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Evaluation of Meat and Bone Meal and Mono-Sodium Phosphate as Supplemental Dietary Phosphorus Sources for Broodstock Nile Tilapia (*Oreochromis niloticus*) Under the Conditions of Hapa-in- Pond System

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Abstract

An experiment was conducted to evaluate if phosphorus (P) supplement is required in Nile tilapia *Oreochromis niloticus* broodstock diet under hapa-in-pond system. Seven isonitrogenous (33% crude protein), isocaloric (4400 kcal kg^{-1}) diets were formulated. A corn-soybean meal based diet, deficient in P, was used as the basal diet. Three levels of meat and bone meal (MBM), and mono-sodium phosphate (MSP) were substituted for corn-starch in the basal diet to produce experimental diets containing 0.56, 0.67, or 0.78% P. Males and females with mean body weights of (270±1.52 g) and (250±1.17 g), respectively, were stocked at a density of 4 fish m^{-1}, (8 fish $hapa^{-1}$) with a male: female ratio of 1:3. Irrespective of P source, it was observed that, increasing P level significantly ($P \leq 0.05$) increased broodstock fecundity. Spawning performance and egg weight were not significantly affected by dietary P source. However, dietary MBM increased the absolute fecundity and total egg production ($P \geq 0.05$) compared to the MSP diets. While, broodstock fed MSP diets showed the highest egg weight. This result revealed that Nile tilapia broodfish reared in the green water under hapa-in-pond system require a source of dietary P for optimum spawning performance.

Keywords: Phosphorus, Nile Tilapia Broodstock, Hapa-in Pond, Reproductive Performance.

Introduction

One of the most important and fundamental approaches to aquaculture development is to ensure a year-round supply of high quality fish eggs. For this purpose, broodstock that produce good quality fertile eggs with high survival and growth rates must be maintained and nurtured in captivity. The most promising species for freshwater aquaculture development in the short and medium term is tilapia (Suloma and Ogata, 2006). Tilapia broodstock handling, eggs and fry harvesting are easy (Lovshin and Ibrahim, 1989). Furthermore, Tilapia fry can be produced in ponds, hapas, and concrete tanks (Bautista, 1987; AIT, 1994). Hapas are commonly used in Egypt (Hammouda *et al*., 2008; Magouz *et al*., 2009), Philippines (Santiago *et al*., 1985; Bautista 1987) and Thailand (Little *et al*., 1995; Little *et al*., 1997) to breed tilapias.

Knowledge of finfish broodstock nutrition is limited and not well understood research area (Izquierdo *et al*., 2002). Rapidly growing animal nutritional requirements are often different from broodstock as in humans and livestock nutrition (Leboulanger 1977). Phosphorus is an essential nutrient effect on growth, osmotic function and skeletal development in fish (Roy and Lall, 2004). Furthermore, spawning, fecundity, gonadal growth, and maturation of broodstock are primarily dependent upon an adequate supply of P irrespective of the culture system in which they are grown (Little and Hulata, 2000). In addition, dietary P content is responsible for vitellogenesis (yolk accumulation in the fish egg), and ovary development (Kishida and Specker, 1993; Nagler *et al*., 1987; Al-Kobaby, 2008). Due to the low concentration of P in freshwater and seawater, P uptake is not sufficient to fulfill the fish and shellfish nutritional requirements (Boyd, 1971; Lall, 1991). Dato-Cajegas and Yakupitiyage (1996) found that P and calcium concentration in green water fertilized with urea and triple super-phosphate (as condition of hapa-in pond system in Egypt) are not enough for normal growth. Significant amounts of P or P-rich ingredients should be incorporated in aquaculture feed diets to meet the P requirement of fish. Rendered animal by-products, such as MBM contain relatively high levels of protein and P and are commonly included in swine and poultry diets (Traylor *et al*., 2005). Although MBM available P content (% of total P) is generally lower than that of inorganic P sources such as MSP and di-calcium phosphate (DCP), the P in MBM is still considered highly available to swine and poultry when compared to MSP or DCP (Traylor *et al*., 1999, 2005; Waldroup, 2002). Using MBM as a source of P in comparison to inorganic P ingredients commonly used in fish feeds is still debated because of the considerable P variation in tested MBM (Waldroup, 2002), suggesting for the further, and continual, testing to ensure that the data employed in feed formulations are accurate. A series of studies were conducted at Animal Production Department, Faculty of Agriculture, Cairo University, Egypt, to evaluate MBM as a source of P in comparison to inorganic P such as MSP and DCP on growth and reproductive performance of Nile tilapia. The first study was conducted to test MBM as a potential source of P in plant-protein-based diets for Nile tilapia (Suloma *et al*., 2013). Thereafter, the objective of the present study was to evaluate the importance of P from various origins as MBM and MSP on the reproductive performance of Nile tilapia broodstock under hapa-in-pond system.

Materials and Methods

Experimental Fish

Nile tilapia *O. niloticus* broodstock were obtained from a commercial fish farm located in Kafr El-Sheikh Governorate, Egypt. A total of 168 (126 females + 42 males) were selected from more than 2000 tilapia broodstock that were over-wintered in order to minimize the initial weight variation. Selected broodstock were sexed, transferred to conditioning hapas, and kept separately for 20 days for adaptation to the new environment. The experiment was conducted in 21 hapas each of 2 m^3 net volume (2×2×0.5 m) in ponds. Adult males and females with mean body weights of 270 g and 250 g, respectively, were stocked at a rate of 4 fish m^{-3} (8 broodstock $hapa^{-1}$) with a male: female sex ratio of 1:3.

Experimental Diets and Feeding Practices

Meat and bone meal was obtained from a feed mill (Rothsay Maple Foods Inc, Dundas, Ontario, Canada). The chemical composition of the MBM and other ingredients used in this study is presented in Table 1. Plant-based diets (27% corn; 15% corn gluten; 40% soybean meal (SBM); 5% wheat middling) deficient in P was formulated to meet all known nutrient requirements of Nile tilapia based on nutrient requirement values proposed by the NRC (1993). Step-wise increments in P levels (0.56%, 0.67% and 0.78%) were achieved through gradual substitution of cornstarch with MBM or MSP (Table 2). The diets were processed by blending the ingredients into a homogeneous mixture, and then passing the mixed feed through a laboratory pellet mill. The formulated diets were dried in an oven and stored in a refrigerator (5-7°C) throughout the experiment. Each experimental diet allocated to three replicate hapas according to a completely randomized design. Each hapa was considered as an experimental unit. During the 65 days culture experimental period, all fish were hand-fed at 2% feeding level three times a day on weekdays and once daily on weekends.

Samples and Chemical Analysis

The experimental diets, ingredients and fish samples were dried, grounded into homogeneous slurry in a food processor, and stored at −20°C until analysis. Diets and fish samples were analyzed for dry matter (DM) and ash content according to A.O.A.C. (1995) methods, for crude protein (N x 6.25) by the Kjeldahl method using a Kjeltech auto-analyzer (Model 1030, Tecator, Hoganas, Sweden), and for crude fat (Bligh and Dyer, 1959). P content was determined photometrically by the molybdovanadate method (AOAC, 1995). Gross energy was calculated using conversion factors of 9.45, 5.6, and 4.2 kcal/g for lipid, protein, and total carbohydrate, respectively (Young *et al*., 2005). Nitrogen-free extract (NFE) content was determined by the difference:

NFE = 100 - (% crude protein + % crude fat + % crude fiber + % total ash).

Calculations and Statistical Analyses

Growth Performance Parameters: Growth rate was expressed as specific growth rate (SGR) and calculated as follows:

Table 1. Proximate composition of the ingredients used in the experimental diets

Composition	Meat and bone meal	Corn	Soybean meal	Corn gluten meal	Wheat middling
Dry matter, %	89.8	92.3	90.2	93.4	90.1
Crude protein, %	55.6	7.9	43.3	61.5	14.3
Lipid, %	13.1	3.4	3.5	8.2	4.4
Ash, %	23.8	2.5	6.3	2.3	5.0
Total carbohydrate (%)	7.35	86.2	46.9	28.0	76.3
Phosphorus, %	4.8	0.3	0.6	0.5	0.9
Gross energy (kcal kg^{-1})	4351.6	4060.7	4313.8	5117.7	4005.4

Table 2. Formulation and chemical composition of the experimental diets

Ingredient	Diets						
	control	$MSP_{0.56}$	$MSP_{0.67}$	$MSP_{0.78}$	$MBM_{0.56}$	$MBM_{0.67}$	$MBM_{0.78}$
Corn	27.0	27.0	27.0	27.0	27.0	27.0	27.0
Corn gluten meal	15.0	15.0	15.0	15.0	15.0	15.0	15.0
soybean meal	40.0	40.0	40.0	40.0	39.6	39	38.3
Starch, raw	3.0	2.5	2.0	1.5	2.5	2.0	1.5
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Soybean oil	4.0	4.0	4.0	4.0	3.6	3.5	3.2
Meat-bone meal 56% CP	-	-	-	-	2.3	4.5	7.0
NaH2PO4	-	0.5	1.0	1.5	-	-	-
Calcium carbonate	3.0	3.0	3.0	3.0	2.0	1.0	-
Lysine	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Carboxy-methyl cellulose	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin& mineral premix*	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Total	100	100	100	100	100	100	100
Analyzed composition (dry matter basis)							
Dry matter (%)	89.63	88.61	88.35	89.17	88.27	89.59	90.01
Crude protein (%)	33.16	33.79	32.26	32.04	33.54	32.48	34.34
Lipid (%)	11.18	10.06	10.72	11.02	11.65	10.45	12.11
Ash (%)	7.54	7.19	7.82	8.69	6.96	7.27	7.04
Total carbohydrate (%)	48.12	48.96	49.2	48.25	47.85	49.8	46.51
Phosphorus (%)	0.41	0.51	0.61	0.71	0.53	0.62	0.75
Gross energy (kcal Kg^{-1})	4499.00	4420.90	4396.70	4407.30	4496.20	4460.80	4601.30

*Vitamins and minerals mixture each 3Kg of mixture contains: 10 000 000 I.U. vit A, 2 500 000 IU vit D3, 10 000 mg vit. E, 1000 mg vit. K, 1000 mg vit. B1, 5000 vit. mg.B2, 1500 mg vit.B6, 10mg vit B12 , 30 000 mg Niacin, 10 000 mg Pantothenic acid,.1000 mg Folic acid, 50 mg Biotin, 300 mg Iodine, 30 000 mg Iron, 60 000 mg Manganese, 4000 mg Copper,100 mg. Cobalt , 100 mg Selenium, 50 000 mg Zinc, 3000g Calcium Carbonate

SGR = (ln FBW - ln IBW) x 100/d.

where: FBW is final body weight (g); IBW is initial body weight (g); and d is the number of days. Feed conversion ratio was calculated for each hapa as follows:

FCR = feed intake (dry matter) / live weight gain

Reproductive Performance Parameters: Reproductive parameters were estimated according to Mair *et al*. (2004) as follows:

Absolute Fecundity = the number of egg per spawning per female.

Relative Fecundity = the number of egg per unit weight of female.

Water Quality Parameters: Water temperature was recorded daily using a mercury thermometer suspended at 30-cm depth. Dissolved oxygen (DO) was measured using a YSI model 56 oxygen meter (Yellow Springs Instrument, Yellow Springs, OH, USA), Total ammonia nitrogen (TAN) and total alkalinity (TA) were measured at weekly intervals according to APHA (2005) and pH by using a pH meter (Orion pH meter, Abilene, TX, USA).

Statistical Analysis: One-way ANOVA procedure was used to compare water quality, growth and reproductive parameters among treatments, using the the GLM procedure of SAS (SAS Inst. 1988, Inc., Cary, NC, USA). Tukey's multiple range test was used to compare differences among individual means. Treatment effects were considered significant at ($P \leq 0.05$).

Results and Discussion

Water Quality

The average of water quality data are shown in Table 3. The DO levels ranged from 4.7 to 8.0 (mg L^{-1}), and were within the desirable range as described by Boyd (1971). Total ammonia nitrogen values ranged between 0.08 and 0.3 (mg L^{-1}), and were lower than the undesired maximum limit of TAN concentration (1.0 mg L^{-1}) as reported by (Meade, 1989; Lawson, 1995; Ridha and Cruz, 1998). Water temperature of experimental hapas ranged from 26–29°C and TA values of the experimental hapas water remained within the acceptable limits (158-220 mg L^{-1} as Ca Co_3) as reported by Meade (1989). These values were acceptable for the normal growth and reproduction of tilapia according to (Little and Hulata, 2000; Tahoun *et al*., 2008). The high concentrations of total P in the pond (1.3 mg L^{-1}), was suitable to test the objective of the current study that phosphorous concentration in the green water under hapa-in-pond system is not enough to meet the nutritional requirements of tilapia broodstock.

Table 3. Physico-chemical characteristics of experimental hapa water

Parameters	Mean	Range
Maximum temp., °C	27 ±0.25	26-29
Dissolved oxygen, mg L^{-1}	7.5 ±0.18	4.7-8.0
pH	7.9 ±0.12	7.5-9.0
Alkalinity as $CaCO_3$, mg L^{-1}	195 ±2.54	158-220
Total ammonia nitrogen, mg L^{-1}	0.10 ±0.001	0.08-0.30
Total phosphorus mg L^{-1}	1.3 ±0.05	1.1-1.5

Growth and Feed Utilization Performance

Data on growth performance are presented in Table 4. Survival rate of Nile tilapia ranged between 96 to 98% and fish maintained healthy and active during the experimental period. Fish fed diets containing either MBM or MSP as sources of supplemental P exhibited similar patterns in terms of growth and feed efficiency (weight gain, SGR, feed intake and FCR), which were not statistically different from the control values (Table 4). The SGR, WG and FCR values of tilapia broodstocks were comparable with those reported by (Ridha and Cruz, 1999; Tahoun, 2007; Tahoun *et al*., 2008) for *O. niloticus* under similar conditions. No significant results obtained for growth parameters in this study were probably due to the short duration of the feeding study (65 days). Sugiura *et al*. (2008) suggested that for fish of 500 g body weight, it takes 232 days of feeding to respond to P deficiency, and for fish of 1 kg their growth will never respond to the diet. The authors reported that the major factors responsible for that are: (1) large fish may have large initial body P store, (2) large fish have lower feed efficiency than small fish, and (3) large fish have lower feeding rate per body weight. Another explanation for growth performance results could be due to quite resistance of large fish to nutrient deficiency compared with small fish (Sugiura *et al*., 2008). Large initial body P pool in mature fish could be the reason for not responding of fish growth to dietary restriction of nutrients, and the growth reduction can be immediate if the diet is P deficient and the body P store (pool size) is small and below a certain threshold level (Sugiura *et al*., 2008). Similarly, Hardy *et al*. (1993) reported that symptoms of P deficiency did not appear on rainbow trout growth until the body P store was lessened below a specific threshold level.

Reproductive Performance

The present results showed that reproductive parameters increased significantly ($P \leq 0.05$) by increasing dietary P level regardless of P source (Table 5). Breeders fed diet containing $MBM_{0.67\%}$ had significantly higher ($P \leq 0.05$) mean values for total egg production, egg $female^{-1}$, egg g $female^{-1}$ and egg/day and egg day^{-1} m^{-2} (8333, 1388, 4.40, 128.2 and 64.1 respectively), than control diet deficient in P (6765, 1127, 3.58, 104.1 and 52.1 respectively). These results are in consistent with the findings of Watanabe *et al*. (1984) who reported that red sea bream broodstock fed fish meal based diet deficient in available P resulted in low fecundity, and produced eggs and larvae of much lower hatchability and higher abnormality than those fed P-enrichment. Additionally, Watanabe (1988) reported that the broodstock of ayu *Plecoglossus altivelis* fed P-non supplemented diet had lower growth and fecundity than those fed P-supplemented diet. Moreover, Nagler *et al*. (1987) found a linear relationship between serum P precursor concentrations total phosphor-protein P (TPP) and alkali-labile phosphor-protein P (ALPP) with the serum concentration of the vitellogenin (Vg) in mature female of rainbow trout during active vitellogenesis. These studies support the important role of P in tilapia breeder's through its function on develop spawning, fecundity, gonadal growth, and maturation of broodstock by enhancing vitellogenesis and improving ovary development (Kishida and Specker, 1993; Nagler *et al*., 1987; AlKobaby, 2008).

In spite of the importance of P in fish reproduction, just a few studies have been conducted to study the effects of dietary P supplementation on the reproductive performance of Nile tilapia. Present results showed that the source of dietary P had no detectable effect on the reproductive performance (Table 5), but were still numerically highest in those fish fed MBM diets. The non-significant differences in fish reproductive parameters between the two sources of P could be attributed to the highly available P in both MBM and MSP. Extensive research has been conducted in swine and poultry to estimate the availability of P in MBM to MSP based on slope ratios assay (MSP considered as 100%). Huang and Allee (1981) clearly demonstrated that P availability in MBM is high (approximately 93%) for growing pigs. Parallel studies in swine (Traylor *et al*., 2005) also reported a high estimate of P bioavailability (91%) in MBM. These values also confirmed by Traylor *et al*. (1998, 1999) who reported that the bioavailability of P for MBM ranged from 72 to 94% with an overall mean of 85%, which consequently increased performance and feed efficiency for swine. Subsequently, Coffey and Cromwell (1993) reported a relatively high estimate of P bioavailability in MBM (78%) for poultry. The present results confirmed that MBM, which was previously used in the diets of farm animals, such as pigs and chickens, is a good source

Table 4. Growth performance and feed efficiency of *O. niloticus* broodstocks fed experimental diets for 65 days

Diet	Female FBW (g)	Male FBW (g)	Female WG (g)	Male WG (g)	Hapa WG (g)	Feed Intake (g)	FCR (Feed: gain)	Female SGR (%)	Male SGR (%)
Control	315.5±1.0	343.2±0.7	65.7±1.6	70.2±0.7	534±8.5	1371±3.5	2.6±0.1	0.36±0.0	0.35±0.0
$MSP_{0.56}$	313.3±1.3	341.2±3.4	63.9±0.7	72.5±1.3	528±6.7	1372±9.3	2.6±0.1	0.34±0.0	0.36±0.0
$MSP_{0.67}$	313.9±1.0	341.9±2.5	63.9±1.2	70.7±3.4	524±13.9	1374±1.1	2.6±0.1	0.35±0.0	0.35±0.0
$MSP_{0.78}$	315.5±1.9	335.7±0.7	64.6±1.1	67.0±4.0	521±14.0	1366±7.6	2.6±0.1	0.36±0.0	0.35±0.0
$MBM_{0.56}$	313.2±2.7	337.7±0.5	63.8±1.6	64.7±0.4	512±10.3	1371±1.9	2.7±0.1	0.35±0.0	0.33±0.0
$MBM_{0.67}$	315.5±3.1	340.8±0.8	65.5±1.8	70.8±0.8	534±10.1	1367±1.2	2.6±0.1	0.35±0.0	0.35±0.0
$MBM_{0.78}$	310.4±2.9	339.6±2.9	62.5±1.7	68.3±2.8	511±12.4	1361±5.3	2.7±0.1	0.34±0.0	0.34 ±0.0

Mean ± SE values in each row followed by a common letter are not significantly (P≤0.05) different

Table 5. Reproductive performance of *O. niloticus* broodstocks fed experimental diets for 65 days

Diet	Total egg production	Absolute fecundity (egg Female^{-1})	Relative fecundity (egg g female^{-1})	egg / day	System productivity (egg day^{-1} m^{-2})	egg weight (mg)
Control	6765±204.1^{b}	1127±34.0^{b}	3.58±0.2^{b}	104.1±3.1^{b}	52.1±1.6^{b}	7.76±0.3^{c}
$MSP_{0.56}$	7546±606.3^{ab}	1257±101.2^{ab}	4.01±0.3^{ab}	116.1±9.3^{ab}	58.0±4.7^{ab}	8.87±0.2^{a}
$MSP_{0.67}$	7870±159.5^{ab}	1311±26.6^{ab}	4.18±0.1^{ab}	121.1±2.4^{ab}	60.5±1.3^{ab}	9.24±0.1^{a}
$MSP_{0.78}$	8006±404.7^{a}	1334±67.3^{a}	4.24±0.2^{a}	123.2±6.2^{a}	61.6±3.1^{a}	8.75±0.4^{a}
$MBM_{0.56}$	8095±313.3^{a}	1349±52.2^{a}	4.31±0.2^{a}	124.5±4.8^{a}	62.3±2.4^{a}	8.81±0.2^{a}
$MBM_{0.67}$	8333±401.4^{a}	1388±66.8^{a}	4.40±0.2^{a}	128.2±6.2^{a}	64.1±3.1^{a}	7.93±0.2^{ab}
$MBM_{0.78}$	8111±371.2^{a}	1351±61.9^{a}	4.33±0.2^{a}	124.8±5.7^{a}	62.4±2.6^{a}	8.59±0.1^{ab}

Mean ± SE values in each row followed by a common letter are not significantly (P≤0.05) different

of P in *O. niloticus* broodstock diets reared in hapa-in-pond system for increasing fecundity. Moreover, the current results concluded that MBM could be used as an alternative source of P to replace MSP the commonly P source in aquaculture feeds without compromising broodstock reproductive performance.

Body Chemical Composition

Very little work has been done on the influence of broodstock diets on body chemical composition of male and female Nile tilapia broodstock (El-Sayed, 1999; El-Sayed and Kawanna, 2008). Influence of dietary P level and source on female and male body compositions are presented in tables 6 and 7. There were no significant differences (P≥0.05) in body composition for both male and female tilapia, except for lipid content (Table 6 and 7). The results were inconsistent with previous results indicated that increasing dietary P content significantly changed the chemical composition content of protein and ash in the carcasses of carp, rainbow trout, and Nile tilapia (Ogino *et al*., 1979; and Robinson *et al*., 1987). Male and female broodstock fed $MBM_{0.56}$ had the highest body lipid content (P≤0.05, Table 6 and 7). The decreased body lipid content for female broodstock with increasing dietary P from 0.67 to 0.78%, and from 0.56 to 0.78% for male broodstock in the present study (P≤0.05, Table 6 and 7) was consistent with some previous studies, including common carp (Takeuchi and Nakazoe, 1981), channel catfish (Eya and Lovell, 1997), rainbow trout (Skoberg *et al*., 1997), haddock (Roy and Lall, 2004). Onishi *et al*. (1981) observed that P deficiency in carp accompanied accumulation of lipid in muscle and viscera, and increase in the activity of the hepatopancreatic enzyme. In Chavez-Sanchez *et al*. (2000) high lipid was deposited in fish fed diet deficient in P. Similarly, Sakamoto and Yone (1980) reported inverse relationship between carcass lipid levels and dietary P in carp. This result could be attributed to the negative impact of P deficiency on oxidative phosphorylation pathway, leading to inhibit Krebs citric acid cycle and accumulation of acetyl-CoA that can be used in the formation of fat (Sakamoto and Yone, 1980; Roy and Lall, 2004).

Conclusion

In conclusion, the current study demonstrated that P is essential for enhancing egg quality and quantity and improving reproductive performance of Nile tilapia broodstock. Furthermore, the results suggest that with commercial diet that promotes growth to adequate level; there's still necessity to develop a particular broodstock diet (with respect to P level) to enhance reproductive performance in tilapia under the conditions of hapa-in- pond system. Furthermore, MBM and MSP have proven their suitability as sources of P and the potential to be used, even as an alternative to each other without any negative impact on growth and reproductive efficiency of Nile tilapia broodstocks.

Table 6. Effect of dietary treatments on the female body (whole fish) composition (g $100g^{-1}$ fresh weight basis) of *O. niloticus* broodstock

Diet	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Phosphorus (%)
Control	74.01±0.4	15.44±0.3	2.64^{bcd}±0.3	7.01±0.8	0.97±0.1
$MSP_{0.56}$	72.93±1.3	16.32±1.3	2.66^{bcd}±0.2	8.02±0.3	0.90±0.0
$MSP_{0.67}$	70.74±1.0	16.67±0.6	3.68^{ab}±0.4	7.85±0.1	1.01±0.2
$MSP_{0.78}$	71.30±0.1	16.59±0.3	3.02^{bc}±0.1	7.57±0.0	0.77±0.1
$MBM_{0.56}$	69.84±0.1	18.08±0.9	4.61^{a}±0.0	7.23±0.1	0.77±0.0
$MBM_{0.67}$	73.98±2.4	14.06±1.8	4.19^{a}±0.5	5.93±0.5	1.04±0.1
$MBM_{0.78}$	73.36±0.1	16.83±0.1	1.91^{d}±0.2	7.40±0.1	0.78±0.1

Mean ± SE values in each row followed by a common letter are not significantly (P≤0.05) different

Table 7. Effect of dietary treatments on the male body (whole fish) composition (g $100g^{-1}$ fresh weight basis) of *O. niloticus* broodstocks

Diet	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Phosphorus (%)
Control	74.49±0.3	16.37±1.0	1.16^{b}±0.0	7.92±1.1	1.10±0.1
$MSP_{0.56}$	72.51±2.2	16.56±0.3	4.76^{ab}±2.1	5.92±0.2	0.80±0.1
$MSP_{0.67}$	72.80±0.1	16.73±0.1	4.41^{ab}±0.2	7.17±0.1	0.77±0.1
$MSP_{0.78}$	69.42±0.7	18.31±0.9	1.70^{b}±0.2	6.99±0.5	0.90±0.1
$MBM_{0.56}$	71.62±0.2	16.86±0.1	7.34^{a}±0.2	8.04±0.7	1.05±0.2
$MBM_{0.67}$	72.80±3.3	16.80±2.6	3.21^{b}±0.0	6.33±0.3	1.02±0.1
$MBM_{0.78}$	66.89±0.5	18.21±0.9	2.68^{b}±1.9	6.92±0.9	0.77±0.0

Mean ± SE values in each row followed by a common letter are not significantly (P≤0.05) different

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