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Effect of Live and Formulated Diets on Growth, Feed Conversion and Meat Quality of Juvenile Milkfish, *Chanos chanos* (Forsskal, 1775) Reared in Seawater

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Abstract Juvenile milkfish, *Chanos chanos* (weight 7.4±0.2 g and length 9.1±0.2 cm) were use into three treatment groups (10 fish each) and were fed with Artemia, floating and sinking feeds with two replications. Growth parameters were measured fortnightly. Water quality was determined daily; salinity 28ppt, water temperature 26.3±1.5°C, dissolved oxygen 7.3±0.6 ml L^{-1}, pH 8.0±0.1 and ammonia 0.002±0.0001 ml L^{-1}.Fish were given daily ration of 2% body weight three times. Highest weight gain (WG) of the fish fed artemia (42.0+2.3 g) and floating feed (40.1±1.6 g) was achieved than those of the sinking one (32.3±1.5 g) and control group (20.2±1.7 g). Specific growth rate (%) remained considerably (P<0.05) higher in both treatment groups fed live feed (3.16%) and floating feed (3.099%) as compared to the fish fed sinking (2.79%) and control diet (2.19%). Feed conversion ratio (FCR) values of the fish fed artemia (1.4±0.2) and floating feed (1.3±0.03) were significantly different than sinking diet (2.0+0.03) and control group (1.8+0.02). The protein (16.6%-17.4%), moisture (12.6%-13.7%), lipids (7.9%-8.3%),and ash (2.3%-2.5%) contents of fish meat did not differ significantly (P>0.05) in all treatment groups. The concentration of sodium (75.8%-76.2%), potassium (128.7%-129.5%), magnesium (64.4%-64.7%), calcium (11.0%-11.5%), copper (0.1%-0.3%), zinc (1.4%-1.9%), manganese (0.1%), iron (1.4%-1.7%) remained consistent among all treatment groups. In conclusion, *Chanos chanos* showed significantly (P<0.05) higher growth on both live (Artemia) as well as on floating feed. Since, floating feed over the live feed is cost effective and cheaper source of protein, thus, floating feed can be suggested for raising milkfish under the culture conditions of this experiment.

Keywords Body composition, growth, nutrient utilization, live feed, milkfish, *Chanos chanos*, floating and sinking feed

1 INTRODUCTION

Milkfish, *Chanos chanos* (Forsskål, 1775) is widely cultured in the Asian region and constitutes over 30% of the total marine fish species of aquaculture (Swanson, 1998; Lin *et al.*, 2003; 2006). In 2010, total milkfish production by aquaculture in this region was 750,466 tonnes with an increase of 6% per year (FAO, 2017). Despite this, Indonesia and Philippines are the biggest aquaculture producing countries with 90% of its total production (Yuwono and Sukardi, 2009; Prayogo *et al*., 2016a,b; FAO, 2017; Sukardi, *et al*., 2018; Sukardi *et al*., 2019.In Pakistan, juveniles of milkfish are found abundantly in brackish and coastal waters of Baluchistan and Sindh region (Memon *et al.*, 2015).

Considerable research on the nutrition, feeding strategies and development of cost-effective feed for various species including milkfish has been documented by several authors (Carter and Hauler, 2000; Kissil *et al*., 2000; Farhangi and Carter, 2001). Among these studies, aqua-culturists used artificially compound feed and live feed for fish rearing. Artificial fish feed is produced in two different forms i.e., extruded feed (floating) and pressure-pelleted feed (sinking). Such type of supplementary diets is considered as effective for growth of milkfish (Sumagaysay, 1998; Craig *et al.*, 2017). Whereas, live feed steadily improves development and endurance of fish larval forms either separately or combined with artificial feed (Bryant and Matty, 1981; Stuart and Drawbridge, 2011). Rotifers and brine shrimp have been widely used as live feed for culturing of fresh and marine water fish species (Dhert *et al*., 2001; Aragão *et al*., 2004; Mæhre *et al*., 2013; Thepot *et al*., 2016). In addition, live and artificial feed have been suggested for juvenile *Hippocampus andominalis* (Woods and Valentino, 2003), *Oncorhynchus mykiss* larvae (Akbary *et al.*, 2010), *Clarias macrocephalus* (Evangelista *et al*., 2005), *Ctenopharyngodon Idella* and *Hypophthalmicthys molitrix* (Prinsloo and schoonbee, 1986), goldfish, *Carassius auratus* (Kaiser, 2003) and barramundi larvae, *Lates calcarifer* (Thépot, 2016).

The larval rearing of milkfish depends on the live organisms such as, rotifers, *Brachionus plicatilis* and Artemia nauplii (Juario and Duray, 1982). Live feed during the initial few days after hatching is essential for the proper growth in marine fishes (Kaiser, 2003; Tocher, 2010; Hamre *et al.*, 2013) but the long-term use of live food for larval rearing is frequently unfeasible and costly; thus artificial diets have been prepared to grow milk fish larvae (Gatesoupe and Luquet, 1982;

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Wang *et al*., 2005, Akbary *et al*., 2010). Milkfish can eat different forms of meal i.e. artificial formulated pellets that increased the feeding efficiency rate (Martinez, 2006). Santiago *et al*., (1983) mentioned that milkfish fry willingly accepted formulated diets, which directly effect on the growth and survival rate in seawater and brackish water ponds. Nothing has so far been documented on the effects of floating and sinking feeds on growth of milkfish in captivity. It was in view of this paucity of information, present research was planned to assess the influence of live and artificial diets either pelleted floating or sinking on growth performance, feed efficiency ratio, nutrient utilization and meat quality of milkfish juvenile, *Chanos chanos* under controlled conditions.

2 MATERIALS AND METHODS

This trial was conducted for 60 days. Fish Juvenile milkfish, *Chanos chanos* (mean initial total length 9.1±0.2 cm and total weight 7.4±0.2 g) were collected randomly after acclimatization and stocked into 60 L of seawater tanks. Three feeding treatments and a control was designed having two replicates of each containing 10 fishes per tank, with provided aeration. Fish were fed daily with 2% wet body weight, three times d^{-1}. Siphoning was done once a day usually after 1 hour of feeding to remove debris and maintained water level by adding 50% water. Growth parameters were measured fortnightly. Fish were fed with live feed (Artemia) and artificial pelleted feed (floating and sinking), while rice bran was used as control diet. Hatched Artemia nauplii were collected and stored in tank for experimental use. Pelleted feeds were formulated on dry matter basis (g^{-1}100 g) in one batch to contain 40% protein **(Table 1).** Dry ingredients were mixed to ensure homogeneity. The mixture was then passed through a fish feed pellet making machine. The resulting pellets were stored in bags at -10°C until fed. Proximate analysis of Gulf Breeze Premium Artemia and pelleted feeds are given in Table 1. All fish were hand-fed three times daily at 09:00, 13:00 and 17:00 h at a fixed feeding rate of 2% body weight daily during the study period. The amount of daily ration was readjusted every 15 days after individually weighing the fish. Fecal samples were collected every morning by siphoning, 15 h after removal of uneaten feed. The weight of sun-dried uneaten feed was subtracted by the total weight of feed supplied to each tank of that day, so as to determine the daily food consumption for the fish. Water temperature (portable thermometer HI 8053, Hanna Instruments, Manila, Philippines), dissolved oxygen (oxygen meter HI 8543, Hanna Instrument, Manila, Philippines), salinity (Atago SC28 salino-meter), pH (Orion 250A pH meter) and contents of ammonia and nitrate (DREL 2000 spectrophotometer, Hach Co., Loveland, Colorado, USA) were measured daily.

At the end of the trial, two fish from each tank were killed and preserved at -20°C for proximate carcass analysis. Fish were homogenized separately and at least three samples were taken from the minced material of each fish for the analysis. Moisture content of the diet and minced fish was determined by oven drying at 100°C for 24 h, crude protein by Kjeldahl method (N×6.25), crude fat by a Soxhlet extraction method, and ash content was determined in a muffle furnace at 600C (AOAC, 2000). Carbohydrate content of the both feed and fish was determined by difference [NFE=100-(% protein+%fat+%ash+%fiber)]. Crude fiber was obtained in a fat-free material sample by dilute acid and alkali treatment. Mineral analysis of the fish was carried out by using a nitric acid-perchloric acid digestion procedure (AOAC, 2000). Reference standards were prepared from Fixanal, Riedel-DC Heanang atomic absorption standards (1000 ppm). Sodium, potassium, magnesium, calcium, copper, zinc, manganese and iron were determined by using an atomic absorption spectrophotometer.

Specific growth rate (SGR, % d^{-1}) was calculated by the formula: 100×[lnWf-lnWi/t], where Wi and Wf are the initial and final body weights. Feed conversion ratio (FCR) was estimated as dry food given/body weight gain. Condition factor was calculated by the formula: $100\times W/L^3$, where W is the body weight and L is total length of the fish. The data was thus analyzed to determine any difference among the means of each treatment group by using Minitab 16.

3 RESULTS

Water quality parameters are given in **(Table 2)**. Water temperature did not differ significantly (P>0.05) among tanks during the experiment. The mean water temperature ranged from 26.3 to 26.5°C with a mean of 26.4°C. Dissolved oxygen concentration remained within the range 7.3 to 7.4 mL L^{-1} (mean 7.35+0.05 mL L^{-1}). Generally, pH was around 8.0 to 8.2. The salinity was between 27.9 to 28.1 ppt. Ammonia never exceeded 0.003 mL L^{-1}.Total length and weight relationship of the juvenile milkfish did not differ significantly (P>0.05) among treatment groups and both the estimates for intercept and slop constants were highly significant **(Fig. 1).** No significant difference was found in condition factor (2.84 to 3.12) values **(Table 3).** Survival remained 100% among all treatment groups except control tanks where 50% mortality was recorded. Highest percent weight gain (WG) of the fish fed live feed (567.5+1.8 g) and floating feed (541.8±1.6 g) was achieved than those of the sinking feed (436.4±1.3 g) and control one (272.9±2.2 g) **(Fig 2).** This shows that floating pellets were nutritionally adequate and highly significant (P<0.05) for optimum growth of milkfish juveniles. Specific growth rate (SGR) was significantly

(P<0.05) higher in both treatment groups fed live feed (3.16%) and floating feed (3.19%) as compared to the fish fed sinking (2.79%) and control diet (2.19%). Feed conversion ratio (FCR) values of the fish fed live feed (1.4±0.2) and floating feed (1.3±0.4) were significantly different than sinking diet (2.0+0.03) and control diet (1.8+0.02). The protein (16.6%-17.4%), moisture (12.6%-13.7%), lipids (7.9%-8.3%), ash (2.3%-2.5%) contents of fish whole body were not significantly (P>0.05) different among all treatment **(Table 4)**. The moisture content showed a significant inverse relationship with the protein and fat contents (P>0.05, Table 5). Correlation coefficients of ash and carbohydrate with protein, fat, and body length, weight and condition factor were statistically significant (P>0.05, Table 5). The statistical relationship of fish body weight and length versus calcium, magnesium, potassium and zinc remained significant (P>0.05, **Table 5).** Of these four trace elements, calcium and potassium, however, showed indirect influence on growth performance.

Table 1. Formulation and chemical analysis of diets supplied to the juveniles of

	Diets (g^{-100-g})			
Ingredients	Control	Live (Artemia)	Floating	Sinking
Rice bran	65.00	0.00	10.50	10.50
Artemia†	0.00	100.00	0.00	0.00
Tapioca flour	1.25	0.00	10.50	10.50
Wheat flour (whole)	1.25	0.00	5.50	5.50
Vitamin-mineral premix††	2.50	0.00	5.00	5.00
Corn gluten meal	3.50	0.00	10.50	10.50
Fish oil	5.50	0.00	5.50	5.50
Fish meal	10.50	0.00	35.5	35.5
Soybean meal	10.50	0.00	17.00	17.00
Chemical analysis†††				
Moisture	10.2±0.03	8.0±0.03	8.6±0.03	9.7±0.03
Crude Protein††††	37.90±0.03	56.7±0.03	39.2±0.03	39.6±0.03
Crude Lipid	11.3±0.03	20.1±0.03	11.0±0.03	6.7±0.03
Crude Fiber	14.5±0.03	2.0±0.03	7.6±0.03	8.7±0.03
Ash	7.3±0.03	6.30±0.03	9.4±0.03	8.3±0.03
NFE†††††	29.00±1.20	14.9±0.50	32.8±3.80	36.7±2.99
Energy (kJ $^{-100-g}$)	2696.2±4.5	2714.7±5.0	2715.4.0±4.4	2726.6±8.2

†Gulf Breeze Premium Artemia®

††In g $^{-100-g}$ of vitamins and mineral mixture; vitamin K, 0.04; copper, 1.1; iron, 1.2; calcium, 1.23; pyridoxine, 1.2; folic acid, 0.5; magnesium, 2.6; inositol, 39.3; choline chloride, 3.6; manganese, 2.2; vitamin D, 7.4; nicotinic acid, 4.2; vitamin E, 5.6; iodine, 2.1; vitamin B12, 0.005; ascorbic acid, 15.56; phospholipids, 3.0; zinc, 1.1; sodium, 1.0; biotin, 0.35; vitamin A, 1.0; vitamin K, 0.04; riboflavin, 1.6; thiamin, 1.1 and phosphorus, 3.4;

†††Percent dry matter basis; mean±S.E., n = 3.

††††N×6.25.

†††††NFE = nitrogen-free extract [carbohydrate content = 100 – (% protein+% fat+% ash+% fiber)].

Table 2 Water quality variables of the experimental tanks during study period of 60 d†

	Diets			
Parameters	Control	Live (Artemia)	Floating	Sinking
Temperature °C	26.3±2.3^a	26.3±2.1^a	26.4±2.0^a	26.5±2.2^a
Dissolved oxygen(mL L^{-1})	7.4±1.0^a	7.4±1.3^a	7.3±1.1^a	7.4±1.2^a
pH	8.1±0.3^a	8.0±0.1^a	8.1±0.2^a	8.2±0.3^a
Salinity (‰)	28.0±0.5^a	28.1±0.4^a	27.9±0.1^a	28.0±0.2^a
Ammonia (mL L^{-1})	0.002±0.0001^a	0.003±0.0002^a	0.002±0.0001^a	0.001±0.0001^a

Table 3 Growth increment of milk fish, *chanos* fed on different diets (% initial body weight d^{-1}) during the experimental period of 60 d

Parameters	Diets			
	Control	Live (Artemia)	Floating	Sinking
Initial weight (g)	7.4±0.1^{a}	7.4±0.3^{a}	7.4±0.2^{a}	7.4±0.4^{a}
Initial length (cm)	9.1±0.3^{a}	9.1±0.1^{a}	9.1±0.2^{a}	9.1±0.3^{a}
Final weight (g)	27.6±1.2^{c}	49.4±2.3^{a}	47.5±2.4^{a}	39.7±3.2^{b}
Final length (cm)	9.9±0.02^{c}	11.9±0.02^{a}	11.5±0.01^{a}	11.0±0.01^{b}
Weight gain (g)	20.2±1.7^{c}	42.0±2.3 ^{a}	40.1±1.6^{a}	32.3±1.5^{b}
Specific growth rate (% d^{-1})	2.19±0.02^{c}	3.16±0.4^{a}	3.099±0.2^{a}	2.79±0.5^{b}
WG, % of initial weight	272.9±2.2^{c}	567.5±1.8^{a}	541.8±1.6^{a}	436.4±1.3^{b}
Feed conversion ratio (FCR)	1.8±0.02^{b}	1.4±0.2^{a}	1.3±0.4^{a}	2.0±0.03^{b}
Condition factor	2.8±0.1^{a}	2.9±0.3^{c}	3.1±0.2^{c}	2.9±0.2^{b}
Survival rate (%)	50^{b}	100^{a}	100^{a}	100^{a}

Values (mean ±SD based on two replicates) in the same line with different superscript are significantly different by Duncan's multiple range test (P <0.05).

Table 4 Proximate composition (% dry basis) of milk fish, *C. chanos* fed control and experimental diets for 60 d†

Constituents	Diets			
	Control	Live (Artemia)	Floating	Sinking
Moisture	13.5±1.3^{a}	12.9±1.6^{a}	12.6±1.3^{a}	13.7±1.4^{a}
Crude Protein	16.6±1.1^{a}	17.0±1.5^{a}	17.2±1.3^{a}	17.4±1.2^{a}
Crude Lipid	8.3±1.2^{a}	7.9±1.4^{a}	8.1±1.3^{a}	8.3±1.5^{a}
Crude Fiber	4.5±0.3^{a}	4.0±0.8^{a}	4.6±0.5^{a}	4.7±0.4^{a}
Ash	2.3±0.1^{a}	2.5±0.3^{a}	2.4±0.4^{a}	2.3±0.2^{a}

Values (mean ±SD based on two replicates) in the same line with different superscript are significantly different by Duncan's multiple range test (P <0.05).

Table 5. Pearson's correlation coefficients between growth parameters and body constituents of *C. chanos* fed the diets for 60 d

	Length	Weight	K†	Moisture	Protein	Fat	NFE††	Ash	Sodium	Potassium	Magnesium	Calcium	Copper	Zinc	Manganese
Weight	0.98*														
K	-0.73*	-0.35													
Moisture	-0.412	-0.17	-0.36												
Protein	0.76*	0.98*	0.33	-0.89*											
Fat	0.58*	0.42	0.33	-0.89*	0.96*										
NFE[1]	0.82*	0.81*	0.64*	-0.74*	-0.99*	-0.68*									
Ash	0.65*	0.91*	0.83*	-0.67*	-0.79*	-0.75*	0.56*								
Sodium	0.62*	0.55*	0.78*	0.33	0.13	0.26	0.83*	0.12							
Potassium	0.54*	0.56*	0.66*	0.38	0.24	0.26	0.35	0.21	-0.82*						
Magnesium	0.65*	0.59*	0.59*	0.37	0.26	0.33	0.25	0.25	-0.62*	0.63*					
Calcium	0.66*	0.68*	0.56*	0.39	0.68*	0.72*	0.22	0.32	0.46*	0.33	-0.99*				
Copper	0.62*	0.64*	0.43	0.41	0.21	0.17	0.42	0.30	-0.53*	-0.51*	0.53*	0.47*			
Zinc	0.78*	0.92*	0.59*	0.43	0.54*	0.38	0.34	0.29	0.62*	0.58*	0.67*	0.53*	-0.54*		
Manganese	0.35	0.43	0.28	0.31	0.35	0.17	0.24	0.11	0.72*	0.66*	0.58*	-0.86*	0.14	-0.55*	
Iron	0.13	0.26	0.17	0.29	0.18	0.25	0.36	0.22	0.62*	0.57*	-0.66*	-0.63*	0.33	0.55*	0.53*

* (P< 0.05).

† K = condition factor

†† NFE (nitrogen-free extract) = carbohydrates

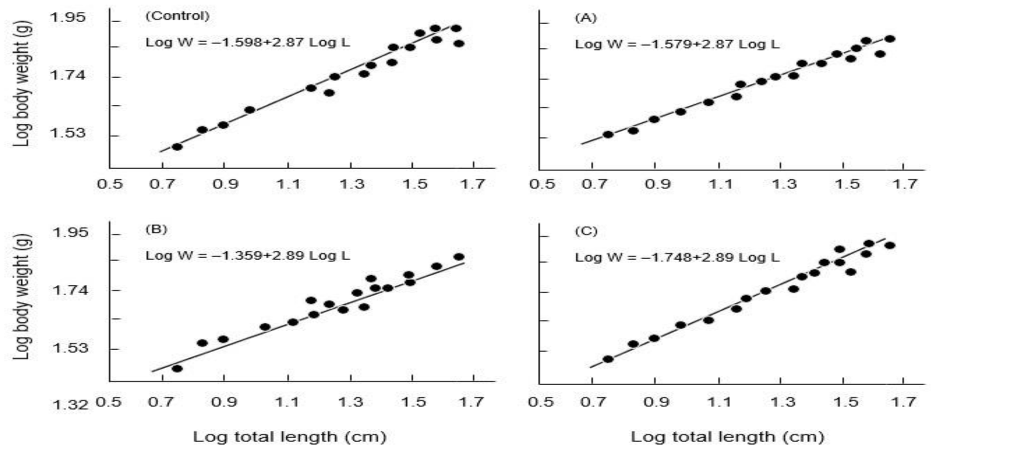

Fig. 1 Length-weight relationship of *C. chanos* fed with diets of A: Live (Artemia), B: floating, C: sinking.

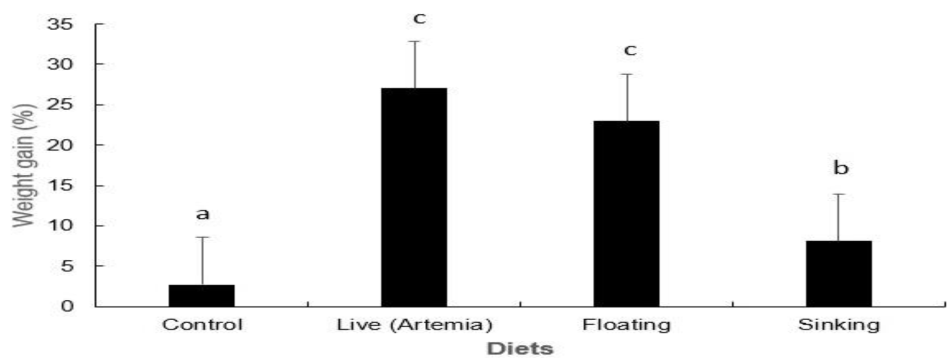

Fig. 2 Body weight gain (%) of milk fish, *C. chanos* fed different types of diets for 60 days. Values are based on two replicate groups (*n* = 2, each n consists of 10 fish per replicate. Vertical lines show S.E. Means with different superscripts are significantly different (*P*< 0.05). Average initial body weight of fish was 7.4±0.2 g.

4 DISCUSSION

In the present study, live feed (Artemia) and pelleted feed (floating and sinking) significantly ($P<0.05$) effected the growth performance of juvenile milkfish, *Chanos chanos* under all treatment groups. Mean individual weight gain (WG) of the fish was higher with live and floating feeds than sinking one. Milkfish fed the control diet grew slowly, showing body WG than other treatments. Similar results have been reported by Duray and Bagarinao (1984) and Akbary *et al*. (2010). According to them, live feed (artemia nauplii) increased body weight of the fish as compared to commercial diets. Similarly, Prinsloo and Schoonbee (1986) found significant increase in body weight gain of Chinese grass carp, *Ctenopharyngodon Idella* (157.9 mg) and silver carp, *Hypophthalmicthys molitrix* (103.0 mg) which were fed with live feed (rotifers) rather than artificial feed (26.5 mg and 27.5 mg). Abi-Ayad and Kestemont (1994) also investigated higher weight gain (66 mg) in gold fish, *Carassius auratus* fed with artemia nauplii than mixed and artificial diet (39.7 mg and 14.2mg). Although, on the same species, Kaiser *et al*. (2003) reported combination food and artificial diet showed lower growth in gold fishes as compared to artemia (15.8±1.8 mm). El-Fattah *et al*. (2008) also reported that fish fed live feed (zooplankton) showed significantly higher weight gain than those of the fish fed with artificially compounded feed. These results might have been due to the fact that live feeds are more digestible than artificial ones as reported by Wilcox *et al*. (2006), Koueta *et al*., (2002), Girri *et al*. (2002) and Tocher, 2010). Likewise, Woods (2003) investigated the effect of live, artificial and frozen feeds on juvenile *Hippocampus abdominalis.* They found higher weight gain by feeding artemia naupli (0.26±0.0 g to 0.53±0.01 g) during the whole experimental period.Similarly, Thepot *et al*. (2016) found that mixed diet (compound and live) might be more beneficial. They investigated nutritional requirement of *Lates calcarifer* larvae by using rotifers enriched with algae and concluded that mixed diet with 50% ratio were best with 85% survival rate. Limbu (2015) observed higher weight gain in *C. gariepinus* fed with with floating feed in comparison to sinking feed though the final weight of *C. gariepinus* did not differ significantly between floating and sinking diets. Ajani *et al*. (2011) investigated higher growth on the same species (*Clarias gariepinus*) by providing floating diet. Alava and Lim, (1988) supported artificial diets which gave best growth of *Chanos chanos* by feeding artificial diets.

In this study, SGR (%) was significantly ($P<0.05$) higher in fish fed live feed and floating feed than sinking and control groups. Similar results were reported by Evangelista *et al*. (2005) with higher SGR in cat fish larvae, *Clarias microcephalus* fed on tubifex worm (live food). Similar results were described by Abi-Ayad and Kestemont (1994) who tested different feeds on gold fish juvenile and found higher SGR (21.4+0.77%) by feeding fish larvae with Artemia than mixed and artificial diets (18.5±0.09 and 17.3±1.02%), respectively. Whereas, Sukardi *et al*. (2019) found similar specific growth rate of *Chanos chanos* fed spirulina microcapsule and commercial diet was range from 1.39 to 2.16% d^{-1}, and 2.00% d^{-1}, respectively.

In the present study, FCR was found to be significantly ($P<0.05$) higher in fish fed sinking diet than the fish fed live feed, floating feed and control. Similar findings were reported for goldfish, *Carassius auratus* (Abi-Ayad and Kestemont, 1994) and *Chanos chanos* (Duray and Bagarinao, 1984) fed with artificial diet as compared to live feed. Furthermore, Santiago *et al*., (1989) observed comparable FCR in milk fish juvenile, *Chanos chanos* for two different feeds, Spirulina + formulated diet and formulated diet but it was lower than rice bran. Bergot (1986) pointed out that, water quality deterioration in fish tanks due to the use of artificial feeds may also affect the growth and survival rate of early stage larvae. Many researchers have been studied survival rate and growth were influenced by live food on *Plelteobagrus fulvidraco* (Wang *et al*., 2005), *Tinca tinca* (Wolnicki *et al*., 2003), and *Wallago attu* (Girri *et al*., 2002). Higher survival ratio (100%) were found in all treatment tanks in our study but only (50%) in control. Similarly, (98% to 99%) survival rate was found by Santiago *et al*. (1983) with formulated diets, except for *Moina* feed and water hyacinth meal had only 18% of survival ratio. Comparable, Kaiser *et al*. (2003) found highest survival (96–99%) in goldfishes by feeding combination (dry-food and artemia) and only artemia (95-98%). Sukardi *et al*. (2019) found 80-84% survival ratio in milkfish fed spirulina-based microcapsules diet for 42 days. Although, Daudpota *et al*., (2016) found equivalent survival rate in Nile Tilapia (*Oreochromis niloticus*) fed with formulated diet. Borlongan *et al*. (2003) observed 90% survival ratio in juvenile milk fish by feeding pea meal (30% dietary-protein source).

The moisture content showed a significant inverse relationship with the protein and fat contents. The moisture content decreased as the length and subsequently the weight increased indicating the addition of dry matter in the form of protein and fat contents in the fish (Abbas, 2002). Similar relationship between protein and water contents have also been reported in different fish species. Eliassen and Vahl (1982), for instance, described that when protein contents are removed from the muscle of non-fatty fish, the moisture contents increase gradually. Weatherly and Gill (1983) and Al-Asgah (1992) concluded that the water content fell when fats are increased. In the present study, a significant inverse relationship between fat and water contents was found and there appeared to be a mechanism for some homeostasis of tissue volume. The correlation among growth parameters and body constituents including micro- and macro-nutrients indicates interdependence on each other. This relationship could be advocated by the findings of Ashley (1972) and Abbas (2002).

In conclusion, *Chanos chanos* showed significantly ($P<0.05$) higher growth on both live (Artemia) as well as on floating feed. Since, floating feed over the live feed is cost effective and cheaper source of protein, thus, floating feed can be suggested for raising milkfish under the experimental conditions of this study.

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Conflict of interest

Nothing declared

REFERENCES:

Abbas, G., (2002). Growth, feed conversion, and body composition of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Pisces, Lutjanidae) reared in concrete tanks. *Pakistan Journal of Zoology*, 34: 147-154.

Abi-Ayad, A., and P. Kestemont, (1994). Comparison of the nutritional status of goldfish (*Carassius auratus*) larvae fed with live, mixed or dry diet. *Aquaculture*, 128: 163-176.

Ajani, F., M. O. Dawodu, and O.A. Bello-Olusoji, (2011). Effects of feed forms and feeding frequency on growth performance and nutrient utilization of *Clarias gariepinus* fingerlings. *African Journal of Agricultural Research*, 6: 318-322.

Akbary, P., S. A. Hosseini, M. Imanpoor, M. Sudagar, and N.M. Makhdomi, (2010). Comparison between live food and artificial diet on survival rate, growth and body chemical composition of *Oncorhynchus mykiss* larvae. *Iranian Journal of Fisheries Sciences*, 9: 19-32.

Al-Asgah, N. A., (1992). Variation in the carcass composition of *Oreochromis niloticus* in relation to body weight and length. *Pakistan Journal of Zoology*,24: 47-51.

Alava, V. R., and C. Lim, (1988). Artificial diets for milkfish, *Chanos chanos* (Forsskal), fry reared in seawater. *Aquaculture*, 71: 339-346.

AOAC., (2000). Official Methods of Analysis of Association of Official Analytical Chemists. Vol. I. 17th edn. pp. 684. Association of Official Analytical Chemists, Arlington, USA.

Aragão, C., L. E. C. Conceic¸ M.T. Dinis, and H. J. Fyhn, (2004). Amino acid pools of rotifers and Artemia under different conditions: nutritional implications for fish larvae. *Aquaculture*, 234: 429–445.

Ashley, L. S., (1972). Nutritional Pathology. In: Fish Nutrition (ed. J. E. Halver), Academic Press Inc. London. 439-530.

Bergot, P., (1986). Elevage larvaire de la carpe commune (*C. carpio*): alimentation artificielle. In: R. Billard and J. Marcel (Editors). *Aquaculture of Cyprinids*. INRA, Paris, 227-234.

Bryant, P. L., and A.J. Matty, (1981). Adaptation of carp (*Cyprinus carpio*) larvae to artificial diets: 1. Optimum feeding rate and adaptation age for a commercial diet. *Aquaculture*, 23: 275-286.

Carter, C. G., and R.C. Hauler, (2000). Fish meal replacement by plant meals in extruded feeds for Atlantic salmon, *Salmo salar* L. *Aquaculture*, 185: 299-311.

Craig, S., L.A. Helfrich, D. Kuhn, and M.H. Schwarz, (2017). Understanding fish nutrition, feeds, and feeding. Publication Number 420-256.

Daudpota, A. M., G. Abbas, H. Kalhoro, S.A. Shah, S. Ferrando, L. Gallus, and M. Hafeez-ur-Rehman, (2016). Comparison of growth, feed conversion and body composition of juvenile hybrid Red Tilapia (*Oreochromis niloticus* x *O. mossambicus*) and Nile Tilapia (*O. niloticus*) reared in concrete tanks. *Pakistan Journal of Zoology*, 48 (3): 809-816.

Dhert, P., G. Rombaut, G. Suantika, and P.Sorgeloos, (2001). Advancement of rotifer culture and manipulation techniques in Europe. *Aquaculture*, 200: 129–146.

Duray, M., and T. Bagarinao, (1984). Weaning of hatchery-bred milkfish larvae from live food to artificial diets. *Aquaculture*, 41: 325-332.

Eliassen, J. E., and O. Vahl, (1982). Seasonal variations in the gonad size and the protein and water content of cod, *Gadus amorhu* (L.) muscle from northern Norway. *Journal of Fish Biology*, 120: 527-533.

El-Fattah, I. M. S. A., M. H. Ahmed, and M.A. Aal, (2008). Zooplankton as live food for fry and fingerlings of Nile tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) in concrete ponds. Eighth international symposium on tilapia in aquaculture. Proceedings, Cairo, Egypt, 12-14 October, 2: 757-771. Aqua-fish collaborative research support program.

Evangelista, A. D., N.R. Fortes, and C.B. Santiago, (2005). Comparison of some live organisms and artificial diet as feed for Asian catfish *Clarias macrocephalus* (Günther) larvae. *Journal of Applied Ichthyology*, 21: 437-443.

FAO., (2017). FAO Aquaculture Newsletter. No. 56 (April). Rome.

Farhangi, M., and C.G. Carter, (2001). Growth, physiological and immunological responses of rainbow trout (*Oncorhynchus mykiss*) to different dietary inclusion levels of dehulled lupin (*Lupinus angustifolius*). *Aquaculture Research*, 32: 329-340.

Farquhar, S. D., S.M. Sims, S. J. Wang, and K. Morrill, (2017). A brief answer: Why is China's aquaculture industry so successful? *Environmental Management and Sustainable Development*, 6: 234-241.

Flüchter, J., (1982). Substance essential for metamorphosis of fish larvae extracted from Artemia. *Aquaculture*, 27: 83-85.

Gatesoupe, F. J., and P. Luquet, (1982). Weaning of the sole (*Solea solea*) before metamorphosis. *Aquaculture*, 26: 359-368.

Girri, S. S., S. K. Sahoo, B.B. Shu, A.K. Sahu, and S. Ayyapan, (2002). Larval survival and growth in *Wallago attu* (Bloch and Schneider): Effect of light, photoperiod and feeding regimes. *Aquaculture*, 213:157-161.

Hamre, K., M. Yúfera, I. Rønnestad, (2013). Fish larval nutrition and feed formulation: knowledge gaps and bottlenecks for advances in larval rearing. *Reviews inAquaculture,* 5: 526–558.

Juario, J. V., and M. N. Duray, (1982). A guide to induced spawning and larval rearing of milkfish *Chanos chanos* (Forsskal). (Technical Report No. 10). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center. http://hdl.handle.net/10862/845

Kaiser, H., F. Endemann, and T.G. Paulet, (2003). A comparison of artificial and natural foods and their combinations in the rearing of goldfish, *Carassius auratus* (L). *Aquaculture Research*, 34: 943-950.

Kissil, G.W., L. Lupatsch, D.A. Higgs, and R.W. Hardy, (2000). Dietary substitution of soy and rapeseed protein concentrates for fish meal, and their effects on growth and nutrient utilization in gilthead seabream *Sparus aurata* L. *Aquaculture Research,* 31: 595-601.

Koueta, N., F.E. Boucaud-Camou, and B. Noel, (2002). Effect of enriched natural diet on survival and growth of juvenile cuttle fish *Sepia officinalis* L. *Aquaculture,* 203: 293-310.

Limbu, S. M., (2015). The effect of floating and sinking diets on growth performance, feed conversion efficiency, yield and cost-effectiveness of African sharptooth catfish, *Clarias gariepinus* reared in earthen ponds. *International Journal of Fisheries and Aquatic Studies*, 2: 253-259.

Lin, Y. M., C.N. Chen, and T. H. Lee, (2003). The expression of gill Na, K-ATPase in milkfish, *Chanos chanos*, acclimated to seawater, brackish water and fresh water. *Comparative Biochemistry and Physiology Part A:*
Molecular & Integrative Physiology, 135: 489-497.

Lin, Y. M., C.N. Chen, T. Yoshinaga, S.C. Tsai, I.D. Shen, and T.H. Lee, (2006). Short-term effects of hyposmotic shock on Na+/K+-ATPase expression in gills of the euryhaline milkfish, *Chanos chanos*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 143: 406-415.

Mæhre, H. K., K. Hamre, and E.O. Elvevoll, (2013). Nutrient evaluation of rotifers and zooplankton: feed for marine fish larvae. *Aquaculture Nutrition*,19: 301–311.

Martinez, F. S., M. Tseng, and S. Yeh, (2006). Milkfish (*Chanos chanos*) culture: situations and trends. *Journal of the Fisheries Society of Taiwan*, 33: 229-233.

Memon, A. J. A., M.H. Soomro, M. Zafar, and A. M. Ishaqui, (2015). To evaluate growth performance of milkfish, (*Chanos chanos* Forsskål, 1755) (fingerling) applied range of food treatments in captivity. *Journal of the Korean Society of Fisheries Science*,2:438-438.

Prayogo, N. A.,A. Siregar, and P. Sukardi, (2016b) . The disruptive effect mercurychloride (HgCl) on gene expression of cGnRH-II, sGnRH, and estradiol level in Silver Sharkminnow (*Osteochillus hasseltii* CV). *Turkish Journal of Fisheries and Aquatic Sciences*, 16: 1003-1009.

Prayogo, N., G. Wijayanti, and P. Sukardi, (2016a). Identification and expression of two types of chicken GnRH-II genes in mature hard-lipped barb, *Osteochilus hasselti*. *Biodiversitas Journal of Biological Diversity*, 17: 523-530.

Prinsloo, J. F., and H.J. Schoonbee, (1986). Comparison of the early larval growth rates of the Chinese grass carp *Ctenopharyngodon idella* and the Chinese silver carp *Hypophthalmichthys molitrix* using live and artificial feed. *Water SA.*, 12: 229-234.

Santiago, C. B., M. Bañes-Aldaba, and E.T.Songalia, (1983). Effect of artificial diets on growth and survival of milkfish fry in fresh water. *Aquaculture*, 34: 247-252.

Santiago, C. B., J.B. Pantastico, S.F. Baldia, and O. S. Reyes, (1989). Milkfish (*Chanos chanos*) fingerling production in freshwater ponds with the use of natural and artificial feeds. *Aquaculture*, 77: 307-318.

Stuart, K. R., M. Drawbridge, (2011). The effect of light intensity and green water on survival and growth of cultured larval California yellowtail (*Seriola lalandi*). *Aquaculture*, 321: 152–156.

Sukardi, P., N. Yansah, T. Winanto, S. Marnani, N.A. Prayogo, and A. Sudaryono. (2019). A dietary microcapsule based on single cell protein (*Spirulina Platensis*) for milk fish, *Chanos chanos*, larvae. *Biotropia*,26:*In press*. DOI: 10.11598/btb.2019.26.3.1103

Sukardi, P., N.A. Hana,T. Prayogo, and P.H. Soedibyo, (2018). A Lipid-walled microcapsule diet as co-feed for early weaning the *Osphronemus gouramy* Lacepede larvae. Acta Scientiarum. *Animal Sciences*, 40: e38335. Doi: 252 10.4025/actascianimsci.v40i1.38335

Sumagaysay, N. S., (1998). Milkfish (*Chanos chanos*) production and water quality in brackishwater ponds at different feeding levels and frequencies. *Journal of Applied Ichthyology*, 14: 81-85.

Swanson, C., (1998). Interactive effects of salinity on metabolic rate, activity, growth and osmoregulation in the euryhaline milkfish (*Chanos chanos*). *Journal of Experimental Biology*, 201: 3355-3366.

Thépot, V., A. Mangott, and I. Pirozzi, (2016). Rotifers enriched with a mixed algal diet promote survival, growth and development of barramundi larvae, *Lates calcarifer* (Bloch). *Aquaculture Reports*, 3: 147–158.

Tocher, D. R., (2010). Fatty acid requirements in ontogeny of marine and fresh water fish. *Aquaculture Research*, 41: 717–732.

Villaluz, A. C., W. R. Villaver, and R.J. Salde, (1983). Milkfish fry and fingerling industry of the Philippines: methods and practices. Technical Report No. 9. SEAFDEC Aquaculture Department, International Development Research Centre (IDRC), Tigbauan, Iloilo, Philippines, 84 PP.

Wang, C., S. Xie, K. Zheng, X., Zhu, W. Lei, Y. Yang, and J. Liu, (2005). Effects of live food and formulated diets on survival, growth and protein content of first-feeding larvae of *Plelteobagrus fulvidraco*. *Journal of Applied Ichthyology*, 21: 210-214.

Watanabe, T., V. Verakunpiriya, V. Kiron, V., and S. Satoh, (1997). Feeding of rainbow trout with non-fish meal diets. *Fisheries Science*, 63: 258-266.

Wearherley, A. H., and H.S. Gill, (1983). Protein, lipid, water and caloric contents of immature rainbow trout, Salmo gairdneri Richardson, growing at different rates. *Journal of Fish Biology*,23: 653-673.

Wilcox, J. A., P.L.Tracy, and N.H. Marcus, (2006). Improving live feeds: effect of a mixed diet of copepod nauplii (*Acartia tonsa*) and rotifers on the survival and growth of first-feeding larvae of the southern flounder, *Paralichthys lethostigma*. *Journal of the World Aquaculture Society*, 37: 113-120.

Wolnicki, J., L. Myszkowski, and R. Kaminski, (2003). Effect of supplementation of a dry feed with natural food on growth, condition andsize distribution of juvenile tench *Tincatinca* (L.). *Applied Ichthyology*, 19:157-160.

Woods, C. M. C., and F. Valentino, (2003). Frozen mysids as an alternative to live Artemia in culturing seahorses *Hippocampus abdominalis*. *Aquaculture Research*, 34, 757-763.

Woods, C. M. C., and F. Valentino, (2003). Frozen mysids as an alternative to live Artemia in culturing seahorses *Hippocampus abdominalis*. *Aquaculture Research*, 34, 757-763.

Yuwono, E., and P. Sukardi, (2009). Development of an environment-friendly feeding management for pond-reared fish species in the *Segara Anakan* region. *Regional Environmental Change*. 9: 329-333.