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THE EFFECTS OF SUBSTITUTING FISHMEAL WITH RAPESEED MEAL AT THREE PROTEIN LEVELS ON GROWTH AND BODY COMPOSITION OF NILE TILAPIA FINGERLINGS (*Oreochromis niloticus*)

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ABSTRACT

A 6-week feeding experiment was conducted to evaluate the effects of substituting fishmeal with rapeseed meal in the diets of Nile tilapia (*Oreochromis niloticus)* with mean initial weight of 3.1 g. Seven different experimental diets were used in this feeding trial. Six diets were calculated isoenergetic with gross energy (GE) of 16,800 MJ/kg while the seventh diet was calculated to have GE of 21,861 MJ/kg, crude protein of 34% and fat 25%. Three of the six prepared diets (1, 3 and 5) were formulated at three different protein levels (35, 27.5 and 20%) respectively using fishmeal as the main protein source. Part of fishmeal in diets 1, 3 and 5 was substituted with rapeseed meal to form diets 2, 4 and 6 respectively while the crude protein levels were maintained. The substitution of fishmeal with rapeseed meal was 54% in diet 2 (35% CP), 80% in diet 4 (27.5% CP) and 72% in diet 6 (20% CP). Growth performance and feed utilisation were significantly affected when fishmeal was replaced with rapeseed meal. Rapeseed meal supplementation has significant effects on body composition at low protein level. Based on the growth and feed utilisation results, 54% replacement of fishmeal with rapeseed meal is not recommended in the diet of Nile tilapia at the size of 3.1 g.

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1 INTRODUCTION

In many developing countries, the basic and affordable animal protein is provided by aquatic organisms, mainly fish from capture fisheries as protein from terrestrial animals is very expensive for ordinary or low income earners. The main source of fish in the Gambia is artisanal capture fisheries (DOF, 2011) and the productivity of this sector is declining. For the country to meet the demand for fish for its population, one of the available feasible options is aquaculture. Currently, aquaculture is the fastest growing food producing sector globally. According to FAO (2013), world aquaculture production of food fish was 62.7 million tonnes totaling to USD 130 billion in 2011. Therefore, the sector is playing an important role in providing products which are very essential to human basic needs and also providing employment opportunities to many people worldwide.

Fish farming requires the provision of feed especially in intensive and semi-intensive systems. Since feed represents about 50-80% of the operational costs in intensive system (Oliveira-Cavalheiro *et al*., 2007), special attention should be given to protein, the most expensive macro component of feed (Lim *et al*., 2007), particularly fishmeal, the most expensive protein source (Tacon, 1993). It is high time to search for alternatives to replace fishmeal because in the near future, its usage in aqua-feeds will be limited in many developing countries due to high cost (El-Sayed, 1998), unavailability or both. Cheap ingredients that are currently used in aqua feeds in The Gambia are by-products of plants and animals. Most of the plant ingredients have imbalance amino acid profiles that do not match the dietary requirements of fish as fishmeal does. That being the case, in order to get alternative substitutes for fish meal, there should be thorough investigation of the ingredients feasible for the cultured species. This can be done through formula manipulations and mixing of various ingredients, in order to come out with ideal formulations. Once alternative substitutes are obtained, the cost of production can be estimated, productivity can be enhanced and this will go a long way in helping the Government to achieve its Millennium Development Goal on eradicating extreme poverty and hunger.

Tilapia is an economically important fish which is being farmed in both tropical and subtropical regions. It has high yield potentials of output and it can be cultured by using simple technology in earthen ponds, tanks, raceways, etc. These qualities make it a good candidate for subsistence and commercial aquaculture.

1.1 Developmental stages of aquaculture in the Gambia

The earliest freshwater aquaculture trials were carried out in the late1970’s and involved culturing of Tilapia and African catfish in small fish ponds. Catholic Relief Services (CRS) with assistance from the US Peace Corps and the Department of Fisheries carried out the culture trials. Though the trials did not produce the expected output, important lessons were learnt.

Shrimp farming started in 1986 by a Scandinavian Company called Scan-Gambia Ltd. The company was raising *Peneaus monodon*, imported from Sri Lanka. It has hatchery, grow out ponds and processing plant. The farm consists of 54 ponds and each pond is 4 ha. After about six years of production, the company was bankrupt and stopped production in 1992. Three species polyculture was carried out by Fisheries Department in 1995. *Tilapia nilotica, Heterotis niloticus* and *Clarias garipinus* were the fish cultured in this trial. Although successful, the trial could not continue due to lack of funds.

The West Africa Aquaculture (WAA) bought Scandinavian shrimp farm in 2000 after several years of dysfunction. West Africa Aquaculture is also raising *P. monodon* from larva to maturity. Of the original 200 ha, only few are being used today.

Taiwan Technical Mission established a fish farm in The Gambia in 2007 consisting of a hatchery, grow out ponds and feed milling machine. The hatchery produces tilapia. It uses hapas for tilapia fry production, concrete nursery ponds for raising fry to fingerlings and earthen ponds for grow out.

The FAO TCP project was established in 2009 but started production in 2010. The project has 20 ponds initially for tilapia farming but later dug an additional 31 ponds.

1.2 Local ingredients available in The Gambia

Local ingredients available that can be used in aqua-feed are: groundnut cake, cotton seed meal, sesame seed cake, rice, maize, millet and sorghum brans; expired wheat flour from stores, cassava peels and leaves, pawpaw leaves, duckweed, moringa leaf meal, by-products from fish and shrimp processing factories, brewers waste, wild fruits, etc.

1.3 Local ingredients currently used in aqua-feeds

In the Gambia, the only fish farm that has a feed mill is Taiwanese Fish Hatchery (presently under Fisheries Department). Feed formulations at that farm are dictated to a large extent by the price of local ingredients. The farm adjusts its feed formulations in order to reduce feed cost but they have yet to produce a formula that is cost effective without compromising fish growth.

1.4 Problem statement

Feed is generally the most expensive cost item in aquaculture production. The high cost of feed is mostly due to the protein component, and feed for most of the cultured fish species contain high protein level (30-50% CP). Fishmeal is commonly a very good protein source in fish feed, due to good digestibility and amino acid content. The problem is that fishmeal is of high price and a limited resource. High cost of raw materials force many aquaculture farmers in developing countries to substitute expensive conventional feed ingredients like fish meal with other local and available ingredients. The substitution of ingredients and formulation of feeds effects the growth response and wellbeing of the fish. If feed selection is not taken into careful consideration, the farming effort will hardly bring any benefit to farmers due to low quality and poor production rate. This does not only discourages the farmers but also scares off potential investors in aquaculture. Aquaculture cannot grow in any country without significant investment. Various sources and by-products can be used in fish feed. Therefore different feed formulations using different raw materials need to be tested. These formulations might be a compromise of low cost and optimal or appropriate fish growth.

The aim of this study is to examine whether replacement of fish meal with rapeseed meal will have significant effects on growth performance of Nile tilapia fingerlings *(Oreochromis niloticus).*

1.5 Objectives

The purpose of this study is to examine if replacing fish meal with rapeseed meal will have significant effects on growth performance of Nile tilapia fingerlings *(O. niloticus).*

The primary aims of this project are:

- To investigate the effects of different protein levels on growth responses of Nile tilapia fingerlings fed on diets prepared from different raw materials.
- To investigate the effects of substituting fish meal with rapeseed meal on growth response of Nile tilapia fingerlings.
- To compare the diets which have fish meal with diets which have fish meal plus rapeseed meal (plant protein) as protein sources or plant based diet.

1.6 Hypothesis and questions

Crude protein level may have significant effect on growth performance of Nile tilapia.
Substituting fish meal protein with rapeseed meal protein in Nile tilapia fingerling diet or may not have significant effects on growth.

Substitution of fish meal with rapeseed meal may have significant effect on body composition of Nile tilapia fingerlings.

1. Will the crude protein level have any significant effects on growth performance of Nile tilapia fingerling, survival and size distribution?
2. Will the substitution of fish meal with rapeseed meal have significant impact on growth performance of Nile tilapia fingerlings?
3. Will the substitution of fish meal with rapeseed meal have significant effect on the body composition of Nile tilapia?

1.7 Justification

The use of low quality feeds in aquaculture is affecting the productivity of fish farming in the Gambia. It is evident that the efforts of fish farmers are not yielding the expected benefits or results from the farms. Therefore, some interventions should be taken to enhance economic returns of the farmers in order to keep them in the sector. Otherwise they will be discouraged. It is also obvious that the Government's aspirations to use aquaculture to reduce pressure on capture fisheries, enhance the production of food fish, improve livelihoods of the populace and as well as generate income for rural resource poor farmers cannot be achieved at the current production levels. Therefore, an important way out is to enhance feed quality which will consequently increase the production and the benefit. Improving feed quality will require extensive research on the nutritional compositions of the available ingredients and the recognition of requirement of the cultured fish especially if one is to use nonconventional ingredients. Tangible results which one can rely on can come through experimental trials. The findings from investigation can be used to improve the present formulations.

2 LITERATURE REVIEW

2.1 Dietary requirements of tilapia

2.1.1 *Protein requirements of tilapia*

Dietary protein requirements of tilapia have been extensively studied worldwide. From the findings, it appears that the protein requirements of tilapia like other finfishes depend on fish size and can be expressed as digestible protein (DP) to digestible energy (DE) ratio (NRC, 2011).

Conflicting results have been obtained by many authors concerning the dietary protein requirements of tilapia. Based on the size/age, small tilapia have higher dietary protein requirement and the requirement decreases as the fish grows bigger (Abdel-Tawwab and Ahmad, 2009; Winfree and Stickney, 1981). Fry of 2.5 g of *O. niloticus* requires about 56% dietary protein while 2.5-7.5 g fry require 34% dietary protein for maximum growth performance (Winfree and Stickney, 1981) although lower dietary protein value of 45% at energy level of 400 kcal/100 g was reported to give maximum growth to swim-up fry (12 mg) when reared under laboratory conditions (El-Sayed and Teshima, 1992). The optimum dietary protein requirements for optimal growth of Nile tilapia fry (~0.5 g) was reported to be 45% whereas the optimal requirements for fingerling (~20 g) and advanced juvenile (~40 g) was found to be 35% (Abdel-Tawwab *et al*., 2010). According to Siddiqui et al., (1988), 0.8g Nile tilapia (*O. niloticus*) require 40% dietary protein while those weighing 40g require 30% dietary protein. The dietary protein level for economical diet for *O. niloticus* fry (0.51 g) and juvenile fish (45 g) was found to be 40% while that of the adult (96 and 264 g) was 30% (Al-Hafedh, 1999). The results of least-cost dietary protein levels evaluation for four species of tilapia (*O. mossambicus, O. niloticus, O. aureus and Tilapia Zillii*) showed maximum growth from the dietary protein levels 34 - 36% for young tilapia (1-5 g), but the authors recommended 25-28% as the most cost-effective protein level (De-Silva *et al*., 1989). The recommended protein level for 21 g grow-out hybrid tilapia fed on all-plant diets and reared in tanks was 28% (Twibell and Brown, 1998). There is inconsistency among the results which could be due to differences in culture methods, raw materials or possible genetic differences in the strains used. The general trend is clear though, protein requirements as a proportion of the mass of the diet, decrease with size (NRC, 2011).

The growth rate of fish is high when the ratio of digestible protein to digestible energy in the diet is optimal for the species but when the ratio of DP to DE in the diet is very high or very low for the species, growth rate becomes constant or declines. Tilapia at fry stage require diets which have high digestible protein to digestible energy ratio but as they grow bigger, they need diets which have low DP to DE protein ratio. Winfree and Stickney (1981) reported that diets which have high protein to energy (P:E) ratio (123 mg protein/kcal) produced better growth than diets which have lower P:E ratio (82 mg protein/kcal) during the first few weeks but high protein to-energy ratios became growth limiting factor as fish approached 5g. At the end of the experiment, fish fed diets with protein to-energy ratio (108 mg protein/kcal) produced the best growth. The best protein to-energy ratio in the diet of tilapia that produced the highest growth (average final weight, 39.04 g) was found to be 89 mg protein/kcal at dietary protein level of 25% and energy level of 2,800 kcal/kg (Li *et al*., 2013).

Physiological conditions can also influence dietary protein needs of tilapia. Broodstock require high dietary protein in their diets for efficient performance and quality eggs. In an experiment where the effects of dietary protein level investigated on spawning performance of Nile tilapia broodstock, the authors concluded that 40% dietary protein is required for optimum spawning performance of this fish reared at 0 ppt., 7 ppt. and 14 ppt salinity in clear water (El-Sayed *et al*., 2003). Although Gunasekera *et al*. (1996a) did not make any conclusive statement about protein requirement of Nile tilapia broodstock when fed on three different dietary protein levels (10, 20 and 35%), the eggs of fish fed on 35% protein have higher protein content and overall total amino acid composition compared to those fed on sub-optimal protein levels (10 and 20%). It was also noticed when broodstock were fed on low protein diet (10% CP), spawning intervals were delayed (Gunasekera *et al*., 1996a) and the eggs produced were not fertilized (Gunasekera *et al*., 1996b).

A review of Luquet (1989) concluded that tilapia's dietary protein requirements seem to be between 30-35% but 30% appears to be a safe level.

2.1.2 Amino acids requirements of tilapia

Amino acids are the end products of protein digestion and they can be used in anabolism to synthesize proteins again or catabolism to generate energy. Tilapia also require the 10 essential amino acids (Santiago and Lovell, 1988) namely: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The quantitative essential amino acids (EAA) requirements of few farmed tilapia have been determined but there were some discrepancies in the reported values from species to species and sometimes even same species. The variations could be caused by amino acid sources used in semi-purified and practical diets or the expression of the requirements as percentage of the diet instead of dietary protein.

Although fish can sufficiently synthesize nonessential amino acids, their inclusion in the diets will reduce or reserve the energy which could have been used in their synthesis to be used for other body functions. Cystine and tyrosine although are nonessential AAs, they are of particular importance as they can only be synthesized by methionine and phenylalanine respectively. Therefore, their inclusion in diets reduces the requirements of these two essential AAs. It was reported that in practical diet formulation when the level of dietary cystine was 0.45% (or 1.61% of dietary protein), methionine at a level of 0.49% of the diet or 1.75% of dietary protein was adequate for meeting the requirement of juvenile Nile tilapia (Nguyen and Davis, 2009a). In another study, the same authors indicated that cystine could replace 49% of methionine in the diet of juvenile Nile tilapia (Nguyen and Davis, 2009b). The ten essential amino acid requirements of Nile tilapia are shown in Table 1.

Table 1. The 10 essential amino acid requirements of Nile tilapia (*O. niloticus*) data adapted from NRC (2011)

Amino acid	Estimated requirement	Reference
Arginine	4,2% of CP	(Santiago and Lovell, 1988)
Histidine	1,7% of CP	(Santiago and Lovell, 1988)
Isoleucine	3,1% of CP	(Santiago and Lovell, 1988)
Leucine	3.4% of CP	(Santiago and Lovell, 1988)
Lysine	5,1% of CP	(Santiago and Lovell, 1988)
	5,4-5,7% of CP	(Furuya *et al.*, 2004a)
	5,23% of CP	(Furuya *et al.*, 2006)
Methionine	2,7% of CP (with 0,5% Cys)	(Santiago and Lovell, 1988)
	2,1% of CP	(Furuya, *et al.*, 2001)
	2,8% CP	(Nguyen and Davis, 2009a)
Phenilalanine	3,8% of CP	(Santiago and Lovell, 1988)
Threonine	3,8% of CP	(Santiago and Lovell, 1988)
Tryptophane	1,0% of CP	(Santiago and Lovell, 1988)
Valine	2,8% of CP	(Santiago and Lovell, 1988)

2.1.3 Lipid requirements of tilapia

Dietary lipids are important sources of highly digestible energy and are the only source of essential fatty acids for fish for normal growth and development. They also improve the flavour of feed and affect feed texture and fatty acid composition of fish. There are varying results for lipid requirements of tilapia. Some researchers reported dietary lipid requirement of more than 10% while others recommended 10% or below. A better growth was obtained from hybrid tilapia fed on 55 and 85 g/kg lipid diets compared to those fed on 25 and 115 g/kg lipid diets (Han *et al.*, 2011). Good growth and feed efficiency were obtained by Chou and Shiau (1996) from juvenile hybrid tilapia (*O. niloticus* x *O. aureus)* when the fish were fed with 10 and 15% lipid diets. They suggested that 5% lipid level appeared to meet the minimum requirement for this species, but for maximum growth, 12% was recommended. Although the augmentation of dietary lipid significantly increase the weight of blue tilapia, lipid level of about 17% was said to be too high for this species (Wille *et al.*, 2002).

2.1.4 Rapeseed meal

Rapeseed meal is the major plant protein source which is substituted with fish meal in this trial. It is made from oilseeds from the genus Brassica which are grown as oil and protein crops. The world production is close to 60 million tons. Rape seed meal (or Canola meal) contains about 35% crude protein, 3,5% crude oil, 6% ash, 12% crude fiber and 10% moisture.

In comparison to fish meal, rapeseed meal is limiting in lysine and few other essential amino acids but have high level of methionine and cysteine (Figure 1). Because of a relatively high content of fiber and phytate, glucosinolate and other factors considered to have anti-nutritional effects, canola or rapeseed meal has a limited use for carnivore fish Drew *et al*., (2007). Few feed trials have been conducted to investigate the potential of rapeseed meal in practical diets for juvenile tilapias. Davies *et al*. (1990) found indications that practical inclusion limit around 15%. Higher inclusion levels lead to progressively poorer feed performance and growth.

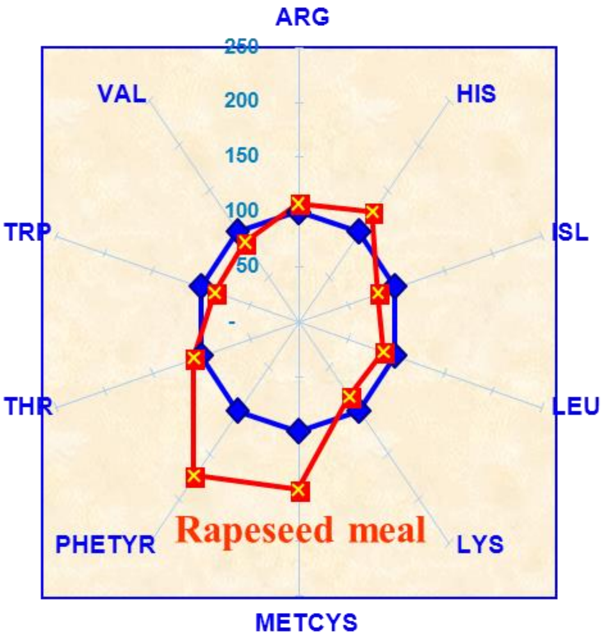

Figure 1 : Comparison of essential amino acid composition of rapeseed meal and fish meal. The composition of fish meal is set as an index of 100 and the figure is showing the deviation

3 MATERIALS AND METHODS

3.1 Experimental design and diet

Formulations and proximate composition of experimental diets are shown in Table 2. Seven different experimental diets were used in this feeding trial and they are: high protein diet (HPFM) where protein source is fishmeal (FM), second high protein diet (HPRM) where protein sources are fishmeal plus rapeseed meal (FM + RSM), medium protein diet (MPFM) where the protein source is fishmeal (FM), second medium protein diet (MPRM) where the sources are fishmeal plus rapeseed meal (FM + RSM), low protein diet (LPFM) where the protein source is fishmeal (FM), second low protein diet (LPRM) where the Protein sources are fishmeal plus rapeseed meal (FM + RSM) and experimental feed made from only plant raw materials or plant based diet (PPBD). Six of the diets were prepared by the author while the seventh diet was prepared at feed extrusion machine, for other purposes. The formulation of the six diets were calculated isoenergetic with GE of 16,800 MJ/kg. Two of the six prepared diets (HPFM and HPRM) contain 35% crude protein and 8.94 and 11.7% crude lipid respectively; another two diets (MPFM and MPRM) have 27.5% crude protein and 8.4 and 10.56% crude lipid respectively; and the last two diets (LPFM and LPRM) contain 20% crude protein and 7.7% crude lipid. The crude protein and lipid levels of the seventh diet (PPBD) were 34 and 25% respectively with GE of 21,861 MJ/kg. The ingredients were ground, thoroughly mixed, then oil and water or water was added to form moist dough then the dough was prepared into feed –through small extrude machine, grounded and sieved to form appropriate particle size for the fish. Feed formulations are outlined in Table 2.

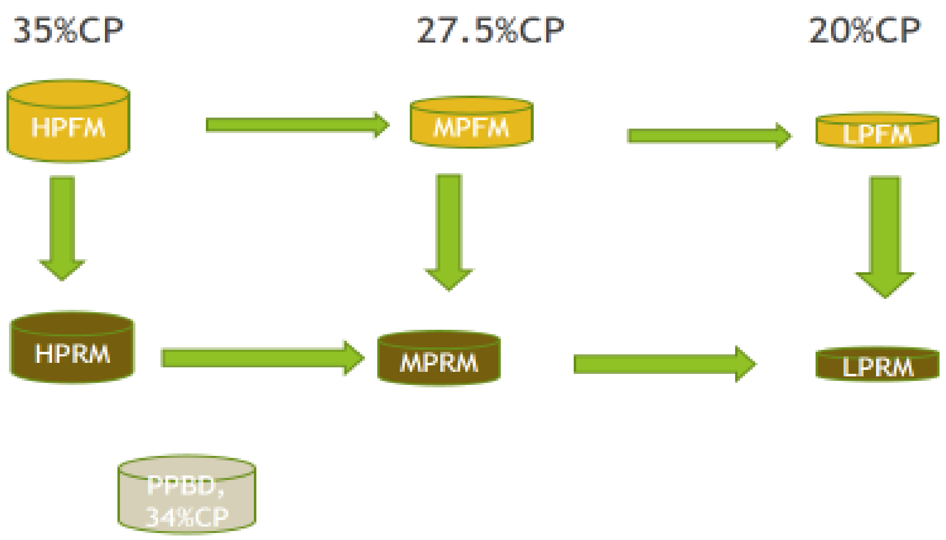

Figure 2. Flow chart of experimental design and diets

Table 2. Formulations and proximate composition of experimental diets (as fed basis).

Ingredient (%)	HPFM	HPRM	MPFM	MPRM	LPFM	LPRM	PPBD
Wheat bran		9,523		8,457		1,965	
Wheat	55,385	8	67,469	21,931	79,958	61,638	8
Rapeseed meal DK		63,182		63,159		29,633	11,544
Premix Laxa	1	1	1	1	1	1	1
NSM Meal 706/105	39,769	18,296	27,006	5,453	14,172	3,966	
Fish oil							22,464
Vegetable oil	3,846		4,525		4,87	1,798	
Soya 47/5 Brasil							45,028
Wheatgluten mealG							10,62
Monoca-Phosphate							1,29
Carophyl Red 10%							0,027
Carophyl Pink 10%							0,027
Total	100	100	100	100	100	100	100
Proximate composition (%)							
Crude protein	33,8	33,7	26,4	27,2	19,1	19,6	39,3
Crude lipid	7,59	11,15	6,3	10,33	6,17	6,81	24,17
Moisture	10,28	8,35	13,17	7,47	14,97	11,21	6,62
Ash	8,05	8,25	5,77	6,3	5,61	3,85	4,7
GE(MJ/kg)	16,8	16,8	16,8	16,8	16,719	16,8	21,861

Estimated raw material price, and contents of crude protein, crude fat, crude ash and moisture of the experimental diets are shown in table 3. Estimated amino acid contents in the experimental diets (g/kg) are shown in Table 4. Estimated percent contents of amino acid in the diets express in percentage of dietary protein and requirement values of tilapia by Santiago and Lovell, 1988 are shown in Table 5.

Table 3. Estimated raw material price and content of crude protein, crude fat, crude ash and moisture of the experimental diets.

Parameter	HPFM	HPRM	MPFM	MPRM	LPFM	LPRM	PPBD
Price/kg diet (Ikr)	146,95	95,02	121,99	69,01	96,17	70,15	147,58
Crude Protein (%)	35	35	27,5	27,5	20	20	34
Crude Fat (%)	8,94	11,7	8,4	10,56	7,7	7,7	25
Crude Ash (%)	8,17	7,48	6,32	5,63	4,46	4,15	5,67
Moisture (%)	10,14	9,58	11,11	10,68	12,12	12,12	8,1
Dry matter%	89,86	90,42	88,89	89,32	87,88	87,88	91,9
%Carbohydrates including fibers	37,75	36,24	46,67	45,63	55,72	56,03	27,23
Calculated brutto energy (MJ/kg)	18,3	19,2	17,9	18,6	17,4	17,5	22,6

Table 4. Estimated amino acid content in the experimental diets (g/kg)

	HPFM	HPRM	MPFM	MPRM	LPFM	LPRM	PPBD
Lysine	20,72	18,97	15,06	13,28	9,37	8,52	16
Arginine	19,12	24,9	14,72	19,92	10,31	11,66	25,24
Histidine	8,04	12,81	6,32	10,81	4,61	6,19	7,59
Threonine	12,86	19,41	9,84	16,05	6,81	9,11	12,25
Valine	16,07	23,38	12,67	19,53	9,28	11,65	14,03
Leucine	23,68	28,65	18,74	23,54	13,8	15,74	22,4
Isoleucine	13,63	18,92	10,78	15,69	7,93	9,52	12,76
Methionine	8,07	7,37	6,05	5,35	4,02	3,69	4,92
Cystine	3,83	6,14	3,43	5,77	3,05	4,17	5,93
Phenylalanine	13,91	19,18	11,32	16,22	8,75	10,31	14,07
Tyrosine	10,36	10,89	8,32	8,43	6,28	5,55	8,39
Tryptophan	3,61	11,84	2,96	10,73	2,31	5,1	10,21
Met + Cyst	11,9	13,61	9,48	11,2	7,07	7,88	10,86

Table 5. Estimated % content of amino acid in the diets express in % dietary protein and requirement values of tilapia by Santiago and Lovell, 1988.

	HPFM	HPRM	MPFM	MPRM	LPFM	LPRM	PPBD	1988[a]
Lysine	5,92	5,42	5,48	4,83	4,69	4,26	4,71	5,12
Arginine	5,46	7,11	5,35	7,24	5,15	5,83	7,42	4,2
Histidine	2,3	3,66	2,3	3,93	2,31	3,09	2,23	1,72
Threonine	3,67	5,54	3,58	5,84	3,41	4,56	3,6	3,75
Valine	4,59	6,68	4,61	7,1	4,64	5,82	4,13	2,8
Leucine	6,77	8,19	6,81	8,56	6,9	7,87	6,59	3,39
Isoleucine	3,9	5,41	3,92	5,71	3,97	4,76	3,75	3,11
Methionine	2,31	2,11	2,2	1,94	2,01	1,85	1,45	
Cystine	1,09	1,75	1,25	2,1	1,52	2,08	1,75	0,54
Phenylalanine	3,97	5,48	4,12	5,9	4,37	5,16	4,14	
Tyrosine	2,96	3,11	3,02	3,07	3,14	2,77	2,47	1,79
Tryptophan	1,03	3,38	1,08	3,9	1,16	2,55	3	1
MET + CYS	3,4	3,89	3,45	4,07	3,54	3,94	3,19	3,22
PHE + TYR	6,93	8,59	7,14	8,96	7,51	7,93	6,61	5,54

3.2 Growth trial

Mixed sex Nile tilapia *O.niloticus* fingerings were used in the feeding trial. At the initiation of the experiment, individual weight and length of a random pool of fishes was measured for estimation of initial weight. The acclimatized fish were randomly distributed in 21 bucket containers of 17 L water capacity each at a stocking density of 50 fish per tank. Water temperature was controlled at 28-29 ^{0}C. Fish were fed by automatic feeder. The automatic feeder was set such that every 10 minutes, it drops feed for 25 seconds. Occasionally, fish were fed by hand if need be. Fish were pooled weighed every 3 weeks to determine the growth rate of the fish. At the end of the trial all fishes were individually measured for length and weight.

3.3 Sampling

At the end of the experiment, all the fish were counted, the weight and the body length of each fish were taken for determination of mean weight (MWT), percentage weight gain (WG (%)), specific growth rate (SGR), percentage feed efficiency (FE (%)), feed conversion ratio (FCR) and survival.

3.4 Calculations of parameters

The following formulae were used for calculations:

Percentage weight gain (WG (%)) = 100 × (final mean weight – initial mean weight)/ initial mean weight.

Specific growth rate (SGR) =100 (ln (final mean weight) – ln (initial mean weight))/ number of days.

Percentage feed efficiency (FE (%)) = 100 × (wet weight gain of fish (g)) / dry weight of feed given (g).

Feed conversion ratio (FCR) = total dry feed fed (g) / total wet weight gain (g)

3.5 Analysis of the diets

In order to determine the proximate composition of feeds, they were finely ground into powder, and then analyzed. Crude protein (total Nitrogen x 6.25) was determined by the use of micro-Kjeldahl method. The sample was digested in sulphuric acid in the presence of $CuSO_4$ as catalyst. Thereafter, the sample was placed in distillation unit, 2400 Kjeltec Auto Sampler System. The acid solution was made alkaline by using of NaOH solution. The ammonia was distilled into boric acid which is then titrated with H_2SO_4. The nitrogen content was multiplied by factor 6.25 to obtain % crude protein. Crude fat was extracted by Soxhlet method. The sample was extracted with petroleum ether, boiling range 40-60 ^{o}C. The extraction apparatus was Soxtec Avanti Automatic System. Ash was determined by incineration of samples in muffle furnace at 550 ^{o}C for 4 h and the residue weighed. Moisture was calculated from the weight difference after oven drying the samples at 105 ^{o}C for 4 h. Percentage of moisture corresponds to the weight loss.

3.6 Analysis of the body composition

The determination of fat, moisture, and protein in fish were done by using the FOSS FoodScan Near-Infrared Spectrophotometer with FOSS Artificial Neural Network Calibration Model (FOSS, Hillerod, Denmark). Approximately 50 g ground sample was placed in a 90 mm round sample dish, and the dish was placed in the FoodScan. Results were displayed for percent (g/100 g) fat, moisture and protein.

3.7 Statistical analysis

All statistical analyses were performed with SPSS version 18 (SPSS, Chicago, IL, USA). Biometric data amongst fish groups reared on different diets were compared using two way analysis of variance (ANOVA); after ascertaining the assumptions of normality and equal variance. In case of significant differences amongst group, means were compared using Bonferroni technique at *P*-values ≤ 0.05.

4 RESULTS

4.1 Water quality parameters

The experiment was conducted at ambient temperature for tilapia and was subjected to continuous 24h light (24L: 0D). Dissolved oxygen concentration was measured daily in each bucket. The water temperature was also measured daily in the total system. The mean temperature during the experiment was 28.2 °C. Dissolved oxygen fluctuation during the experiment is shown in Figure 3. It was observed during the experiment that dissolved oxygen was negatively correlated to temperature. As temperature decreases, dissolved oxygen level increases.

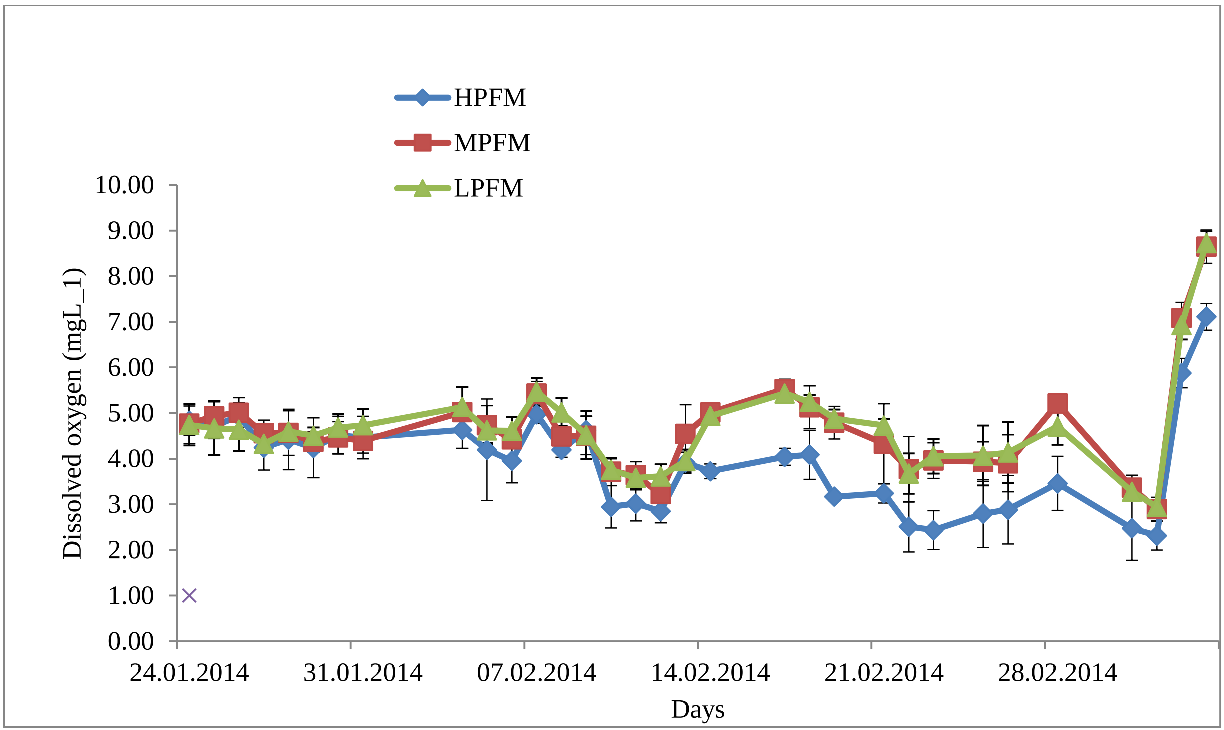

Figure 3. Average dissolved oxygen level (mg/l ±SD) in groups fed fish meal protein diets during the feeding period. n= 3 for each treatment

The aim was to keep the oxygen level close to 5mg/l. As seen in Figure 3, there were some fluctuations in oxygen concentration in the experimental tanks but for long time the concentration was between 4-5mg/l. The lowest oxygen level was in the treatments where fish were growing fastest and is related to the biomass increase. The oxygen level was not at the optimum during the whole trial period and therefore it might have affected the growth in general although the growth in the best growing groups seems to be close to what can be expected for fish at this particular size and temperature. In the final experimental days the oxygen level was considered to be critical and therefore extra oxygen was added to the water system. It explains the sharp rise in the oxygen concentration at the end.

The water temperature was in the range of 26-29°C, and rather stable, close to 28°C most of the period as illustrated in Figure 4. The fluctuations did not have any detected effect on the feed intake of the fish. It was noticed that biomass increase has no effect on temperature fluctuation.

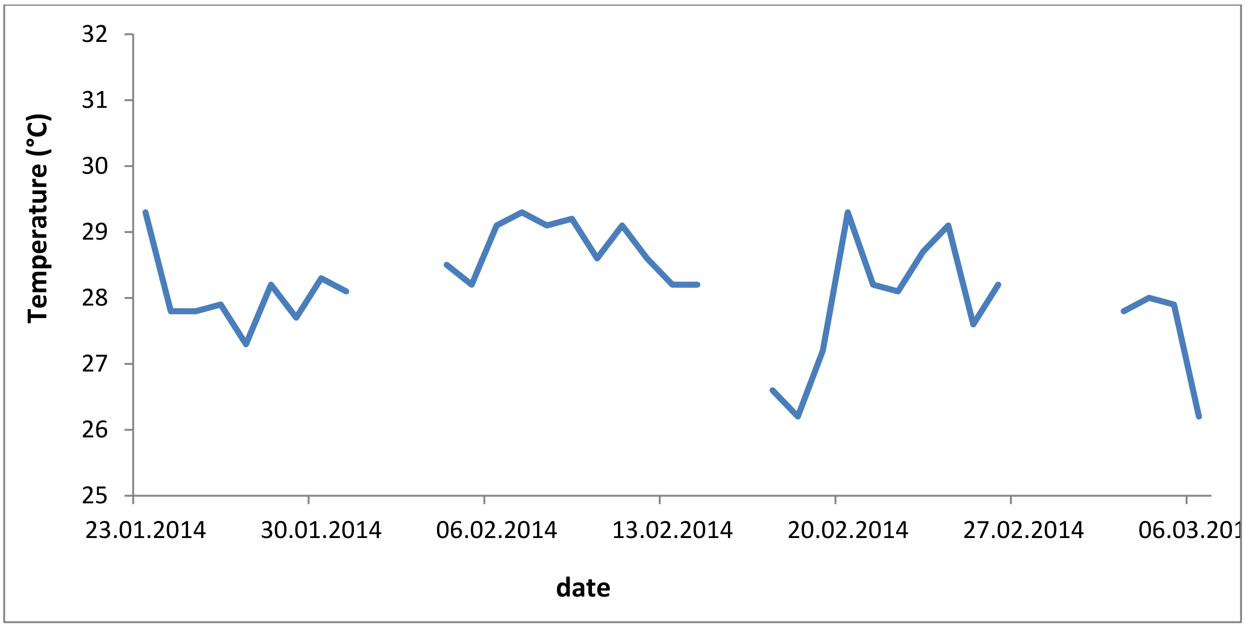

Figure 4. Temperature (°C) in the experimental tanks during the trial period.

4.2 Growth and Survival

In this experiment, no pathological signs and symptoms were observed throughout the study which shows that both the diets and the culture environment were conducive to the fish. The survival ranged from 89-100%.

The effects of crude protein source and level on growth and feed utilisation parameters at the end of 3 weeks are shown in Table 6. From the results, it was noticed that the higher the dietary protein level the better the WG %, SGR, FE and FCR. It was also observed from the results that fish performance was significantly higher on fishmeal based diets compared to fishmeal plus rapeseed meal diets.

The ranking of the treatments based on the growth performances and feed utilisation at the end of the experiment is shown in Table 7. Although the prepared diets were formulated to be isoenergetic, the calculated gross energy values were different. HPFM gained the highest mean weight (MWT), percentage weight gain (WG (%)), specific growth rate (SGR), percentage feed efficiency (FE (%)) and the best feed conversion ratio (FCR) followed by MPFM, then HPRM. There were no significant differences between MPFM and LPFM in these parameters. PPBD gained the lowest values of MWT, WG (%), SGR and FE (%) but there were no significant differences between this diet and LPRM.

The effect of fishmeal as crude protein source at different protein levels on growth and feed utilisation at the end of experiment is shown in Table 8. From the results, it was observed that when fishmeal was used as the main dietary protein source, fish fed on HPFM diet (35% CP) obtained the best MWT, WG (%), SGR, FE (%) and FCR followed by MPFM diet (27.5% CP) and then LPFM diet (20% CP).

The effect of fishmeal plus rapeseed meal as crude protein sources at different protein levels on growth and feed utilisation at the end of the experiment is shown in Table 9. It was observed that when fishmeal and rapeseed meal (plant protein) were used as protein sources, fish fed on HPRM diet (35% CP) obtained the highest MWT, WG (%), SGR, FE (%) and the best FCR followed by MPRM diet (27.5% CP) then LPRM diet (20% CP).

The effect of crude protein sources at the same protein level at the end of the trial on growth and feed utilisation is shown in Table 10. It was observed from the results that at the same protein level, fish fed fishmeal based diet performed significantly better than those fed fishmeal plus rapeseed meal based diet.

Changes in total body weight (g) of Nile tilapia fingerlings fed different experimental diets is shown in. figure 5 Although at the initiation of the experiment there were no significant differences among the treatment groups however, at the end of the trial there were significantly differences among the treatment groups.

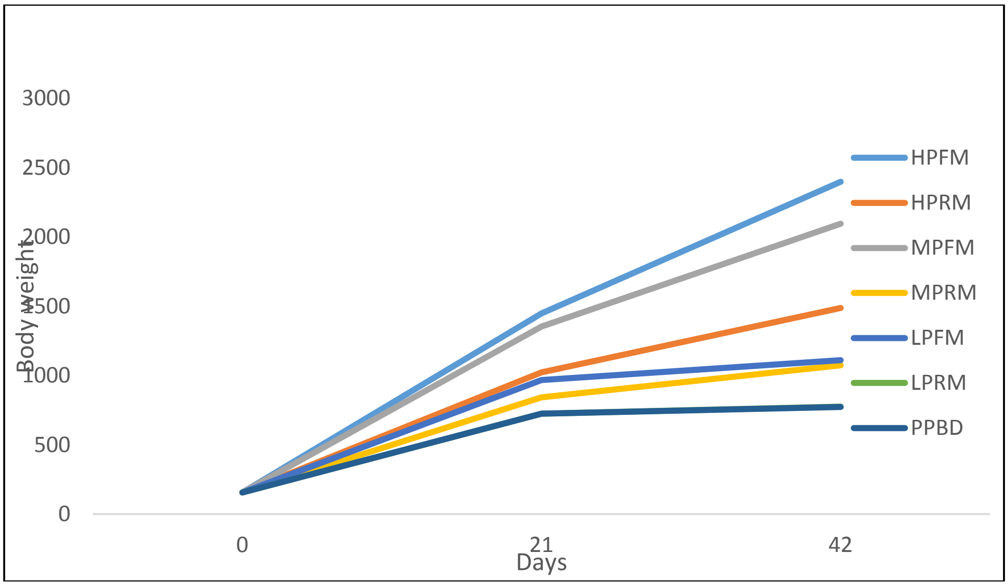

Figure 5. Changes in total body weight (g) of Nile tilapia fingerlings fed different experimental diets

The effects of protein level and source and their interaction on final average weight is shown in fig. 6. It was observed that both crude protein level and crude protein source have significant effects on final average weight and there was significant interaction between the two. It was noticed that as protein level increases, the interaction also increases. It was also observed that when high quality (FM) protein source was used, final average weight increases.

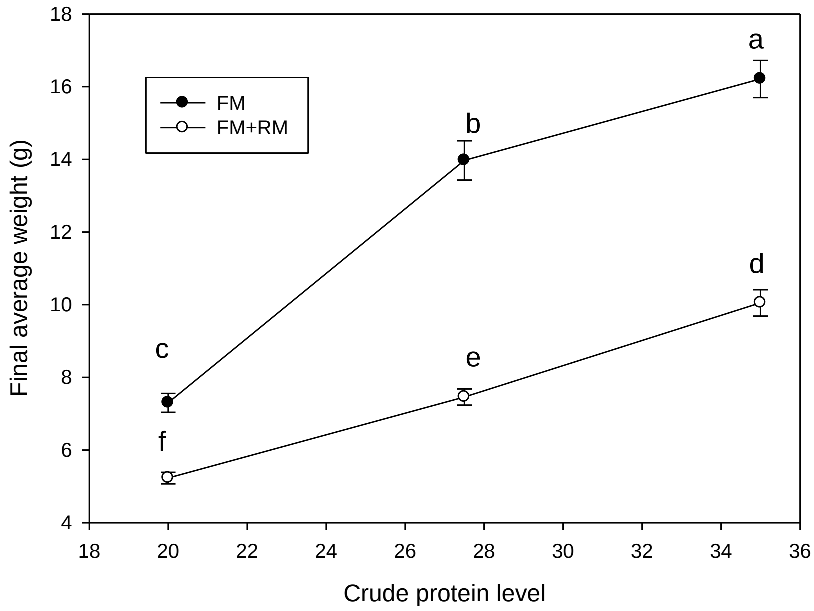

Figure 6. Effects of dietary protein level and source and their interaction on final average weight of Nile tilapia fingerlings (Values are mean of the triplicate ±SD)

The effects of protein level and source on other growth parameters (SGR & WG (%)) and their interaction are shown in Figures 7 and 8. The effects of crude protein level and source and their interaction followed the trend observed on final average weight.

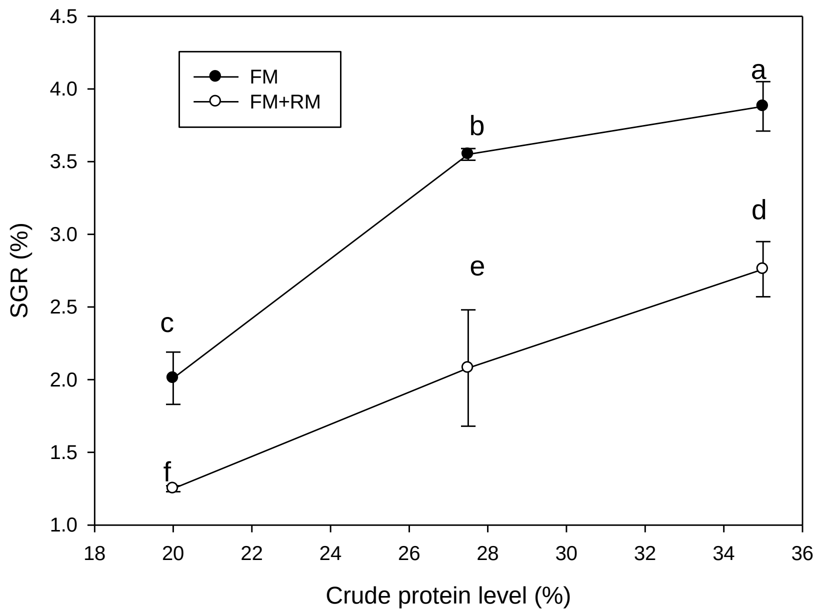

Figure 7. Effects of dietary protein level and source and their interaction on specific growth rate (SGR) of Nile tilapia fingerlings (Values are mean of the triplicate ±SD)

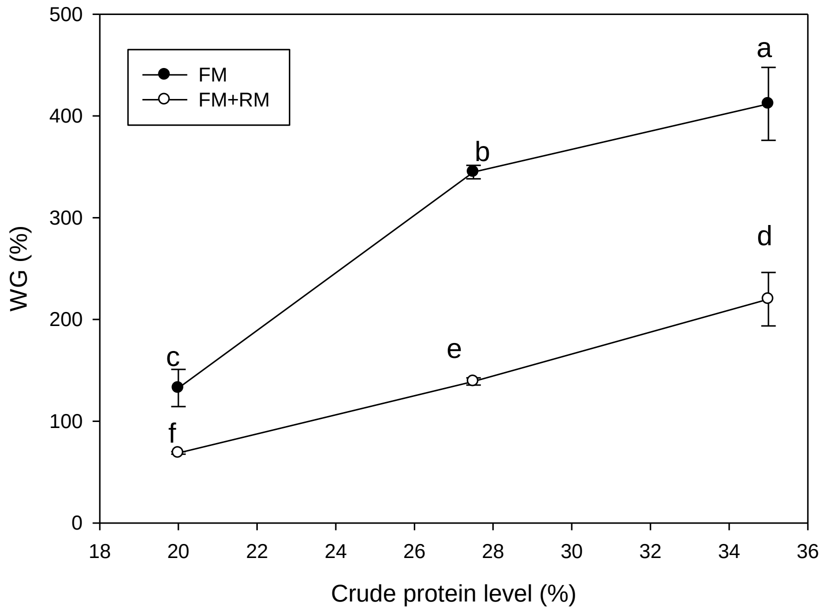

Figure 8. Effects of dietary protein level and source and their interaction on percentage weight gain (WG (%)) of Nile tilapia fingerlings (Values are mean of the triplicate ±SD)

The effects of protein level and source on feed utilisation parameters (FE (%) & FCR) and their interaction are shown in fig. 9-10. It was observed that both protein level and source have significant effects on these parameters. As protein level increases, FE (%) increases but FCR decreases. When high quality source (FM) was used, FE (%) increases and FCR decreases. When the blend protein source (FM plus RSM), FE (%) decreases and FCR increases.

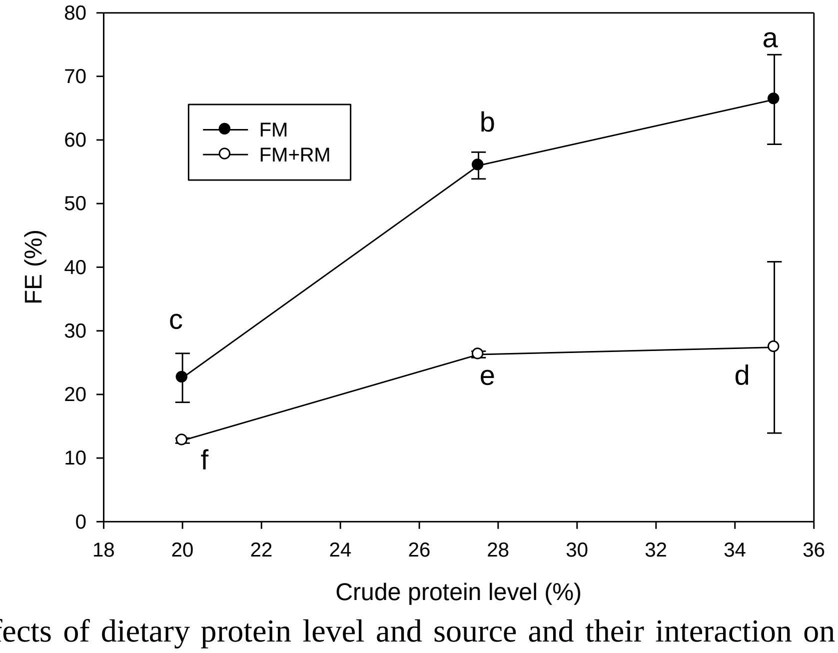

Figure 9.Effects of dietary protein level and source and their interaction on percentage feed efficiency (FE (%)) of Nile tilapia fingerlings (Values are mean of the triplicate ±SD)

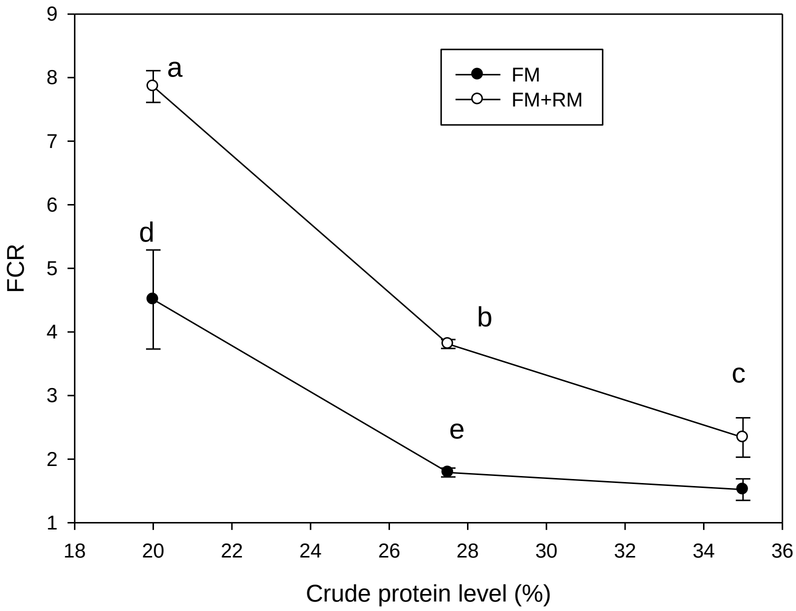

Figure 10. Effects of dietary protein level and source and their interaction on feed conversion ratio (FCR) of Nile tilapia fingerlings (Values are mean of the triplicate ±SD)

4.3 Body Composition

The result of the body composition is shown in Table 6. Fish fed diet PPBD gained the highest protein in the body and was significantly different from the initial, followed by diets MPRM, LPRM and MPFM which were not significantly different from the initial. There were no significant difference between diets HPRM and LPFM and there were no significant difference also between LPFM and HPFM. All treatments significantly increased in fat compared to initial sample. Fish fed diet PPBD gained the highest body fat followed by those fed on diet LPFM which was not significantly different from MPRM and MPRM was not also significantly different from LPRM and MPFM. Among the treatments, HPFM gained the lowest body fat. The initial sample obtained the highest moisture in the body which was significantly different from all the treatment groups. MPRM that followed was not significantly different from PPBD. Diets HPRM and HPFM that followed were not significantly different from each other. Fish fed on diet LPFM gained the lowest body moisture. LPFM gained the highest body salt and was significantly different from the rest of the treatments and the initial sample, followed by MPFM and then MPRM but MPRM was not significantly different from HPRM and HPFM. PPBD gained the lowest body salt but was not significantly from the initial and LPRM. A full breakdown of growth performance and feed utilization parameters observed for the different feed types is in the appendix.

Table 6 : Body composition parameters of Nile tilapia fingerlings before and feeding on different experimental diets. (N=4).

Diet	Parameter			
	Protein	Fat	Moisture	Salt
Initial	13.70 ± 0.1[c]	11.64 ± 0.1[f]	72.14 ± 0.1[a]	0.58 ± 0.20[ef]
HPFM	13.41 ± 0.0[e]	15.66 ± 0.1[d]	69.79 ± 0.1[c]	0.65 ± 0.08[cde]
HPRM	13.55 ± 0.0[d]	15.10 ± 0.1[e]	69.97 ± 0.1[c]	0.68 ± 0.07[cd]
MPFM	13.68± 0.0[c]	16.44 ± 0.1[c]	69.43 ± 0.1[d]	0.82 ± 0.05[b]
MPRM	13.79 ± 0.1[c]	16.54 ± 0.0[bc]	70.95 ± 0.0[b]	0.69 ± 0.04[c]
LPFM	13.43 ± 0.0[de]	16.82 ± 0.2[b]	68.35 ± 0.0[e]	1.05 ± 0.03[a]
LPRM	13.74 ± 0.1[c]	16.47 ± 0.1[c]	69.23 ± 0.1[d]	0.56 ± 0.05[ef]
PPBD	13.95± 0.0[a]	17.17 ± 0.1[a]	70.89 ± 0.1[b]	0.53 ± 0.06[f]

*Values are means of the triplicates ± SD; values within the same column without a common superscript are significantly different (*p *<0.05).*

4.4 Effect of production cost

The effect of feed cost and the growth response on estimated production cost of one kilo fish is shown in Table 12. The feed cost is similar for the high protein diets although the raw material price is very different. This is due to much higher FCR in the plant protein diets in general. The cost is also similar for the medium protein fish meal group, actually the price is lowest in that group. The plant protein based diet (PPBD) gives double feed cost related to the best three groups. That is due to very poor feed efficiency although it contain only plant protein sources, the increased volume of fish oil is raising the feed price.

Table 7. Cost of production of a kilo of fish per diet in Icelandic Kroner (ISK)

Diet	HPFM	HPRM	MPFM	MPRM	LPFM	LPRM	PPBD
Raw material price/kg diet (ISK)	146,95	95,02	121,99	69,01	96,17	70,15	147,58
FCR	1,52	2,34	1,79	3,81	4,51	7,86	7,68
Feed cost per kg fish gain	223	222	218	263	434	551	1133
Relative % feed cost/kg fish gain	100	99,5%	98,2%	120,4%	165,0%	127,1%	205,6%

5 DISCUSSION

Tilapia, like other fish, have dietary protein requirement for optimal growth and growth is negatively affected when fed diets above or below their protein requirement. With regards to the protein level, generally growth increases as the level increases up to a point where increase of protein level does not have any positive effect on growth (Twibell and Brown, 1998; Bahnasawy, 2009). In case of protein source (quality), growth is usually high when high quality source like fishmeal is used but on the other hand when low quality source such as plant protein is used, the reverse occurs (Furuya, Pezzato *et al.*, 2004b). This experiment was set up to investigate the effects of substituting fishmeal with rapeseed meal (plant protein) at different protein levels on growth, feed utilisation and body composition of Nile tilapia fingerlings. The results showed that both protein source and protein level have significant effects on growth and feed utilisation of tilapia fingerlings but protein source has more effect compared to level at this size.

When fishmeal was used as the primary protein source, mean weight, percentage weight gain and specific growth rate increased as protein level increases from low (20% CP) to high (35% CP) and there were significant differences among the diets (HPFM, MPFM and LPFM). This indicates that 20-27.5% dietary crude protein level is below the requirement of 3 g Nile tilapia fingerlings even when fishmeal is used as protein source. The effectiveness of fishmeal seems to be low at low protein diet which could be due to lysine deficiency. The significant high performance of fish fed on 35% CP diet in this trial implies that the optimal protein level in the diet of Nile tilapia at this size should be higher than 27.5%. This is in line with the results of Abdel-Tawwab *et al*. (2010), who found protein requirement for Nile tilapia fingerlings and advance juvenile (~20 and 40 g) to be 35%; De-Silva *et al*. (1989), who obtained maximum growth from dietary protein levels 34-36%; Winfree and Stickney (1981), who reported that 2.5-7.5 g Nile tilapia require 34% dietary protein for maximum growth performance; Bahnasawy (2009), who recommended 30% CP; Hafedh (1999) who reported 40% CP for juvenile Nile tilapia (40 g); Abdel-Tawwab (2012) also indicated that growth of Nile tilapia was improved significantly by increasing the dietary protein level from 35 to 45%. The results of this study are inconsistent with the results of Li *et al*. (2013), who reported that 25% protein level met the requirement of 7.44 g Nile tilapia. The culturing condition, the origin of fish and several water and culturing or management parameters must been taken into consideration when comparing research trials investigating optimal protein requirement. It must be noted that fish in trials in hapas or ponds can have access to some planktonic feed, providing them with some of their nutritional needs.

Percentage feed efficiency follows the trend of MWT, WG (%) and SGR as it increased as the dietary protein level increases from low to high. The feed conversion ratio, decreased as protein level increased, but there was no significant difference between high (35% CP) and medium (27.5% CP) protein levels but the two diets (HPFM and MPFM) were significantly different from LPFM diet (20% CP) in FCR. This is in line with the results of other authors on tilapia growth (Bahnasawy, 2009; Al-Hafedh, 1999).

In this experiment, the substitution of fishmeal with rapeseed meal was 54% in HPRM diet (35% CP), 80% in MPRM diet (27.5% CP) and 72% in LPRM diet (20% CP) and there was no addition of crystalline amino acids or dicalciumphosphate. Plant protein based diet (34% CP), which did not contain any fishmeal, was supplemented with monocalciumphosphate but not crystalline amino acids. The results revealed that growth and feed utilisation were significantly affected when plant protein based diet (PPBD) or fishmeal substituted diets (HPRM, MPRM and LPRM) were used which could be attributed to high inclusion levels of plant protein. This is in agreement with the results of Soltan *et al*. (2008), who found that growth and feed utilisation were significantly affected when fishmeal replacement with plant protein mixture was more than 45%; Zhou and Yue (2010), who indicated that canola meal can be incorporated in the diet of hybrid tilapia up to 19.02%, which can replace only 30% protein of soybean meal without significant negative effects on growth performance and feed utilisation; Koumi *et al*. (2009), who also reported that incorporation of 50 and 100% plant protein (soya protein) in diet of *O. niloticus* decreased the growth. Davies *et al*. (1990), also found indications that practical inclusion limit around 15% in substituting fish meal with rapeseed meal.

Another possible factor for poor performance of fish fed fishmeal substituted diets and plant based diet could be linked to the size of the fish (3.1 g) used in this experiment. There is evidence that fry and small fingerlings of tilapia need high quality protein source like fishmeal in their diets and as they grow bigger, they gradually accept or feed on plant materials. For instance, Twibell and Brown (1998) obtained good growth when tilapia were fed an all-plant diet at the size of 21 g; Luo *et al*. (2012), also reported that 75% replacement of fishmeal with canola meal (plant protein of same origin as rape seed meal) did not significantly reduce growth performance of GIFT strain of Nile tilapia at the size of 20 g.

Although tilapias are known for their efficient dietary lipid utilisation, they cannot tolerate high dietary lipid levels. The unexpected poor performances of HPRM and PPBD with protein levels of 35 and 34% and lipid levels of 11.70 and 25% respectively could be attributed to the dietary lipid content. Many authors reported growth retardation when tilapia were fed with diets in which lipid levels were above 10%. Han *et al*. (2011), reported better growth of hybrid tilapia fed on 5.5 and 8.5% lipid diets compared to those fed 11.5% lipid diet; Wille *et al*. (2002), reported 17% lipid level as too high for tilapia. Therefore, the poor performances of fish fed diets high in lipid particularly diet which has 25% lipid in this study is in line with the findings of the previous authors.

In this study, rapeseed meal substituted diets were not supplemented with either dicalciumphosphate or crystalline amino acids and PPBD diet was only supplemented with monocalciumphosphate. It was observed from the results that at the same protein level, fish fed fishmeal based diets performed better than those fed diets in which fishmeal was substituted with rapeseed meal or plant based diet. This concurs with the results of Furuyata *et al*. (2004b), who found that when soybean meal based diet was not supplemented with dicalciumphosphate and some essential amino acids or supplemented with only dicalciumphosphate or some essential amino acids, the growth of fish was inferior to fishmeal control diet. In addition to that, tilapia like other fish also require the 10 essential amino acids in their diets and deficiency of any one of them can affect the performance of fish. Lysine content in diets MPRM, LPFM, LPRM and PPBD is below the requirement of tilapia so the poor performances of fish fed on these diets could be attributed to lysine deficiency.

Plant protein based diets and fishmeal plus rapeseed meal diets have high fibre or carbohydrate content which can affect digestibility of the feed and poor digestibility can lead to poor performance of fish. Anti nutritional factors found in plant ingredients (rapeseed meal and soybean meal) are known to affect palatability of feed and once the palatability is affected, feed consumption could be reduced and consequently growth is compromised.

The proximate analyses results of this study indicated that there were significant differences in whole body protein, fat and moisture and salt contents. Body composition analyses revealed that protien, fat and moisture contents of the initial fish used in this research were 13.70%, 11.64% and 72.14% respectively. After feeding on the diets for 6 weeks, protein and fat contents of those fed on PPBD diet increased while their moisture contents decreased. The high fat content of fish fed on plant protein based diet is in agreement with the results of Koumi *et al*. (2009), where fish fed plant protein based diets obtained high fat compared to those fed fishmeal based diet. Fish fed on LPFM diet increased in body fat but decreased in body protien and moisture. Fish fed on MPFM and MPRM diets maintained their body protein contents, increased in fat contents and decreased in moisture content. The protein content of fish fed with HPFM and HPRM diets were decreased, fat content increased and moisture contents decreased compared to the initial fish.

The feed cost as an effect on production of one kilo fish in the HPFM, HPRM and MPFM groups are similar. The feed cost in the other groups is higher, and this does not reflect the total production cost because the growth rate or the growth responce in this groups are quite different. This can affect the production time and other cost parameters. Therfore the MPFM- diet or the HPRM-diet are not recommended for tilapia fingerlings of this size.

6 CONCLUSIONS AND RECOMMENDATIONS

In this research, the best growth and feed utilisation performances were obtained by fish fed high protein fishmeal diet while the lowest performances were observed in those fed plant protein based diet and low protein fishmeal plus rapeseed meal diet. The results clearly indicated that both protein source and level have significant influence on the analysed parameters but protein source seems to be more important to the cultured fish compared to protein level at this size. It can be concluded with certainty that even the lowest replacement level of fishmeal with rapeseed meal in this experiment was too high for 3 g Nile tilapia since growth and feed utilisation parameters were significantly affected with the substitution. From the results, it seems that dissolved oxygen consumption increased as biomass increases. All the experimental diets significantly increased the fat content of the fish. Other body composition parameters (protein, moisture and salt) were either increased, maintained or decreased compared to initial composition after feeding on the diets but no clear pattern was observed.

The author would like to recommend the use of quality protein diets for small fingerlings up to certain size then thereafter, progressive substitution of fishmeal with plant protein or other alternatives. Further research for longer period is also recommended in order to find out whether there will be some improvement.

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APPENDIX

Table 8. Comparison of growth and feed utilisation performances of Nile tilapia fingerlings fed on fishmeal and fishmeal plus rapeseed meal protein sources diets at the end of 3 weeks. (N=3).

Protein source	Parameter			
	WG%	SGR	FE	FCR
Fishmeal (FM)				
35% CP (HPFM)	209.28 ± 24.7.23[a]	5.38 ± 0.11[a]	71.12 ± 2.60[a]	1.41 ± 0.05[b]
27.5% CP (MPFM)	187.06 ± 12.40[b]	5.02 ± 0.20[b]	63.62 ± 4.71[b]	1.58 ± 0.12[b]
20% CP (LPFM)	102.37 ± 19.07[c]	3.34 ± 0.45[c]	34.46 ± 7.45[c]	3.00 ± 0.69[a]
FM plus Rapeseed				
35% CP (HPRM)	119.88 ± 9.88[a]	3.75 ± 0.21[a]	49.82 ± 2.79[a]	2.01 ± 0.11[b]
27.5% CP (MPRM)	87.66 ± 13.68[b]	2.99 ± 0.34[b]	34.75 ± 3.84[b]	2.90 ± 0.31[b]
20% CP (LPRM)	57.71 ± 6.65[c]	2.17 ± 0.20[c]	20.10 ± 2.17[c]	5.01 ± 0.52[a]

*Values are means of the triplicates ± SD; values within the same column and the same protein source without a common superscript are significantly different (*p *<0.05).*

WG (%) = percentage weight gain; SGR = specific growth rate; FE (%) =percentage feed efficiency; FCR = feed conversion ratio.

Table 9. Growth and feed utilisation parameters of Nile tilapia fingerlings fed on different experimental diets at the end of 6 weeks. (N=3).

Diet	Parameter					
	IW	MWT	WG (%)	SGR	FE (%)	FCR
HPFM	3.1	16.21 ± 0.5[a]	411.85 ± 20.7[a]	3.88 ± 0.1[a]	126.28 ± 9.0[a]	1.52 ± 0.17[a]
HPRM	3.1	10.05 ± 0.4[c]	219.95 ± 15.1[c]	2.76 ± 0.11[c]	82.04 ± 7.8[c]	2.34 ± 0.31[a]
MPFM	3.1	13.97 ± 0.6[b]	344.81 ± 3.8[b]	3.55 ± 0.0[b]	107.18 ± 3.0[b]	1.79 ± 0.07[a]
MPRM	3.1	7.46 ± 0.2[d]	139.1 ± 2.1[d]	2.08 ± 0.0[d]	50.12 ± 1.4[d]	3.81 ± 0.07[b]
LPFM	3.1	7.30 ± 0.3[d]	132.62 ± 10.6[d]	2.01 ± 0.1[d]	45.93 ± 4.7[d]	4.51 ± 0.78[b]
LPRM	3.1	5.23 ± 0.2[e]	68.85 ± 0.7[e]	1.24 ± 0.0[e]	27.15 ± 0.3[e]	7.86 ± 0.25[c]
PPBD	3.1	5.22 ± 2[e]	64.1 ± 1[e]	1.18 ± 0.1[e]	25.51 ± 1.7[e]	7.68 ± 0.80[c]

*Values are means of the triplicates ± SE; values within the same column without a common superscript are significantly different (*p *<0.05).*

IW = initial weight; MWT = mean weight; WG (%) = percentage weight gain; SGR = specific growth rate; FE (%) =percentage feed efficiency; FCR = feed conversion ratio.

Table 10. Comparison of growth and feed utilisation performances of Nile tilapia fingerlings fed on fishmeal protein source diets at different protein levels at the end of 6 weeks. (N=3).

Protein source	Parameter				
Fishmeal	MWT	WG (%)	SGR	FE (%)	FCR
35% CP (HPFM)	16.21 ± 0.5[a]	411.85 ± 20.7[a]	3.88 ± 0.1[a]	126.28 ± 9.0[a]	1.52 ± 0.17[a]
27.5% CP (MPFM)	13.97 ± 0.6[b]	344.81 ± 3.8[b]	3.55 ± 0.0[b]	107.18 ± 3.0[b]	1.79 ± 0.07[a]
20% CP (LPFM)	7.30 ± 0.3[c]	132.62 ± 10.6[c]	2.01 ± 0.1[c]	45.93 ± 4.7[c]	4.51 ± 0.78[b]

*Values are means of the triplicates ± SE; values within the same column without a common superscript are significantly different (*p *<0.05).*
IW = initial weight; MWT = mean weight; WG (%) = percentage weight gain; SGR = specific growth rate; FE (%) =percentage feed efficiency; FCR = feed conversion ratio.

Table 11. Comparison of growth and feed utilisation performances of Nile tilapia fingerlings fed on fishmeal plus rapeseed meal protein sources diets at different protein levels at the end of 6 weeks. (N=3).

FM plus Rapeseed	MWT	WG (%)	SGR	FE (%)	FCR
35% CP (HPRM)	10.05 ± 0.4[a]	219.95 ± 15.1[a]	2.76 ± 0.11[a]	82.04 ± 7.8[a]	2.34 ± 0.31[a]
27.5% CP (MPRM)	7.46 ± 0.2[b]	139.1 ± 2.1[b]	2.08 ± 0.0[b]	50.12 ± 1.4[b]	3.81 ± 0.07[b]
20% CP (LPRM)	5.23 ± 0.2[c]	68.85 ± 0.7[c]	1.24 ± 0.0[c]	27.15 ± 0.3[c]	7.86 ± 0.25[c]

*Values are means of the triplicates ± SE; values within the same column without a common superscript are significantly different (*p *<0.05).*
IW = initial weight; MWT = mean weight; WG (%) = percentage weight gain; SGR = specific growth rate; FE (%) =percentage feed efficiency; FCR = feed conversion ratio.

Table 12. Comparison of growth and feed utilisation performances of Nile tilapia fingerlings fed on fishmeal and fishmeal plus rapeseed meal protein sources diets at the same protein level at the end of 6 weeks. (N=3).

At same CP level	MWT	WG (%)	SGR	FE	FCR
35% CP (HPFM)	16.21 ± 0.5[a]	411.85 ± 20.7[a]	3.88 ± 0.1[a]	126.28 ± 9.0[a]	1.52 ± 0.17[a]
35% CP (HPRM)	10.05 ± 0.4[b]	219.95 ± 15.1[b]	2.76 ± 0.11[b]	82.04 ± 7.8[b]	2.34 ± 0.31[a]
27.5% CP (MPFM)	13.97 ± 0.6[a]	344.81 ± 3.8[a]	3.55 ± 0.0[a]	107.18 ± 3.0[a]	1.79 ± 0.07[a]
27.5% CP (MPRM)	7.46 ± 0.2[b]	139.1 ± 2.1[b]	2.08 ± 0.0[b]	50.12 ± 1.4[b]	3.81 ± 0.07[b]
20% CP (LPFM)	7.30 ± 0.3[a]	132.62 ± 10.6[a]	2.01 ± 0.1[a]	45.93 ± 4.7[a]	4.51 ± 0.78[a]
20% CP (LPRM)	5.23 ± 0.2[b]	68.85 ± 0.7[b]	1.24 ± 0.0[b]	27.15 ± 0.3[b]	7.86 ± 0.25[b]

*Values are means of the triplicates ± SE; values within the same column without a common superscript are significantly different (*p *<0.05).*
IW = initial weight; MWT = mean weight; WG (%) = percentage weight gain; SGR = specific growth rate; FE (%) =percentage feed efficiency; FCR = feed conversion ratio.