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# LYSINE REQUIREMENT FOR DIFFERENT STRAINS OF TILAPIA *OREOCHROMIS TANGANICAE*

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## ABSTRACT

The optimal dietary Lysine (Lys) levels for two strains of juvenile *Oreochromis tanganicae*, an important component of fish nutrition for growth and maintenance, was studied. Both a Lake Tanganyika strain (T-strain) and a locally bred strain from the Misamfu Research Centre (MRC-strain) in Zambia were used to determine the lysine (Lys) requirements that maximized growth and survival. A factorial experimental design was used, incorporating two factors: three dietary Lys levels (1.13, 1.30, and 1.64% of the feed and the control designated as diet zero with no lysine inclusion) and the two different fish strains. Juvenile fish (50grams) from each strain were assigned to these diets and fed accordingly over a period of 60 days. This allowed for the assessment of the individual and interactive effects of Lys levels and fish strain on growth and health parameters. Various growth performance metrics, including final body weight, weight gain, specific growth rate, feed conversion ratio, and survival rate, were measured. Body composition analysis was done to understand the impact of dietary Lys on the fish's physiological makeup. The varying dietary Lys levels did not have a statistically significant effect on the growth parameters or survival rates of either fish strain. This suggests that within the range tested, Lys was not the limiting factor for growth. However, there was significantly lower ash content in the MRC strain group that fed the lowest Lys level. This difference, while potentially influenced by overall diet composition, warrants further investigation to understand its implications for bone mineralization and overall fish health. Although not statistically significant ($P \geq 0.05$), a slight improvement in growth performance was noted in the groups fed the highest level of dietary Lys. While this trend did not reach statistical significance within the study's power, it suggests that higher Lys levels *might* offer a marginal benefit, especially if the experimental duration were longer or the number of replicates larger. By understanding the Lys requirements, aquaculture producers can formulate more efficient and cost-effective feeds, potentially leading to reduced production costs and increased overall aquaculture productivity.

**Key words**: Dietary Lysine, Fish Growth, *Oreochromis tanganicae*, Strain,Tilapia, Zambia

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## INTRODUCTION

Lysine (Lys), an essential AA, has an important role in various biological functions, including increasing weight gain [1], nitrogen retention [2] and reducing body fat content of fish [3]. Research has focused on improving the nutritional quality of feed for tilapia fingerlings. Studies have underscored the importance of incorporating nutritional enhancers, such as free AA and fatty acids, to enhance feed utilization [4]. This trend is likely driven by the natural advancements in Nile tilapia farming methods. The World Bank [5] projected that global tilapia production will reach 7.3 million tonnes by 2030, an increase from the 4.3 million tonnes reported in 2010, fueled by sustainable management, optimal resource utilization, innovative farming techniques, and improved feeding practices [6]. As a result, the growth, reproduction, and health of tilapia are being enhanced through genetic selection with breeding programs and precise nutritional strategies. However, these requirements can be challenging for tilapia production, including issues related to food security, food safety, feed ingredient shortages, disease prevention, and environmental conservation.

With tilapia farming, optimizing growth performance and supporting fish health through precise amino acid (AA) nutrition is beneficial. Numerous studies have shown that a deficiency in one essential AA (EAA), particularly methionine, can lead to a decline in several physiological functions, affecting growth performance [6,7,8]. Amino acid regulate protein synthesis [9,10] and energy metabolism in Nile tilapia, *Oreochromis niloticus* [11]. Thus, the objective of enhancing feed utilization, lowering feeding expenses, and minimizing nitrogen emissions into the environment can be dealt with by supplying feed that meets their optimal AA needs. Fish muscle tissue is rich in Lys, an EAA important for growth and necessary for the transport of long-chain fatty acids into the mitochondria, where these fatty acids are used for energy [12]. However, plant-based protein sources, frequently used in fish diets, often lack sufficient Lys [13,14]. To optimize the performance of fish predominantly consuming plant-based diets, it is important to incorporate an appropriate amount of Lys into their feed.

Despite tilapia being the second most farmed fish globally, there is a paucity of research regarding the specific Lys requirements of various tilapia strains [15]. This knowledge gap extends to native tilapia strains in Zambia (*Oreochromis tanganicae*), a species within the Cichlidae family, a diverse group of freshwater fish. Phylogenetic studies have classified it within the Oreochromis species, which includes other tilapiine cichlids that are typically compared to Nile tilapia [16]. Therefore, this study sought to determine the optimal Lys requirement for indigenous *Oreochromis tanganicae*. The hypotheses were predicated on the assumption that the Lys requirement for *Oreochromis tanganicae*, in terms of growth responses, would be the same across all the dietary Lys levels evaluated.

## MATERIALS AND METHODS

### Study Site

The research was done within the premises of Kapasa Makasa University, situated in Mulakupikwa Village, Chinsali District, Muchinga Province, Zambia. This location is classified as part of agro-ecological region 3 in Zambia. The region experiences average temperatures ranging from 23 to 25°C throughout the growing season, with a maximum temperature of 32°C and a minimum temperature of 10°C. The area is characterized by deep, well-drained soils that are conducive to fish farming.

### Experimental Design and Facility

The experiment was done using hapa nets 1.8 × 2.5 ×1.4 m (8.75 $m^3$) inserted in concrete ponds, of size 2 × 3 × 1.5 m or simply 9 $m^3$ using a completely randomized 3 × 2 factorial design. Hapa nets inserted were slightly smaller than the concrete ponds to allow for easy placement, and water circulation. In the present study, there were two independent variables, the first independent variable was the two strains of *Oreochromis tanganicae* (Tanganyika Strain – T. and the Misamfu Research Centre's MRC Strain) and the second independent variable was the dietary supplemented Lys levels of 1.13, 1.30 and 1.64%, respectively, of the final feed weight. The Lys content of the other dietary ingredients was not determined. There were two equal treatments done three times. Each treatment was administered thrice, resulting in 18 experimental units (hapas). The experiment consisted of 18 hapas of shed net material made of polyethylene, each measuring 60 cm in length, 30 cm in width and 40 cm in height. The hapas were placed in miniature (outdoor) in 18 separate concrete ponds. Water quality parameters were measured using a handheld probe, LAQUA-PD210 (Laqua Horiba Instrument, Singapore). Every day at 12 p.m. (approximately 4 h after morning feeding), the water temperature, dissolved oxygen (DO), and pH were monitored in the ponds to ensure that these variables were still within acceptable range.

### Experimental Diet and Feeding

All diets were made to meet the protein and energy needs for tilapia as described by Mahbub *et al.* [17]. The solid parts of the four test meals (maize bran, rice bran, fish waste, salt, L-methionine, L-Lys, cassava flour, sunflower oil, mineral premix, vitamin premix, and l-glutamic acid) were crashed to powder and sieved to be smaller than 750 µm. The ingredients were then mixed for 20 min using a Henan Lima Feed Mixer, manufactured by Henan Lima Machinery Manufacture Co., Ltd. purchased by Kapasa Makasa University. Hot water, making up 30-45% of the mix, was added to form a dough. This dough was shaped using a Professional Pasta Machine (Henan Lima Feed Machine). The shaped pellets were dried at 60°C for 4-6 h. A total of 8 kg of each diet was made, with a size of 1.5 mm in diameter and 2 mm in length. The diets were packed in labeled zipper bags and kept at -20°C for 7 days before the experiment started. The fish were fed 5% of their body weight three times a day (8-9 a.m., 12-1 p.m. and 3-4 p.m.). The amount of feed given to each hapa net was recorded daily. Uneaten feed was removed 30 minutes after each feeding, collected, labeled, and stored separately at −20°C. At the end of the experiment, all collected uneaten feed was dried and weighed to determine how much was eaten each day. During the trial, the number of fish that died and their weight were checked daily. The test meal is shown in Table 1. The experimental diets were made specifically for this experiment. The composition of the feeds is shown in Table 1.

**Experimental Fish**

A total of 324 mixed sex fingerlings of *Oreochromis tanganicae* were acquired by Kapasa Makasa University from the Minsamfu Research Center. This included 162 juveniles of the Misamfu strain (MRC) and 162 juveniles of the Tanganyika strain of approximately 10 g (6 weeks). Before being placed in hapas, these juveniles were subjected to an acclimation phase. In the first one week, the fish were fed a commercial tilapia meal from Aller Aqua before start of experiment to ensure the fish does not starve during acclimatization period before the experiment and in the second week of the experiment, they were fed a formulated feed/diet. The fish were not fed on the day before the experiment began. Instead, they were gathered into a hapa and randomly distributed among the experimental hapas. Each hapa contained 20 fishes. This suggests that the stocking density was 0.04 kg/m$^2$. The original average weights were the same for every hapa. The experiment began when the fish were placed in the hapas.

**Sample Collection and Analyses**

Sampling was done at the beginning, at week 2, and at the end of the experiment (week 4). During sampling the fish were anaesthetized using clove oil to ensure fish is not stressed during handling (40-60 mg/L) prior to weighing and then allowed to recover in their allocated hapa following weighing. Each dead fish observed within 48 h of the start of the experiment was replaced. After 48 h, each dead fish was recorded, and the dead body visually inspected to determine any possible signs of disease. On the day of sampling, the fish were not fed and were anesthetized with clove oil before being weighed. After weighing, they were returned to their designated hapa to recover. At the end of the experiment (4 weeks), fish from each hapa were killed using an overdose of clove oil (400-500 mg/L). During this process,

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four to five fish from each hapa were randomly selected for the measurement of weight and length.

**Proximate Composition Analysis**

The whole-body proximate composition of fish, including moisture, crude protein, crude fat, among others was determined following standard procedures outlined by the Association of Official Analytical Chemists (AOAC, 1998). Moisture content was assessed using the oven-drying method. Approximately 5 g of fresh minced fish sample, of sizes 3 mm was weighed into pre-dried crucibles and dried at 105°C for 3 h until a constant weight was attained. Crude protein content was determined using the Kjeldahl method. About 0.5 g of dried, minced fish samples was then digested in a Kjeldahl flask with 6 mL sulfuric acid, 3.5 mL hydrogen peroxide, and a catalyst mixture of copper sulfate and potassium sulfate, heated at 370°C for 4 h until a clear digest was obtained. After cooling, the digest was neutralized with 25 mL of 40% NaOH, diluted, and distilled into a flask containing 25 mL boric acid with methyl red indicator. The distillate was titrated using 0.1 N HCl to determine nitrogen content using a 6.25 Kjeldahl factor. Crude fat was extracted using a semi-continuous Soxhlet extraction method. Roughly 2 g of dried fish sample was placed in a cellulose thimble and extracted with 50 mL of diethyl ether at 55°C for 3 h. The solvent was evaporated and the remaining lipid was quantified gravimetrically.

**Data Analysis**

Growth parameters were determined using the following formula:

- ❖ Weight gain (g) = final body weight (g) − initial body weight (g) [How was this corrected for mortality?]
- ❖ Feed conversion ratio (FCR) = (feed Intake (Dry Mass) (g))/ (Weight Gain (g)) [again how was mortality considered]
- ❖ Specific Growth Rate  SGR = ([Ln (final Body Weight (g) – Ln (initial Body Weight (g)])/ (days of experiment) x100

**Note:** Ln = natural logarithm

- ❖ Survival Rate (SR, %) = ((number of fish harvested))/ ((number of fish stocked)) x 100

**Data Analysis**

All analyses were done using MS Excel (Microsoft, Redman, WA, USA [2019]) and R-Software version 4.4.1 (R core team, 2023). Growth parameters and fish total body proximate composition were evaluated using a two-way analysis of variance (ANOVA) to assess the effects of dietary Lys on fish growth parameters and their interactions. Because no significant differences were observed among the data (P <

0.05), the Tukey HSD test was not applied for mean comparisons, as there were no significant main effects or interactions (P < 0.05).

## RESULTS AND DISCUSSION

### Growth performance of *Oreochromis tanganicae*

This study compared the growth performance of two *O. tanganicae* strains (MRC and Tanganyika strain) at different supplemental dietary Lys levels, concentrating on characteristics such as final body weight (FBW), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), and survival rate (SR). Final body weight and weight gain showed no statistically significant differences attributable to either fish strain (P = 0.495), dietary Lys levels (P = 0.289), or the interaction between strain and Lys level (P = 0.999). These results suggest that Lys was not a limiting factor.

Similarly, the FCR and SGR showed no statistically significant differences (P ≥ 0.05). Strain did not significantly impact FCR (P = 0.41) or SGR (P = 0.166). Dietary Lys levels did not significantly influence FCR (P = 0.21) or SGR (P = 0.83). There was no significant interaction between strain and dietary Lys level on either FCR (P = 0.99) or SGR (P = 0.63). The absence of significant differences in FCR and SGR suggested that the efficiency with which the fish converted feed into biomass and relative growth rate were not significantly affected by either strain or dietary Lys level. These results suggested that the basal diets even at the lowest Lys inclusion level likely provided sufficient Lys to support optimal growth and feed utilization. It also implies that other factors, such as the availability of other EAA, energy content of the diet, or environmental conditions, may have been more influential. While a slight numerical improvement in growth was observed at the highest Lys level, its lack of statistical significance underscores the need for further research, potentially with a wider range of Lys levels or a longer experimental duration.

### Survival Rate

The results show that neither the strain (P = 0.58), dietary lysine level (P = 0.18), nor the interaction between them (P = 0.94) had a statistically significant effect on survival rate. In other words, survival was unaffected by these factors (Table 2).

The body composition data shown in Table 3 showed that ash content in the MCR strain is significantly affected by dietary Lys levels, increasing as Lys increases, which may indicate changes in mineral content or metabolic adjustments. In contrast, the T-strain shows no significant differences in ash content across Lys levels. Other measured parameters (DM, E.E, CP) do not show statistically significant differences among treatments in either strain, suggesting that varying dietary Lys levels within the tested range have minimal effect on these chemical composition aspects. No significant differences were obtained for the dry matter content of all the treatments ($P \geq 0.05$). The ash content of the T1 group was significantly lower than that of the other experimental groups ($P < 0.05$). No significant differences ($P \geq 0.05$) were obtained for lipids or crude protein.

The current research assessed the growth performance of the native tilapia species, *Oreochromis tanganyicae,* where the fed diets contained varying levels of Lys. Initially, the average body weight of the fish was 9.3 g, while the final body weight reached 38.8 g/fish with 1.64% Lys, followed by 37.5 g/fish with 1.30% Lys. The lowest weight was obtained with 1.13% Lys at 33.4 g/fish. Table 2 shows data on the growth rate and feed utilization of the fish throughout the study. The results did not align with those of Rodrigues *et al.* [4] and Valente *et al.* [18], who reported that Lysine (Lys) is the most important essential amino acid (EAA) in the feed and tissues of tilapia across various production stages.

These results are consistent with Michelato *et al*. [19], who discovered that dietary Lys levels of 29.4-21.0 kg yielded optimal growth performance, suggesting improved growth in *Macrobrachium rosenbergii* culture in terms of WG, SGR, and FCR over a 60-day experiment. Similar outcomes were observed by Watanabe *et al.* [20], who reported that Lys supplementation up to 2.05% increased the growth rate, while also improving the feed efficiency of tilapia. This effect may be attributed to Lys' role in promoting muscle growth by rapidly increasing the size and length of muscle fibers through hyperplasia and hypertrophy [21,22]. Consequently, the supplemental Lys requirement for juvenile fish in this study was determined to be 1.64% indicated by a P-value of 0.495 ($P > 0.05$), suggesting no significant difference between the strains across the tested Lys levels. The FCR values for the fish were $2.2 \pm 0.4$ for the MCR strain and $1.8 \pm 0.3$ for the T-strain, consistent with studies evaluating FCR for tilapia raised in tanks, which typically range from 1.2 to 2.0 for extruded feed [22]. Analysis of the chemical composition (Table 3) of the experimental fish showed that while dry matter and ash content in the whole body were not significantly affected by the different dietary treatments, there was a noticeable increase in the percentage of protein and fat in the fish body across all treatment groups over the 42-day experimental period.

This general increase in percentage of protein and fat content reflects the normal growth and development of juvenile fish as they accumulate tissue mass. These results align with previous research, such as the study by the National Research Council of the USA [12], which also reported that dietary Lys levels had minimal impact on the protein and ash content of the fish body. This consistency suggests that within the range of Lys levels tested, the fish were able to deposit protein and fat effectively, regardless of the specific Lys inclusion. Survival rates observed during the study were relatively high, ranging from 70 ± 5% at the lowest dietary Lys level (1.13%) to 82 ± 6% at the highest level (1.64%). Although there was a numerical trend towards higher survival with increasing dietary Lys, these differences were not statistically significant (as implied by the previous growth analysis which included survival). The high overall survival rates across all treatment groups are likely attributable to the optimal water quality parameters maintained throughout the experiment. As highlighted by studies such as those in references [22] and [25], maintaining stable and suitable environmental conditions is important for supporting robust fish growth and survival. The consistent and favorable water quality in this study likely minimized environmental stressors, allowing the fish to thrive regardless of the specific dietary Lys level within the tested range. The lack of significant differences in survival across the different Lys levels further supports the notion that all experimental diets provide adequate nutritional support for survival with these favorable environmental conditions [21]. This underscores the importance of considering both nutritional factors and environmental management for successful aquaculture outcomes.

## CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The present study found that variations in dietary Lys levels and fish strain (T-strain and MRC -strain) did not significantly affect growth parameters, such as final body weight, weight gain, FCR, SGR, or SR. Both strains exhibited comparable performance across different Lys levels, with an estimated supplemental dietary Lys requirement for optimal growth and nutrient utilization of 1.64%. This estimate is statistically justified by the analysis, as indicated by a P-value of 0.495 ($P > 0.05$), suggesting no significant difference between the strains across the tested Lys levels. These results underscore the importance of strain-specific and life-stage considerations in formulating diets for optimal fish growth and supporting sustainable aquaculture practices in Zambia's aquaculture industry.

Given the short duration of the research but the increased growth of the fish strains was observed, further research is required to ascertain the growth responses up to the maturity stage. This would help understand whether this species is appropriate for adoption for use in aquacultural systems and under what conditions.

## ACKNOWLEDGEMENTS

We deeply appreciate the commitment of all those who generously dedicated their time and effort to this experiment, putting aside other obligations to ensure success. Our heartfelt thanks go to Kapasa Makasa University for providing the essential facilities that made it possible to undertake this nutrient requirement study in the Muchinga Province, Zambia.

## AUTHOR CONTRIBUTIONS

Authors: Data collection, manuscript writing, and data analysis.

All the authors have read and agreed to the published version of the manuscript.

## DATA ACCESSIBILITY

The data used in this study are available upon request.

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**Table 1: Composition of Experimental Diets (% Dry Matter Basis)**

| **Ingredient item** | **Diet 0 (%)** | **Diet 1 (%)** | **Diet 2 (%)** | **Diet 3 (%)** |
|---|---|---|---|---|
| Rice Bran | 20.29 | 20.29 | 20.29 | 20.29 |
| Sunflower cake | 27.57 | 27.57 | 27.57 | 27.57 |
| Maize Bran | 20.29 | 20.29 | 20.29 | 20.29 |
| Fish Trash | 27.04 | 27.04 | 27.00 | 27.00 |
| L-Methionine | 0.33 | 0.33 | 0.33 | 0.33 |
| Sunflower Oil | 1.25 | 1.25 | 1.25 | 1.25 |
| Mineral Premix | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin Premix | 0.30 | 0.30 | 0.30 | 0.30 |
| L-Glutamic Acid | 2.15 | 1.64 | 1.30 | 1.13 |
| L-Lysine | 0.0 | 1.13 | 1.30 | 1.64 |
| Salt | 0.30 | 0.30 | 0.30 | 0.30 |
| **Total** | **100** | **100** | **100** | **100** |
| | | | | |
| DM% | 70.05 | 70.05 | 70.02 | 70.05 |
| Ash% | 5.36 | 5.36 | 5.37 | 5.37 |
| GE MJ/kg | 13.35 | 13.35 | 13.33 | 13.35 |
| DE MJ/kg | 8.47 | 8.47 | 8.45 | 8.46 |
| CP% | 22.96 | 22.96 | 22.82 | 22.90 |
| Dig CP% | 21.29 | 21.29 | 21.15 | 21.24 |
| Lipid% | 4.40 | 4.40 | 4.41 | 4.41 |
| Fibre% | 9.86 | 9.86 | 9.88 | 9.86 |
| LOA (18:2n-6)% | 1.21 | 1.22 | 1.23 | 1.22 |
| LNA (18:3n-3)% | 0.03 | 0.03 | 0.03 | 0.03 |
| ARA (20:4n-6)% | 0.00 | 0.00 | 0.00 | 0.00 |
| EPA (20:5n-3)% | 0.01 | 0.01 | 0.01 | 0.01 |
| DHA (22:6n-3)% | 0.06 | 0.06 | 0.06 | 0.06 |
| Total phospholipid% | 0.62 | 0.62 | 0.62 | 0.62 |


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| | | | | |
|---|---|---|---|---|
| Cholesterol% | 10.34 | 10.36 | 10.39 | 10.40 |
| Astaxanthin (mg/kg) | 0.00 | 0.00 | 0.00 | 0.00 |
| Arginine% | 2.16 | 2.16 | 2.17 | 2.16 |
| Histidine% | 0.54 | 0.54 | 0.54 | 0.54 |
| Isoleucine% | 0.82 | 0.82 | 0.82 | 0.82 |
| Leucine% | 1.54 | 1.54 | 1.54 | 1.54 |
| Lysine% | 2.01 | 2.01 | 2.16 | 2.44 |
| Methionine% | 0.82 | 0.82 | 0.82 | 0.82 |
| Phenylalanine% | 0.93 | 0.93 | 0.93 | 0.93 |
| Threonine% | 0.79 | 0.79 | 0.80 | 0.79 |
| Tryptophan% | 0.25 | 0.25 | 0.25 | 0.25 |
| Valine% | 1.00 | 1.00 | 1.00 | 1.00 |
| Available P% | 0.73 | 0.73 | 0.73 | 0.73 |
| COST/kg | 0.54234 | 0.56245 | 0.562831 | 0.561876 |

*Ingredient items of the experimental diets: Diet 0 (%), Diet 1 (%), Diet 2 (%), and Diet 3 (%); Rice bran – RB, Sunflower cake – SFC, Maize bran – MB, Fish trash – FT, L-Methionine – L-Met Sunflower oil – SFO, Mineral premix – Min Premix, Vitamin premix – Vitamix, L-Glutamic acid – L-Glu, L-Lysine Salt – L-Lys or L-Lys DM: Dry Matter, Ash: Ash (Mineral Content) , GE: Gross Energy (MJ/kg) , DE: Digestible Energy (MJ/kg) , CP: Crude Protein Dig CP: Digestible Crude Protein Lipid: Lipid (Fat Content) , Fibre: Crude Fibre, LOA: Length Overall, LNA: Linolenic Acid (Omega-3 Fatty Acid) , ARA: Arachidonic Acid (Arachidonic Acid) EPA: Eicosapentaenoic Acid (EPA, Omega-3 Fatty Acid), DHA: Docosahexaenoic Acid (DHA, Omega-3 Fatty Acid) Proximate values are obtained from International Aquaculture Feed Formulation Database [IAFFD], 2023)* [22] *of the ingredients used in formulating the diets*


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**Table 2: Growth Performance Parameters of the Two *O. tanganicae* Strains**

| Dietary Lysine | Strain | Initial Weight (g) | FBW (g) | FCR | SR | SGR | WG (g) |
|---|---|---|---|---|---|---|---|
| Lys 1.13 | MCR | 9.5 ± 0.3 | 34± 2 | 1.9 ± 0.5 | 69 ± 7 | 2.0 ± 0.1 | 25 ± 2 |
| Lys 1.30 | MCR | 8.9 ± 0.1 | 38 ± 5 | 2.2 ± 0.4 | 74.1 ± 4.9 | 2.3 ± 0.2 | 29.3 ± 5.4 |
| Lys 1.64 | MCR | 9.2 ± 0.2 | 40 ± 3 | 2.5 ± 0.4 | 79.9 ± 9.4 | 2.3 ± 0.2 | 30.7 ± 3.6 |
| Lys 1.13 | T-Strain | 9.5 ± 0.3 | 32 ± 2 | 1.8 ± 0.1 | 72.3 ± 3.1 | 1.9 ± 0.2 | 22.9 ± 2.7 |
| Lys 1.30 | T-Strain | 9.5 ± 0.2 | 37± 2 | 1.8 ± 0.4 | 74.4 ± 4.6 | 2.2 ± 0.1 | 27.3 ± 1.9 |
| Ly 1.64 | T-Strain | 9.3 ± 0.3 | 38 ± 5 | 1.7 ± 0.2 | 83.7 ± 3.5 | 2.2 ± 0.2 | 28.5 ± 4.6 |
| Dietary Lysine | | | | | | | |
| Lys 1.13 | | 9.5 ± 0.3 | 33.4 ± 2.2 | 1.9 ± 0.3 | 70.4 ± 4.8 | 2.0 ± 0.1 | 23.9 ± 2.2 |
| Lys 1.30 | | 9.2 ± 0.2 | 37.5 ± 3.7 | 2.0 ± 0.4 | 74.3 ± 4.3 | 2.2 ± 0.2 | 28.3 ± 3.7 |
| Lys 1.64 | | 9.3 ± 0.2 | 38.8 ± 3.8 | 2.1 ± 0.4 | 81.8 ± 6.5 | 2.3 ± 0.2 | 29.6 ± 3.8 |
| Fish Strain | | | | | | | |
| MCR-Strain | | 9.2 ± 0.2 | 37.5 ± 3.7 | 2.2 ± 0.4 | 74.1 ± 6.9 | 2.2 ± 0.2 | 28.3 ± 3.7 |
| T-Strain | | 9.4 ± 0.2 | 35.6 ± 3.2 | 1.8 ± 0.3 | 76.8 ± 4.5 | 2.1 ± 0.2 | 26.2 ± 3.2 |
| Two-way ANOVA | | | | | | | |
| Fish Strain | | NS | NS | NS | NS | NS | NS |
| Dietary Lysine | | NS | NS | NS | NS | NS | NS |
| Interaction | | NS | NS | NS | NS | NS | NS |

*Two-way analysis of variance (ANOVA) at P < 0.05. FBW: Final Body Weight, WG: Weight Gain, FCR: Feed Conversion Ratio, SGR: Specific Growth Rate, SR: Survival Rate. Values are presented as mean ± standard error of the mean (SEM). NS: Non-Significant; T-strain: Lake Tanganyika strain, MCR-strain: Misamfu Research Centre strain*

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**Table 3: Chemical Analysis of MCR and T-Strain Fed Different Dietary Lysine Levels**

**MCR-Strain**

| Test | Lys 1.13 | Lys 1.30 | Lys 1.64 |
|---|---|---|---|
| DM (%) | 45.0±0.3 | 48.2±2.6 | 46.1±2.3 |
| ASH (%) | 11.2[c]±0.1 | 15.8[a]±0.4 | 16.8[a]±0.6 |
| E.E (%) | 16.4±0.03 | 16.5±0.7 | 16.8±0.7 |
| CP (%) | 63±3 | 62.6±2.4 | 60.2±2.2 |

**T-Strain**

| Test | Lys 1.13 | Lys 1.30 | Lys 1.64 |
|---|---|---|---|
| DM (%) | 45.1±0.3 | 42.1±2.3 | 41.9±1.6 |
| ASH (%) | 15.3±0.2 | 15.7±0.3 | 16.8±0.5 |
| E.E (%) | 16.4±0.04 | 16.5±0.6 | 16.6±0.7 |
| CP (%) | 62.3±3 | 61.7±2.3 | 61.1±2.2 |

*Numbers with different letters indicate significant difference (P>0.05), i.e., ASH (%)*

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