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Water Quality and Growth Performance of Nile Tilapia Fries Fed on Insect-Based Feeds

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Abstract

Fish feed is one of the main constraints on the growth of aquaculture in Kenya. The lack of high-quality and competitively priced feeds means that the fish farmers are unable to expand their production. To ensure that aquaculture remains viable and sustainable, it is necessary to optimize production through the utilization of locally available feeding materials. Insect-based feeds are alternative least-cost feeding resource in fish production. Using alternative protein sources such as black soldier fly larvae (BSF) and daphnia meal in place of fishmeal (Omena and Dagaa) is an ingenious strategy for sustainable fish aquaculture. This study evaluated the effect of four treatments: BSF, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika on the fish pond environmental parameters and fish fries' performance (body weight and length). The experiment was carried out in a greenhouse with 30 fingerlings in each experimental unit. The feeding trials took 23 days. Results indicated that the four treatments have a varied effect on the BW and L of fish fries. A high growth rate was observed in Daphia, followed by BSF, Omena and Dagaa in that order. On the other hand, the treatments have varied effects on pond parameters with BSF promoting too much growth of algae. BSF have higher amounts of ammonia, nitrates and phosphorus, which stimulate the high growth of algae.

Keywords

Black Soldier Fly, Dagaa, Growth, Omena, Replacement of Fish Meal, Tilapia Fries

1. Introduction

The blue economy has been experiencing a declining trend. Production of blue foods (fish, blue foods, aquatic plants, fresh water) has been on the decline from 163,824 metric tons in 2015 to 146,543 metric tons in 2019, which represent a 10.5% reduction [1] [2]. Fish farming is faced with the challenges of limited natural resources and the impacts of climate change. Fish feed is one of the main constraints on the growth of aquaculture. The Lack of high-quality and competitively priced feeds means that fish farmers are unable to optimize their production [3]. Fish and soybean meal are the major components used in aquaculture feeding and since most of these protein sources are imported, they are costly. Such feeds are very expensive and not readily available, thus discouraging their use by many farmers [4]. This is a major challenge to the growth of the fish industry in the country. To ensure that aquaculture remains feasible and sustainable, it is necessary to optimize production, through the utilization of locally available feed coffers [5] [6]. Insect-based non-conventional feeds can be an indispensable least-cost coffer in fish production. Using alternative protein sources such as black soldier fly larvae (BSF), common housefly larvae, silkworms, yellow mealworms and daphnia meal in place of fishmeal is an ingenious strategy for sustainable fish aquaculture [7]. Insects are the most promising protein resources for fish feeding because of their short life cycle and the ability to produce a lot of eggs. Experiments with insect-based diets as feed have resulted in the good growth of several species of fish. However, there is a paucity of information about the effect of insect feed resources on the growth of tilapia fries and pond environment [4] [8]. This study evaluated the effect of BSF, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika on the Nile tilapia fries' performance (bodyweight and length) and their effects on the fish pond environment parameters. Plant protein sources though cheap in Africa, lack essential amino acids and also limiting amino acids [6] [9].

2. Methodology

2.1. Experimental Location

The experiment was set at Egerton University, Njoro campus, which is 20 km from Nakuru town in Kenya. The University's main campus lies at coordinates 0˚22'11.0"S and 35˚55'58.0"E (Latitude: −0.369734; Longitude: 35.932779).

2.2. Source of Tilapia Fries and Feeding Ingredients

One (1) day-old tilapia fries were sourced from Kenya Marine Fish and Research Institute (KEMFRI), Kisii County. Good quality and healthy fries were selected and transported using oxygenated plastic bags.

Black soldier fly and Daphnia were produced at Egerton University on fermented chicken manure and elephant dung, respectively. Their larvae were harvested, cleaned, dried and milled. Fishmeal, Omena and Dagaa were sourced from Lake Victoria and Lake Tanganyika, respectively. All these lakes are within the East African region; hence the fish are easily available in the local markets.

2.3. Experimental Design

Four identical concrete ponds measuring 1 M × 1.5 M × 4 M housed in a greenhouse were used. Equal numbers of fries were stocked in each of the ponds (20 fries per pond) in a completely randomized manner.

2.4. Grow-Out and Pond Management

Checks were done in the ponds every day and fries that died were removed from the ponds on a daily basis. Fries that died within the first week of stocking were replaced with new ones. Fries were fed twice a day (0900 and 1600 hrs) through broadcasting, on pure marsh diets of BSF larvae, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika based on percentage BW adjusted according to weight measurement for 23 days. The amount of feed was adjusted every two weeks according to the new mean fry BW in each treatment.

2.5. Data Collection

Before stocking, fries BW, L and water quality parameters were taken and recorded. During the grow-out period, Atmospheric (top pond) temperatures, pond water temperatures and a number of water quality parameters (pH, dissolved oxygen and conductivity) were recorded for each pond twice daily at 0900 and 1600 hrs using HQ40d portable water quality meter. Fish performance (BW and L) in each pond were taken and recorded from stocking date. Dead fish were removed and recorded on a daily basis. During sampling, 10 fries of the stocked fries in each pond were randomly scooped from each treatment every week. Body weight and L were measured using digital balance and measuring board respectively and fries' growth performances were evaluated.

2.6. Data Analysis

An analysis of variance (ANOVA) was done to determine the effect of BSF larvae, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika on the growth and length of the fries. In total, data for XXX fries were recorded (Table 1). Descriptive statistics and checking of data anomalies were carried out using XXXX for BD and L. Due to the non-normal distribution of residuals, final BW and total L were log transformed. PROC GLM was used to test for significant fixed effects to be included in the model [10] [11] [12] [13].

3. Results

3.1. Effect of BSF Larvae, Daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika on Pond Parameters

Average temperatures (Atmospheric and pond water temperatures), pH, dissolved oxygen and conductivity are presented in Table 1. The trend of the parameter during the growth-out period (day one to day 23) is shown in appendix Figures A1-A6. Water pH values were close ranging from 9.32 to 9.44). Water

conductivity was high (321.57 - 332.35) in pond with Omena followed by pond with Dagaa, Daphnia and lastly BSF.

The four diets have an effect on pond water coloration and algae growth (Figure 1). Among the ponds, only BSF pond has a lot of algae bloom. On day 23, the BSF pond had become full of algae bloom.

Pond with BSF

Pond with Daphnia

Pond with Omena from Lake Victoria

Pond with Dagaa from Lake Tanganyika

Figure 1. Effect of BSF larvae, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika on water colour and algae growth.

Table 1. Temperatures (atmospheric and pond), pH, dissolved oxygen and conductivity in the ponds subjected to four experimental diets.

POND	BSF	Daphnia	Omena	Dagaa
Morning pH	9.44	9.39	9.35	9.36
Evening pH	9.39	9.39	9.33	9.32
Morning Conductivity	301.26	313.30	332.35	314.09
Evening Conductivity	299.04	309.52	321.57	299.91
Pond water Temperature Morning	23.98	23.74	23.81	23.17
Pond water Temperature Evening	26.07	26.30	26.04	25.83
Atmospheric (Top Pond) Temperature Morning	23.87	23.91	23.48	22.94
Atmospheric (Top Pond) Temperature Evening	26.42	26.53	26.39	25.99
Dissolved oxygen Morning	4.87	4.82	4.88	4.86
Dissolved oxygen Evening	4.99	4.96	5.00	4.99

3.2. Fish Performance

3.2.1. Body Weight

Tilapia fries' body weight from day one to day 23 in the study is shown in Figure 2.

3.2.2. Body Length of the Tilapia

See Table 2 and Table 3 and Figure 3.

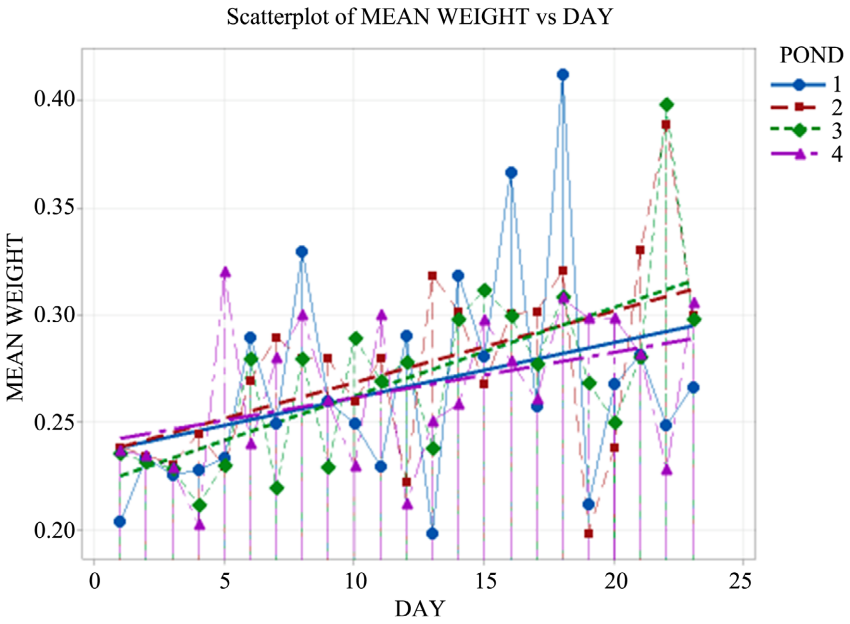

Figure 2. Growth (body weight) pattern for tilapia fries fed with BSF larvae (Pond 1), daphnia (Pond 2), Omena from Lake Victoria (Pond 3) and Dagaa from Lake Tanganyika (Pond 4).

Table 2. Average body weight of fries fed BSF larvae, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika.

Day	BSF	Daphnia	Omena	Dagaa
1	0.20	0.24	0.24	0.24
7	0.25	0.29	0.22	0.28
14	0.32	0.30	0.30	0.26
23	0.27	0.30	0.30	0.31

Table 3. Average body length of fries fed BSF larvae, daphnia, Omena from Lake Victoria and Dagaa from Lake Tanganyika.

Day	BSF	Daphnia	Omena	Dagaa
1	2.31	2.30	2.33	2.31
7	2.50	2.90	2.20	2.80
14	3.20	3.10	3.00	2.60
23	2.85	2.94	2.89	3.07

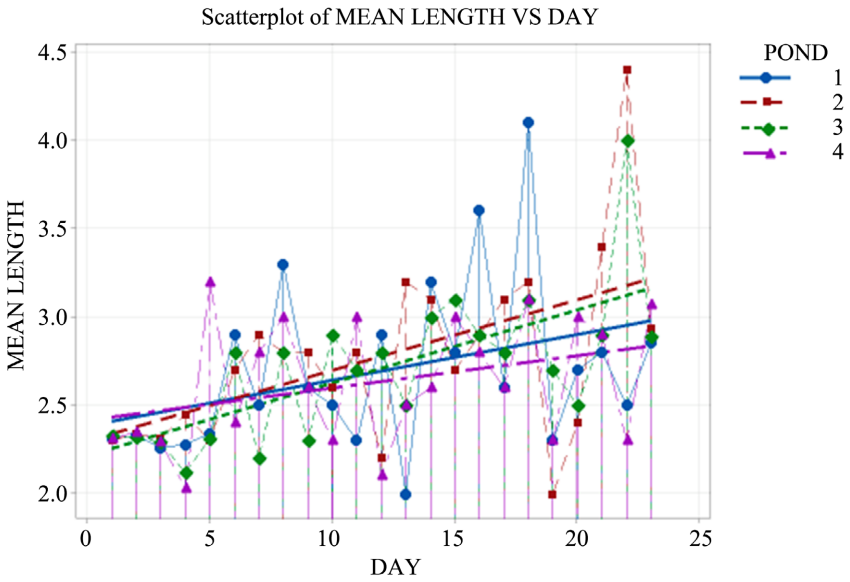

Figure 3. Body length from day 1 to 23 for tilapia fries fed with BSF larvae (Pond 1), daphnia (Pond 2), Omena from Lake Victoria (Pond 3) and Dagaa from Lake Tanganyika (Pond 4).

4. Conclusion

Black Soldier Fly larvae and Daphniameals are good substitutes for Omena in feeding Tilapia fries. However, BSF larvae meal promotes the growth of harmful algae like cyanophytes which kill fish by clogging gills [8] [14] [15]. The major purpose of this project is to remove the animal proteins that animals share with human beings with the aim of removing 'human plate proteins' from all animal feed troughs. For example, blood meal, bone meal and animal meat are shared by both animals and humans [5] [10] [16]. In fish, the price of omena, which is human food, is driven high because all fish feed must have omena for all aquacultural uses hence the need for trials for BSF and daphnia which don't form part of human food [17] [18] [19].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

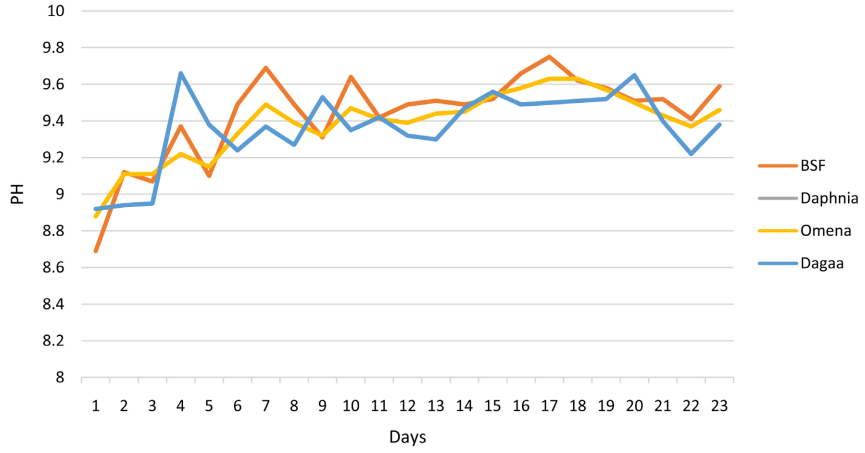

Figure A1. Effect of BSF, daphnia, omena and dagaa diets on PH of fish pond water in the morning hours.

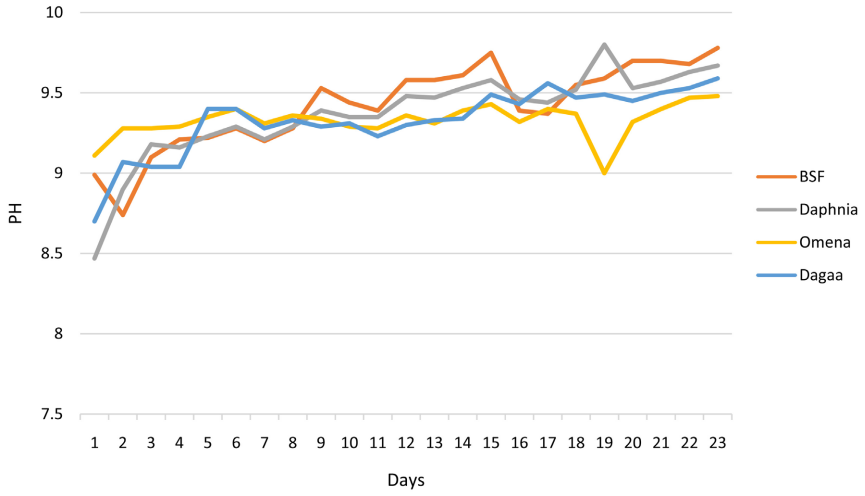

Figure A2. Effect of BSF, daphnia, omena and dagaa diets on PH of fish pond water in the afternoon hours.

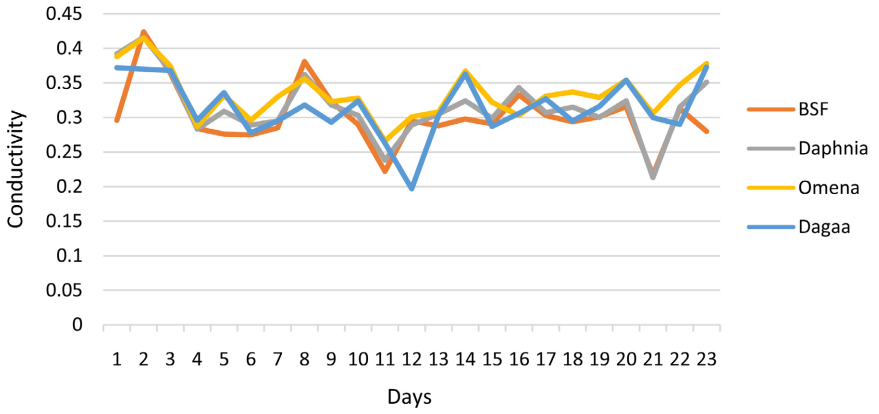

Figure A3. Effect of BSF, daphnia, omena and dagaa diets on water conductivity of fish pond water in the morning hours.

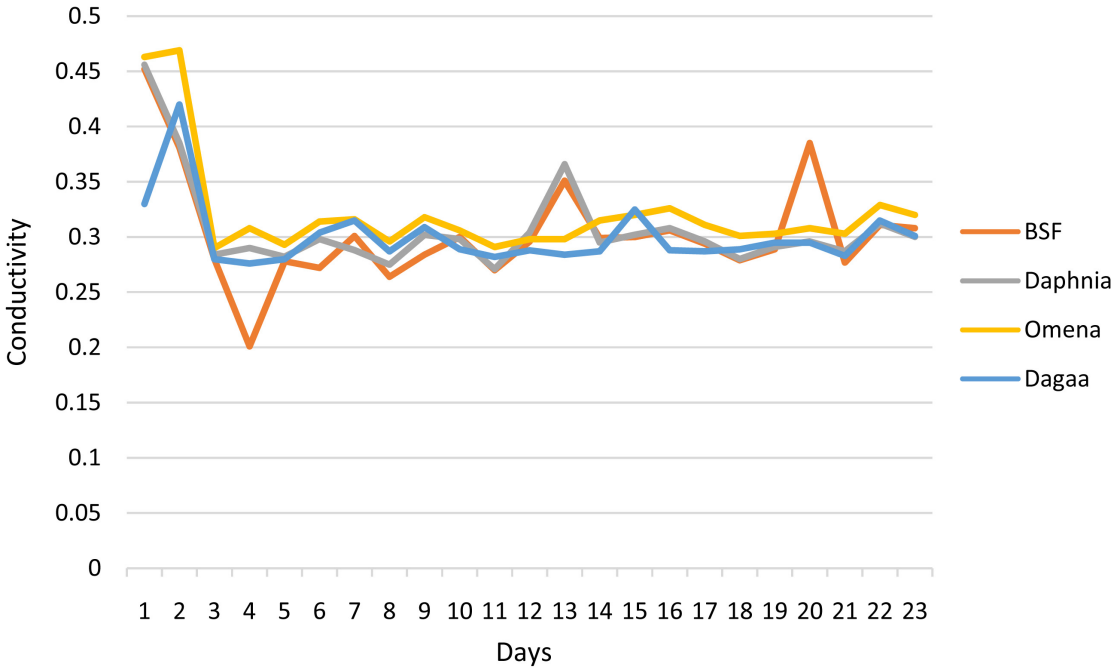

Figure A4. Effect of BSF, daphnia, omena and dagaa diets on water conductivity of fish pond water in the afternoon hours.

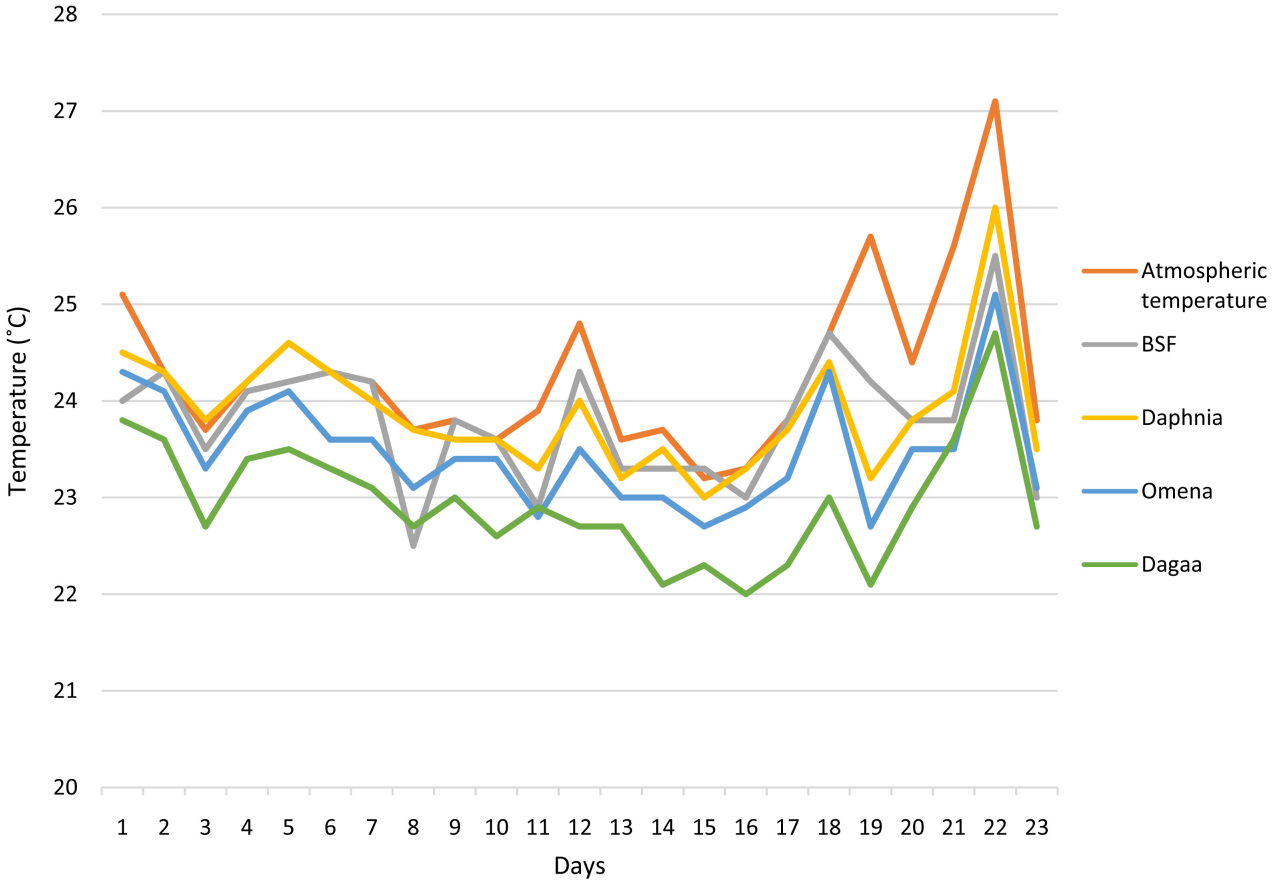

Figure A5. Effect of BSF, daphnia, omena and dagaa diets on pond water temperature in the morning hours.

Figure A6. Effect of BSF, daphnia, Omena and Dagaa diets on pond water temperature in the afternoon hours.

WEIGHT AT 23 DAYS

ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
MODEL	3	0.082078	0.0273593	9.2128	0.0001171***
RESIDUALS	36	0.106910	0.0029697		
CORRECTED TOTAL	39	0.188988			

Signif. codes: 0 “***” 0.001 “**” 0.01 “*” 0.05 “.” 0.1 “ ” 1

$Fitness

Root MSE WEIGHT Mean Coef Var R-square Adj R-sq

0.05449513 0.335425 16.24659 0.4343026 0.3871611

$ “Type I”

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
FEED	3	0.082078	0.027359	9.2128	0.0001171***

Signif. codes: 0 “***” 0.001 “**” 0.01 “*” 0.05 “.” 0.1 “ ” 1

MEAN SEPARATION WITH LSD

FEED	Group	LSmean	Lower CL	Upper CL	SE	Df
DAPHNIA	A	0.4057	0.3707501	0.4406499	0.01723287	36
OMENA	B	0.3446	0.3096501	0.3795499	0.01723287	36
BSF	BC	0.2995	0.2645501	0.3344499	0.01723287	36
DAGAA	C	0.2919	0.2569501	0.3268499	0.01723287	36

LENGTH AT 23 DAYS

Response: Length

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
MODEL	3	0.2747	0.091583	0.4031	0.7516
RESIDUALS	36	8.1790	0.227194		
CORRECTED TOTAL	39	8.4538			

$ Fitness

Root MSE	Length	Mean Coef Var	R-square A	dj R-sq
0.4766492	2.9375	16.22636	0.03250037	−0.0481246

$ "Type I"

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
FEED	3	0.27475	0.091583	0.4031	0.7516

Feed	Group	LSmean	Lower CL	UpperCL	SE	Df
Dagaa	A	3.07	2.764306	3.375694	0.1507297	36
Daphnia	A	2.94	2.634306	3.245694	0.1507297	36
Omena	A	2.89	2.584306	3.195694	0.1507297	36
BSF	A	2.85	2.544306	3.155694	0.1507297	36