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Bio-economic evaluation of tank raised *Tilapia rendalli* (Boulenger, 1896) fed on varying dietary protein levels

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ABSTRACT

An experiment was designed to determine the effects of varying dietary protein levels in feed on bio-economic aspect of tank raised *Tilapia rendalli* production in Malawi. *T. rendalli* of average body weights (23 g) were randomly stocked into 5 m^3 experimental tanks at stocking density of 5 fish/m^3. The experimental diets containing 25, 30 and 35% CP were formulated. Higher significant ($P < 0.05$) average weight gain, feed conversion ratio, break-even price, break even yield, net return were recorded in fish fed on the diet containing 35% CP. However, gross margin profit ratio was the lowest in the diet containing 35% CP. The significance of the study findings is that higher inclusion of protein in feed produce better growth and high overall net return, hence need to use high dietary protein level in this case, 35%.

Keywords: Bio-economic evaluation, dietary protein, *Tilapia rendalli.*

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INTRODUCTION

Protein is the most expensive component in fish feeds and plays an important role in growth of fish (NRC, 1993). Commercial fish farming involves paying critical attention to the financial aspect of production more especially fish diet. In fact, cost of fish diet represents up to 70% of the total operating expenses in aquaculture enterprise (Fotedar, 2004).

Since the success of fish farming depends on maximizing production with minimum feed cost (Abdel-Hakim et al., 2009), information regarding the bio-economic of tilapia production in intensive culture is crucial. Pillay and Kutty (2005) observed that lack of economic information on the feasibility of tank raised tilapia production has adverse effects on aquaculture investments and development and can result into failure and frustration among commercial aquaculture ventures.

Several studies have been conducted in aquaculture using bio-economic models. For instance, Boll and Lanzer (1995) evaluated polyculture of tilapia with Chinese carp using a bio economic analysis. Research has shown that bio-economic models address the systematic integration of biological performance and physical systems and relate them to economic considerations which include market prices, resource allocation and institutions constraints. Hulata et al. (1993) determined the technical viability of polyculture of tilapia with other freshwater organisms such as carp and other cichlids.

More recently, Irz and McKenzie (2003) analyzed the economic feasibility and efficiency of shrimp culture with marine fish species. Bio economic models can be used to assist producers and decision-makers in identifying optimal production system designs, operation management strategies, and alternative development and policy approaches (Pomeroy et al., 2008). The works of Cacho (1997), among others, demonstrated the utility of these bio economic models as an evaluative tool.

Therefore, it is possible to demonstrate the economic viability and overall profitability of tank raised *T. rendalli* fed on different dietary protein levels using bio-economic models in order to make better management decisions in aquaculture production.

MATERIALS AND METHODS

The experiment was conducted in the concrete tanks at Lilongwe University of Agriculture and Natural Resources student fish farm. The experiment was laid out in a completely randomised design

(CRD) with three treatments replicated three times. *Tilapia rendalli* fingerlings with average body weight (23 g) were stocked into 5 m^3 experimental tanks at 5 fish/m^3. Fish were given a formulated diet containing fish meal, maize bran, mineral premix and vitamin premix with an inclusion of 25%, 30%, 35% CP respectively. The fish were fed twice a day (10:00 to 15:00 hrs) for a period of 90 days.

Crude protein in the three tested diets was formulated using Pearson square method (De Silva and Anderson, 1995). Table 1 shows feed formulation. The ingredients were subjected to proximate analysis using standard methods according to AOAC (2003). Crude protein (CP), ether extract (EE), dry matters (DM), crude fibre (CF) and ash content were determined. Table 2 shows chemical composition of the ingredients used to formulate three tested diets.

Table 1. Feed formulation.

Ingredients	Crude protein		
	25% CP	**30% CP**	**35% CP**
Fishmeal	16.3	22.5	28.6
Soybean	16.3	22.5	28.2
Maize bran	65.4	54.05	42.7
Minerals	0.5	0.5	0.5
Vitamin	0.5	0.5	0.5
Binder	0.5	0.5	0.5
Total	99.49	100.5	100.5

Water physio-chemical parameters

Water quality parameters that influence growth of fish such as dissolved oxygen, temperature, pH and ammonia concentration were measured every day at 10 am and 2 pm.

Sampling

Sampling was done every 3 weeks to determine new mean weights for various experimental units. A sample of 30 fish was obtained from each treatment (10 fish from each replicate).

Biological production analysis

After 90 days, fish were harvested and final weight, weight gain, feed conversion ratio and mortality rate were determined.

$$Weight\ gain(g) = W_f - W_{in} \tag{1}$$

Where W_f = final weight (g) and W_{in} = initial weight (g)

Feed conversion ratio (FCR) was calculated as:

$$FCR = \frac{Total\ feed\ consumed\ by\ fish\ (g)}{Weight\ gain\ by\ fish\ (g)} \tag{2}$$

Mortality rate (M) was calculated as:

$$M = \frac{N_0 - N_f}{N_0} \times 100 \tag{3}$$

Where: M = mortality rate, N_0 = initial number of stocking, N_f = final number of harvested fish.

Evaluation of Bio-economic model

The *Tilapia rendalli* culture bioeconomic models included biological, management and economic models.

Biological models were designed as follows:

$$W_t = \beta_0 + \beta_1 + e^{(\beta 2t)} \tag{4}$$

Where W_t = Average weight (g) and β_0, β_1 and β_2 are parameters and t is time in days.

Production system biomass (B) was estimated using the average individual weight and total number of organisms.

$$\beta_t = W_t * N_0 * e^{(s*t)} \tag{5}$$

Where N_0 = number of initial stocked fish and *S* = survive rate.

The production costs (PC) were generated from the beginning of culture cycle to harvest:

$$\rho_c = \sum_{t=0}^{t} \left(C_f + C_L + C_o + C_m\right) + C_s * N_0 \tag{6}$$

Where: ρ_c = total costs, C_s = seed costs (MK), C_f = feed costs (MK), C_l = labour costs (MK), Co = other capital costs (MK), C_M = contingency costs for miscellaneous purchases (MK).

The total cost of feed ingredients per treatment was calculated as shown in Equation 7:

$$\gamma = \rho_s + \rho_m + \rho_{prx} + \rho_f \tag{7}$$

Where Y = Total cost of feed ingredients (US$), Ps = unit cost of soya bean, Pm = unit cost of maize bran (M), P_{prx} = unit cost of premix, Pf = unit cost of fishmeal.

Labour costs

Labour was one of the most important inputs in the *T. rendalli* production process. The sources of supply of human labour were from the researcher for which no payment was made and hired labour, for the researcher had to be paid in cash.

Net profit analysis

Net profit (π) was generated by different between the revenue collection at harvest and production cost.

$$\pi = (N_t * P_t) - \sum_{t=0}^{t} \left(C_f + C_L + C_o + C_m\right) + C_s * N_0 \tag{8}$$

Where P_t = Price of tilapia at time t

Break-even price and break-even production used to determine the possible time when to make the profits for the enterprise at a given price was expressed according to Engle and Neira (2005).

Table 2. Chemical composition of the ingredients used to formulate three test diets on dry weight basis (mean ± SE).

Sample	Proximate composition				
	% dry matter crude	% Ash	% ether extract	% crude fibre	% crude protein
Soybean	90.26 ± 0.78	7.4 ± 0.4	9.0 ± 0.1	0.23 ± 0.01	46.66±0.36
Fishmeal	93.25 ± 0.46	17.08 ± 0.14	4.0 ± 0.01	0.33 ± 0.02	63.98±0.25
Maize bran	89.08 ± 0.58	3.78 ± 0.24	12.47 ± 0.49	10.7 ± 0.03	13.00±0.02

Table 3. Water quality parameters measured in tanks stocked with *Tilapia rendalli* for 90 days (mean ± SE).

Parameter	Treatment			P value
	25% CP	30% CP	35% CP	
PH	8.02 ± 0.1^{a}	8.03 ± 0.12^{a}	8.18 ± 0.1^{c}	0.87
DO(mg/L)	$7.13 \pm 0.0.2^{a}$	7.12 ± 0.2^{a}	7.19 ± 0.3^{c}	0.58
Temp(°C)	26.96 ± 0.1^{a}	26.96 ± 0.1^{a}	26.96 ± 0.2^{a}	2.45
Ammonia (mg/L)	0.014 ± 0.03^{a}	0.02 ± 0.04^{a}	0.019 ± 0.05^{a}	0.06

Values with the same superscript in a row are not significantly different (P > 0.05).

$$Break\ even\ production = \frac{production\quad cost}{price\ \ (US\$/kg)} \qquad (9)$$

Gross profit ratio was expressed according to:

$$Gross\ profit\ ratio\ = \frac{Total\ \ revenue\ \ (US\$)}{Total\ \ expenditure\ \ \ (US\$)} \qquad (10)$$

Statistical analysis

Data was analyzed using Statistical Package for Social Scientists (SPSS) software Version 16 for Windows. The data was tested for normality using Shapiro – Wilk test and the homogeneity of variance using Levine's test for Equality of Variances. One way analysis of variance (ANOVA) was used to determine significant difference in the growth parameters of the harvested fish of the four treatments and to test for significant differences within the water physio-chemical parameters at 5% level of significance. Mean differences were separated using the Least Significant Difference (LSD) test.

RESULTS

Water physio-chemical parameters

The results of water quality parameters are presented in Table 3. The study findings indicated that water quality parameters such as dissolved oxygen, temperature, pH and ammonia concentration did not show significant differences (P > 0.05) among the treatments

Biological component of the bio-economic model

The study revealed significantly (P < 0.05) high growth performance in the diet containing 35% CP comparing to those fed on 25%, 30% CP. However, significantly (P < 0.05) higher survival rate was observed in the fish fed on the diet containing 30% CP. The study further revealed better feed utilisation in the fish fed on the diet containing 35% dietary protein levels than in those fed on 25 and 30% dietary proteins. Evidently, feed conversion ratio was lowest in fish fed on diet containing 35% dietary protein levels comparing to those fed on 25 and 30% dietary protein levels (Table 4).

Economic component of the bio-economic model

Higher net return (MK4772.7) was recorded in the fish fed on 35% CP than those fed on 30% (Mk4159.42) and 25% CP (MK2920.61) after three months of production cycle. Figure 1 showed that net return increased with increase in dietary protein level from 25% CP to 35% CP.

Conversely, lowest gross profit margin was recorded in the fish fed diet containing 35% CP comparing to those fed on 25% CP and 30% CP indicating that operating at 35% CP, the enterprise generated lower level of revenue to pay for operating expenses and net profit than the rest. Break-even price was estimated as MK872 ± 0.04 in 25% CP, MK937.04 in 30% CP, and highest MK947 ± 0.3 in 35% CP dietary treatment.

The fish fed on 35% CP dietary protein level had higher break-even price than the rest suggesting that tilapia production could only be profitable if the price is set above MK947 ± 0.3 which is higher than the rest of the treatments. The highest break-even yield in the diet containing 35% CP suggested that more investment is required when operating at 35% dietary protein level for the enterprise to be successful. Table 5 shows the profitability analysis of tank raised *T. rendalli* production.

Table 4. Experimental *Tilapia rendalli* growth and Feed conversion ratio results (mean ± SE)*.

Parameter	Treatments			P value
	25% CP	30% CP	35% CP	
Initial weight (g)	23 ± 0.03[a]	22.9 ± 0.03[a]	23.1 ± 0.02[a]	0.2
Final weight (g)	50.3 ± 0.54[a]	60.2 ± 0.92[b]	70.4 ± 1.12[c]	0.00
Weight gain	31.9 ± 0.5[a]	39 ± 0.96[b]	49.9 ± 1.2[c]	0.01
Feed conversion ratio	2.8 ± 0.07[a]	2.3 ± 0.11[b]	1.9 ± 0.09[c]	0.012
Survival (%)	90 ± 1.31[a]	98 ± 0.25[b]	96 ± 0.58[c]	0.043

Values with the same superscript in a row are not significantly different (P > 0.05).

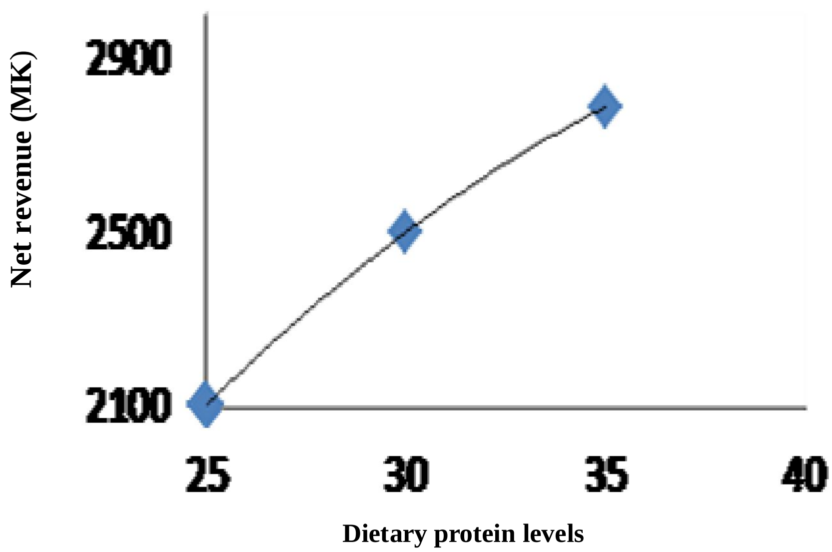

Figure 1. Net revenue over time of *Tilapia rendalli* production.

Table 5. Profitability analysis of tank raised *Tilapia rendalli* production.

Item	Unit	Test diets		
		25% CP	30% CP	35% CP
Total seed cost	MK	750 ± 0.02[a]	750 ± 0.01[a]	750 ± 0.03[a]
Maize bran	MK50/kg	150.8 ± 0.1[a]	156.28 ± 0.21[b]	150.87 ± 0.3[c]
Soybean	MK200/kg	147.5 ± 0.2[a]	260.46[b]	336.82 ± 0.1[c]
Fish meal	K1500/5litter tin	596.8 ± 0.1[a]	1048.39 ± 0.31[b]	1354.84 ± 0.1[c]
Premix	640/100 g	442.6 ± 0.3[a]	1111.29 ± 0.05[b]	1347.2 ± 0.04[c]
Total feed cost	MK	1337.61[a]	2576.42[b]	3189.73[c]
Labour cost	MK	833 ± 0.04[a]	833 ± 0.35[a]	833 ± 0.0[a]
Total variable cost	MK	2920.61[a]	4159.42[b]	4772.7[c]
Production Cycle	Days	90	90	90
Fish market price	MK/Kg	1500 ± 0.4[a]	1500 ± 0.4[a]	1500 ± 0.3[a]
Total Biomass	Kg	3.35 ± 0.2[a]	4.44 ± 0.3[b]	5.04 ± 0.2[c]
Gross revenue	MK	5025 ± 0.14[a]	6660 ± 0.0[b]	7560 ± 0.1[c]
Net return per cycle	MK	2104.4 ± 0.3[a]	2500.58 ± 0.5[b]	2787.2 ± 0.5[c]
Break-even price	MK/Kg	872 ± 0.04[a]	937.04[b]	947 ± 0.3[c]
Break even yield	Kg	1.94 ± 0.01[a]	2.77 ± 0.03[a]	3.18 ± 0.02[b]
Gross profit ratio		0.72 ± 0.003[a]	0.6 ± 0.002[b]	0.58 ± 0.04[c]

Different superscripts in a row indicate significant difference (P < 0.05). Note: US$ = MK 340 (2012).

DISCUSSION

Water quality parameters were within the recommended level in all treatments. For instance Ross (2000) recommended at least 3 mg/L dissolved oxygen level as optimum growth for tilapia. Similar findings were observed in all treatments throughout the study period.Similarly, temperature among the treatments was within the recommended range. This was supported by Mires (1995) who recommended temperature range of 22 to 29°C as optimum growth for tilapia. The pH range was 8.0 to 8.2 among the treatments. Ross (2000) recommended the same for tilapia growth. Ammonia concentration in 25% (0.014 ± 0.03 mg/L), 30% (0.02 ± 0.04 mg/L) and 35% (0.019 ± 0.01 mg/L) dietary treatments was within the optimum range according to Redner and Stickney (1979) who suggested ammonia concentration of not greater than 0.05 mg/L as optimum growth for tilapia.

The higher final weight and weight gain in the fish fed on 35% dietary protein level could be attributed to the fact that the fish fed on diet containing 35% dietary protein had efficient utilisation of essential and non-essential amino acids in the diet which is necessary for muscle formation and enzymatic function and in part provides energy for maintenance (Yang et al., 2002). Webster and Lim (2002) observed that better growth of fish relies on efficient synthesis of dietary protein into tissue protein. Conversely, low growth performance in the fish fed on 25% dietary protein level could be attributed to excessive carbohydrates in the diet which lead to liver cell degeneration, hyperglycaemia and poor growth (Roberts, 1978). Halver (1989) observed that inadequate provision of dietary protein in the diet results into rapid reduction or cessation of growth and eventually loss of weight due to withdrawal of protein from less vital tissues to maintain the functions of more vital tissues.

The low overall profitability in fish fed on diet containing 25% dietary protein level could be attributed to poor growth performance and low survive rate. Moksness and Støle (1997) examined the economic feasibility of sea ranching of cod and concluded that it could be economically feasible only if juvenile cost and post release mortality were reduced significantly. Makwinja et al. (2013) reported that feeding the fish low dietary protein level below optimum level (30%) significantly reduces growth performance which consequently affects overall profitability negatively.

Furthermore, low gross profit ratio in the fish fed on diet containing 35% showed that the profitability of *T. rendalli* production was affected by production costs which to the large extent affected by feed input cost accounting for higher percentage within the production costs than other input costs such as fingerlings and labor. Despite high profitability, the enterprise generated lower level of revenue to pay for operating expenses and net profit than the rest. This explains that high investment in feed is required when operating at 35% dietary protein levels to achieve high economic profit. Similarly, Shang (1991) mentioned economic factors which affect profitability as the amount and value of output, and the cost of production. Thus, an increase in income can be achieved by higher production; a decrease in the cost of production; or a combination of both. Therefore, the findings from the study suggest that 35% dietary protein level should be used to promote maximum growth performance and energy supplied by this dietary level is adequate enough for maintenance and growth of *T. rendalli*.

CONCLUSION

In conclusion, it is economic viable for tank raised tilapia production to direct much efforts towards production at 35% dietary protein level to influence the viability of the culture practices positively, and amplifies the net returns.

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