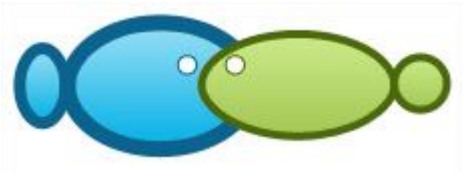

Effect of replacing fishmeal with palm kernel meal supplemented with crude attractants on growth performance of *Macrobrachium rosenbergii*

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Abstract. A 60-day feeding trial was conducted to study the effect of partial replacement of fishmeal with palm kernel meal (PKM) on growth performance and oxidative stress of Malaysian prawn, *Macrobrachium rosenbergii*. A closed aquaculture system with 21 fibreglass tanks with the capacity of 150 liter was used for the experiment. Five iso-energetic (19 KJ/g DM gross energy) test diets were formulated by replacing 0, 10, 20, 30 and 40% of fishmeal with PKM and labelled as PKM0, PKM10, PKM20, PKM30 and PKM40, respectively. Another two diets were prepared by the supplementation of 2% shrimp meal and 2% squid meal in PKM30 (PKM30+) and PKM40 (PKM40+) diets, respectively. Triplicate groups of 30 post-larvae (0.041±0.001 g) were stocked in previously prepared tanks and fed the test diets at the rate of 10-15% of their body weight, twice a day. The results showed that there were no significant differences ($p > 0.05$) in weight gain and specific growth rate of prawn fed PKM0, PKM10, PKM20 and PKM30 diets. However, the growth parameters were significantly decreased in prawn fed PKM40 diet. Supplementation of crude attractants recovered the depleted growth performances in PKM30+ and PKM40+ groups. The feed utilization parameters also followed the similar trends. The superoxide dismutase activity was similar in all the dietary treatments except in PKM30. It is concluded that 30% fishmeal can be replaced with PKM in the diets of prawn without any detrimental effects on growth performance and feed utilization. Supplementation of small amount of crude attractants such as squid meal and shrimp meal could replace 40% or more fishmeal from the diet of Malaysian prawn.
Key Words: fishmeal, palm kernel meal, attractant, growth, Malaysian prawn *Macrobrachium resenbergii*

Introduction. *Macrobrachium rosenbergii* (de Man, 1879) also known as the giant river prawn, giant freshwater prawn, Malaysian prawn, freshwater scampi or cherabin, is native to the Indo-Pacific region, northern Australia and Southeast Asia (New 2000). It is a very lucrative aquaculture species for its high value and delicious taste. This species is widely cultured in Asian region including Malaysia. Since the aquaculture technology of *M. rosenbergii* was first developed in Marine Fisheries Research Institute in Penang, Malaysia (New 2000), this species is termed as Malaysian prawn and is considered as a brand of Malaysia. Because of the high demand of this prawn species and outbreak of infectious diseases for other prawn species, farmers are paying more attention to culture Malaysian prawn as an alternative to marine shrimp. Thus, the production of this species has started to increase rapidly since 1996. The annual global production was only 2861 tonnes in 1980, while it was increased at about 80 times higher at 229419 tonnes in 2009 (FAO 2011). The increasing trend of prawn production demands high quality juveniles and commercial feeds. However, the feed cost is an alarming issue for the

greater expansion of aquaculture industry because the feed cost incurred 40-60% of operational costs in Malaysian prawn production (D'Abramo & Sheen 1994). Fishmeal has been used as a major protein source in prawn feed because of its unique characteristics such as high quality protein and lipid, balanced amino acids and fatty acids, attractants, micronutrients, unidentified growth factors etc. However, fishmeal is a finite resource and its demand and price are increasing day by day. Therefore, replacement of fishmeal with cost-effective alternative protein sources is a current demand for aquaculture industry (Du & Niu 2003; Bulbul et al 2013; Wattanakul et al 2017).

Although, considerable research have been conducted to find for alternative protein sources for commonly available fish and shrimp species, research on *M. rosenbergii* is scarce. It has been reported that 20-30% fishmeal protein can be replaced with soybean meal (Du & Niu 2003), seaweed meal (Felix & Brindo 2014) and snail meal (Jintasataporn et al 2004) from the diets of Malaysian prawn. Hossain & Islam (2007) found no significant difference between the performance of juvenile prawn by feeding 25% fishmeal and 14% meat and bone meal based diet and a commercial diet. It was reported that 50% fishmeal can be substituted with *Spirulina platensis*, *Chlorella vulgaris* and *Azolla pinnata* for *M. rosenbergii* (Radhakrishnan et al 2014). Complete fishmeal replacements were also reported with *Artemia* biomass (Anh et al 2009) from the diets of prawn. While Du & Niu (2003) reported that growth of prawn was significantly decreased when fishmeal was completely replaced with soybean meal.

Palm kernel cake is a by-product of oil extraction from palm kernel. To date, Malaysia is the second largest producer of palm oil after Indonesia, but it remains as the world's leading exporter of palm oil. The palm oil industry plays an important role in the Malaysian economic growth and development. This is evident by foreign exchange earnings from the exports of crude oil and oil based products being the second largest source of export income to the country, with the total exports of RM 59.8 billion in 2010 (Azizan et al 2012). The high production of palm oil also provides a huge amount of palm kernel byproduct. Usually, these byproducts or cakes are used as a fertilizer and a small portion in ruminants, poultry, swine and supplementary feed for semi intensive fish culture or dumped in the sea (Onwudike 1988; Agunbiade et al 1999; Ng 2004). However, palm kernel cake can be converted to palm kernel meal (PKM) which has great potential in aquaculture feed (Ng & Chen 2002; Ng et al 2002; Ng 2004). It has been reported that 10-20% fishmeal can be replaced with PKM in the diets of hybrid Asian-African catfish (*Clarias macrocephalus* × *C. gariepinus*) (Ng & Chen 2002) and red hybrid tilapia (*Oreochromis* sp.) (Ng et al 2002). There is no report on the utilization of PKM for *M. rosenbergii*.

The utilization of plant protein by aquatic animals can be limited because of the unique characteristics of plant protein such as lower protein, imbalanced amino acids, indigestible carbohydrate, antinutritional factors etc. which negatively affected the feed intake and health status of fish (Kader et al 2010; Bulbul et al 2013). Therefore, supplementation of feeding stimulants is recommended while using plant protein as dietary sources for fish and shrimp (Kader et al 2010; Bulbul et al 2013; Bulbul et al 2015). Based on this hypothesis, a feeding trial was conducted to study the effect of fishmeal replacement with PKM on the performance of Malaysian prawn, *M. rosenbergii*. The high PKM based diets were supplemented with squid meal and shrimp meal to achieve higher fishmeal replacement levels with PKM in this study.

Material and Method

Feed formulation and preparation of diet. Table 1 shows the feed formulation of experimental diets. All the feed ingredients were collected commercially except PKM. The palm kernel cake (PKC) was collected from a commercial palm industry in Perak, Malaysia. The PKC was dried, blended and sieved to prepare PKM. The Danish fishmeal and PKM were used as the main protein sources. The diets were formulated according to Goda (2008). Five experimental diets were prepared by gradually replacing 0, 10, 20, 30 and 40% of fishmeal protein with PKM protein and were assigned to five dietary treatments as PKM0, PKM10, PKM20, PKM30 and PKM40, respectively. Another two diets

were prepared by supplementing 2% shrimp meal and 2% squid meal to the PKM30 and PKM40 diets which designated as PKM30+ and PKM40+, respectively.

All the dietary ingredients were first grinded into a small particle size by using the hammer mill and passed through a 100 µm mesh sieve. The diets were prepared by thoroughly mixing all the dry ingredients in a food mixer for 10 minutes. Then, fish oil was added to the dry ingredients and mix for another 10 minutes. The required amount of water (depends on texture) was added to the premix ingredients and was mixed for another 10 minutes. The mixture was then allowed to pass through a meat grinder with appropriate diameter (1.0 mm) to prepare pellets, which then dried in an oven at about 60^{o}C for overnight. The test diets were stored at -20^{o}C in a refrigerator until use.

Table 1

Ingredient composition of the formulated diets

Ingredients (% dry matter basis)	*Test diets*						
	PKM0	*PKM10*	*PKM20*	*PKM30*	*PKM40*	*PKM30+*	*PKM40+*
Fishmeal[a]	25.00	22.50	20.00	17.50	15.00	17.50	15.00
Palm kernel meal[b]	0.00	10.99	21.99	32.98	43.98	16.52	27.51
Soybean meal[c]	20.50	21.25	22.00	22.75	23.50	22.75	23.50
Shrimp meal[d]	0.00	0.00	0.00	0.00	0.00	2.00	2.00
Squid meal[d]	0.00	0.00	0.00	0.00	0.00	2.00	2.00
Corn starch[e]	20.00	15.00	10.00	5.00	0.00	10.00	5.00
Wheat flour[e]	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Fish oil[e]	5.00	3.75	2.50	1.75	0.50	3.00	1.50
Cod liver oil[e]	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Soybean lecithin[e]	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin mixture[e]	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Mineral mixture[e]	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Carboxymethyl cellulose[e]	2.00	2.00	2.00	2.00	2.00	2.00	2.00
α-cellulose[e]	12.50	9.51	6.51	3.02	0.02	9.23	6.49
Total	100	100	100	100	100	100	100

[a] Sri Purta Trading, Alor Star, Kedah: proximate composition (% dry matter): crude protein - 72.7, crude lipid - 11.7, ash - 11.8, and moisture - 8.9; [b] Collected from local Palm Oil Industry in Kedah, Malaysia: proximate composition (% dry matter): crude protein - 16.5, crude lipid - 16.1, ash - 19.4, and moisture - 4.1; [c] Sri Purta Trading, Alor Star, Kedah: proximate composition (% dry matter): crude protein - 50.37, crude lipid - 1.2, and moisture - 12.7; [d] Collected raw material from local market, dried and made shrimp and squid meal in laboratory; [e] Sri Purta Trading, Alor Star, Kedah.

Experimental system and feeding protocol. The experiment was conducted in the Institute of Tropical Aquaculture, Universiti Malaysia Terengganu (UMT), Malaysia during February to April 2015. The experimental system was consisting of 21 rectangular fibreglass tanks with a capacity of 150 L water each, connected to a closed freshwater system and continuous aeration. The postlarvae of *M. rosenbergii* was produced in UMT hatchery using wild catch broodstock and used for this experiment. Seven groups of postlarvae with an initial average weight of 0.041±0.003 g (mean±SD) were stocked in triplicates in previously prepared 21 tanks at density of 30 postlarvae per tank. The prawn was supplied with the respective test diets at 10-15% of their body weight. Daily ration was divided into two equal feedings at 9.00 am and 6.00 pm. The uneaten feed and faecal matter were removed from the tanks by siphoning before the feeding in every morning. About 15-20% water was exchanged daily. Natural illumination was followed during the feeding period. The duration of the feeding trial was 60 days. Every 10 days interval, the prawn was counted and weighed in bulk to adjust the ration size. During each sampling, all the experimental tanks were cleaned and the water was 100% renewed. The water quality parameters during the experimental period were measured and recorded everyday.

Sample collection and biochemical analysis. At the end of the feeding trial, all the prawn was subjected to fasting for 24 hours prior to final sampling. The total number was counted and the individual body weight of the prawn was measured for each replicate tanks. Three prawns were dissected on ice from each replicate tank and collected the muscle sample for the analysis of superoxide dismutase (SOD) activity. The SOD activity was measured by using commercial kit (StressMarq Biosciences Inc.) by following the manufacturer protocol. Briefly 10 µL muscle sample was added to 50 µL substrate in 96 well plate. Then, 25 µL xanthine oxidase was added to the well. After 20 min incubation at room temperature, optical density was read at 450 nm. The activity of SOD was expressed as U mL^{-1}. The rest of the prawns were kept in -20^{o}C in refrigerator for whole body analysis. The prawn whole body were analysed for moisture, crude protein, crude lipid and ash in triplicates using standard Association of Official Analytical Chemists methods (AOAC 1990). The moisture was determined by drying at 105ºC in an oven until constant weight, crude protein by measuring nitrogen (N×6.25) using the Kjeldahl method (2300-Auto-analyzer, FOSS, Denmark) while crude lipid was determined with ether extraction (SoxtecTM2043). Ash content was measured by Muffle furnace at 600ºC for 6 hours.

Data calculation and statistical analysis. Growth performance and feed utilization parameters were calculated using the following formula:

Weight gain (%) = (final weight – initial weight) × 100 / initial weight
Specific growth rate (% day^{-1}) = {ln (final weight) – ln (initial weight) / duration} × 100
Feed intake (g $prawn^{-1}$ 60 $days^{-1}$) = dry diet given / no. of prawn
Feed efficiency ratio = live weight gain (g) / dry feed intake (g)
Protein efficiency ratio = live weight gain (g) / protein intake (g)

All the experimental data were analyzed using one-way analysis of variance. Level of significance between individual treatment ($p < 0.05$) was evaluated by Duncan's test. The statistical analyses were performed in SPSS 21.0 for Windows (SPSS Inc., Chicago, IL).

Results

Chemical composition of test diets. The nutritive values of the diets are recorded in Table 2. All the diets contain similar levels of nutrients, with about 5% moisture, 30% crude protein, 12% crude lipid and 19 KJ/g gross energy. However, dietary ash content increases with the increasing values of PKM in diets.

Table 2

Chemical composition of the test diets

Proximate composition	*Test diets*						
	PKM0	*PKM10*	*PKM20*	*PKM30*	*PKM40*	*PKM30+*	*PKM40+*
Moisture (%)	4.79	4.76	4.64	4.62	4.94	4.84	4.94
Crude protein (% DM[a])	30.79	30.69	30.05	30.16	30.29	30.28	30.75
Crude lipid (% DM)	12.35	12.61	12.60	13.67	13.64	12.41	12.63
Ash (% DM)	5.40	6.18	8.22	10.09	12.10	10.44	12.49
Gross energy (KJ/g DM)[b]	20.17	20.09	19.72	19.65	19.25	19.28	18.99

[a] Dry matter basis; [b] Calculated using combustion values for protein, lipid and carbohydrate of 236, 395 and 172 KJ kg^{-1}, respectively. Carbohydrate calculated by difference: 100-protein-lipid-ash-moisture.

Water quality parameters. The water quality parameters are shown in Table 3. Significant differences were not detected in all the measured water quality parameters among treatments. The lowest temperature was recorded as 25.4^{o}C and the highest as 29.1^{o}C. For the DO, the lowest and the highest values recorded throughout the feeding

trials were 4.94 and 6.57 (mg L^{-1}), respectively. The pH values were varied between 8.13 and 8.88.

Table 3

Water quality parameters (mean ± SD) during the experimental period

Parameters	*Test diet*						
	PKM0	*PKM10*	*PKM20*	*PKM30*	*PKM40*	*PKM30+*	*PKM40+*
Temperature (°C)	26.8-28.4 (27.37± 0.90)	26.1-28.9 (27.43± 1.40)	25.4-28.8 (26.01± 1.70)	26.9-29.1 (27.70± 1.21)	26.9-28.5 (27.60± 0.81)	27.7-28.3 (27.60± 0.75)	26.9-27.6 (27.03± 0.51)
DO (mg L^{-1})	5.38-6.57 (6.13± 0.65)	6.12-6.18 (6.16± 0.03)	5.66-6.20 (5.94± 0.27)	5.88-6.22 (6.03± 0.17)	5.27-6.22 (5.70± 0.48)	4.94-5.61 (5.56± 0.65)	5.45-6.36 (5.80± 0.49)
pH	8.37-8.51 (8.43± 0.07)	8.36-8.88 (8.59± 0.27)	8.24-8.52 (8.36± 0.14)	8.13-8.66 (8.48± 0.30)	8.13-8.43 (8.33± 0.17)	8.18-8.75 (8.39± 0.31)	8.28-8.34 (8.30± 0.03)

Values are range of parameter from lowest to highest reading recorded while Mean±SD tabulated in parenthesis.

Growth performance and feed utilization parameters. The growth performance and nutrient utilization parameters of prawn fed the test diets containing different levels of PKM are shown in Table 4 and Figure 1. The initial weight was similar in all the treatments. It was found that weight gain (%) and specific growth rate (SGR) (% day^{-1}) were not significantly different ($p > 0.05$) when the prawn fed diets with up to 30% fishmeal replacement with PKM (PKM30). However, when the level of fishmeal replacement was increased to 40%, all of these growth performance parameters were significantly ($p < 0.05$) decreased. Interestingly, the growth performance parameters were recovered by adding 2% of shrimp meal and 2% of squid meal as crude attractants in PKM30+ and PKM40+ diets. The significantly highest growth was found in prawn fed PKM30+ compared to the control. Although not significant, the numerically higher growth was also found in PKM40+ group of prawn compared to the fishmeal based control group (PKM0) which suggested higher fishmeal replacement with PKM by supplementing crude attractants. The feed intake was not significantly different among the treatments. In line with the growth performances of prawn, feed efficiency ratio (FER) showed no significant difference up to 30% fishmeal replacement groups. However, FER was significantly decreased in prawn fed PKM40 diet. The depleted FER was recovered in PKM30+ and PKM40+ diets by the supplementation of shrimp meal and squid meal. Similarly, protein efficiency ratio (PER) was also found to significantly decreased in PKM40 diet and the values were similar ($p > 0.05$) among PKM0, PKM30+ and PKM40+ groups.

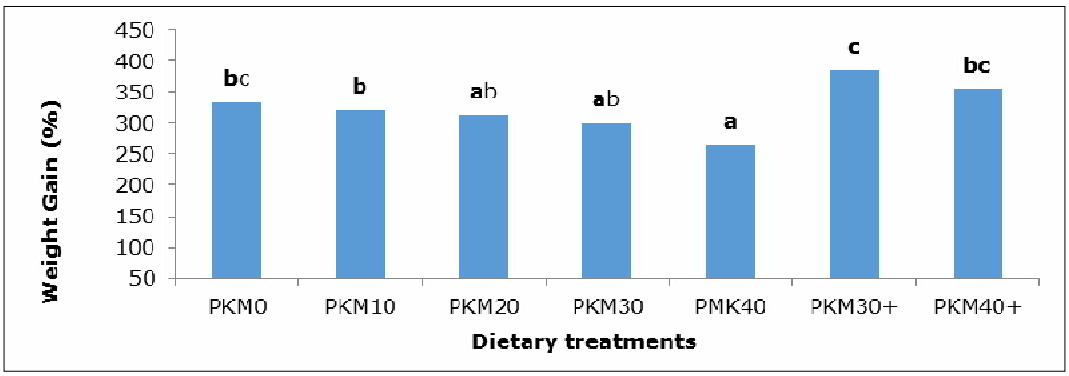

Figure 1. Weight gain (%) of *M. rosenbergii* fed test diets for 60 days. Values with same labels are not significantly different ($p > 0.05$).

Table 4

Growth performance and feed utilization of *M. rosenbergii* fed test diets for 60 days

Parameters	Test diet						
	PKM0	*PKM10*	*PKM20*	*PKM30*	*PKM40*	*PKM30+*	*PKM40+*
IBW[a]	0.04± 0.000[a]	0.04± 0.002[a]	0.04± 0.001[a]	0.04± 0.002[a]	0.04± 0.001[a]	0.04± 0.002[a]	0.04± 0.001[a]
SGR[b]	2.45± 0.02[bcd]	2.39± 0.06[bc]	2.36± 0.02[bc]	2.31± 0.04[ab]	2.16± 0.04[a]	2.62± 0.12[d]	2.52± 0.05[cd]
FI[c]	0.46± 0.01[a]	0.49± 0.03[a]	0.51± 0.01[a]	0.49± 0.03[a]	0.50± 0.01[a]	0.51± 0.05[a]	0.53± 0.04[a]
FER[d]	0.29± 0.01[bc]	0.27± 0.01[abc]	0.24± 0.01[bc]	0.25± 0.02[abc]	0.21± 0.01[a]	0.31± 0.03[c]	0.29± 0.03[bc]
PER[e]	0.95± 0.04[bc]	0.87± 0.03[abc]	0.78± 0.05[bc]	0.84± 0.07[abc]	0.72± 0.03[a]	1.03± 0.11[c]	0.95± 0.09[bc]

Values are means±SD. Within a row, means with the same letters are not significantly different ($p > 0.05$); [a] Mean initial body weight (g); [b] Specific growth rate (% day^{-1}); [c] Feed intake (g prawn^{-1} 60 days^{-1}); [d] Feed efficiency ratio; [e] Protein efficiency ratio.

Oxidative stress parameter. Figure 2 shows the SOD activity of prawn after the end of the experiment. The SOD was significantly decreased in prawn fed PKM30 diet compared to PKM0 diet, while no differences was found among the other treatments.

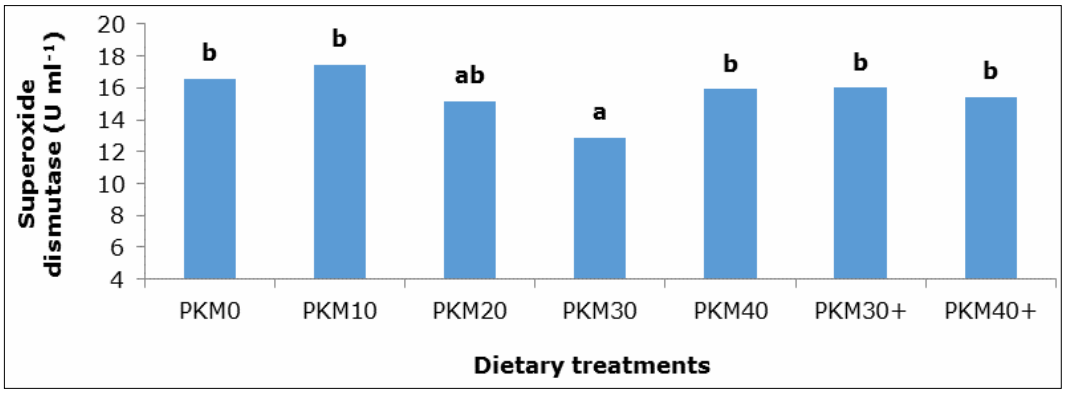

Figure 2. Superoxide dismutase activity of *M. rosenbergii* fed test diets for 60 days. Values with same labels are not significantly different ($p > 0.05$)

Discussion. Fishmeal is considered as the best protein source for fish and shrimp, thus it contributes the major dietary contents for aquatic species, more specifically carnivorous fish and shrimp. Because of the unavailability, higher demand and rising cost, this finite ingredient must be substituted with alternative dietary ingredients from aquafeed (Du & Niu 2003; Kader et al 2010; Bulbul et al 2013; Wattanakul et al 2017). The present study took an attempt to replace fishmeal with PKM from the nursery diets of Malaysian prawn, *M. rosenbergii*. It was found that there was no significant difference in growth performance of prawn fed fishmeal based control diet and diets replacing 10-30% fishmeal with PKM. Growth performance was significantly degraded by replacing 40% fishmeal while the depleted growth performance was recovered by supplementing each of 2% squid meal and shrimp meal.

It is well documented that aquatic animals have limited capacity to accept vegetable protein sources in their diets. Research on dietary inclusion of PKM for aquatic animals is limited. Omoregie (2001) formulated diets by the inclusion of 0, 10, 20 and 30% PKM and fed to carp (*Labeo senegalensis*) for 12 weeks. It was found that growth was significantly decreased by the inclusion over 10% PKM. Ng & Chen (2002) have tried to incorporate 0, 10, 20 and 40% PKM as replacement of fishmeal in the diets of Asian-African catfish and found that 20% PKM inclusion is suitable in terms of growth and feed utilization. In another study, Ng et al (2002) investigated the dietary effects of PKM, enzyme treated PKM and fermented PKM for red hybrid tilapia. It was concluded that tilapia did not accept fermented PKM while 20% PKM and 40% fermented PKM had no

significant difference compared to those of control diet. Similarly, present study also showed that *M. rosenbergii* could accept 30% PKM in their diets without any alteration on growth performance and feed utilization. This result also compares favourably with those found in other alternative protein sources from prawn (Du & Niu 2003; Jintasataporn et al 2004; Hossain & Islam 2007; Felix & Brindo 2014; Radhakrishnan et al 2014).

Growth and feed utilization were significantly decreased by replacing 40% fishmeal with PKM which agrees with the findings of previous studies (Omoregie 2001; Ng & Chen 2002; Ng et al 2002). There are number of factors that limit the incorporation of PKM in prawn diets such as relatively lower protein, essential amino acid defficiencies, presence of anti-nutritional factors and lower digestibility (Ng et al 2002; Ng 2004). Cell wall materials constitute about 73% of PKM and non starch polysaccharides accounted for 75% of these water-insoluble, indigestible, cell wall materials (Dusterhoft et al 1991; Ng et al 2002). Dry matter, protein, lipid and energy digestibility were significantly decreased by replacing 20% PKM for tilapia (Ng et al 2002).

Supplementation of small amount of crude attractants (squid meal and shrimp meal) recovered the depleted growth performances and feed utilization of prawn fed diet replacing 40% PKM. It is noteworthy that the performance parameters and feed intake were numerically highest in supplemented diets (PKM30+ and PKM40+) which suggested a nutrient balance and more attractibility of these diets. Similarly, Kader et al (2010) and Bulbul et al (2015) investigated that supplementation of 10% of squid meal, krill meal or fish soluble with soybean meal could replace 60% soybean meal from the diets of red sea bream (*Pagrus major*) and kuruma shrimp (*Marsupenaeus japonicus*), respectively while lower replacement (30-40%) values were achieved without supplementation.

All the water quality parameters monitored during the experimental period were within the acceptable tolerance for normal growth performance of prawn (Hossain & Islam 2007; Hasanuzzaman et al 2009). The water quality parameters were almost similar in all the dietary treatments without any significant difference which provided evidence that the inclusion of PKM did not impaired the water quality parameters. Thus, the differences in growth performances of prawn among different treatments were not influenced by water quality parameters.

It is high priority to study the physiological effects of dietary inclusion of low quality plant proteins in aquatic animals. In all aerobic biological systems including fish and crustaceans, reactive oxygen species (ROS) is continuously generated as a result of cellular metabolism, environmental perturbations or dietary alterations that increase the susceptibility to oxidative stress and diseases (Kolkovski et al 2000; Kader 2016). In our study, SOD was analyzed which is considered as a reliable parameter for oxidative stress responsiveness of an animal. SOD is an enzyme that helps break down ROS in cells and prevent damage to tissues (Fontagné-Dicharry et al 2014). Although clear trend on SOD activity was not found in the present study, it was evident that higher levels of PKM inclusion decreased SOD activity. Supplementation of crude attractants with PKM mimic the negative effects of SOD activity. Therefore, in line with the growth performance, it is also indicated that higher levels of PKM inclusion could enhance oxidative stress to prawn (Radhakrishnan et al 2014).

Conclusions. This research showed that fishmeal can be replaced up to 30% with palm kernel meal without showing any significant effects on growth performance and feed utilization of freshwater prawn. The performance of the prawn decreased significantly by replacing 40% fishmeal with PKM. However, growth performance significantly recovered by introducing 2% squid meal and 2% shrimp meal as the attractants with PKM. Since PKM is locally available and low cost dietary ingredients, inclusion of PKM in aquafeed would reduce the reliance on high price fish meal and cost of *M. rosenbergii* production.

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References

Agunbiade J. A., Wiseman J., Cole D. J. A., 1999 Energy and nutrient use of palm kernels, palm kernel meal and palm kernel oil in diets for growing pigs. Animal Feed Science and Technology 80:165-181.

Anh N. T. N., Hien T. T. T., Mathieu W., Hoa N. V., Sorgeloos P., 2009 Effect of fishmeal replacement with *Artemia* biomass as a protein source in practical diets for the giant freshwater prawn *Macrobrachium rosenbergii*. Aquaculture Research 40:669-680.

AOAC, 1990 Official Methods of Analysis of the Association of Analytical Chemists, 15th ed. Association of Analytical Chemist (AOAC), Arlington, VA, USA, 1298 pp.

Azizan A. A., Darawi Z., Mamat M. N., 2012 [Future scenario and marketing of Malaysia palm oil for planning strategies in enhancing competitiveness in international markets]. Prosiding Perkem 7:6-19. [in Malay]

Bulbul M., Koshio S., Ishikawa M., Yokoyama S., Kader M. A., 2013 Performance of kuruma shrimp, *Marsupenaeus japonicus* fed diets replacing fishmeal with a combination of plant protein meals. Aquaculture 372:45-51.

Bulbul M., Kader M. A., Ambak M. A., Hossain M. S., Ishikawa M., Koshio S., 2015 Effects of crystalline amino acids, phytase and fish soluble supplements in improving nutritive values of high plant protein based diets for kuruma shrimp, *Marsupenaeus japonicus*. Aquaculture 438:98-104.

D'Abramo L. R., Sheen S. S., 1994 Nutritional requirements, feed formulation and feeding practices for intensive culture of freshwater prawn *Macrobrachium rosenbergii*. Reviews in Fisheries Science 2:1-21.

Du L., Niu C. J., 2003 Effects of dietary substitution of soybean meal for fish meal on consumption, growth, and metabolism of juvenile giant freshwater prawn, *Macrobrachium rosenbergii.* Aquaculture Nutrition 9(2):139-143.

Dusterhoft E. M., Voragen A. G. J., Engels F. M., 1991 Non-starch polysaccharides from sunflower (*Helianthus annuus*) and palm-kernel (*Elaeis guineensis*) meal - preparation of cell wall material and extraction of polysaccharide fractions. Journal of the Science of Food and Agriculture 55:411-422.

FAO, 2011 Fishstat Plus (v. 2.32) issued 07.04.2011. FAO, Rome, Italy.

Felix N., Brindo A., 2014 Substituting fish meal with fermented seaweed, *Kappahhycus alvarezii* in diets of juvenile freshwater prawn *Macrobravchium rosenbergii*. International Journal of Fisheries and Aquatic Studies 1(5):261-265.

Fontagné-Dicharry S., Lataillade E., Surget A., Larroquet L., Cluzeaud M., Kaushik S., 2014 Antioxidant defense system is altered by dietary oxidized lipid in first-feeding rainbow trout (*Oncorhynchus mykiss*). Aquaculture 424-425:220-227.

Goda A. M., 2008 Effect of dietary protein and lipid levels and protein-energy ratio on growth indices, feed utilization and body composition of freshwater prawn, *Macrobrachium rosenbergii* (de Man 1879) post larvae. Aquaculture Research 39:891-901.

Hasanuzzaman A. F. M., Siddiqui M. N. Chisty M. A. H., 2009 Optimum replacement of fishmeal with soybean meal in diet for *Macrobrachium rosenbergii* (De Man 1879) cultured in low saline water. Turkish Journal of Fisheries and Aquatic Sciences 9:17-22.

Hossain M. A., Islam S. F., 2007 Meat and bone meal as partial substitute for fish meal in nursery diet for giant freshwater prawn *Macrobrachium rosenbergii* (de Man). Journal of the World Aquaculture Society 38:272-280.

Jintasataporn O., Tabthipwon P., Yenmark S., 2004 Substitution of golden apple snail meal for fishmeal in giant freshwater prawn, *Macrobrachium rosenbergii* (de Man) diets. Kasetsart Journal 38:66-71.

Kader M. A., 2016 Role of quantitative and qualitative dieatary proteins in oxidative responsiveness of aquatic organisms. Fishamag 2:39.

Kader M. A., Koshio S., Ishikawa M., Yokoyama S., Bulbul M., 2010 Supplemental effects of some crude ingredients in improving nutritive values of low fishmeal diets for red sea bream, *Pagrus major*. Aquaculture 308:136-144.
Kolkovski S., Czesny S., Yackey C., Moreau R., Cihla F., Mahan D., Dabrowski K., 2000 The effect of vitamins C and E in (n-3) highly unsaturated fatty acids-enriched *Artemia* nauplii on growth, survival and stress resistance of freshwater walleye, *Stizostedion vitreum* larvae. Aquaculture Nutrition 6:199-206.
New M. B., 2000 History and global status of freshwater prawn farming. In: Freshwater prawn culture: the farming of *Macrobrachium rosenbergii*. New M. B., Valenti W. C. (eds), Blackwell Science Ltd, Oxford, UK, pp. 1-11.
Ng W. K., 2004 Researching the use of palm kernel cake in aquaculture feeds. Malaysian Palm Oil Board 41:19-21.
Ng W. K., Chen M. L., 2002 Replacement of soybean meal with palm kernel meal in practical diets for hybrid Asian-African catfish, *Clarias macrocephalus* x *C. gariepinus*. Journal of Applied Aquaculture 12:67-76.
Ng W. K. Lim H. A., Lim S. L., Ibrahim C. O., 2002 Nutritive value of palm kernel meal pretreated with enzyme or fermented with *Trichoderma koningii* (Oudemans) as a dietary ingredient for red hybrid tilapia (*Oreochromis* sp.). Aquaculture Research 33:1199-1207.
Omoregie E., 2001 Utilization and nutrient digestibility of mango seeds and palm kernel meal by juvenile *Labeo senegalensis* (Antheriniformes: Cyprinidae). Aquaculture Research 32:681-687.
Onwudike O. C., 1988 Palm kernel meal as a feed for poultry. 4. Use of palm kernel meal by laying birds. Animal Feed Science and Technology 20:279-286.
Radhakrishnan S., Bhavan P. S., Seenivasan C., Shanthi R., Muralisankar T., 2014 Replacement of fishmeal with *Spirulina platensis, Chlorella vulgaris* and *Azolla pinnata* on non-enzymatic and enzymatic antioxidant activities of *Macrobrachium rosenbergii*. Journal of Basic and Applied Zoology 67:25-33.
Wattanakul W., Wattanakul U., Thongprajukaew K., Muenpo C., 2017 Optimal protein replacement of fish meal by mackerel condensate in diet for giant freshwater prawn (*Macrobrachium rosenbergii*). Aquaculture Research 48:697-710.

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