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Research Article
Evaluation of Guar Meal as a Dietary Protein Source for Nile Tilapia (*Oreochromis niloticus*) Reared in Hapa-in-pond System

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Abstract
Background: This study was carried out to investigate the effect of Guar Meal (GM) as a protein source for Nile tilapia (*Oreochromis niloticus*) fingerlings. **Methodology:** Six isonitrogenous (280 g crude protein kg^{-1}), isoenergetic (19 MJ GE kg^{-1}) test diets were prepared. The GM was incorporated into the diets at 0, 20, 40, 60, 80 and 100% of dietary soybean meal (SBM). The diets were fed to triplicate groups of all-male Nile tilapia juveniles (20 g) reared in hapa-in-pond system, at 2-3% of their body weight, twice a day for 105 days. **Results:** The results indicated that fish performance was excellent at all GM inclusion levels. However, growth rates significantly decreased with increasing GM levels beyond 20%. Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER) and Protein Productive Value (PPV) were significantly retarded ($p<0.05$) with increasing dietary GM up to 20% level. Further increase in GM up to 100% level did not result in any further retardation in feed utilization efficiency. **Conclusion:** The cost/benefit analysis including Incidence Cost (IC) and Profit Index (PI) of the test diets indicated that GM-based diets, even at 100% substitution were economically better than the control, SBM-based diet. These results suggest that GM can totally replace SBM in Nile tilapia feeds.

Key words: Guar meal, protein, growth rates, cost/benefit analysis, Nile tilapia

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Global tilapia aquaculture has been expanding at an exceptional rate during the past few decades, especially in Asia, Africa and America. As a result, the global production of farmed tilapia has increased from 383,654 t in 1990 representing 4.5% of total farmed fish production to 4,507,002 t in 2012, representing 6% of total aquaculture production and 10.2% of farmed fish production, with an average annual growth of 13.5%[1]. This rapid industrialization of tilapia production has also led to gradual shift in tilapia culture from extensive and semi-intensive production systems to more intensive, high input and costly systems with an increasing dependence on formulated feeds[2]. Therefore, the formulation and production of appropriate and cost-effective tilapia feeds have become a major challenge facing tilapia feed industry.

Fishmeals (FMs) have been considered as the main protein source in commercial fish diets. However, the limited FMs supply, competition for their use with other animal production sectors and continuous increase in their prices are presently the main constraints limiting the use of FMs as a protein source in fish feeds[3]. Therefore, plant-based protein sources, particularly soybean meal (SBM) have been widely used as partial or total fishmeal replacers in aquafeed industry[2,4]. These sources have good protein contents and Essential Amino Acid (EAA) profiles[2,5,6]. But, the increased demand and competition for these sources have also made them more costly and of limited availability[7,8]. Therefore, the study for less costly and more available aquafeed sources has become a major challenge facing aquafeed industry and fish nutritionist.

Guar (*Cyamopsis tetragonoloba* L.) is a drought-tolerant annual legume grown primary for the guar gum (galactomannan polysaccharide) production. It is traditionally used in some parts of the world as a human and animal food[9-12]. Guar Meal (GM), which is a by-product of guar gum manufacturing is a relatively cheap meal (compared to FM and SBM). It also contains reasonably high protein levels (33-60%) and good amino acid profile, depending on fraction type and processing methods[13,14]. However, GM contains several antinutritional factors that limit its use as an animal feed ingredient. These include trypsin inhibitor[13] saponins[15], polyphenols[16] and beta galactomannan gum[17,18].

Despite the high potential of GM as an animal feed source, very few studies have considered the use of GM as a feed ingredient in aquafeeds with varying results. El-Saidy *et al.*[19] reported that GM can replace up to 50% of fishmeal protein in common carp (*Cyprinus carpio*) diets. On the other hand, when guar meal was included at 30% in diets for rohu (*Labeo rohita*), it resulted in a significantly lower apparent nutrient digestibility coefficient of dry matter, crude protein and energy than meat meal[20]. Similarly, feeding raw and autoclaved guar to mrigal (*Cirrhinus mrigala*) fingerlings resulted in lower growth rate, survival and carcass composition than feeding soybeans[21].

Al-Hafedh and Siddiqui[22] evaluated milled guar seeds as a fish meal replacer in Nile tilapia (*Oreochromis niloticus*) diets. They found that guar seeds could successfully replace up to 50% of fish meal in the diets of the fish, without adverse effects on growth and feed utilization. On the other hand, no studies have considered GM as an alternative dietary protein source for farmed tilapia. Therefore, the present study was carried out to evaluate the use of GM as a dietary protein sources for all-male Nile tilapia reared in hapa in-pond-system.

MATERIALS AND METHODS

Fish and culture facilities: Monosex (all male) Nile tilapia juveniles (20 g) used in the present study were obtained from a commercial tilapia farm at Hamool, Kafr El-Shaikh governorate, Egypt. Triplicate groups of fish were stoked in 2 m^3 hapas (2×1×1 m) fixed in an earthen fish pond (2000 m^2, 100 cm deep) at a commercial fish farm at Hamool, Kafr El- Shaikh governorate, Egypt at a density of 10 fish m^{-3}. The fish were acclimated to the culture system for 2 weeks, during which they were fed the test diets. At the end of the acclimation period, a random sample of 8 fish were netted from each hapa, weight collectively and the average initial weights were recorded.

Water quality parameters, including water temperature (T), Dissolved Oxygen (DO), ammonia (NH_4-N), nitrites (NO_2-N), pH and Total Alkalinity (TA, $CaCO_3$) were monitored weekly using Hanna instrument, Inc., Jud-Cluj Romania. The average values of these parameters throughout the study were; T = 27.5±1°C, DO = 7.8±1.2 mg L^{-1}, NH_4-N = 1.12 mg L^{-1}, NO_2-N = 1.13±0.14 mg L^{-1} pH = 7.75±0.20 and total alkalinity 145.6 mg L^{-1}.

Test diets and feeding regime: Six isonitrogenous (280 g crude protein kg^{-1}), isoenergetic (19 MJ GE kg^{-1}) test diets were prepared. Guar meal (46.7% crude protein, 6.3% crude lipid, 10.8% crude fiber, 4.8% ash and 31.4% NFE) were incorporated into the test diets, as a soybean meal (SBM)

Table 1: Composition and proximate analysis (g kg^{-1}) of the test diets

	Guar meal level (%)					
Ingredients (g kg^{-1})	0.0	20	40	60	80	100
Fish meal[1]	100	100	100	100	100	100
Soybean meal	340	272	204	136	68	0.0
Guar meal	0	68	136	204	272	340
Wheat bran	200	210	221	230	242	240
Corn flour	300	300	300	302	301	314
Corn oil	50	40	30	20	10	0.0
DCP[2]	5	5	4	3	2	1
Vitamin and mineral premix[3]	5	5	5	5	5	5
Total	1000.0	1000	1000	1000	1000	1000
Crude protein	281.8	282.4	283.1	283.4	284.3	284.5
Crude lipid	82.5	76.5	71.2	68.1	65.3	59.7
Ash	30.9	47.0	46.9	46.7	46.6	45.9
Crude fiber	53.6	57.7	61.8	65.7	70.0	73.2
NFE[4]	547.8	532.9	534.1	536.1	536.8	539.7
GE (MJ kg^{-1})[5]	19.54	19.06	18.77	18.81	18.73	18.57
Cost (USD kg^{-1})[6]	0.75	0.71	0.68	0.65	0.62	0.57

[1]720 g kg^{-1} crude protein (Denmark), [2]Di-calcium phosphate, [3]Contains (Kg^{-1}): Vitamin A: 3,333,333 IU, Vitamin D_3: 833.333 IU, Vitamin E: 3,333 mg, Vitamin K: 333 mg, Vitamin B_1: 333.3 mg, Vitamin B_2: 1,667 mg, Vitamin B_6: 500 mg, Vitamin B_{12}: 3.33 mg, Niacin: 10,000 mg, Pantothenic acid: 3,333.3 mg, Folic acid: 333.3 mg, Biotin: 16.7 mg, Iodine: 100 mg, Iron: 10,000 mg, Manganese: 20,000 mg, Copper: 1,333 mg, Cobalt: 33.3 mg, Selenium: 33.3 mg, Zinc: 16,667 mg, Calcium carbonate: 1,000 mg, [4]Nitrogen free extract, determined by differences, [5]Gross energy, calculated based on 23.64, 39.54 and 17.57 (kJ g^{-1}) for protein, lipid, carbohydrate, respectively, [6]Values were originally in Egyptian pound and were converted into USD (One USD = 7.04 Egyptian pounds in July, 2013)

replacer, at 0, 20, 40, 60, 80 and 100% levels (Table 1). The test diets were fed to the fish twice a day (at 0800 and 1300 h) for 105 days. The diets were initially offered at 3% of the fish body weights during the first two months and reduced to 2% beginning of the 3rd month, until the end of the experiment. A random sample of 8 fish from each hapa were netted at 15-day intervals, their average weights recorded and the daily rations were readjusted accordingly.

Body composition analysis: At the end of the experiment, fish in each hapa were netted, counted, weighed and frozen at -20°C for final body composition analysis. Initial body analysis was performed on a pooled sample of 5 fish, which was weighed and frozen before the experiment. A sample of each test diet was also stored at -20°C for chemical analysis. Proximate analysis of the test diets and whole-body moisture, protein, lipid and ash were performed according to standard AOAC[23] methods.

Calculations of fish performance: Growth rates and feed efficiency were calculated as follows:

$$\text{Percent Weight Gain (PWG)} = \frac{\text{Wf-Wi}}{\text{Wi}} \times 100$$

$$\text{Specific Growth Rate (SGR)} = \frac{\text{LnWf-LnWi}}{t} \times 100$$

where, Wi and Wf are initial and final weights (g) and t is time of experiment (days).

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Dry feed intake (g)}}{\text{Fish live weight gain (g)}}$$

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}} \times 100$$

$$\text{Protein Productive Value (PPV)} = \frac{\text{Protein gain (g)}}{\text{Protein fed (g)}} \times 100$$

Cost/benefit analysis of the diets, including Incidence Cost (IC) and Profit Index (PI) were performed according to Miller[24] as follows:

$$\text{Incidence cost} = \text{Cost of kg feed consumed/kg fish produced}$$
$$\text{Profit index} = \text{Value of fish crop/cost of feed consumed}$$

Statistical analysis: All data were subjected to one-way analysis of variance (ANOVA) at a 95% confidence limit, using SPSS software, version 12. Duncan's multiple range test was used to compare means when F-values from the ANOVA were significant ($p<0.05$).

RESULTS

The results of the present study revealed that *Nile tilapia* juveniles fed all the test diets showed excellent growth rates

Table 2: Growth rates, feed utilization and cost benefit (Mean±SE) of Nile tilapia fed the test diets

GM (%)	IW (g)	FW (g)	Weight gain (%)	SGR	FCR	PER	PPV	Survival (%)	IC	PI
0	19.95	222.00±2.15^{a}	1012.7±3.64^{a}	2.29±0.003^{a}	1.47±0.007^{a}	2.40±0.01^{a}	43.74±0.71^{a}	99.6±0.072	1.10±0.03^{a}	1.58±0.003^{a}
20	19.93	219.33±1.20^{a}	1000.3±3.6^{a}	2.28±0.003^{a}	1.57±0.011^{b}	2.25±0.02^{b}	33.22±1.64^{b}	100.0±0.00	1.10±0.08^{a}	1.58±0.012^{a}
40	20.02	207.00±1.73^{b}	934.0±7.81^{b}	2.23±0.007^{b}	1.57±0.013^{b}	2.25±0.02^{b}	34.89±1.33^{b}	100.0±0.00	1.07±0.08^{a}	1.59±0.014^{a}
60	19.97	200.00+2.89^{c}	901.6±13.04^{c}	2.19±0.015^{c}	1.57±0.026^{b}	2.25±0.04^{b}	34.15±1.13^{b}	99.6±0.072	1.02±0.02^{b}	1.67±0.035^{b}
80	20.02	194.00±2.10^{d}	869.2±4.65^{d}	2.16±0.005^{cd}	1.58±0.007^{b}	2.22±0.01^{b}	34.63±1.58^{b}	100.0±0.00	0.98±0.06^{b}	1.73±0.011^{c}
100	19.97	190.00±1.80^{d}	851.6±4.42^{d}	2.15±0.005^{d}	1.60±0.019^{b}	2.21±0.03^{b}	35.00±0.70^{b}	99.6±0.072	0.91±0.01^{c}	1.87±0.023^{d}

Values in the same column with different superscripts are significantly different at $p<0.05$

Table 3: Body composition (g kg^{-1}) on dry matter basis of Nile tilapia fingerlings fed the test diets

GM (%)	Moisture	Crude protein	Ether extract	Ash
Initial	768.9	512.1	249.8	235.0
0	730.1± 6.22^{a}	650.1±19.8^{a}	165.7±18.2^{a}	166.7±6.0^{a}
20	766.6±12.4^{b}	628.8±16.0^{b}	171.6±23.2^{ac}	186.0±11.0^{b}
40	754.8±4.7^{ab}	606.4±4.9^{c}	209.0±3.1^{b}	181.0±3.1^{c}
60	759.3±7.7^{b}	619.2±27.4^{cb}	180.7±19.5^{c}	195.7±2.2^{d}
80	760.4±14.0^{b}	632.1±24.3^{b}	182.6±32.7^{c}	180.0±3.0^{c}
100	747.4±12.3^{ba}	620.3±11.4^{bc}	201.5±11.2^{b}	179.5±6.9^{c}

Values in the same column with different superscripts are significantly different at $p<0.05$

and feed efficiency (Table 2). However, growth rates significantly decreased ($p<0.05$) with increasing GM inclusion levels. Feed Conversion Ratio (FCR) significantly increased ($p<0.05$), while Protein Efficiency Ratio (PER) and Protein Productive Value (PPV) decreased ($p<0.05$) with increasing dietary GM up to 20% level. Further increase in GM up to 100% level did not result in any further retardation in feed utilization efficiency.

The inclusion of guar meal in Nile tilapia diets significantly affected ($p<0.05$) the carcass composition of the fish (Table 3). Body moisture and protein were higher in fish fed the control, SBM-based diet than those fed the GM-based diets, but there were no significant differences ($p>0.05$) in fish fed the GM diets. Body lipid and ash contents were significantly lower ($p<0.05$) in the fish fed the control diet than in those fed the GM diets. However, no regular patterns were found in body lipid and ash contents of fish fed the GM-based diets.

The cost/benefit analysis including Incidence Cost (IC) and Profit Index (PI) of the test diets indicated that IC significantly decreased ($p<0.05$), while PI increased with increasing dietary GM inclusion level. The GM-based diets, even at 100% substitution were economically better ($p<0.05$) than the control, SBM-based diet.

DISCUSSION

Despite the high potential of guar seeds and meals as a nutrient source for humans and land animals, very little attention has been paid to the use of this source in tilapia feeds. Only Al-Hafedh and Siddiqui[22] evaluated the use milled guar seeds as a fish meal replacer in Nile tilapia (*Oreochromis niloticus*) diets. They reported that 50% of dietary fish meal can be replaced by guar seeds, without adverse effects on growth and feed utilization.

The present study provides a strong evidence of the possibility of the use of Guar Meal (GM) as a dietary protein source for Nile tilapia. The study revealed that growth rates and feed efficiency and survival were excellent at all GM inclusion levels, despite the significant reduction in fish growth beyond 20% level. The percent weight gain and ADG were much better than that reported by Al-Hafedh and Siddiqui[22], presumably due to the differences in fish sizes used, guar source (guar seed vs. guar meal), processing methods and dietary protein contents.

In accordance with the present results, the inclusion of guar meals or seeds in diets of carps depressed fish performance. El-Saidy *et al*.[19] reported that GM protein can replace up to 50% of fishmeal protein in common carp (*Cyprinus carpio*) diets without significant retardation in fish performance. Garg *et al*.[21] found also that feeding raw and autoclaved guar seeds to mrigal (*Cirrhinus mrigala*) fingerlings resulted in lower growth rate, survival and carcass composition than feeding soybeans. Similarly, when GM was included at 30% in diets for rohu (*Labeo rohita*), it resulted in significantly lower digestibility coefficient of dry matter, crude protein and energy than fish meal[20].

The reduction in the performance of fish fed on guar meal-based diets could be attributed to the presence of antinutrients and gum residue in guar meals and their deficiency in sulfur amino acid methionine. Guar seeds have been reported to contain several antinutrients, such as polyphenols, lignins, tripsin inhibitors, saponin, residual gums, phytase-phosphorus, tannin and possibly organic acids, aldehydes and cyanogens[25]. The deleterious effects of these antinutrients on productive performance and feed utilization of domestic animals fed guar meals is well documented. These effects include; retarded growth, low survival, low feed intake, low digestibility and poor feed utilization[13,15,16,18,26]. Most of these antinutrients can be removed by guar processing, including soaking, germination, boiling, autoclaving and fermentation[25].

The effects of antinutrients on the quality of guar meal for farmed fishes is not well-investigated, since very few studies have considered this issue. Only Garg *et al.*[21] reported that hydrothermal treatment of leguminous seeds, including soybeans, moong (*Vigna radia*), cowpea (*Vigna ungiculata*) and guar, reduced their trypsin inhibitor activity and improved their quality for Indian major carp species; namely mrigal (*Cirrhinus mrigala*) and rohu (*Labeo rohita*). The performance of fish fed thermally treated seeds were significantly better than that of fish fed on raw seeds.

Guar gum, which is a soluble non-starch polysaccharide (NSP) isolated from guar seeds, may cause adverse effects on growth rates, feed intake, digestibility and utilization of monogastric animals[27,28]. In fish, the effect of guar gum residues is varying, depending on fish species and size, feeding habits, diets composition and gum structure and concentration. For example, guar gum was reported to increase digesta viscosity and decrease gastric emptying time and in turn leads to low nutrient digestibility and delay of nutrient absorption in rainbow trout[29] and African catfish[30]. The increase in digesta viscosity may also lead to depression of growth rates and feed efficiency. On the contrary, Amirkolaie *et al.*[31] reported that guar gum reduced faeces stability in Nile tilapia due to its high water-binding capacity and therefore does not act as appropriate faeces binder in this species.

On the other hand, inclusion of guar gum (0.3%) in rainbow trout *Oncorhynchus mykiss* feed enhanced faeces stability in water, without reducing fish growth and feed utilization[32-34]. Similarly, guar gum did not have adverse effects on growth and feed efficiency of white sea bream[35].

Feed ingredients used in fish feeds are generally evaluated from biological and nutritional points of view. Economic evaluation of such feed inputs for farmed fish has not been given enough attention, despite the fact that they could be economically better than traditional, standard sources. For example, economic evaluation of cottonseed meal[5], corn gluten feed and meal[36] and animal by-product meal[37] as protein sources for Nile tilapia indicated that profit indices of these protein sources were better than for FM-based feeds. These studies suggest the use of these sources as total fish meal replacers for tilapia.

The present results indicated also that despite the significant performance retardation caused by feeding guar meal-based diets, cost/benefit analysis indicated that these diets were economically superior to the control SBM diet. For example, at 100% GM inclusion level, average final fish weight was decreased by 14.4%, compared to the control diet, while profit index increased by 18.4%. This means that GM can be used as a total SBM replacer in Nile tilapia feeds.

CONCLUSION

The present study suggests that guar meal could be used as a total replacement of soybean meals in Nile tilapia feeds. It also stresses the necessity for both biological and economic evaluation of feed inputs for farmed fish.

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