Effect of mono and binary diets on growth and reproduction of cyclopoid copepod

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Abstract. This study compared the efficiency of different diets on the growth, survival and reproduction of the cyclopoid copepod *Apocyclops ramkhamhaengi* as a potential live food species for fish larvae and crustaceans in aquaculture. The experimental diets consisted of four mono diets (chicken manure, palm kernel cake (PKC), *Tetraselmis* sp. and *Nannochloropsis* sp. (control) and two binary diets (chicken manure + PKC and *Tetraselmis* sp. + *Nannochloropsis* sp.). The experiment was carried out for 15 days and the population growth, specific population growth rate, survival and reproductive performance (hatching time, hatching rate, generation time, life spawning times, daily offspring production, lifespan and sex ratio) were used to assess the responses of *A. ramkhamhaengi* to different food types. The diets were given at the concentration of 500 mg L^{-1}. Population growth (10.18±1.84 ind mL^{-1}; p = 0.245) and survival (126.16±23.27%; p = 0.370) of copepods were not significantly affected (p = 0.245, p = 0.370; p > 0.05) by the mono and binary diets. However, the reproductive performance of the copepods was significantly affected by the diets used (p < 0.05). Among all the diets used, the mono diets; *Tetraselmis* sp. produce the highest population growth (10.59±1.93 ind mL^{-1}), survival (130.35±25.77%) and reproduction (e.g. hatching rate, 84.01±6.02%) compared with other mono and binary diets. The present study indicates that organic fertilizers used in this study are able to substitute microalgae as an alternative feed and assists in the production of *A. ramkhamhaengi* as live food for marine larvae in hatcheries.

Key Words: algae, *Apocyclops ramkhamhaengi*, organic fertilizer, marine zooplankton, live food, copepod.

Introduction. In nature, copepods constitute a first vital link in the marine food chain starting from primary producers to fish. Copepods are the natural prey for marine fish larvae and crustaceans, and their nutritional composition is believed to be optimal for the marine fish larvae. Cyclopoid copepod are the main food source for marine organisms (Chen et al 2018), due to its nutritional profile of which appears to match the nutritional requirements of marine fish larvae (Delbare et al 1996). Apart from that, copepods can be administered under different forms, either as nauplii or copepodites at the beginning of feeding period and as ongrown copepods until weaning (Dey et al 2015). According to Drillet et al (2006), copepods as supplemental live feed can improve the survival and growth of fish larvae and crustaceans in hatcheries.

Production of zooplankton is controlled by its dietary requirements especially on food types and quality (Pajk et al 2012). In laboratory experiments, the cyclopoid copepod fed artificial diets produced 254 to 416 nauplii per female (Støttrup 2006). Therefore, food quality is the most crucial factor for the growth and reproduction of copepods. According to Rasdi & Qin (2018), population growth, survival and reproductive of cyclopoid copepod was significantly affected by the mono and binary diets. In this study, bio-organic fertilizers as well as microalgae were used because microalgae represent the natural nutritional base and primary source of bulk nutrients in the aquatic food chain (Guedes & Malcata 2012).

Organic fertilizers decompose and release nitrogen, phosphorous and potassium which can be used by phytoplankton and zooplankton for growth and reproduction. Nowadays, poultry manure is being used in some commercial freshwater aquaculture practices. Manures have been found to influence the natural productivity differently in terms of abundance and prevalence of phyto and zooplankton as well as the benthic organisms in ponds (Gangadhar et al 2017). Chicken manure is an excellent food and has many advantages to live foods in improving its nutrition. According to Hyder et al (2014) chicken manure have many benefits in terms of its availability in large quantities, can be purchased easily at a very low price, and also can be used directly after drying, as well as can be stored for longer periods of time, easy to dose and it has none of the problems involved in algal stock maintainance and cultures.

Cyclopoid copepods have highly tolerance to a wide range of environmental conditions. They are generally very productive, can attain high population densities in culture, and are relatively tolerant to decreased water quality and to invasive species such as ciliates, nematodes and rotifers (Støttrup 2003). To achieve this, optimal conditions for culturing cyclopoid copepods, including temperature, salinity, diet, substratum and rearing density, must be considered (Punnarak et al 2017). In this study, we studied the growth and reproduction responses of the copepod *Apocyclops ramkhamhaengi* to different food sources. The objective of this study was to evaluate the impacts of different feeding types on the growth performance and reproduction of this cyclopoid copepod.

Material and Method

Sampling and copepod stock culture. *A. ramkhamhaengi* was sampled from Setiu waters, Terengganu, Malaysia. The copepods were cultured and sustained in Universiti Malaysia Terengganu, UMT hatchery since October 2017. Temperature and salinity were controlled and maintained in an optimal range. Normal habitat condition for optimal temperature is at 26 until 27°C and the optimal salinity is at 24 to 26 ppt (Zaleha & Busra 2012). The water used in this culture was also prepared from filtered seawater and the optimal salinity was obtained by adding the demineralized water. As a stock culture, the copepod was first cultured in 500 mL tank. Daily observation and feeding was provided, and 20% of water in the culture was exchanged in order to avoid any contaminations and toxicities from food given.

Experimental design and diets preparation. Mono and binary diets were prepared according to the feeding treatments. Six treatments consisted of four mono diets (marine *Nannochloropsis sp.,* marine *Tetraselmis sp.,* palm kernel cake (PKC), and chicken manure) and two binary diets (marine *Nannochloropsis sp.* + marine *Tetraselmis sp.,* and PKC + chicken manure) were set up. The algal diets were cultured in a temperature-controlled room using a 500 mL flasks in the laboratory at UMT Hatchery. Furthermore, for PKC and chicken manure, the substances were initially prepared before being fed to the copepods. The concentration of the algal diets used was 500 mg L^{-1} which is equivalent to 2×10^7 algal cells mL^{-1} (Zaleha & Busra 2012). Copepods were fed PKC and chicken manure at the concentration of 500 mg L^{-1} (Paray & Al-Sadoon 2016). As for binary diets, the concentration used is based on 1:1 ratio. Copepods were fed daily throughout the experimental period. Each treatment was done in triplicates. A population consists of 8 ind mL^{-1} (Broach et al 2017) of cyclopoid copepod was transferred first from the stock culture to the 100L tank and feed on the respective diets for at least one generation before start recording the data needed to remove any effects of previous diets on the copepods (Rasdi & Qin 2018).

Population growth and specific population growth rate. Population growth of copepods were identified by preparing a culture of copepods from 100 mL tank with population consisting of nauplii (4 ind mL^{-1}), copepodite (2 ind mL^{-1}), and adult (2 ind mL^{-1}) in the 500 mL ornamental fish aquarium with triplicates for each dietary treatment and cultured for 15 days. Water quality management were controlled and maintained. Gentle aeration was provided. From 500 mL culture, 5 mL subsample was taken daily from each treatments with six replicates in order to calculate and record the development stages (nauplii, copepodite, and adult) and density of the copepods. Specific population growth rate (r) was calculated from the density data by using the following equation (Lee et al 2013; Rasdi & Qin 2018):

$$r = (\ln Ne - \ln Ni)/t$$

where: t is cultured days, Ni are the initial density of copepods and Ne is the end density of copepods.

Survival rate*.* Eight (8) ind mL^{-1} of copepods nauplii were transferred from the 100 L culture tank into the 500 mL ornamental fish aquarium with triplicate for each diet treatment in order to calculate and record the survival rate of the copepods throughout the experiment. The experiment was done for 15 days, equivalent with the average generation time of the copepods life cycle from nauplii to adult. Once in two days, the copepods density was calculated. Survival rate of copepods was calculated by using the following equation:

$$\text{Survival rate} = [(\text{total number of six samples taken once in two days}) / \text{total number of initial copepod density in tank}] \times 100\%$$

Reproductive performances

Hatching time and hatching rate. Five individual berried female copepods were randomly collected from the culture tank and transferred into triplicate of 500 mL ornamental fish aquarium in order to observe the hatching time and hatching rate of the copepods. Total number of eggs from all the berried female was calculated and recorded. Once in 6 hours the eggs were observed and checked in order to count the newly hatched nauplii over a 24 hours period. After 48 hours of hatching time, the unhatched egg was counted and recorded. According to Pan et al (2012), equation use to calculate the hatching rate is as follows:

$$\text{Hatching rate} = 1 - (\text{number of unhatched eggs} / \text{number of total eggs})$$

Generation time. Two individual of newly hatched nauplii was selected in order to observe the development time of the copepods from nauplii to adult. The development was observed once in 6 hours until the nauplii reached an adult stage. The developmental stages were observed under the microscope in order to calculate the development time of the copepods to reach the matured stage (i.e., from a nauplius to copepodite; from a copepodite to an adult and from a nauplius to a gravid female).

Offspring production, spawning and lifespan. One pair of adult male and female copepods with triplicates for each diet treatment was placed into a 50 mL beaker from the preconditioning stocks of 100 L tank and covered with parafilm with holes for ventilation. The copepods were fed with the mono and binary diets with triplicates each and the beakers were supervised daily for occurrence of new egg sacs. After spawning, each male-female pair was transferred to a new beaker to facilitate observation of the later spawning. The individuals produced from the previous egg sacs were counted in a Sedgewick-Rafter chamber (Pyser – SGI Limited, Kent, UK) on a dissecting stereo-microscope (Model Nikon: SMZ, 1500, Tokyo, Japan) by collecting through a 50 μm mesh. Daily offspring production and offspring per egg sacs were obtained from the mean of triplicate pairs of *A. ramkhamhaengi* in each diet treatment. Total spawns in lifetime were recorded and the lifespan of females was obtained by averaging all individual life duration in 15 days.

Sex ratio*.* At the end of experiment, all male and female adults were separately counted to obtain the sex ratio. All adult copepods were counted on a dissecting stereo-microscope (Model Nikon: SMZ, 1500, Tokyo, Japan) by collecting through 200 until 300 μm mesh.

Data analysis. Data were presented as mean±standard deviation (SD). All the data were collected throughout the experiment and analyzed by using one-way analysis of variance (ANOVA) to see the impacts of different diets on the population growth, survival and reproductive performances of the cyclopoid copepods. Differences were considered significant at the $p < 0.05$ level. When the main treatment effect was significant, post-hoc comparisons were made using Tukey's test. All the data were tested for normality, homogeneity and independence to satisfy the assumptions for ANOVA.

Results and Discussion

Population growth and specific population growth rate. Figure 1 shows the overall population growth of cyclopoid copepods *A. ramkhamhaengi* in each dietary treatment after being cultured for 15 days.

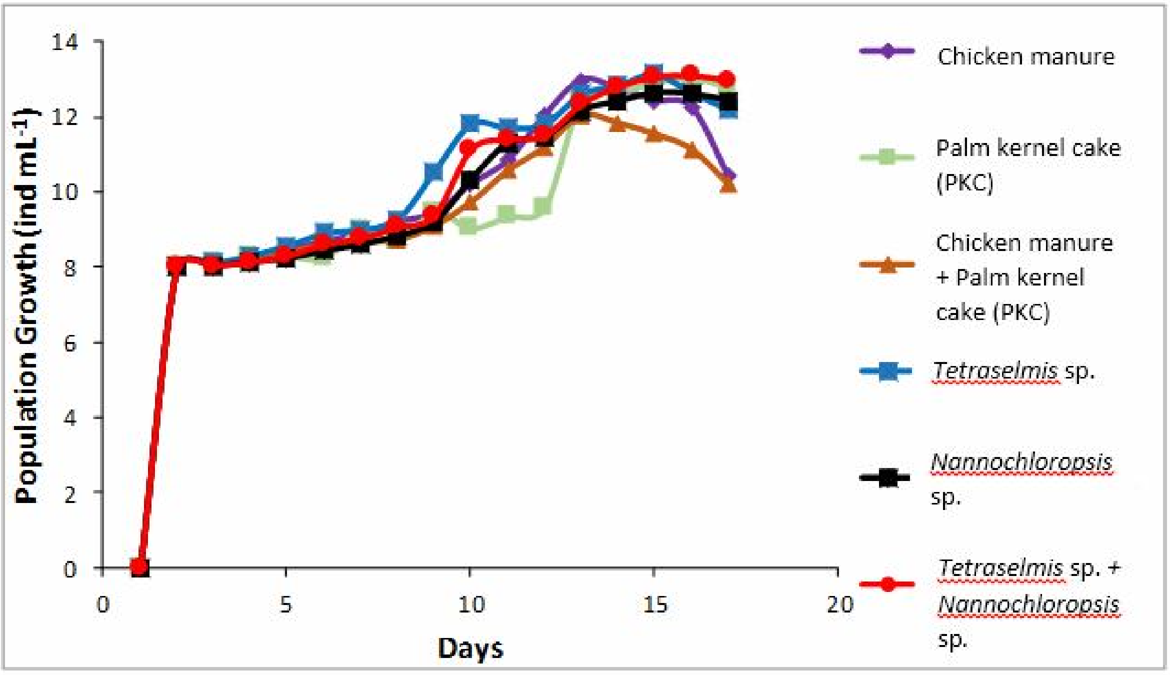

Figure 1. The populace growth of copepods fed with different mono and binary diets.

The highest population densities of copepods occurred when copepods fed with monoalgal diets of fresh *Tetraselmis* sp. (10.59±1.93 ind mL^{-1}) compared with other feeding treatments such as *Nannochloropsis* sp. (10.17±1.91 ind mL^{-1}) and chicken manure (10.17±1.81 ind mL^{-1}) ($p > 0.05$, Table 1). Copepods fed with fresh *Nannochloropsis* sp. produced lower population density (10.17±1.91 ind mL^{-1}) than those fed with mixed fresh algae (*Tetraselmis* sp. and *Nannochloropsis* sp.) (10.41±2.05 ind mL^{-1}) but these were not statistically different ($p > 0.05$, Table 1).

Table 1

The population growth of copepods fed with different mono and binary diets

Diets	*Population growth (ind mL^{-1}) / (mean±SD)*
Chicken manure	10.17 ± 1.81^a
Palm kernel cake (PKC)	9.98 ± 1.99^a
Tetraselmis sp.	10.59 ± 1.93^a
Nannochloropsis sp. (control)	10.17 ± 1.91^a
Chicken manure + PKC	9.75 ± 1.46^a
Tetraselmis sp. + *Nannochloropsis* sp.	10.41 ± 2.05^a

All values are mean±standard deviation (n = 6). The different small letters indicate significant difference between different treatments ($p < 0.05$).

The specific population growth rate of copepods depended on food type ($p < 0.05$, Table 2). Copepods fed with the mono and binary diets of *Tetraselmis* sp., *Nannochloropsis* sp., chicken manure, PKC, *Tetraselmis* sp. and *Nannochloropsis* sp., or chicken manure and PKC achieved higher growth rates ($p < 0.05$).

Table 2
The specific population growth rate of copepods fed with different mono and binary diets

Diets	*Specific population growth rate (mean±SD)*
Chicken manure	0.017 ± 0.005^{a}
Palm kernel cake (PKC)	0.031 ± 0.003^{a}
Tetraselmis sp.	0.028 ± 0.011^{a}
Nannochloropsis sp. (control)	0.029 ± 0.004^{a}
Chicken manure + PKC	$0.016 \pm 0.005^{a,b}$
Tetraselmis sp. + *Nannochloropsis* sp.	$0.032 \pm 0.008^{a,c}$

All values are mean±standard deviation (n = 6). The different small letters indicate significant difference between different treatments ($p < 0.05$).

Survival rate. There was no difference on the survival rate of the copepods among the dietary treatments ($p = 0.370$; $p > 0.05$, Figure 2). Copepods fed with *Tetraselmis* sp. (130.35±25.77%) produced the highest number of survival rate compared with other diets. Apart from that, mixed diets of chicken manure and PKC (120.27±18.57%) produced the lowest number of survival rate.

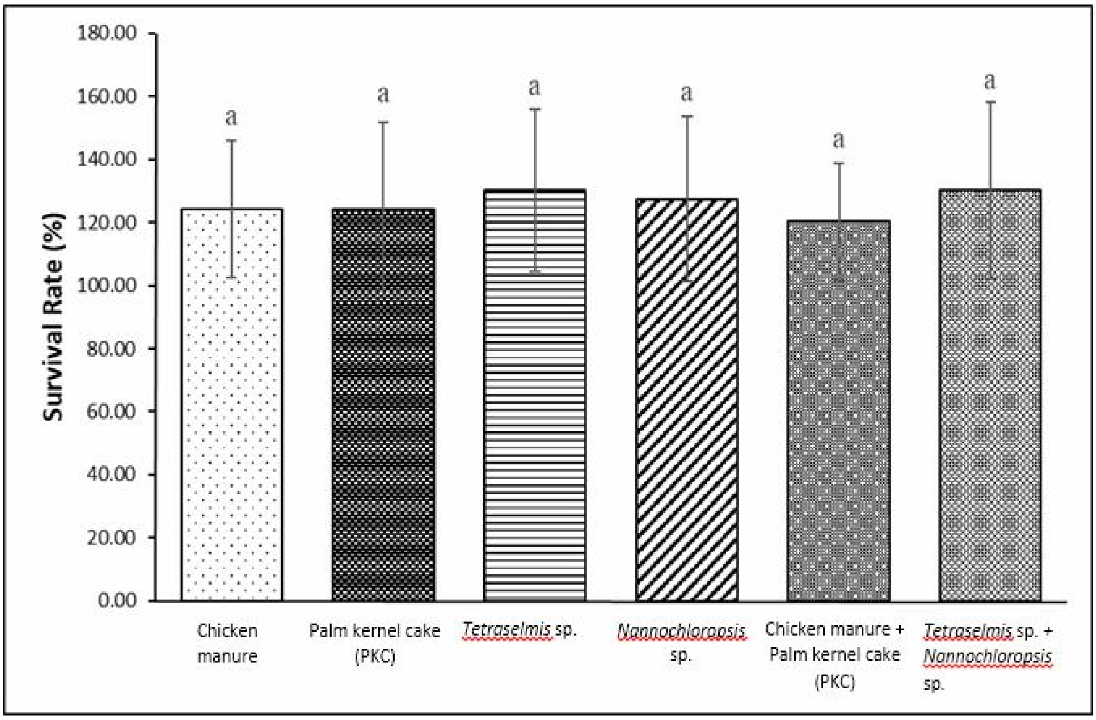

Figure 2. The survival rate of copepods fed with different mono and binary diets.

Reproductive performance

Hatching time and hatching rate. Mono and binary diets used had significant impact on hatching time of copepods eggs ($p < 0.05$, Figure 3). Among all the mono and binary diets used, copepods fed with mono diets of fresh *Tetraselmis* sp. (1.87±0.05 days) have the shortest time to hatch their eggs. Meanwhile, copepods fed with mixed diets of chicken manure and PKC (2.40±0.12 days) had the longest time to hatch their eggs.

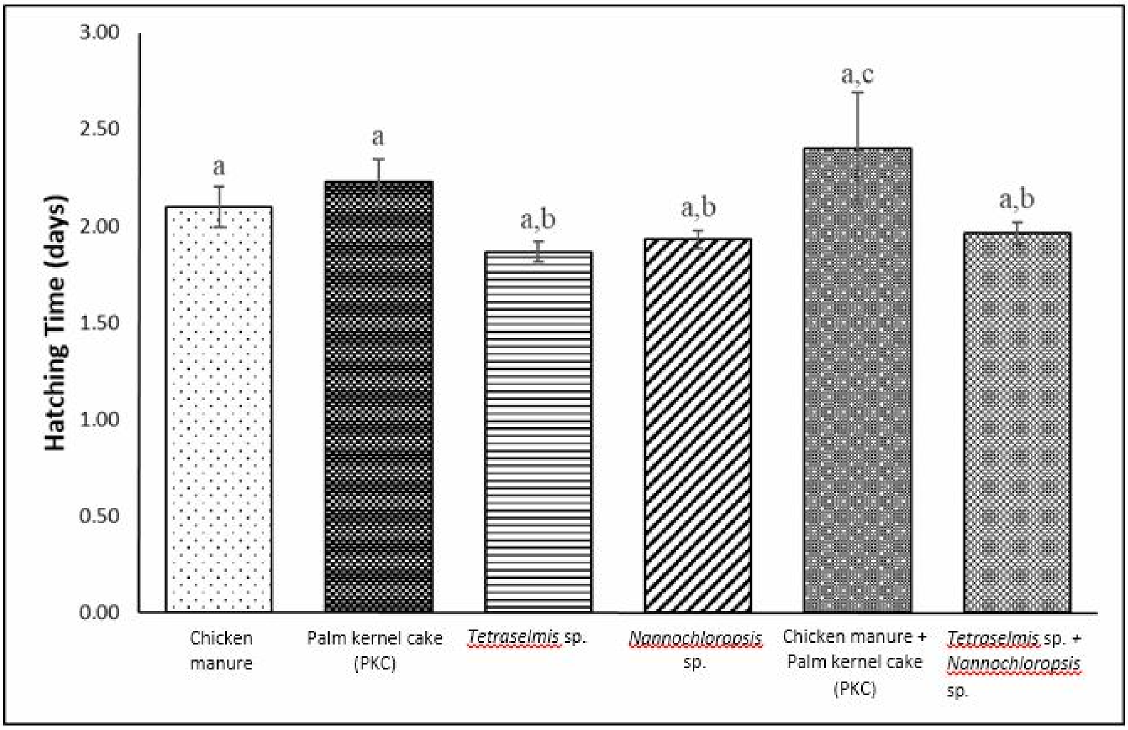

Figure 3. The hatching time of copepods fed with different mono and binary diets.

The type of mono and binary diets used significantly affected the female copepods' hatching rate ($p < 0.05$, Figure 4). The highest and the lowest number of hatching rate in copepods responding to different dietary treatments were recorded in Table 3. The highest hatching rates were achieved when copepods fed monoalgal diets of *Tetraselmis* sp. (84.01±6.02%). Meanwhile, the lowest hatching rate was recorded when the copepods being fed with binary diets of chicken manure and PKC (60.63±3.53%).

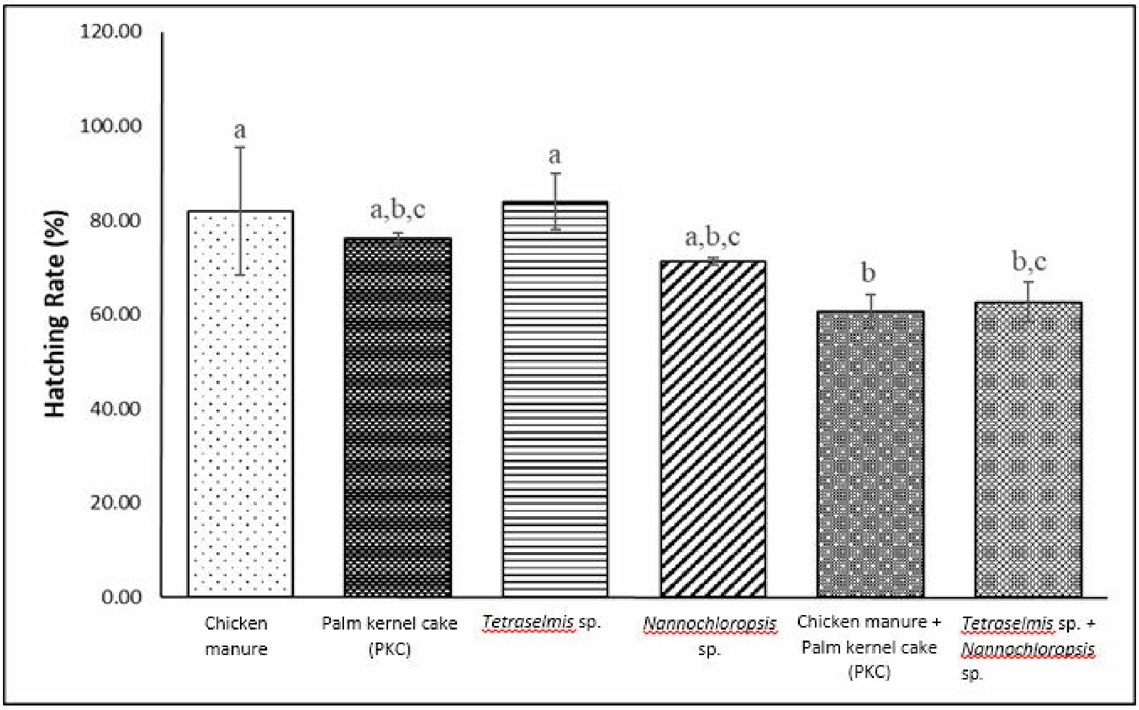

Figure 4. The hatching rate of copepods fed with different mono and binary diets.

Generation time. Development time from newly hatched nauplii stage I to stage VI was significantly affected by the different types of food used ($p < 0.005$, Figure 5).

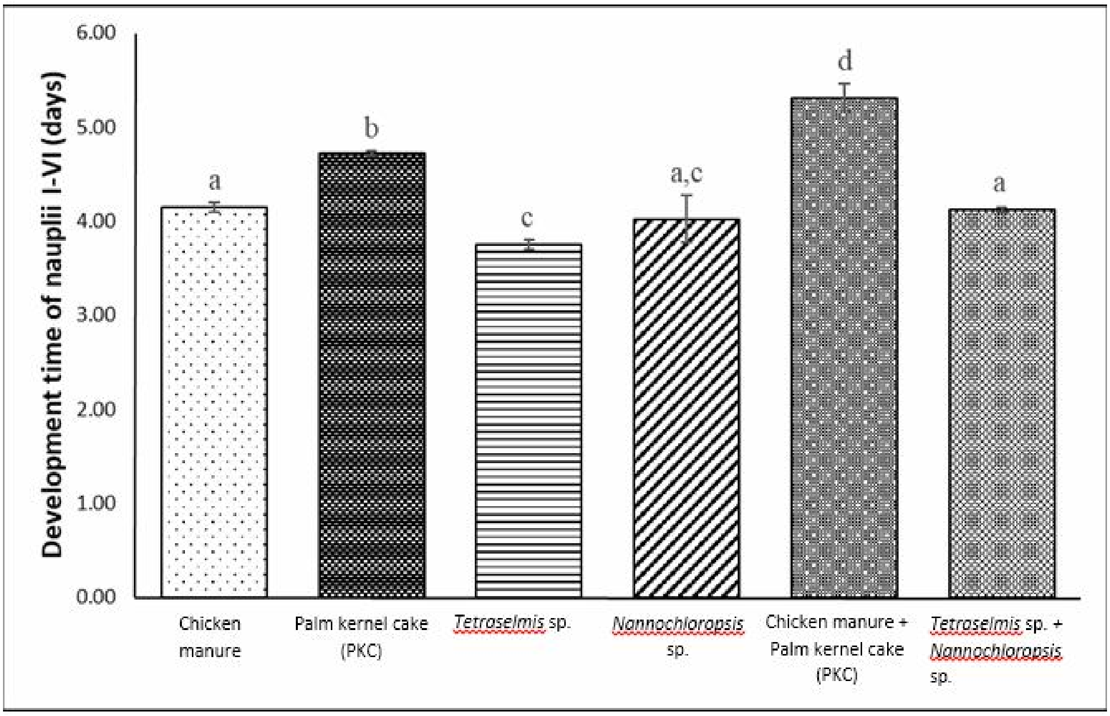

Figure 5. The development time of copepods from nauplii I until VI fed with different mono and binary diets.

Copepods fed mixed diets of chicken manure and PKC had the longest development time (5.31±0.15 days) compared to other dietary treatments ($p < 0.05$; Table 3). Maturation period of copepodite was not significantly different among food types ($p = 0.091$, Figure 6).

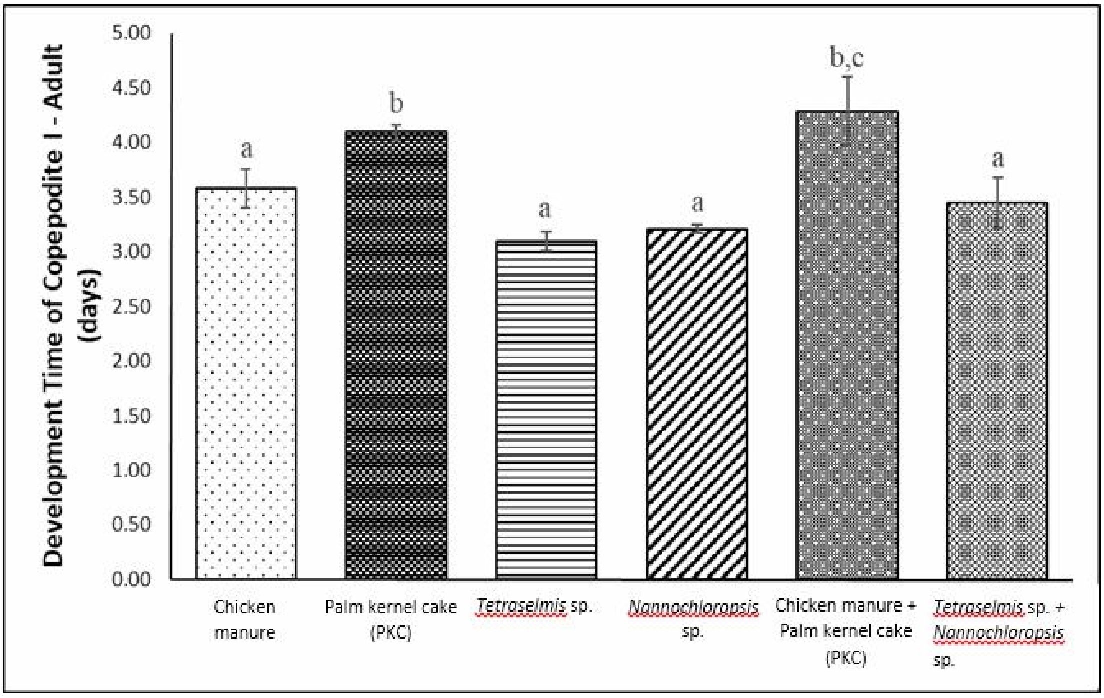

Figure 6. The development time of copepodite I until adult fed with different mono and binary diets.

Table 3

Life table of copepods fed with different mono and binary diets

Diets	*Hatching time (days)*	*Hatching rate (%)*	*Generation time of nauplii I-VI (days)*	*Generation time of copepodite I-adult (days)*	*Generation time of nauplii I-gravid (days)*	*Mean lifespan of copepods (days)*	*No. of spawning/ lifespan*	*Total offspring/egg sacs*	*Total offspring/ female*	*Sex ratio (%)*
Chicken manure	2.10± 0.11[a]	81.94± 13.51[a]	4.15± 0.05[a]	3.58± 0.18[a]	10.80± 0.05[a]	13.33± 0.58[a]	9.00± 1.73[a]	34.00± 5.29[a]	6.80± 1.06[a]	25.70± 15.61[a]
Palm kernel cake (PKC)	2.23± 0.12[a]	76.12± 1.14[a,b,c]	4.72± 0.03[b]	4.09± 0.07[b]	12.35± 0.17[b]	12.67± 1.15[a]	8.00± 1.00[a,b]	37.67± 7.00[a]	7.60± 1.40[a]	57.56± 26.14[a]
Tetraselmis sp.	1.87± 0.05[a,b]	84.01± 6.02[a]	3.75± 0.05[c]	3.10± 0.09[a]	9.18± 0.08[b]	14.67± 0.58[a]	12.00± 1.00[a,c]	43.33± 3.51[a,b]	8.67± 0.70[a,b]	79.68± 6.03[a]
Nannochloropsis sp. (control)	1.93± 0.05[a,b]	71.35± 0.66[a,b,c]	4.02± 0.25[a,c]	3.21± 0.04[a]	9.57± 0.06[d,f]	13.33± 1.53[a]	10.67± 1.53[a,e]	33.33± 4.58[a]	6.62± 0.95[a]	48.49± 2.68[a]
Chicken manure + PKC	2.40± 0.29[a,c]	60.63± 3.54[b]	5.31± 0.15[d]	4.29± 0.31[b,c]	13.31± 0.14[e]	11.67± 1.15[a]	6.33± 0.58[a,d]	28.33± 3.46[a,c]	5.60 ± 0.69[a,c]	44.31± 22.36[a]
Tetraselmis sp. + *Nannochloropsis* sp.	1.96± 0.06[a,b]	62.65± 4.29[b,c]	4.12± 0.03[a]	3.45± 0.23[a]	9.82± 0.04[f]	13.67± 1.53[a]	9.00± 1.00[a]	27.33± 5.29[a,d]	5.47 ± 1.06[a,d]	72.04± 40.28[a]

All values are mean ± standard deviation (n = 6). The different small letters indicate significant difference between different treatments ($p < 0.05$).

The generation time from nauplii to a gravid female was longer in copepods fed mixed diets of chicken manure and PKC (13.31±0.14 days) or the single diet of PKC (12.35±0.17 days) than the other diets (Figure 7).

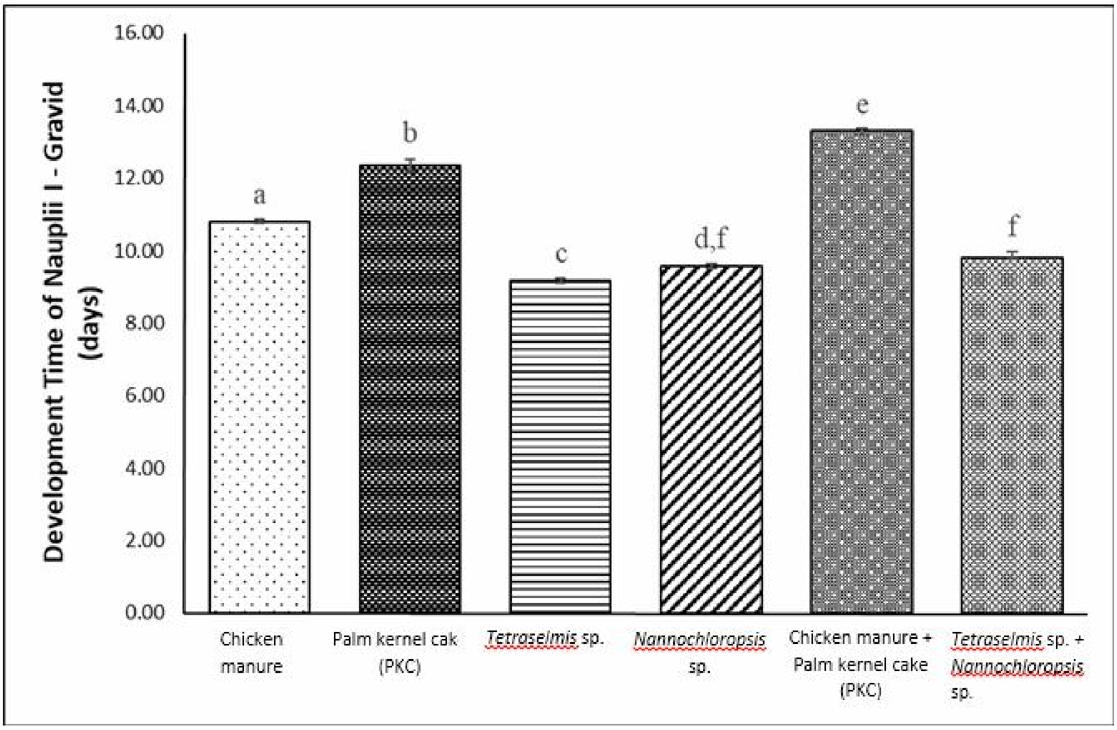

Figure 7. The development time of nauplii I until gravid fed with different mono and binary diets.

Lifespan. The lifespans of female *A. ramkhamhaengi* under different dietary treatments are shown in Table 3. The longest lifespan in copepods was observed in treatments with monoalgal diets of fresh *Tetraselmis* sp. (14±0.58 days; Figure 8).

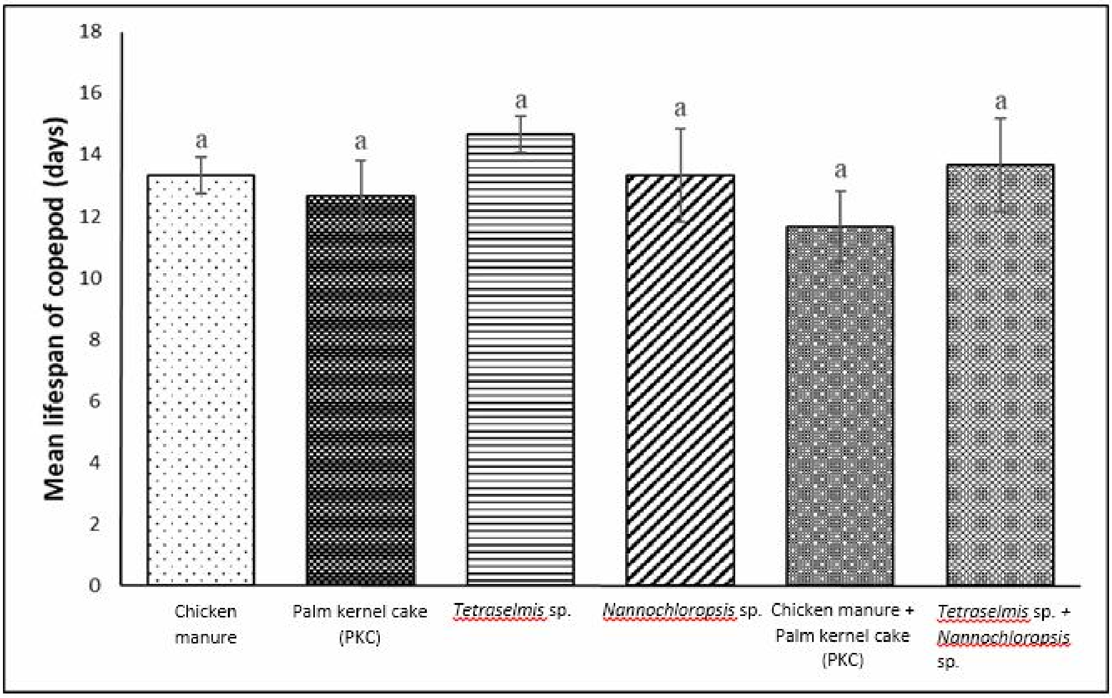

Figure 8. The lifespan of copepods fed with different mono and binary diets.

The shortest lifespan occurred in copepods fed mixed diets of chicken manure and PKC (11±1.15 days; Figure 8). All mono and binary diets used had no significant impact on the lifespan of female *A. ramkhamhaengi* ($p > 0.05$, Table 3).

Spawning. Copepods had most spawns in lifetime when fed on monoalgal diet *Tetraselmis* sp. (12.00±1.00). The number of spawns in lifetime was not impacted by the type of different diets used ($p > 0.05$, Figure 9). The lowest spawns were recorded when the copepods fed with binary diets of chicken manure and PKC (6.33±0.58; Table 3).

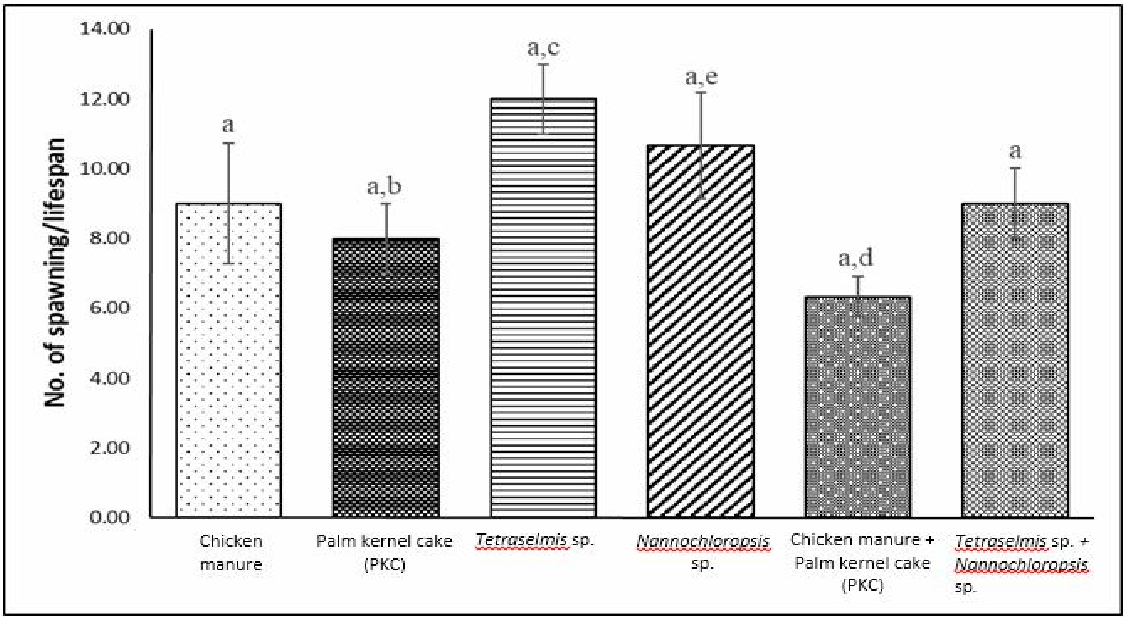

Figure 9. The number of spawning of copepods fed with different mono and binary diets.

Offspring production. The total number of offspring per egg sacs produced in 15 days was not depended on food type ($p > 0.05$, Figure 10). However, it was higher in treatments using a single diet of fresh *Tetraselmis* sp. (43.33±3.51; Table 3).

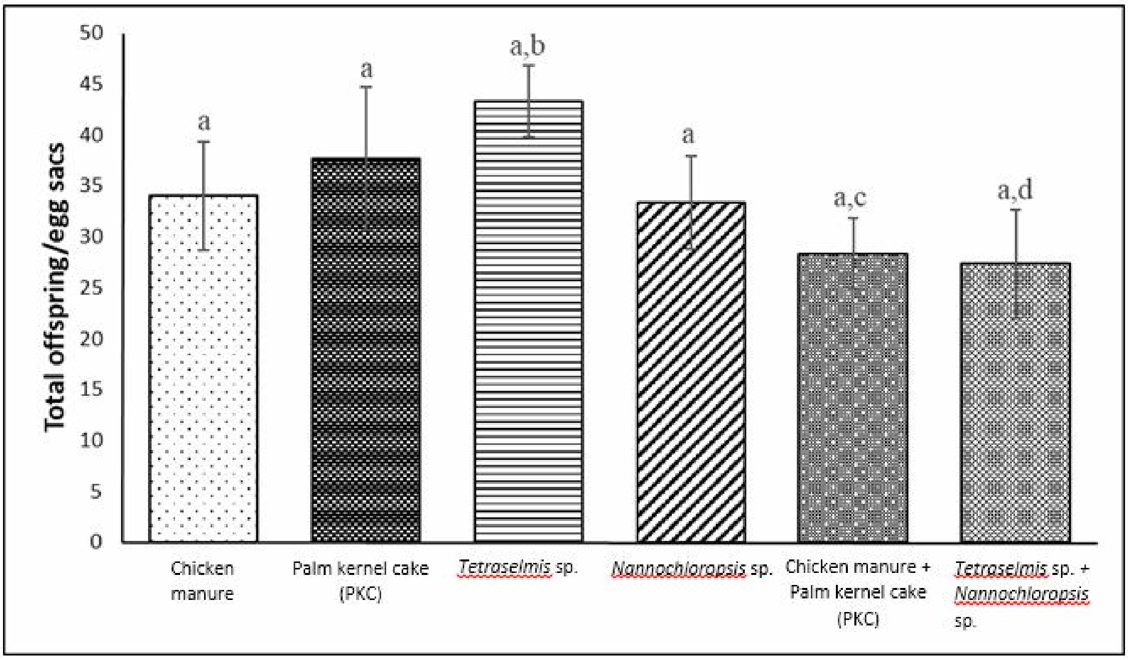

Figure 10. The number of offspring production per eggs sacs of copepods fed with different mono and binary diets.

The production of offspring copepods per female was also not significantly associated with the type of mono and binary diets used (p > 0.05, Figure 11). Total offspring production per female was lowest in the treatment using mixed diets of chicken manure and PKC compared to other dietary treatments (Table 3) but there was a difference between feeding treatments with mono and binary diets used in this study (p < 0.05, Figure 11).

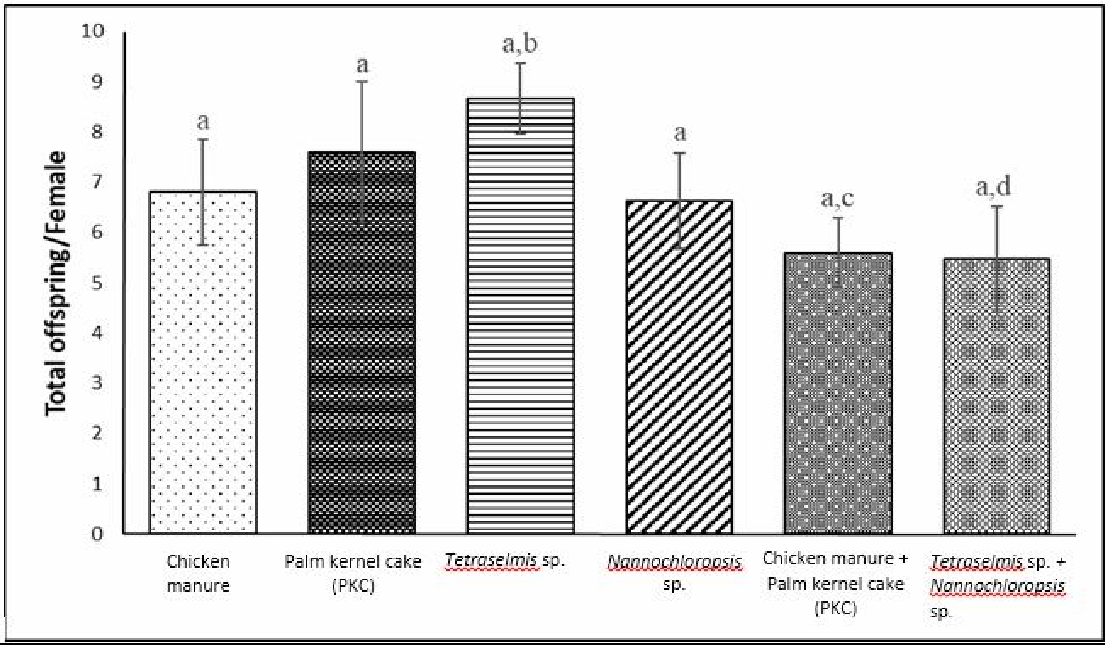

Figure 11. The number of offspring production per female of copepods fed with different mono and binary diets.

Sex ratio. There are no significantly difference on the sex ratio of *A. ramkhamhaengi* (p = 0.118; p > 0.05, Figure 12). The highest number of sex ratio where female is dominant are copepods fed with *Tetraselmis* sp. (79.68±6.04%; Table 3) followed by copepods fed with mixed diets of *Tetraselmis* sp. and *Nannochloropsis* sp. (72.04±40.28%; Table 3) compared with other diets such as copepods fed with single diet of chicken manure (25.70±15.61%).

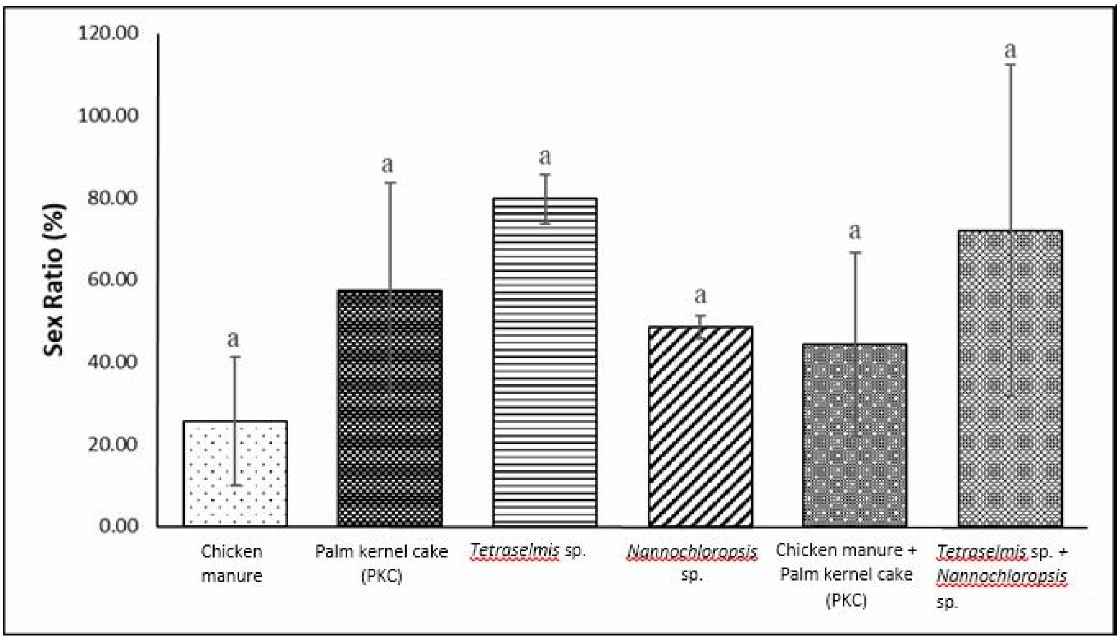

Figure 12. The number of sex ratio of copepods fed with different mono and binary diets.

Discussion. Results from the present study clearly indicated that different food types are important for a successful propagation of *A. ramkhamhaengi*. Among all the diets used, *A. ramkhamhaengi* fed with mixed diet of *Tetraselmis* sp. and *Nannochloropsis* sp. has the highest number of population growth rate (0.032±0.001%) compared with other dietary treatments. However, based on this study, the results also showed that other types of feed are applicable to be used by aquaculturist in order to increase and sustain the copepods production since there are only slightly differences in terms of the number of population growth rate between all the dietary treatments. This indicates that chicken manure and PKC fed to *A. ramkhamhaengi* as single diets or mixed diets have a potential to be used as one of the commercial diets that can substitute algae as the vital food source for zooplankton culture. Different types of microalgae (*Tetraselmis* sp. and *Nannochloropsis* sp.) were used in this study in order to identify the effect of those two on *A. ramkhamhaengi* population growth, survival and reproduction. Microalgae are undeniable as the crucial nutritional enhancement for marine animals in the open sea, and consequently in aquaculture (Guedes & Malcata 2012). Both marine algae are generally high in eicosapentaenoic acid (EPA) (Rasdi et al 2015) even both algae are slightly different in terms of size. However, based on the result obtained from single diets of *Tetraselmis* sp. produce high population growth (10.59±1.93 ind mL^{-1}), survival (130.35±25.77%) and reproduction (e.g. hatching rate, 84.01±6.02%) compared with single diets of *Nannochloropsis* sp. Similarly, a cyclopoid copepod *Paracyclopina nana* fed *Isochrysis* sp. produced maximum population densities and increased reproduction capacities compared to feeding on *Tetraselmis suecica* (Lee et al 2006; Rasdi et al 2015). The *A. ramkhamhaengi* fed with *Nannochloropsis* sp. relatively produce low population growth and reproductive performance, which was mainly due to derived low DHA and other HUFAs content of copepods (Rasdi et al 2015). However, the combinations of those two diets (*Tetraselmis* sp. and *Nannochloropsis* sp.) as mixed diets also give higher population (10.41±2.05 ind mL^{-1}) and survival (130.28±28.11%) than single diets of *Nannochloropsis* sp. Therefore, according to Payne & Rippingale (2001), the toughness and indigestibility of microalgae *Nannochloropsis* sp. cell wall also would be the main reason for the poor performance of this diet. Apart from that, this study also indicates that, even using mono diets, copepods also can be cultured and produced commercially by aquaculture hatcheries without invest highly on food cost. Chicken manure and PKC were not commercially used in aquaculture because of their nature source and underdeveloped research among aquaculturists. However, the nutritional content in these organic fertilizers has been found to influence the productivity in terms of abundance and prevalence of phytoplankton and zooplankton (Gangadhar et al 2017). In this study, cyclopoid copepods *A. ramkhamhaengi* fed with single diets of chicken manure and PKC also produces high population growth (10.17±1.81 ind mL^{-1}; 9.98±1.99 ind mL^{-1} respectively) and survival (124.24±21.86%; 124.31±27.26% respectively) as well as mixed diets of chicken manure and PKC (9.75±1.46 ind mL^{-1}; 120.28±18.57% respectively). Our study indicates that chicken manure and PKC are the most cost effective feed since both feed products can be obtained at a reasonable price. Therefore, the nutritional content in chicken manure and PKC is also suitable to feed on copepod culture. Thus, make both chicken manure and PKC applicable to be used as one of the food sources for copepods enrichment in aquaculture industry. Based on the life table (Table 3), microalgae *Tetraselmis* sp. are undeniable feed that significantly affected the reproductive performance (hatching time, hatching rate, generation time, and lifespan, number of spawning, offspring production and sex ratio) of *A. ramkhamhaengi*. *Tetraselmis* sp. is recommended as a suitable diet to produce high reproductive performances parameters (Alajmi & Zeng 2015). However, the mono and binary diets used in the present study are acceptable to be used as a feed sources to improve and sustain the copepods production in hatcheries.

Conclusions. The population growth, survival and reproductive performances of *A. ramkhamhaengi* are affected by mono and binary algal diets. Copepods produced better growth, survival and productivity when fed on mono diets of *Tetraselmis* sp., *Nannochloropsis* sp., and binary diets of *Tetraselmis* sp. and *Nannochloropsis* sp. Apart from that, food sources from organic materials can also be utilized for a sustainable production of copepods. Based on the present study, the use of chicken manure and PKC are able to substitute common microalgae practices in hatcheries because the hatching rate and offspring production in copepods are comparable to other dietary sources. This is consistent with previous studies where organic fertilizer such as chicken manure and PKC that contain high content of nitrogen and phosphorus are more desirable for feeding by zooplankton. This study showed that organic fertilizers are one of the options to be used as a cost-effective feed for copepods production in hatcheries. This study will enhance and assist the consistent live feed supply for continuous larval fish production.

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