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# The Growth Performance, Feed Efficiency and Body Composition of Juvenile Nile Tilapia (*Oreochromis Niloticus*) Feed by Caterpillars (*Imbrasia Truncate* Aurivillius, 1908) Meal in Replacement of Fish Meal

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**ABSTRACT**

Effects of caterpillar (*Imbrasia truncate* Aurivillius, 1908*)* meal as a protein source in the diet of *Oreochromis niloticus* were investigated on growth performance, feed efficiency, whole body mineral composition and the cost/benefit analysis. The experiment was conducted in a completely randomized design with duplicate observations (3 treatments × 2 replicates × 35 fish per hapa-in-earthen pond systems) during ten weeks of duration using an open system. Water temperature and dissolved oxygen ranged respectively between 27.7 to 28°C and 4.5 to 6.0 mg $l^{-1}$. The Nile tilapia (12.67±1.88 g initial body weight and 10.45 ± 0.03cm initial length) were fed three times a day with three calculated isonitrogenous and isoenergetic diets prepared by replacing fishmeal with caterpillar meal at 15% and 30%. The diets were coded $T_1$ and $T_2$ respectively. A control diet without caterpillar meal was coded $T_0$. The fish fed with $T_1$ and $T_0$ diets were superior in specific growth rate (p< 0.05) when compared with fish fed with diet $T_2$ treatment. On the other hand, the feed utilization parameter: feed conversion ratio (FCR), did not show significant differences(p> 0.05) between the fish in the control group and diet $T_1$, although a significant difference between $T_1$ and $T_2$ treatments was observed. Results of body composition in response to dietary treatments showed no significant statistical difference (p>0.05) for moisture, fiber and minerals in contrast to protein, lipid and ash content where the difference was significant (p<0.05).The highest profit index (1.82) was recorded on diet $T_2$. The lowest profit index was in the control but the differences were not significant (p> 0.05).These results indicate that incorporation of less than 30 % of caterpillar meal as a substitute for fishmeal could be feasible in the diet of Nile tilapia. Further studies are recommended for other fish species such as catfish, and the conditions to optimize the level of that ingredient to improve growth performance.



## Introduction

Due to the increase in world population there is need for high production of fish to supplement the catch from the wild. Meanwhile under intensive and semi-intensive aquaculture regimes, feed constitutes the largest proportion of the overall costs, often ranging from 30% to 60% of the total variable expenses, depending on the intensity of the culture operation (Charo-Karisa et al., 2013).Therefore, the success of commercial aquaculture operations depends mainly on the availability of suitable diets, which provide required nutrients for optimum growth at minimal cost (Mohapatra, 2013). High-quality fish meals constitute the major fraction of the protein supplied in commercial fish feeds. For this reason, fishmeal and fish oil prices have been increasing as their availability has been decreasing (Van Huis et al., 2013). Consequently, that has stimulated research interest to seek alternative protein source for feeds in aquaculture. The utilization of non-conventional protein supplements of both animal and plants origin in aquaculture has been the focal point of research in the world in recent times.

Many studies have evaluated the inclusion of various ingredients in aquafeeds (Begum et al; 1994; Imorou et al., 2008;Nyima-Wamwiza et al., 2010; Luoet al., 2012; Alegbeleye et al., 2012;de Azevedo et al. 2013; Souza et al,. 2013;Stadtlander et al., 2013; El-Asely et al.,2014; Thongprajukaew et al., 2015; Khalifa et al., 2017; Monsengo et al., 2017;Rapatsa and Moyo 2017; Youniset al. 2017) with varying results on their effects on growth, survival and yield on fish. Unlike plant meal, which has anti-nutritional factors and the potential to cause inflammation in the digestive tracts of fish, insects (which are rich in amino acids, lipids, vitamins and minerals) are part of the natural diet of freshwater and

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marine fish. Insects also have a smaller ecological footprint than protein-rich plants, since there is no need for arable land, and require low energy and water for production (Seung and JiWoong, 2015).Alternative protein sources of comparable value are therefore urgently needed. Thus, the potential of insect-based protein in animal feed diets has attracted much attention (Nugroho and Nur, 2018; Adeniyi and Folorunsho, 2015)

Mealworms, silkworm pupae and maggots are the most promising species for feed because they are valuable sources of protein (50–71% dry matter) and lipids (30%) (Wei & Liu, 2001; Rumpold and Schluter, 2013) and the animals show good digestion and growth, even compared to fishmeal in some cases, but replacing fishmeal entirely with insect feed is usually not successful because of dietary imbalances ( Henry et al., 2015). However no studies have been undertaken on the use of caterpillar's meal in fish diet. In the Democratic Republic of the Congo (DRC) where commercial feeds are unavailable, caterpillars are widely distributed in several regions and are cheaper than fishmeal but very rich in protein. Dried caterpillars of 23 species (including 17 Saturniidae) were analyzed, with samples prepared in a manner identical to that which precedes their culinary preparation (DeFoliart, 1999). The crude protein content averaged 63.5%; kilocalories per 100 g averaged 457 (ranging up to 543); and most species proved an excellent source of iron, with 100 g averaging 35% of the recommended daily requirement (DeFoliart, 1999). Kondondi et al., (1987) analyzed three species of Saturniids for vitamins and conducted feeding trials with rates that showed that vitamins supplied by the caterpillars, except for B1 and B6, are sufficient to allow proper growth. When sold in markets as dried food, they are also an important source of income (Lisingo et al., 2010). They are often dried for use later in the year as food.

The high local availability of more than 12 species of caterpillars in Kisangani region(DRC) presents an opportunity to use them as fish feed ingredients especially in regions where good fish meal is not available or is very expensive in inland regions(Okangola et al.,2016). The use of caterpillar meal in aquaculture could add value to this important but often neglected protein source (Diomande et al., 2017). Indeed, replacement of fish meal by less expensive protein sources in diets for fish culture is becoming important not only to improve the economy of production by reducing feed costs, but also to provide viable and low-cost scientific based feeding information to fish farmers for improved production using resources available in their local settings (Limbu et al., 2016). That will promote other ingredients and contribute to the sustainable management of natural resources by increasing the number of ingredients that can be used in fish feeding.

The Nile tilapia (*Oreochromis niloticus*) was selected as an experimental animal for this study because it is one of the most cultured fish species in Africa. It also easily reproduces in captivity, without any hormonal stimulation and is adaptable to a wide variety of water conditions. Under constant photothermal conditions (26 - 28 °C and 14 h light/10 h dark photoperiod), females spawn regularly throughout the year (Genotte et al., 2012). Therefore, the great challenge for searching for unconventional feed sources is a necessity to make tilapia production more economically feasible (Fitzsimmons, 2006).In view of the importance of developing low cost feed, this study was undertaken to assess the dietary effects of the partially or completely fishmeal replacement by caterpillar meal as major protein sources in the formulated diet for Nile tilapia (O. *niloticus)*. The study focused on growth performance, feed efficiency, whole body composition and the cost/benefit analysis of using caterpillar meal as a fishmeal substitute.

## Materials and Methods

### Experimental Design

Experimental fish, *Oreochromis niloticus,* (initial body weight: 12.67±1.88 g) were collected from the nursery pond and were kept in hapa nets (3.42m²) for an adaptation period of 2 weeks. During acclimatization period, the fish were fed the mixed experimental feeds containing 325 g/ kg protein at the rate of 5 % of body weight per ration. The hapa nets were then placed in ponds (300 m²) in which lime ($CaCO_3$) had been applied at the rate of 125 kgha$^{-1}$. The level of water fluctuated about 0.6 m during the experiment. The experiment was set up in a completely randomized design. The feeding trials were conducted in 6 rectangular hapa nets. Water was supplied by a stream without being recirculated. The individual length and weight of 30 fish were measured and recorded at the beginning and the end (per hapa) of experimentation. The total length of fish (L) was measured to the nearest centimeter from the tip of the mouth to the tip of the caudal fin using a graduated ruler. Thirty five juveniles (initial mean weight: 12.67±1.88 g) were stocked in each hapa net in to a pond, water supplied at a flow rate of 30 - 35 L min$^{-1}$. Replicate hapa nets were used for each dietary treatment. The water quality parameters like temperature, dissolved oxygen, pH, conductivity and saturation were measured in each hapa, at the point of supply and drainage of the pond once a week with multi-meter (HACHHQ40D). The parameters remained within the acceptable range reported for the rearing of Tilapia Abdel-Tawwab et al.,(2015), which is one of the most important fresh-water fish because of their capabilities to tolerate a wide range of environmental factors and stress conditions (El-Sayed, 2006).Water quality parameters were not significantly different between the experimental hapa nets.

### Experimental diets

Three isonitrogenous (32.5%) and isoenergetic (16.5kJ/g) diets were formulated for *Oreochromis niloticus* juveniles as shown in Table 1.The cost of each diet was also determined. The diets were formulated using locally available diets ingredients. The diet in which fishmeal was used as the sole source of protein was designated diet $T_0$ (control). Caterpillar meal combined with fishmeal was designated diet $T_{1,}$ and the diet in which Caterpillar meal was used as the sole source of protein was designated diet $T_{2.}$Diets were prepared by mixing the dry milled feed ingredients with the addition of boiling water until a desirable paste-like consistency was reached. This paste was manually divided in small sizes and sun-dried at about 27–33°C and preserved in a plastic bag until it was to be used.

### Determination of diet and fish body chemical compositions

The tested diets and whole-fish body from each treatment were analyzed according to the standard methods of AOAC (2005) for moisture, protein, fat, ash and minerals (Fe, Ca, Mg, K, Na, P). Moisture content was estimated by drying the samples to constant weight at 105 °C in a drying oven and nitrogen content using a micro Kjeldahl apparatus. Crude protein was estimated by multiplying nitrogen content by 6.25. Lipid content was determined by ether extraction in a multi-unit Soxhlet extraction apparatus for6 hours according

**Table 1. Formulation of three experimental diets ($T_0$ (control) = fishmeal; $T_1$ = caterpillar + fishmeal; $T_2$ = caterpillar meal).**

| Ingredients | Protein level (%) | Gross energy (kJ/g) | $T_0$ | $T_1$ | $T_2$ |
|---|---|---|---|---|---|
| FM | 66.75 | 20.3 | 300 | 150 | 00 |
| SBM | 45.3 | 19.8 | 70 | 90 | 90 |
| PM | 56.4 | | 100 | 90 | 100 |
| CM | 61 | 19.33 | 00 | 150 | 300 |
| CsM | 2.7 | 17.3 | 270 | 190 | 180 |
| MM | 9 | 17 | 150 | 220 | 220 |
| PKC | 20.6 | 20 | 100 | 100 | 100 |
| NaCl | | | 10 | 10 | 10 |

N.B. Fish Meal (FM), Soya Bean Meal (SBM), Peanut Meal (PM), Caterpillar Meal(CM), Cassava Meal (CsM), Maize Meal(MM), Palm Kernel Cake (PKC)

**Table 2. Proximate composition, calculated nutrients and cost of three experimental diets ($T_0$ (control) = fishmeal; $T_1$ = caterpillar + fishmeal; $T_2$ = caterpillar meal).**

| Proximate composition | $T_0$ | $T_1$ | $T_2$ |
|---|---|---|---|
| Calculate Crude protein (%) dry matter) | 32.97 | 32.87 | 32.54 |
| Calculate Gross energy (kJ/g) | 16.7 | 16.75 | 16.44 |
| Cost of diets per kg (US$) | 0.85 | 0.72 | 0.58 |
| Chemical analysis (g $kg^{-1}$ DM) | | | |
| Dry matter (DM) | 85.57±0.6 | 86.75±2.02 | 87.96±0.32 |
| Crude protein (CP) | 20.18±0.49 $^a$ | 24.06±0.72 $^b$ | 26.65±0.67 $^b$ |
| Crude lipid (CL) | 10.28±0.84 | 9.24±0.64 | 11.47±0.33 |
| Fiber content (%) | 1.57 | 1.92 | 1.82±0.01 |
| Ash | 10.92±6.96 | 12.79±2.67 | 3.69±2.21 |
| NFE | 42.62 | 38.74 | 44.33 |
| Gross energy (kJ $g^{-1}$) | 18.93 | 18.63 | 20.86 |
| Minerals | | | |
| Ca (%) | 7 | 7 | 7.4 |
| Fe (mg/Kg) | 232±2 | 230±1 | 227 |
| K (%) | 0.47±0.01 | 0.41±0.01 | 0.41 |
| Mg (%) | 0.13. | 0.13 | 0.12. |
| Na (%) | 0.51±0.02. | 0.49 | 3.49±2.6 |
| P (%) | 4.20 ±0.01 | 3.95±0.01 | 3.99±0.01 |

NFE: nitrogen-free extract = 100 − (%) (Moisture content + crude protein + crude lipid + ash + fiber).

to Bligh and Dyer (1959). Ash was determined by combusting dry samples in a muffle furnace at 550 °C for 6 h. Chemical analyses were done in triplicates, and the values were reported on % dry matter basis. Gross energy values were calculated based on 23.64, 39.54 and 17.57 (KJ g-1) for protein, lipid, and carbohydrate, respectively (NRC 2011).Mineral composition was analyzed using Philips PU9200Xatomic absorption spectrophotometer after dry ashing (550° C during 4 h) and nitric acid (1.4 N) digestion (Wolf et al., 2003).]

**Experimental procedures**

**Feeding rate and frequency:** The juvenile fish were handfed daily rations of 5% of their body weight for ten weeks, three times daily (0800hrs, 1200hrs; 1700hrs). After 2 weeks, the ration was adjusted after determination of weight gain. The weight of the fish was measured and recorded every two weeks using a sensitive weighing balance. With the same frequency, the total numbers of survivors in each hapa net were counted and fish biomass determined. Any dead fish were removed immediately. After 70 days, the total number and biomass of survivors in each hapa net were recorded.

**Growth performance and Feed Efficiency**

The effects of diets on fish growth were determined by calculating the following growth and nutrient utilization indices: weight gain (WG), specific growth rate (SGR), condition factor(K), survival ratio (SR), feed conversion ratio (FCR)and protein efficiency ratio (PER).The following formulas were used:

$$\mathbf{WG = Final\ mean\ fish\ weight1 - Initial\ mean\ fish\ weight} \ldots$$

$$\mathbf{SGR}\ \% = \frac{\mathbf{Lnmean\ final\ body\ weight - Ln\ mean\ initial\ body\ weight}}{\mathbf{Time}} \boldsymbol{x100} \ldots$$

$$\mathbf{K = 100}\boldsymbol{x}\ \left(\frac{\mathbf{Weight}}{\mathbf{Length^3}}\right)$$

Feed conversion ratio (FCR): This refers to the weight gain in fish due to increase in feed taken

$$\mathbf{FCR}\ \% = \frac{\mathbf{Fish\ feed\ given}}{\mathbf{Body\ weight\ gain}} \ldots$$

$$\mathbf{Protein\ efficiency\ ratio(PER)} = \frac{\mathbf{body\ weight\ gain}}{\mathbf{protein\ intake}}$$

Where protein intake per fish is the total feed given multiplied by the % crude protein in feed, Effiong et al., (2009) were calculated at the end of the experiment.

Survival rate

$$\%\ (\mathbf{SR}) = \frac{\mathbf{Number\ of\ initial\ fish - Number\ of\ harvested\ fish}}{\boldsymbol{N}\mathbf{umber\ ofinitialfish}} \boldsymbol{x100}$$

**Body composition analysis**

Before the onset of the experiment, a sample of 5 fish was taken randomly for initial whole body composition analysis. At the end of the feeding trial, five fish randomly taken from each hapa net (n=10 fish/treatment) were stored in plastic bags, and frozen (-20 °C) for final whole body composition analysis.

**Feed cost determination**

The following economic indicators were used to determine the cost of different feed formulations according to Bahnasawy et al., (2003)

$$\textbf{Incidence cost} = \frac{\textbf{cost of feed}}{\textbf{quantity of fish produced (Kg)}}$$

$$\textbf{Profit index} = \frac{\textbf{local market value of fish}}{\textbf{Cost of feed}}$$

The underlying assumption is that all operating costs are constant and the cost of ingredient was the only variable cost.

**Statistical analysis**

All data were subjected to a one-way analysis of variance (ANOVA) at a 95% confidence limit using SPSS software, version 12 (SPSS Inc., Chicago, IL, USA). Where the F-ratio was significant (i.e. $p<0.05$), treatment means were separated using Duncan's multiple test. The results were considered statistically significant when p-values were less than 0.05.

**Results**

**Growth performance**

The summary of the growth performance parameters is shown in Table 3.The highest final mean weight, weight gain, and SGR were obtained with diets $T_0$ and $T_1$ but growth response declined with diet $T_2$wherecaterpillar protein exceeded 15%. There were no significant differences ($p>0.05$) between diets $T_0$ and $T_1$ on all growth performance parameters. Significant differences ($p<0.05$) were observed between diets $T_0$ and $T_2$and also between diets $T_1$ and $T_2$with respect to growth performance parameters(final mean weight, weight gain, and SGR).The same trend was recorded with condition factor (K) where $T_2$ value was significantly lower than $T_0$ and $T_{1.}$ Diet $T_2$ recorded the highest survival rate, but there were no significant differences ($p<0.05$) in survival rates among the diets.

**Feed utilization**

The results of feed utilization in the form of the feed conversion ratio (FCR) and the protein efficiency ratio (PER) are also represented in Table 2. The best value for the FCR (4.53) was recorded on fish fed with diet $T_1$ whereas the highest PER value of 1.03 was recorded on fish fed with diet$T_{0.}$ However there were no significant differences between these diets with respect to these parameters. The highest FCR (10.63) value and the lowest PER (0.36) value were recorded with diet $T_{2.}$ Diet $T_2$ was significantly different ($p< 0.05$) from diets $T_0$ and $T_1$.

**Fish carcass composition**

The summary of the whole carcass composition of the Nile tilapia fed with different test diets is presented in Table 4. All the diets had an average of about 75% moisture content and there were no significant differences among fish taking different test diets. The protein content for fish from diet $T_2$ (54.75%) was the highest among the diets, while fish on diet $T_0$ (46.68%), had the lowest protein content. There were significant differences ($p < 0.05$) between diets $T_0$and $T_1$on protein content. The highest whole carcass lipid level was observed in fish fed with diet, $T_0$ (20.95%), which was significantly greater ($p< 0.05$) than the lipid content of the fish on diet $T_2$ (17.92%). Although the ash content varied with different experimental diets .The ash content of fish fed with diet $T_0$ was the highest (3.85), whilst the fish fed with diet $T_2$ recorded the lowest percentage of whole carcass ash (2.81). There were no significant differences ($p> 0.05$) among the experimental diets with respect to this parameter. Diet $T_2$recorded the highest values of minerals carcass composition, but there were no significant differences among the diets ($p> 0.05$).

**Table 3. Growth performance, feed utilization parameters and economic analysis of O. niloticus fed the experimental diets$T_0$ (control) = fishmeal; $T_1$ = caterpillar + fishmeal; $T_2$ = caterpillar meal).**

| | Diets | | |
|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ |
| Initial weight (g) | 12.79±0.33 | 11.78±0.12 | 12.83±0.74 |
| Final weight (g) | 29.73±0.3 $^{a}$ | 27.36±0.54 $^{a}$ | 18.66±0.1.13 $^{b}$ |
| Weight gain (g) | 15.27±0.7$^{a}$ | 14.68±0.39$^{a}$ | 5.06±0.82$^{b}$ |
| SGR (%/day) | 1.20±0.02$^{a}$ | 1.20±0.03$^{a}$ | 0.54±0.04$^{b}$ |
| K | 1.54±0.01 $^{a}$ | 1.56±0.04 $^{a}$ | 1.26±0.11 $^{b}$ |
| Feed Intake (g/fish/day) | 1.05±0.01$^{a}$ | 0.95±0.03$^{a}$ | 0.76±0.04$^{b}$ |
| FCR | 4.81±0.16$^{b}$ | 4.53±0.04$^{b}$ | 10.63±1.19$^{a}$ |
| PER | 1.03±0.03 $^{b}$ | 0.92±0.01 $^{b}$ | 0.36±0.04 $^{a}$ |
| SR (%) | 88.57±4.04 | 92.86±2.02 | 94.29 |
| Incidence cost | 4.09 $^{a}$ | 3.26 $^{a}$ | 6.17 $^{b}$ |
| Profit Index | 1.22 $^{a}$ | 1.53 $^{a}$ | 1.82 $^{b}$ |

N.B. Values in the table represent are means ± standard deviation. Values in each row with the same superscript are not significantly different from each other ($p> 0.05$).

**Table 4. Body composition of *O. niloticus* fed the experimental diets$T_0$ (control) = fishmeal; $T_1$= caterpillar + fishmeal; $T_2$ = caterpillar meal).**

| Proximate composition | Initial | $T_0$ | $T_1$ | $T_2$ |
|---|---|---|---|---|
| Moisture (%) | 73.76 ± 2.1 | 74.43 ±0.23 | 75.47 ±1.64 | 75.7 ± 0.04 |
| Protein (%) | 62.84 ± 0.73 $^{a}$ | 46.68±1.81 $^{b}$ | 52.39±0.77 $^{b}$ | 54.75± 4.31 $^{ab}$ |
| Lipid (%) | 1.94 ± 0.98$^{a}$ | 20.95 ± 4.87$^{b}$ | 18.28 ± 3.15 $^{b}$ | 17.92 ± 5.90$^{c}$ |
| Fiber (%) | 1.93±0.01 | 1.95±0.04 | 1.86±0.01 | 1.87±0.05 |
| Ash content (%) | 5.95$^{a}$ | 3.85 ± 0.80$^{b}$ | 3.70 ± 1.26$^{b}$ | 2.81 ± 0.15$^{b}$ |
| Minerals (g/100g) | | | | |
| Ca | 67±0.1 | 65.31±0.02 | 64.73±0.01 | 66.23±0.03 |
| Fe | 22.867±1.53 | 5.78±0.02 | 5.44±0.01 | 5.91±0.01 |
| K | 420±0.1 | 391.66±0.02. | 390.25±0.03 | 392.7±0.01 |
| Mg | 13±0.01 | 27.33±0.02 | 26.25±0.02 | 28.1±0.01 |
| Na | 47±0.01 | 25.8±0.01 | 22.88±0.01 | 26.15±0.04 |

N.B. Values in the table represent mean ± SE. Values in each row with the same superscript are not significantly different from each other ($p> 0.05$).

## Economic analysis of diets

The economic analysis experiment showed that diet $T_1$ was more profitable than diets $T_0$ and $T_2$ and it also has a lower incidence cost compared to the two others diets (Table 5).

**Table 5. Economic analysis of experimental diets ($T_0$ (control) = fishmeal; $T_1$ = caterpillar +fishmeal; $T_2$ = caterpillar meal).**

| Parameter | $T_0$ | $T_1$ | $T_2$ |
|---|---|---|---|
| Incidence cost | 4.09 | 3.26 | 6.17 |
| Profit Index | 1.22 | 1.53 | 1.82 |

## Discussion

This study constitutes the first investigation on the potentialities of replacing fish meal with caterpillar meal in practical diets for Tilapia, *O. niloticus*. Water quality parameters measured in the present study were within the optimum ranges required for survival and growth of *O. niloticus*. The main water quality parameters for optimal growth and survival of *O. niloticus* are temperature ranging from 25.0 to 30.0 °C; dissolved oxygen 4.0–8.0 mg/L; and pH 6.5–9.0 (Shahabuddin et al., 2012). Although pH was slightly low (6.0 to 6.2), the levels recorded are not worrisome because *O. niloticus* can successfully survive, grow and tolerate a pH range of between 4.00 and 11.00 (El-Sayed, 2006; Bombardellia et al., 2017). Therefore, any variation in fish growth performance or feed efficiency in the present study could not be attributed to water-quality effects.

No significant differences were found between treatments $T_0$ and$T_1$ with respect to growth performance, feed utilization parameters and economic analysis. Diet $T_2$ was significantly different from diet $T_0$ and $T_1$ on growth performance, feed utilization and economic analysis. The comparability in growth performance, survival rates and condition factors between *O. niloticus* fed with diets $T_0$ and $T_1$ is attributed to the relatively similar nutrient composition of these two diets when compared to diet $T_2$. Diet $T_0$had protein of higher biological value and a high content of lipid whereas diet $T_1$ had comparatively higher protein proportion. This differs from most of the studies that have used insects as part of fish diet ingredients (Rapatsa and Moyo 2017, Okangola et al*;* 2016, Foua Bi et al; 2015).

The SGR obtained in the present study for diets $T_0$ and $T_1$are in conformity with the results reported by Abdel-Tawwab et al., (2015) and Younis et al.; (2017) who used diets containing 35 % and 32 % crude protein respectively to fed Nile tilapia (*O. niloticus*) for a duration of 12 weeks. Imorou et al. (2007) also reported similar results for Juvenile *Clarias gariepinus* fed with a diet containing 34% crude protein for 10 weeks at a density of 6 fish $m^{-3}$. Specific Growth Rates for diets $T_0$ and $T_1$werecomparatively higher than that of diet $T_2$.This was attributed to the better feed consumption and nutrient digestibility of diets $T_0$ and $T_1$ which contained a proportion of fish meal when compared to diet $T_2$ which had only caterpillar meal.

In this study, the specific growth rate of *O. niloticus* decreased with higher caterpillar meal inclusion levels. This is in agreement with most previous studies where insect meals replaced fishmeal. In most of these studies, growth of fish declined at 25% fishmeal replacement (Sanchez-Muros et al., 2014; Alegbeleye et al., 2012), the probable reason of the decline in fish growth at high insect meal replacement levels has been attributed to chitin. Chitin is not hydrolyzed in the intestinal tract of most fish because of the absence of the relevant enzyme, chitinase. So the probable high level of chitin in $T_2$ could have a negative effect on nutrient digestibility. The decreased specific growth rate can also be explained by the dietary amino acid imbalances Gan et al., (2016) and high fiber level limiting nutrient bioavailability (Novoa-Olvera et al., 2002).

Increase in fiber content could impair the transit time of intestinal contents and thus reduce the protein and energy digestibility (Shiau, 1989; Hertrampf and Piedad-Pascual, 2000; Imorou et al., (2008)). However, the fiber content in the present study was not significantly different among our diets but it was comparatively lower than the values obtained from the following studies (Ogello et al., 2011; Ngugi et al., 2017; Kock et al., 2017).Furthermore the lower level of SGR in tilapia from the present study, suggests that all diets had an imbalance in amino acid level.

Data from the present study showed that survival rates (SR) were not significantly different in all the treatments. The percentage survival rates for *O. niloticus* fed with diets $T_0$ and $T_1$ were 88.57% and 92.86% respectively. Similar results were also reported by Charo-Karisa et al., (2006) who recorded survival rates of 87.7 % and 89.3 % for *O. niloticus* fed on a 40% protein pelleted diets in hapas. The results of the present study are also in conformity with the study by Imotou et al., (2008) who recorded survival rates of 85.7-92.4 % for juvenile Vundu catfish in tanks fed with a diet containing 34% crude protein. The survival rates obtained in this study are higher than those reported by Ogello et al., (2017); who recorded survival rates of (70.4 to 87.4%). However survival rates obtained in the present study were comparatively lower than the values obtained by Imorou et al., (2007) who recorded a 100 % survival rate for juvenile *Clarias gariepinus* fed with a diet containing 34% crude protein. The higher SR recorded in the present study could be attributed to the absence of stressful factors during the experimental period.

The values of the condition factor "K" recorded in the present study for $T_0$ and $T_1$ are 1.54 and 1.56 respectively. The results are conformity with the study by Limbu et al., (2016) who recorded the K values of 1.85 and 1.89 for *O. niloticus* fed with mixed ingredients (MI) and rice bran alone (RB), respectively. Opiyo et al., (2014) also recorded the condition factor values of 1.69–1.70 for *O. niloticus* fed on a commercial diet. The length-weight relationship is an important tool that provides information on growth patterns of fishes (Ighwela et al., 2011). The fact that the mean condition coefficient (K) was above 1 (1.45) suggests good fish health condition and further confirms an isometric growth pattern, which is desirable on fish farms (Ayode, 2011; Kembenya et al., 2014).

The feed intake and feed conversion efficiency obtained for diets $T_0$ and $T_1$ are statistically comparable, but significantly different from diet $T_2$. However, all our values were higher than the values obtained by Abdel-Tawwab et al. (2015), but the feed intake was comparable with the values reported by Rapatsa and Moyo (2017).The FCR value for diet $T_1$ (4.53) obtained in the present study is much higher than the value reported by Ogello et al., (2017) for *O. niloticus* fed with a diet containing 25% sunflower seed meal as a replacement for fish meal. The FCR value for diet $T_1$ is also much higher than the value recorded by Younis et al. (2017) for *O. niloticus* fed with a diet supplemented with red algae, *Gracilaria arcuate*. The FCR results showed that the consumption of our diets was higher than the growth of fish; it suggests very bad feed utilization. The differences in FCR values from the present study and the aforementioned studies may be attributed to the differences in feed sources (such as the complexity of carbohydrate source), environmental conditions and the particular strain of the species used Hemre et al., (2002) and Guimaraes et al., (2008). In addition the lack of the incorporation of fish or vegetable oil, minerals, and vitamin premixes to improve the nutritional quality of our diets can also explain the poor FCR recorded in this study (NRC, 2011).

Proximate body composition means the determination of the water, protein, fat and ash content of the fish and this is considered as a good indicator of its physiological condition and health (Saliu et al., 2007). Fish fed with diets $T_0$and $T_1$had a lower proximate protein composition than fish fed with diet $T_2$.. However fish fed with diets $T_0$and $T_1$had an increased PER when compared to fish fed with diet $T_2$. The increased PER in fish fed with diets $T_0$ and $T_1$can be due to the fact that fishmeal has a higher biological value and a well-balanced amino acid profile (NRC 2011). That can also be explained by the fact that diet $T_2$ had only caterpillar and plant proteins. Drew et al., (2007) pointed out that, digestion of plant materials by fish resulted in lower PER because most plant materials had lower crude protein levels and are used as sources of energy in the form of carbohydrates. The PER obtained in this study are lower than the values reported by Younis et al., (2017), who fed juvenile Nile tilapia with red algae, *Gracilaria arcuate* instead of fishmeal. Rapatsa and Moyo (2017) also reported a higher PER than those reported in the present study when they substituted fish meal with 10, 20, 40 and 60% mopane worm(*Imbrasia belina*) meal on *O. mossambicus* (PER= 2.53, 2.54, 2.74 and 2.80)

There were no significant differences in the carcass content of Nile tilapia among the experimental diets with respect to ash content, moisture content and minerals .In the present study, fish fed with diet $T_0$ accumulated higher lipid content in the body. The lipid content in fish fed with diet $T_2$ was lower when compared to fish fed with diets $T_0$ and diet $T_1$.The results of fish lipid content reported in this study were generally in accordance with the findings of Younis et al., (2017). The values of minerals recorded in the present study were lower than the values reported by (Imorouet al., (2008)).This was most likely because no mineral premix was added in our experimental diets. In general the reduced growth performance and body minerals composition of tilapia in the present study can be attributed to the fact that efficient utilization of diets may vary even within a single species because of the particular strain of fish, the environmental factors and season (Guimaraes et al., 2008).Oil, minerals, and vitamin premixes have to be added to improve the nutritional quality of the experimental diets.

The economic analysis of this study indicated that there is a potential for higher economic returns when diet $T_1$ is used to feed *O. niloticus* instead of diet $T_0$, considering the fact that, fish meal is not only expensive but it is also becoming less available (Van Huis et al., 2013). The present study suggests that, diet $T_1$ can act as a good replacement for diet $T_0$. Reducing the quantity of fishmeal incorporated in fish feed will result in the increased economic return. Hence further researches must be done in different conditions.

In conclusion, it has been shown that the caterpillar meal could be incorporated into Nile tilapia diets instead of fish meal by less than 30%. The preliminary economic analysis suggests that more profit may be realized when $T_1$ is used. This study is a preliminary study, future studies are needed in order to optimize the level of caterpillar meal in the diets of Nile tilapia. Optimizing the level of caterpillar meal may result in improved growth performance. Hence the authors recommend further studies on the digestibility of the experimental diets, as this was beyond the scope of the current study.

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