from the coastal area of central Vietnam were acclimated and fed formulated diet in tank condition. After spending several moltings, the healthy juveniles at average body weight of 11.44-14.01 g with no common disease syndrome (red body, milky haemolymph or black gill) were selected for the culture trial. The trial had two periods following traditional technique in order to reduce stocking density and select healthy lobsters. In the first period, a total of 2655 juveniles were selected, assigned evenly into three tanks and cultured for three months before being selected for the next period. In the second period, a total of 2334 healthy ones from 2354 survivals in the first period (equivalent to 99.15%) were selected and evenly assigned in to seven tanks and grown out for ten months. The detail for the two periods is presented in Table 2.

Table 2. *Time, size and stocking density of scalloped spiny lobsters.*

Criteria	Culture tanks						
	1	2	3	4	5	6	7
1st period (Feb. 2019)							
Number of lobster juveniles	885	885	885				
Average body weight (g)	11.44	14.01	13.33				
Stocking density (individualm^2)	36.88	36.88	36.88				
2nd period (May 2019)							
Number of lobster juveniles	326	327	338	338	335	335	335
Average body weight (g)	52.18	55.11	61.75	62.96	57.55	69.97	72.12
Stocking density (individualm^{-2})	13.58	13.63	14.08	14.08	13.96	13.96	13.96

2.4. Feeding

Daily two meal feeding was carried out at 7h00 and 17h00. For each meal, half of feed was supplied first by hand and then 30 minutes later the rest would be added. The daily feed was adjusted every week. The daily feed was considered to be enough when after feeding 30 minutes, several lobsters stopped feeding and stayed on the vertical netting and a few pellets were found on the bottom of the tank. Daily feeding rate was 2.2% of total body weight in the beginning and reduced to 1.6% at the end.

2.5. Management and Data Recording

In the first period, a pump of 12 m^3 h^{-1} was operated to circulate water current and the daily recycled water was at approximately 200%. In the second period, pumps of 24 m^3 h^{-1} were applied. The skimmer of 24 m^3 h^{-1} was daily operated in 6-10 hours.

Every day, scored the supplied feed, cleaned the tanks, removed the shells from molting as well as siphoned waste and fecal products on the tank bottom. The daily water percentage removed by these activities was about 2% of a total water volume of 200 m^3 in the whole system. The new seawater was added to maintain the water volume. Any lobsters showing common disease were isolated. The red shell (red body) ones were in particular killed immediately in hot water.

Every week, BZT®, Tetrasul Intlpharmar, a product of *Bacillus* was supplied to maintain the useful bacteria community in the system. The water quality was maintained as follows: Temperature: 28-30°C, pH: 7.5-8.2, salinity: 26-

38‰, dissolved oxygen (DO) ≥ 4.6 mg L^{-1}, total ammonia nitrogen (TAN) < 0.9 mg L^{-1}, NO_2-N ≤ 2.0 mg L^{-1}; NO_3-N ≤ 50 mg L^{-1}; alkalinity: 90-140 mg L^{-1}. These parameters were measured by Hanna HI83306-02 Environmental Analysis Photometer. The salinity was controlled by exchange of new treated water. The BIO-II (*Bacillus subtilis; Lactobacillus sp; Nitrosomonassp* and *Nitrobacter sp*), BIO Nha Trang Vietnam were periodically supplied to the biofilter when observed TAN or NO_2-N were out of expected range. Bikap C. P. Vietnam was periodically added to maintain the alkalinity.

Every month, the lobsters were immerged in 40 ppm H_2O_2 (50%) treated seawater for 20 minutes for sterilisation. Also, counted the number of survival lobsters, checked their health and scored body weight of all survivals for each tank. Only the healthy lobsters were selected and restocked whereas the unhealthy were removed. The removed ones were considered as deads.

After thirteen months, scored number and total body weight of all survive lobsters in each tank, and analyse flesh quality of three lobsters in intermoult stage from this study to compare with three lobsters fed seafood in sea cage farming. Nine biochemical compositions of flesh were analysed in the lab of Upscience, Vietnam branch. Analysis method of ash, HUFA, carbohydrate, dry matter, protein, total lipid were presented in previous section. Three others were calcium: WRT/TMM/EN/01.01: 2019 (Ref. AOAC 2013.06), magnesium: WRT/TM/EN/01.01: 2019 (Ref. AOAC 2013.06), and sodium: WRT/TM/EN/01.02: 2019 (Ref. AOAC 969.23). Picture of berried female, lobster ventral view and the colour of their cooked flesh were taken by iphone 7.

2.6. Data Analysis

The specific growth rate (*SGR*)= ln (*Wt2/Wt1*)/(*t2-t1*)*100 (%) where *Wt2* and *Wt1* (g) were the average body weight of the lobsters recorded at the time *t2* and *t1* (day), respectively.

The average body weight at the time *t* (*Wt*) = *TWt* /*Nt* (g); where *TWt* was total body weight (g) of lobsters at the time t and *Nt* was the number of final survival lobsters at the time *t*.

Survival rate (%) for a period from time *t1* to *t2* = *Nt2*/*Nt1*100 where *Nt2* and *Nt1* were the number of survival lobsters at time *t2* and *t1*, respectively. Cummulative survival (%) for two periods = *Nsv*/2655*100; where *Nsv* was the total number of final survivals in seven tanks recorded.

Feed conversion rate (*FCR*) = total supplied feed (kg)/ weight gain (kg); where weight gain = final biomas – initial biomas + total weight of dead lobsters. The average criteria were calculated using the recorded data from three tanks for the first period and from seven tanks for the second period. The equation for body weight fluctuation was obtained by Excell.

3. Results

3.1. Water Quality

The water environmental parameters were: 28.4-29.8°C, pH: 7.6-8.0, salinity: 26.8-36.4 ppt, DO ≥ 5.2 mg L^{-1}, TAN ≤ 0.82 mg L^{-1}, NO_2-N ≤ 0.5 mg L^{-1}, NO_3-N ≤ 4.3 mg L^{-1}, alkalinty: 96.4-132.4 mg L^{-1}. In the tanks of 0.6 m water column, water transparency was so high that the colour shell and movement of lobsters on the tank bottom could be observed clearly by naked eyes.

3.2. The Growth Performance of Lobsters

In the first period of three months, the lobsters at size of 12.9 g had an average body weight of 40.2-76.6 g. The survival was 88.66% and most of the dead was the ones showing red shell syndrome. The dead rest was due to cannibalism during molting. In the second period of ten months, the lobsters at averaged size of 61.66 g had average body weight of 224.2 - 676.6 g. The survival was 92.65% and most of the unhealthy lobsters showed no specific disease syndrome. The unhealthy lobsters moved slowly and stayed away from its community. Cannibalism, milky haemolymph or black gill syndrome were not observed. The growth in body weight, survival, FCR are given in Table 3. The cumulative body weight of two periods is illustrated in Figure 3.

Table 3. *Growth performance of the lobsters.*

	Average ± SE
1st period (Feb. 2019–Apr. 2019)	
Initial average body weight (g)	12.9 ± 1.3
Final average body weight (g)	61.1 ± 2.3
SGR (% day^{-1})	1.73 ± 0.13
Survival (%)	88.6 ± 0.9
FCR	1.65 ± 0.03
2nd period (May 2019–Feb. 2020)	
Initial average body weight (g)	61.7 ± 7.4
Final average body weight (g)	349.5 ±9.9
Productivity (kg m^{-2})	4.51 ± 0.28
SGR (% day^{-1})	0.58 ± 0.03
Survival (%)	92.6 ± 2.3
FCR	2.23 ± 0.02
Total survival (%) (1st and 2nd)	81.50

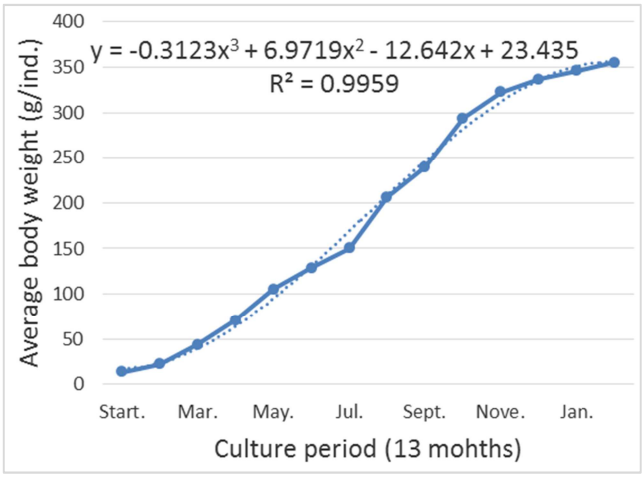

Figure 3. *Cumulative body weight of lobsters in 13 months.*

In Figure 3, the average body weight of the lobsters increased following a polynomial with r^2 = 0.99. The weight

increased very fast in first five months, lower at 6th month and became quickly again until they reached an average harvest size of 300 g at 9th month. After that the weight increased slightly. Interestingly, the berried females were observed and this phenomenon occurred almost from July to September 2019. At this time, the lobsters were at 3-5 cm carapace length (CL) and the smallest berried lobster was at 3.5 cm CL (180 g in body weight). The berried females were full of eggs (Figure 4) and most of them developed well giving healthy larvae.

Figure 4. *Berried RAS lobster, ventral view of RAS lobster (left) and of sea cage lobster (right), and cooked flesh of RAS lobster (belove) and of sea cage lobster (above).*

3.3. Product Quality

The ventral view, the colour of cooked flesh and biochemical compositions of the RAS lobsters fed formulated diet and those fed seafood in sea cage farming are presented in Figure 4 and Table 4. The ventral view of RAS lobster looked brighter and cleaner than those of sea cage lobster. However, the cooked flesh of RAS lobster was less reddish than those of sea cage lobster. Almost the biochemical compositions of flesh between the two types of lobsters were not much different except for lipid and HUFA. The lipid and HUFA content in flesh of sea cage lobster were two fold relative to those of RAS lobsters.

Table 4. *Flesh biochemical composition of two types of lobster.*

No.	Indices (% dry weight)	RAS lobsters	Sea cage lobsters
1	Ash (g 100 g^{-1})	1.77 ± 0.14	2.10 ± 0.14
2	Carbohydrate (g 100 g^{-1})	1.05 ± 0.12	1.35 ± 0.14
3	Dry Matter (g 100 g^{-1})	26.4 ± 2.8	30.5 ± 3.6
4	Protein (g 100 g^{-1})	21.7 ± 1.4	22.5 ± 1.7
5	Total lipid (g 100 g^{-1})	1.91 ± 0.15	4.68 ± 0.34
6	HUFA (mg 100 g^{-1})	506.8 ± 67.4	1135.2 ± 98.6
7	Sodium (mg 100 g^{-1})	272.2 ± 32.6	321.3 ± 46.4
8	Calcium (mg 100 g^{-1})	19.1 ± 1.6	16.67 ± 1.8
9	Magnesium (mg 100 g^{-1})	32.9 ± 1.4	39.2 ± 1.4

4. Discussion

4.1. Water Quality and Biofilter

The observed data indicate suitable water quality demonstrating an applicability of the submerged bed biofilter to lobster RAS. Spiny lobsters live in coral marine habitat so they prefer a stable and clean seawater. In captivity, scalloped spiny lobster had a good response in salinity of 30-40 ppt [14]. Its growth was better in temperature of 24-28°C comparred to lower levels [15] and was the best in salinity of 35 ppt with its high capacity to tolerate a lower salinity [8]. Similarly, ornate spiny lobster had a better growth in temperature of 25-31°C and salinity of 35 ppt with its capacity to tolerate reduced salinity [16]. Furthermore, optimal water quality recommended for spiny lobsters were temperature: 25-30°C, DO: 2.7-5.4 mg L^{-1}, NH_3 < 0.1 mg L^{-1} and NO_3-N < 100 mg L^{-1} [17], NO_2-N < 2 mg L^{-1} [18]. For marine crustacean farming, requirement of water quality was suggested as salinity of 32-36 ppt, pH of 7.8-8.5, NH_3 < 0.1 mg L^{-1} and NO_3-N < 100 mg L^{-1} [19]. Thus, temperature, salinity, DO, TAN, NO_2-N and NO_3-N in our study were in a favourable range to the spiny lobsters.

The nitrification in biofilters consume alkalinity and releases H+ ion then reducing pH. Consequently, water acidity should increase and might reduce the ability of lobsters to precipitate their $CaCO_3$ cuticles [20]. In the present study, pH and alkalinity were reduced to 7.6 and 96.4 mg L-^{1}, respectively. These levels were in a range monitored in the major zones of sea cage lobster culture in Vietnam [1]. At three levels of alkalinity (68-89; 160-176 and 240-288 mg L^{-1}) physiological response of this species did not exhibit any signs of stress nor significant difference in performance [9]. Moreover, no soft shell lobsters was observed in our study demonstrating suitable pH and alkalinity to scalloped spiny lobsters. It is interesting that at a high rate of the recycled water (1-2% daily removal), indices of water quality including TAN, NO_2-N and NO_3-N in the culture system were quite low. This exhibits that beside nitrification, a denitrification happened reducing concentration of NO_3-N as reported previously [21]. The above discussion indicates submerged bed biofilter in our study had a high capacity in maintenance of nitrogen compounds, pH and alkalinity suitable to spiny lobsters.

4.2. Growth and Sexual Maturity of Lobsters

The observed lobster performance in the present study was similar to those fed seafood in sea cage farming and much better than those reported previously. The spiny lobster juveniles fed seafood in sea cage farming could reach an average harvest size of 300 g in total body weight, a survival of 70-80% and productivity of 3-4 kg m^{-2} within a year [1]. However, survival of the juveniles in tank condition was quite low: 75% after 135 days [22], 56.32% after 30 days [10], and 86.11% after 30 days [11]. The good growth and survival in the present study confirm optimal water quality and shows the suitability of husbandry and formulated diet to lobsters. The lobster juveniles were caught from wild so a few were likely infectious of pathogenic agents such as *Vibrio alginolyticus* causing red body (shell) disease or Rickettsia-like bacterium causing milky haemolymph disease [6]. In tank captivity, the *Vibrio alginolyticus* infected lobsters could survive in a few days and caused a high risk of rapid infection to others within a day via cannibalism. In our study, usage of formulated diet and selection of the healthy juveniles after several their moltings removed the unhealthy ones on time and eliminated the pathogenic agents

effectively. A high tranparency of water column also allowed an efficient removal of red body and other unhealthy, subsequently minimizing disease risk.

The body weight of scallopped spiny lobsters increased following a polynomial ($r^2 = 0.99$) and got a slower ratio in July 2019. The presence of berried females, mainly from July to September 2019 indicates seasonally sexual maturity. The maturity could explain for the slower growth in July because at that time, a shift in energy use from growth to reproduction rather than influence of temperature, reduced their growth [23]. There were differences in CL of berried females and sexual mature periods. The lobster size at first sexual maturity was 3.5-5 cm CL in our study while it was 3.8-7.0 cm CL depending on locations [24, 25]. Additionally, seasonal presence of berried females was in around year [25] but from July to September in our study. The captive condition different from natural diverse habitat should be explained for these differences.

The presence of berried females in captive condition have confirmed a suitability of formulated diet to scalloped lobsters not only in growth performance but also in sexual maturity. The feed in the present study had 49.63% protein, 11.94% lipid, 1.66% HUFA and 0.33% cholesterol. This protein content was within a potential range of protein requirement reported previously. Growth performance of this species was better at 54.9% versus 34.8 and 45.9% protein [26], and at 46% versus 34 and 40% protein [5]. Until now, data on its other nutrient requirements such as lipid, HUFA has not been reported yet.

4.3. Formulated Diet and Flesh Quality of Lobsters

The observed results here shows that formulated diet was quite suitable to scalloped lobsters in growth and maturity. However, the less reddish flesh and its low composition of lipid have indicated a deficiency of astaxanthin in the diet and possibly a poor assimilation of lipid by lobsters. In aquatic animals, astaxanthins contribute not only to the colouration of shell and muscle but also to reproduction and immunity. It is frequently utilized as an additive in formulated diets to boost and improve the coloration of aquatic species, and subsequently product quality and price [27]. Although studies in lobsters [28, 29] was unable to demonstrate an improved productivity response to dietary carotenoid, and thus could not define a true requirement, a minimum carotenoids and astaxanthin for lobsters was suggested as 100 and 70 mg kg^{-1}, respectively [30]. The astaxanthin content of 0.1 mg kg^{-1} in our feed was much lower than those suggested.

The lipid requirement suggested for spiny lobsters was 9-10% [32] which was lower than those in our diet (11.94%). However, the lipid content of our lobsters was half of the one fed seafood from sea cage farming. Deposits of HUFA in lobster larvae such as triacylglycerol were low, although they were available in the formulated diet. The authors suggested a poor assimilation of the fatty acids by captive lobster larvae [31]. This might be explained for low contents of lipid and HUFA in our lobster flesh.

5. Conclusion

In RAS, scalloped spiny lobsters at average body weight of 11.4-14.0 g fed formulated diet reached a final weight of 349.5 ± 9.9 g, survival of 81.5% and productivity of 4.51 ± 0.28 kg m^{-2} after 13 months. The berried RAS females were observed at a minimum CL of 3.5 cm from July to September. The cooked lobster flesh and its content of lipid and HUFA were less reddish and half compared to those fed seafood in sea cage farming, respectively.

Acknowledgements

This paper used data sets from the national project: "Completion of techniques in commercial grow out of spiny lobsters in land based system, DM. 35. DN/18" granted by the Vietnamese Ministry of Science and Technology. We would like to thank Dac Loc Fisheries Ltd company for the experimental facilities.

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