FATS AND PROTEINS RESEARCH FOUNDATION, INC
Final report
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Project title: Feather Meal and Meat and Bone Meal in Aquaculture Feeds and Production Strategies for the Culture of Nile tilapia in Egypt

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1. Objectives:

The objective of the proposed project was to:

1) Determine the relative bioavailability of Phosphorus in meat and bone meal (MBM) using slope ratio procedures compare to mono sodium phosphate (MSP) and to determine whether MBM could serve as the sole source of supplemental P in diets for Nile tilapia.

2) Examine the nutritive evaluation of rendered animal protein by-product (Feather meal) as suitable alternative for fish meal and soybean meal in diets for the culture of Nile tilapia *Oreochromis niloticus* in Egypt.

3) Examine the effect of L-tryptophan supplementation on the performance of Nile tilapia fingerlings fed high levels of meat and bone meal.

4) Study the phosphorus values in meat and bone meal compared to monosodium phosphate for Nile tilapia broodstock reared in a hapa-in-pond hatchery system.

5) Organize workshops with farmers, government, aquaculture extension personnel and feed manufacturers to present the results from these projects and seek industry inputs on research, development and technological needs to support the fish feed industry development in Egypt.

Technology Transfer

A poster on phosphorus bioavailability in MBM compared to mono sodium phosphate (MSP was presented at the X International Symposium on Aquaculture Nutrition, 2010 in Nuevo Leon, Mexico and two oral presentations on using North American rendered protein (MBM & FEM) compared to local animal protein ingredients in Nile tilapia diets were given at the 9th Asian Fisheries & Aquaculture Forum, 2011 in Shanghai.

At least four manuscripts should result from this work. The student is currently working on writing his thesis and manuscripts. I presented prelimary findings of the feeding trial to government personals and stakeholders at a meeting at the Central Laboratory for Food and Feed (CLFF) with Dr Hussein Soliman (Minister of agriculture for animal production) and Dr Akila Hamza (Former head of the CLFF) in Giza, Cairo, Egypt and at the ministry of agriculture with Dr. Tawfeik Shalaby (Chairman of animal production sector at minister of agriculture, MOA). I have discussed the experiment results with industry personnel and producers during tours of the feedlot facility at Cairo University or at meetings. Other industry publications and additional presentations will likely result from this work.

List of Publications

1) Measured the relative bioavailability of Phosphorus in MBM using slope ratio procedures compared to mono sodium phosphate (MSP). “The results presented at the X International Symposium on Aquaculture Nutrition. Monterrey, Nuevo Leon, Mexico, **November 8-10, 2010**“

2) Examined the Nutritive evaluation of rendered animal protein by-product (Feather meal) as suitable alternative for fish meal and soybean meal in diets for the culture of Nile tilapia *Oreochromis niloticus* in Egypt. The results accepted to be presented as an oral presentation at the 9th Asian Fisheries & Aquaculture Forum April, 21-25 2011 Shanghai China**.**

3) Studied the phosphorus values in meat and bone meal compared to monosodium phosphate for Nile tilapia broodstock reared in a hapa-in-pond hatchery system. The results were accepted to be presented as an oral presentation at the 9th Asian Fisheries & Aquaculture Forum April, 21-25 2011 Shanghai China.

4) Meat and bone meal phosphorus bioavailability in comparison with mono sodium phosphate for Nile tilapia (Oreochromis niloticus). Submitted to the Journal of aquaculture. ID AQUA-D-11-00863

5) Development of a suitable broodstock diet for Nile tilapia under the conditions of hapa-in- pond system: Is phosphorus necessary? Submitted to the Journal of aquaculture research. ID ARE-OA-11-Jul-536

Detailed Accomplishments

Experiment 1

The feeding trial (experiment 1) has been completed. The results are summarized below with tables of results at the end of the report. A total number of 630 tilapia fry with an average body weight of 1.53 ± 0.02 g were used in a completely randomized block design to determine the bioavailability of Phosphorus (P) in meat and bone meal (MBM) in comparison to that of mono-sodium phosphate (MSP) using a slope ratio assay experimental design. A corn-soybean meal based diet, deficient in P (0.45% diet; as-fed basis), was used as the basal diet, three levels of MBM, and MSP were substituted for corn starch in the basal diet to produce experimental diets containing 0.56, 0.67, or 0.78% P.

Growth performance and nutrients retention: Weight gain (WG), feed conversion ratio (FCR), and phosphorus retention (PR) increased significantly ($P \leq 0.05$) with P addition. Diets containing MBM recorded significantly greater WG, specific growth rate (SGR), and PR compared to MSP ($P \leq 0.05$).

Phosphorus bioavailability: Slope ratio analysis (MSP considered to be 100% bioavailable), resulted in bioavailability estimates of 109 to 142%, with an average of 124%. Results suggest that the bioavailability of P in MBM is high (approximately 124%) in comparison to that of MSP for Nile tilapia.

Conclusion (Experiment 1): The results of this study highlight the importance of MBM as a source of P in comparison with MSP in fish diets. In general, the bioavailability of P in MBM was relatively high, averaging 124% of the bioavailability of P in MSP. These results suggest that MBM could be used as a P source for tilapia diets to avoid negative environmental impact. A poster on phosphorus bioavailability in MBM compared to mono sodium phosphate (MSP was presented at the X International Symposium on Aquaculture Nutrition, 2010 in Nuevo Leon, Mexico

Experiment 2

The feeding trial (experiment 2) has been completed. The results are summarized below with tables of results at the end of the report. The aim of this study was to evaluate the effectiveness of substituting rendered animal protein ingredient, feather meal (FEM), to replace FM and SBM at 33, 66 and 100% levels in diets for Nile tilapia that should be mainly based on matching of digestible amino acids content and the growth performance of feeding trials. Nile tilapia was evaluated in an 8-week tank experiment. Triplicate groups of fish (initial body weight 2.35g) were fed seven isonitrogenous and isocaloric diets formulated to contain 32% crude protein and 11% crude lipid. The control diet contained 22% herring meal and 30% soybean meal, whereas in the remaining six diets, FEM was incorporated at 5 (SBM1), 10 (SBM2), and 15% (SBM3) to replace 33, 66, and 100% of the SBM; FEM was incorporated at 5 (FM1), 10 (FM2) and 15% (FM3) to replace 33, 66, and 100% of the FM.

Growth performance and feed efficiency: Feed intake was significantly lower in fish fed diet FM3 than fish fed the control diet. There were no significant differences ($p>0.05$) with respect to growth performance in fish fed the control diet, SBM1, SBM2 and FM1. Feed conversion ratio (FCR) was higher significant different ($p < 0.05$) in fish fed the diets SBM3, FM1, FM2 and FM3 than fish fed the control diet.

Body chemical composition analysis: No differences were found among diets in terms of fish whole body proximate composition.

Conclusion (Experiment 2): The results from this study show that feather meal have a good potential for use in Nile tilapia diets at high levels of incorporation. The optimal inclusion rate of FEM to substitute FM and SBM are 33 and 66% respectively.

An oral presentation on the nutritive evaluation of rendered animal protein by-product (Feather meal) as suitable alternative for fish meal and soybean meal in diets for the culture of Nile tilapia *Oreochromis niloticus* in Egypt was presented at the 9th Asian Fisheries & Aquaculture Forum, 2011 Shanghai China**.**

Experiment 3

The feeding trial (experiment 3) has been completed. The results are summarized below with tables of results at the end of the report. To evaluate weather phosphorus supplement is required in tilapia bloodstock diets under hapa-in-pond system, a basal diet (deficient in P, 0.45%) was supplemented with graded levels of added P (0.12, 0.24, and 0.36%) from mono-sodium phosphate (MSP) or meat and bone meal (MBM) to formulate seven isonitrogenous, isocaloric diets. Males and females with mean body weights of 270 g and 250 g, respectively, were stocked at a rate of 4 fish m^{-1}, (8 fish $hapa^{-1}$) with a male: female ratio of 1:3.

Reproductive performance: MBM treatments were reported to have greater reproductive performance ($P \leq 0.05$) compared with diets containing MSP. Irrespective of P source, it was observed that increasing P level significantly ($P \leq 0.05$) increased broodstock fecundity. Broodstock fed diets supplied with 0.67% MBM recorded the highest total egg production (8333 seeds), absolute fecundity (1344 seed $female^{-1}$), relative fecundity (4.33 seed $gfemale^{-1}$), and system productivity (64.1 seed day^{-1} m^{-2}). On the contrary, broodstock fed MSP diets showed the highest egg weight.

Conclusion (Experiment3): The results indicate that P concentration in the green water under the hapa-in-pond system is not enough to meet the nutritional requirements of tilapia broodstock. The optimum requirement for tilapia broodstock was estimated by polynomial (second-order) regression model to be 0.70%. An oral presentation on the phosphorus values in meat and bone meal compare to monosodium phosphate for Nile tilapia broodstock reared in a hapa-in-pond hatchery system was presented at the 9th Asian Fisheries & Aquaculture Forum, 2011 Shanghai China**.**

Experiment 4

The feeding trial (experiment 4) has been completed. The results are summarized below with tables of results at the end of the report. An experiment was conducted to assess the effects of L-tryptophan additions to meat and bone meal (MBM) used in the diet of Nile tilapia. Seven experimental diets were formulated to be isonitrogenous and isoenergetic on a digestible basis. Diets were formulated to examine the nutritive value of partially (75%) or totally (100%) replacing fish meal with MBM on growth performance and feed utilization of Nile tilapia. The diets containing MBM were supplemented with L-tryptophan, this amino acid predicted to be the most limiting AA, based on the amino acid requirements of Nile tilapia. L-tryptophan was also supplemented at two levels (0.07 and 0.14%). All diets except the control were supplemented with L-lysine (0.5%).

Growth performance and feed utilization: Addition of 45% meat and bone meal to the diet (75% replaced of FM) reduced growth rate ($P < 0.05$) during over the entire test period. This level of MBM also depressed efficiency of feed utilization ($P < 0.05$ for the entire experiment). A greater depression in feed intake and in rate and efficiency of gain ($P < 0.01$) occurred when 58% MBM was included in the diet (100% replaced of FM) compared to the control diet. The results indicated that tryptophan supplementation did not completely overcome the reduction in efficiency of performance and feed utilization when 45 and 58% MBM was fed compared to fish fed FM control diet but numerically minimized the reduction in feed intake, growth rate, and feed/gain. On the other side, MBM diets without tryptophan supplementation considered as a reference diets, supplementation of tryptophan at two levels (0.07 and 0.14%) to references diets resulted in a trend toward a higher growth rate and feed efficiency in fish over the entire test period compared with references diets. Feeding the highest supplemental level of tryptophan (0.14%) at 100% MBM showed lower growth rates and feed utilization compared to the lowest tryptophan supplementation (0.07%) at 75% MBM replacement.

Conclusion (Experiment 4): The results of this research indicate that high levels of meat and bone meal can be used in fish meal diets invigorated with lysine for Nile tilapia *Oreochromis niloticus*, provided that the diets are supplemented with L-tryptophan. Tryptophan seems to be the limiting amino acid in meat and bone meal diet enriched with lysine formulated to meet the lysine requirement of Nile tilapia.

Experiment (1)

Table 1 Composition of the ingredients used in test diets.

Composition	Meat and bone meal	Yellow 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
Gross energy (kJ/g)	19.16	18.33	19.75	22.55	18.48
Phosphorus, %	4.8	0.28	0.61	0.52	0.93

Table 2 Formulation and chemical composition of the experimental diets.

Ingredient	**Diet**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Corn	27	27	27	27	27	27	27
Corn gluten meal	15	15	15	15	15	15	15
soybean meal	40	40	40	40	39.6	39	38.3
Starch, raw	3	2.5	2	1.5	2.5	2	1.5
Wheat middlings	5	5	5	5	5	5	5
Soybean oil	4	4	4	4	3.6	3.5	3.2
Meat-bone meal 56% CP	-	-	-	-	2.3	4.5	7
NaH2PO4	-	0.5	1	1.5	-	-	-
Calcium carbonate	3	3	3	3	2	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[1]	2	2	2	2	2	2	2
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
Phosphorus (%)	0.41	0.51	0.61	0.71	0.53	0.62	0.75

[1]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.

Table 3 Source (monosodium phosphate vs. meat and bone meal) and level of P on performance and feed efficiency of Nile tilapia[1] fed the experimental diets for 56 days

Parameters	Diet							
Phosphorus source	Control	MSP			MBM			
Phosphorus (%)	0.45%[3]	0.56%	0.67%	0.78%	0.56%	0.67%	0.78%	SEM[2]
Live weight gain (g/fish)	3.31[c]	3.40[c]	3.65[c]	3.41[c]	3.76[c]	4.90[b]	6.54[a]	0.34
Feed intake (g)	8.54[c]	8.98[c]	9.29[c]	9.11[c]	8.79[c]	9.86[b]	11.29[a]	2.32
Feed conversion ratio (feed :gain)	2.65[a]	2.66[a]	2.54[ab]	2.68[a]	2.37[ab]	2.03[bc]	1.74[c]	0.56
Specific growth rate (%/day)	1.97[c]	2.00[c]	2.10[c]	2.02[c]	2.13[c]	2.47[b]	2.86[a]	0.47
Retained phosphorus (%)	30.49[bc]	26.47[c]	25.85[c]	25.43[c]	36.95[b]	34.37[b]	45.74[a]	3.24

[1] Initial body weight = 1.53 g/fish

[2] SEM =Pooled standard error of a mean. Means in the same row with different superscription are significantly different (P≤0.05).

[3] Calculated phosphorus content of the diet (g/100g)

Table 4 Source (monosodium phosphate vs. meat and bone meal) and level of P on chemical composition of the whole carcass of Nile tilapia fed the experimental diets for 56 days

Composition	Diet							
Phosphorus source	Control		MSP			MBM		SEM[1]
Phosphorus (%)	0.45%[2]	0.56%	0.67%	0.78%	0.56%	0.67%	0.78%	
Moisture, %	73.9	74.3	73.9	73.9	74.6	75.2	75.1	0.27
Crude protein, %	15.2	15.2	15.1	15.2	15.4	15.8	15.4	0.13
Lipid, %	8.0	8.2	8.4	7.7	7.6	6.5	6.4	0.16
Ash, %	2.8	2.6	2.9	2.8	2.9	2.9	3.1	0.08
Phosphorus, %	0.44	0.43	0.46	0.50	0.47	0.48	0.54	0.12

[1] SEM= Pooled standard error of a mean. Means in the same row with different superscription are significantly different ($P \leq 0.05$).
[2] Calculated phosphorus content of the diet (g/100g)

Table 5 Relative bioavailability of phosphorus in meat and bone meal, relative to mono-sodium phosphate (assumed to be 100% bioavailable), based on different parameters: specific growth rate; body phosphorus level; and retained phosphorus

Parameters	MSP	MBM
Specific growth rate (%/day)	100	120
Body phosphorus level (%)	100	109
Retained phosphorus (%)	100	142
Average	100	124

Experiment (2)

Table 6 Formulation and chemical composition of the experimental diets.

Ingredient	**Diet**						
Protein source	**Control**	**MBM 75%**	**MBM 100%**	**MBM 75%**	**MBM 100%**	**MBM 75%**	**MBM 100%**
Tryptophan add%	**-**	**-**	**-**	**0.07**	**0.07**	**0.14**	**0.14**
Fish meal	51	12.5	-	12.5	-	12.5	-
Meat and bone meal	-	45	58	45	58	45	58
Corn	24.0	20.5	20.5	20.5	20.5	20.5	20.5
Wheat bran	10	10	10	10	10	10	10
Starch	7.25	3.75	3.25	3.68	3.18	3.61	3.11
L-Lysine	-	0.5	0.5	0.5	0.5	0.5	0.5
L-tryptophan	-	-	-	0.07	0.07	0.14	0/14
Ascorbic acid	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Carboxy-methyl cellulose	0.5	0.5	0.5	0.5	0.5	0.5	0.5
NaCl	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fish oil	5	5	5	5	5	5	5
Vitamin & mineral premix	2	2	2	2	2	2	2
Analyzed composition (dry matter basis)							
Dry matter (%)	88.11	89.43	88.11	91.34	89,67	90.23	88.45
Crude protein (%)	30.24	31.43	30.54	29.62	30.11	30.43	30.21
Lipid (%)	10.12	9.06	12.13	12.26	9.87	13.45	12.11
Ash (%)	6.43	8.09	6.91	7.78	8.76	8.54	8.44

[1]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.

Table 7 Growth performances and feed efficiency of Nile tilapia[1] fed the experimental diets for 56 days

Parameters	**Diet**							
Protein source	**Control**	**MBM 75%**	**MBM 100%**	**MBM 75%**	**MBM 100%**	**MBM 75%**	**MBM 100%**	**SEM[2]**
Tryptophan add (%)	**-**	**-**	**-**	**0.07**	**0.07**	**0.14**	**0.14**	
Final body weight (g/fish)	3.35[a]	1.76 [c]	1.43 [cd]	2.24 [b]	2.03 [b]	1.84 [c]	1.56 [cd]	0.15
Feed intake (g)	3.56 [a]	2.41 [c]	2.29 [cd]	2.72 [b]	2.91 [b]	3.03 [ab]	2.59 [b]	0.05
Feed conversion ratio (gain: feed)	1.21 [d]	1.77 [c]	2.20 [a]	1.50 [c]	1.79 [c]	2.09 [a]	2.23 [a]	0.03
Gain (g/fish)	2.95[a]	1.37 [c]	1.03 [cd]	1.85 [b]	1.64 [b]	1.45 [c]	1.16 [cd]	0.12
Specific growth rate (%/day)	3.44 [a]	2.40 [b]	2.07 [b]	2.80 [ab]	2.65 [ab]	2.49 [c]	2.22 [b]	0.9

[1] Initial body weight = 0.395 g/fish
[2] Pooled standard error of a mean

Experiment 3

Table 8 Formulation and chemical composition of the experimental diets.

Ingredient	**Diet**						
Levels of substitution	**Control**	**33% SBM**	**66% SBM**	**100% SBM**	**33% FM**	**66% FM**	**100% FM**
Corn	42	47	52	57	44	46	48
Soybean meal, 44% CP	30	20	10	0	30	30	30
Local Fishmeal, 62% CP	21.95	21.95	21.95	21.95	14.95	7.95	0
Feather meal	0	5	10	15	5	10	15.95
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ascorbic acid	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Carboxy-methyl cellulose	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fat	4	4	4	4	4	4	4
Vitamin& mineral premix	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100
Analyzed composition (dry matter basis)							
Dry matter (%)	88.11	89.43	88.11	91.34	89,67	90.23	88.45
Crude protein (%)	30.24	31.43	30.54	29.62	30.11	30.43	30.21
Lipid (%)	10.12	9.06	12.13	12.26	9.87	13.45	12.11
Ash (%)	6.43	8.09	6.91	7.78	8.76	8.54	8.44

[1]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.

Table 9 Growth and feed efficiency of Nile tilapia[1] fed the experimental diets for 56 days

Parameters	Diet							
Levels of substitution	**Control**	**33% SBM**	**66% SBM**	**100% SBM**	**33% FM**	**66% FM**	**100% FM**	**SEM[2]**
Final body weight (g/fish)	13.85[a]	14.13 [a]	13.41 [a]	11.75 [b]	12.14 [ab]	10.20 [c]	8.29 [d]	0.55
Feed intake (g)	14.15 [a]	13.97 [a]	14.00 [a]	13.25 [ab]	13.93 [a]	13.78 [ab]	12.75 [b]	0.15
Feed conversion ratio (feed :gain)	1.24 [d]	1.19 [d]	1.28 [d]	1.42 [c]	1.43 [c]	1.76 [b]	2.18 [a]	0.09
Specific growth rate (%/day)	3.14 [a]	3.19 [a]	3.10 [a]	2.87 [b]	2.93 [ab]	2.62 [c]	2.23 [d]	0.09

[1] Initial body weight = 2.35 g/fish
[2] Pooled standard error of a mean

Experiment 4

Table 10 Chemical composition of different ingredient used in formulates broodstock 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
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 11 Composition and proximate analysis of broodstock diets.

Ingredient	Diet						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Corn	27	27	27	27	27	27	27
Corn gluten meal	15	15	15	15	15	15	15
soybean meal	40	40	40	40	39.6	39	38.3
Starch, raw	3	2.5	2	1.5	2.5	2	1.5
Wheat middlings	5	5	5	5	5	5	5
Soybean oil	4	4	4	4	3.6	3.5	3.2
Meat-bone meal 56% CP	-	-	-	-	2.3	4.5	7
NaH2PO4	-	0.5	1	1.5	-	-	-
Calcium carbonate	3	3	3	3	2	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[1]	2	2	2	2	2	2	2
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
Phosphorus (%)	0.41	0.51	0.61	0.71	0.53	0.62	0.75
Gross energy (kcal Kg-^{1})	4499.0	4420.9	4396.7	4407.3	4496.2	4460.8	4601.3

[1] 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

Table 12 Reproductive performance of tilapia broodstocks fed experimental diets for 65 days

P Source	P (%)	Total seed production	Absolute fecundity (Seed Female^{-1})	Relative fecundity (Seed g female^{-1})	Seed / day	System productivity (Seed day^{-1} m^{-2})	Egg weight (mg)
Control	**0.45**	6765[b] ±204	1127[b] ±34.0	3.58[b] ±0.15	104.1[b] ±3.1	52.1[b] ±1.57	7.76[c] ±0.31
MSP	**0.56**	7546[ab] ±606	1257[ab] ±101.2	4.01[ab] ±0.31	116.1[ab] ±9.3	58.0[ab] ±4.67	8.87[a] ±0.18
	0.67	7870[ab] ±159	1311[ab] ±26.6	4.18[ab] ±0.08	121.1[ab] ±2.4	60.5[ab] ±1.23	9.24[a] ±0.07
	0.78	8006[a] ±404	1334[a] ±67.3	4.24[a] ±0.22	123.2[a] ±6.2	61.6[a] ±3.10	8.75[a] ±0.35
MBM	**0.56**	8095[a] ±313	1349[a] ±52.2	4.31[a] ±0.19	124.5[a] ±4.8	62.3[a] ±2.41	8.81[a] ±0.22
	0.67	8333[a] ±401	1388[a] ±66.8	4.40[a] ±0.19	128.2[a] ±6.2	64.1[a] ±3.08	7.93[bc] ±0.17
	0.78	8111[a] ± 371	1351[a] ±61.9	4.33[a] ±0.19	124.8[a] ±5.7 [a]	62.4[a] ±2.58	8.59[ab] ±0.14

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

Table 13 Female whole body chemical composition for different experimental treatments.

P Source	P (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Phosphorus (%)
Control	**0.45**	74.01[a] ±0.41	15.44[ab] ±0.30	2.24[cd] ±0.34	7.01[ab] ±0.82	0.97 ±0.14
MSP	**0.56**	72.93[ab] ±1.30	16.32[ab] ±1.26	2.66[bcd] ±0.19	8.02[a] ±0.30	0.9 ±0.01
	0.67	70.74[ab] ±1.03	16.67[ab] ±0.64	3.68[ab] ±0.44	7.85[a] ±0.06	1.01 ±0.24
	0.78	71.30[ab] ±0.05	16.59[ab] ±0.29	3.02[bc] ±0.11	7.57[a] ±0.02	0.77 ±0.09
MBM	**0.56**	69.84[b] ±0.05	18.08[a] ±0.96	4.16[a] ±0.00	7.23[ab] ±0.04	0.77 ±0.02
	0.67	73.98[a] ±2.42	14.06[b] ±1.78	4.19[a] ±0.51	5.93[b] ±0.46	1.04 ±0.13
	0.78	73.36[ab] ±0.13	16.83[ab] ±0.07	1.91[d] ±0.20	7.40[a] ±0.12	0.78 ±0.02

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

Table 14 Male whole body chemical composition for different experimental treatments

P Source	P (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Phosphorus (%)
Control	**0.45**	74.49[a] ±0.33	16.37 ±1.00	1.16[b] ±0.01	7.92 ±1.14	1.1 ±0.05
MSP	**0.56**	72.51[a] ±2.22	16.56 ±0.31	4.41[ab] ±2.06	5.92 ±0.18	0.8 ±0.06
	0.67	72.80[a] ±0.05	16.73 ±0.14	1.70[b] ±0.23	7.17 ±0.07	0.77 ±0.10
	0.78	69.42[ab] ±0.68	18.31 ±0.92	4.76 [ab] ±0.17	6.99 ±0.49	0.9 ±0.10
MBM	**0.56**	71.62[ab] ±0.20	16.86 ±0.04	2.68[b] ±0.18	8.04 ±0.69	1.05 ±0.24
	0.67	72.80[a] ±3.27	16.80 ±2.56	3.21[b] ±0.02	6.33 ±0.28	1.02 ±0.10
	0.78	66.89[b] ±0.49	18.21 ±0.85	7.34[a] ±1.90	6.92 ±0.99	0.77 ±0.01

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

Table 15 Egg chemical composition for different experimental treatments.

P Source	P (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Phosphorus (%)
Control	**0.45**	64.8 [ab] ±0.0	23.5 ±0.2	4.85 [b] ±0.15	1.6[de] ±0.0	0.82[a] ±0.00
MSP	**0.56**	65.8 [ab] ±2.1	21.7 ±2.1	6.77 [a] ±0.07	2.2[bc] ±0.1	0.51[b] ±0.07
	0.67	63.9 [ab] ±1.2	23.2 ±0.6	6.84 [a] ±0.27	1.5[e] ±0.2	0.44[b] ±0.02
	0.78	61.8 [b] ±2.2	24.2 ±1.5	7.99 [a] ±0.32	1.9[cd] ±0.1	0.73[a] ±0.03
MBM	**0.56**	62.7 [ab] ±0.0	23 ±0.5	7.76 [a] ±0.18	2.6[a] ±0.0	0.48[b] ±0.09
	0.67	67.3 [a] ±0.9	20.6 ±0.7	6.65 [a] ±0.78	2.4[ab] ±0.1	0.40[b] ±0.04
	0.78	61.4 [b] ±1.4	24.5 ±1.2	7.05 [a] ±0.48	2.1[bc] ±0.0	0.50[b] ±0.05

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