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Original article

Influence of *Moringa*-Enriched Diets on Proximate Composition of Fish Muscle and Feed Formulation

Aml Younes*[1], Basit Abdullah[2], Sultana Hussien[3]

[1]Department of Animal Production, Faculty of Agriculture, Omar Al-Mokhtar University, El-Beida, Libya
[2]Agriculture Research Center, El-Beida, Libya
[3]Department of Food Science Technology, Faculty of Agriculture, Omar Al-Mokhtar University, El-Beida, Libya
Corresponding authors. amal.alhamary@omu.edu.ly

Abstract
This study aimed to evaluate the effect of dietary inclusion of *Moringa oleifera* at two levels (30% and 50%) on the proximate chemical composition of fish muscle and experimental diets. A total of three groups were investigated: a control group and two treatment groups fed diets supplemented with Moringa at 30% and 50%, respectively. Proximate analysis included protein, fat, moisture, ash, carbohydrates (in fish muscle), and fiber (in diets). The results revealed that the proximate composition of fish muscle showed no statistically significant differences among groups ($P > 0.05$). Protein content slightly increased from 18.63 ± 1.95% in the control group to 19.32 ± 0.67% and 20.96 ± 0.42% in the Moringa 30% and 50% groups, respectively. Fat content decreased from 7.67 ± 1.35% (control) to 4.86 ± 0.19% and 4.96 ± 0.92% in treated groups. Moisture content remained relatively stable (71.27 ± 0.12%, 71.45 ± 0.24%, and 70.87 ± 0.26%), while ash content showed slight variation (2.11 ± 0.35%, 3.49 ± 0.50%, and 2.71 ± 0.55%). Carbohydrate levels were low across all groups, ranging from 0.50 ± 0.10% to 0.79 ± 0.09%. In contrast, the proximate composition of the experimental diets exhibited highly significant differences ($P < 0.001$). Protein content decreased from 30.12 ± 0.49% in the control diet to 22.02 ± 0.09% and 21.25 ± 0.15% in Moringa 30% and 50% diets, respectively. Fat content increased markedly from 2.70 ± 0.03% to 25.43 ± 0.17% and 35.41 ± 0.32%. Moisture content decreased from 10.50 ± 0.11% to 8.78 ± 0.02% and 6.86 ± 0.06%, while ash content declined from 6.28 ± 0.04% to 3.51 ± 0.06% and 3.96 ± 0.02%. Fiber content increased significantly from 3.63 ± 0.01% (control) to 4.38 ± 0.01% and 4.19 ± 0.014% in the treated diets. In conclusion, the inclusion of *Moringa oleifera* at 30% and 50% levels significantly altered the nutritional composition of the diets, particularly increasing fat and fiber while reducing protein and moisture content. However, these dietary changes did not significantly affect the proximate composition of fish muscle. These findings suggest that Moringa can be incorporated into fish diets without adverse effects on muscle nutritional quality, despite notable modifications in feed composition.
Keywords: *Moringa oleifera*, Proximate Composition, Fish Muscle, Experimental Diets, Substitution.

Introduction
Fish represent a vital source of high-quality animal protein, essential fatty acids, vitamins, and minerals, making them a key component of human nutrition and food security worldwide. The proximate composition of fish muscle, including protein, fat, moisture, and ash content, is an important indicator of its nutritional value and is influenced by several factors such as diet composition, environmental conditions, and feeding strategies [1]. Improving fish diet formulation is therefore essential to enhance both growth performance and the nutritional quality of fish products.
In recent years, there has been growing interest in the use of natural plant-based additives in aquaculture nutrition as sustainable alternatives to conventional feed ingredients. Among these, *Moringa oleifera* has gained considerable attention due to its rich nutritional profile, including high levels of protein, vitamins, minerals, and bioactive compounds such as flavonoids and phenolics [2]. These compounds are known for their antioxidant properties and potential to improve metabolic efficiency in animals. The inclusion of *Moringa oleifera* in fish diets has been reported to influence feed composition and may subsequently affect the biochemical and nutritional characteristics of fish muscle.
Previous studies have demonstrated that Moringa supplementation can enhance protein content and reduce lipid accumulation in some fish species, although the effects may vary depending on inclusion level and species-specific responses [3-10]. Additionally, Moringa leaves are considered a cost-effective and locally available feed resource, especially in developing countries, making them a promising candidate for sustainable aquaculture practices. Despite these promising attributes, there is still limited information regarding the impact of higher inclusion levels of Moringa (such as 30% and 50%) on both the proximate composition of fish muscle and the nutritional quality of formulated diets [11-20]. Therefore, this study aims to evaluate the effect of different levels of *Moringa oleifera* inclusion on the proximate chemical composition of fish muscle and experimental diets, with particular emphasis on protein, fat, moisture, ash, and carbohydrate content.

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Materials and methods

Experimental Design

This study was conducted to evaluate the effect of dietary inclusion of *Moringa oleifera* on the proximate chemical composition of Nile tilapia (*Oreochromis niloticus*) muscle and experimental diets. Fish were randomly assigned to three experimental groups: a control group fed a basal diet without Moringa supplementation, and two treatment groups fed diets containing 30% and 50% *Moringa oleifera*, respectively. All fish were maintained under similar environmental and management conditions throughout the experimental period.

Study Area

The experiment was carried out at the Department of Animal Production, Faculty of Agriculture, Omar Al-Mukhtar University, Libya.

Diet Preparation

Experimental diets were formulated by incorporating *Moringa oleifera* leaf powder at inclusion levels of 0% (control), 30%, and 50%. The feed ingredients were finely ground, thoroughly mixed to ensure uniform distribution, and prepared in a form suitable for tilapia feeding. The diets were stored under clean and dry conditions until use.

Fish and Feeding Regimen

Nile tilapia (*Oreochromis niloticus*) were obtained from a local source and acclimatized prior to the experiment. Fish were fed their respective diets at regular intervals throughout the experimental period. Feeding management and environmental conditions were kept consistent across all groups.

Sample Collection

At the end of the experimental period, fish were randomly sampled from each group. Muscle tissues were carefully excised, washed with distilled water, and prepared for proximate analysis. Samples of the experimental diets were also collected for chemical evaluation. The proximate composition of fish muscle and experimental diets was determined according to the standard methods of the Association of Official Analytical Chemists (AOAC, 2016). Crude protein was determined using the Kjeldahl method, crude fat by Soxhlet extraction, moisture by oven drying at 105°C until constant weight, and ash by incineration at 550°C in a muffle furnace. Carbohydrate content in fish muscle was calculated by difference, while crude fiber in diets was determined using standard methods.

Statistical Analysis

All data were expressed as mean ± standard deviation (Mean ± SD). Statistical analysis was performed using one-way analysis of variance (ANOVA). Differences among groups were considered significant at $P < 0.05$.

Results

The data presented in Table (1) indicate that the inclusion of *Moringa oleifera* at levels of 30% and 50% did not result in significant differences ($P > 0.05$) in the proximate chemical composition of Nile tilapia muscle. Protein content showed a gradual increase from 18.63 ± 1.95% in the control group to 19.32 ± 0.67% and 20.96 ± 0.42% in the Moringa 30% and 50% groups, respectively ($P = 0.434$). Fat content decreased from 7.67 ± 1.35% in the control group to 4.86 ± 0.19% and 4.96 ± 0.92% in the treated groups ($P = 0.138$). Moisture content remained relatively constant, with values of 71.27 ± 0.12% (control), 71.45 ± 0.24% (Moringa 30%), and 70.87 ± 0.26% (Moringa 50%) ($P = 0.234$). Ash content ranged between 2.11 ± 0.35% and 3.49 ± 0.50%, while carbohydrate content varied from 0.50 ± 0.10% to 0.79 ± 0.09%, with no significant differences observed ($P = 0.21$ and 0.252, respectively).

Table 1. Effect of Dietary Moringa oleifera Inclusion Levels on the Proximate Chemical Composition of Nile Tilapia (Oreochromis niloticus) Muscle.

Group	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrates (%)
Control	18.63 ± 1.95^a	7.67 ± 1.35^a	71.27 ± 0.12^a	2.11 ± 0.35^a	0.65 ± 0.14 ^{a}
Moringa 30%	19.32 ± 0.67^a	4.86 ± 0.19^a	71.45 ± 0.24^a	3.49 ± 0.50^a	0.79 ± 0.09^a
Moringa 50%	20.96 ± 0.42^a	4.96 ± 0.92^a	70.87 ± 0.26^a	2.71 ± 0.55^a	0.50 ± 0.10^a
P-Value	0.434	0.138	0.234	0.21	0.252

"Means in the same column with the same superscript letter are not significantly different ($P > 0.05$)."

In contrast, the results in Table (2) demonstrate significant differences ($P < 0.001$) in the proximate composition of the experimental diets among all groups. Protein content decreased significantly from 30.12 ± 0.49% in the control diet to 22.02 ± 0.09% and 21.25 ± 0.15% in the Moringa 30% and 50% diets, respectively. Fat content increased markedly from 2.70 ± 0.03% in the control group to 25.43 ± 0.17% and

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35.41 ± 0.32% in the treated diets. Moisture content decreased progressively from 10.50 ± 0.11% in the control to 8.78 ± 0.02% and 6.86 ± 0.06% in the Moringa 30% and 50% diets, respectively. Ash content declined from 6.28 ± 0.04% to 3.51 ± 0.06% and 3.96 ± 0.02%, while crude fiber content increased from 3.63 ± 0.01% in the control group to 4.38 ± 0.01% and 4.19 ± 0.014% in the treated groups.

Table 2. Proximate Chemical Composition of Experimental Diets Containing Different Levels of *Moringa oleifera*

Group	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Fiber(%)
Control	30.12 ± 0.49[a]	2.70 ± 0.03[c]	10.50 ± 0.11[a]	6.28 ± 0.04[a]	3.63 ± 0.01[c]
Moringa 30%	22.02 ± 0.09[b]	25.43 ± 0.17[a]	8.78 ± 0.02[b]	3.51 ± 0.06[c]	4.38 ± 0.01[a]
Moringa 50%	21.25 ± 0.15[c]	35.41 ± 0.32[b]	6.86 ± 0.06[c]	3.96 ± 0.02[b]	4.19 ± 0.014[b]
P-Value	0.000	0.000	0.000	0.000	0.000

"Means in the same column with the same superscript letter are not significantly different (P > 0.05)."

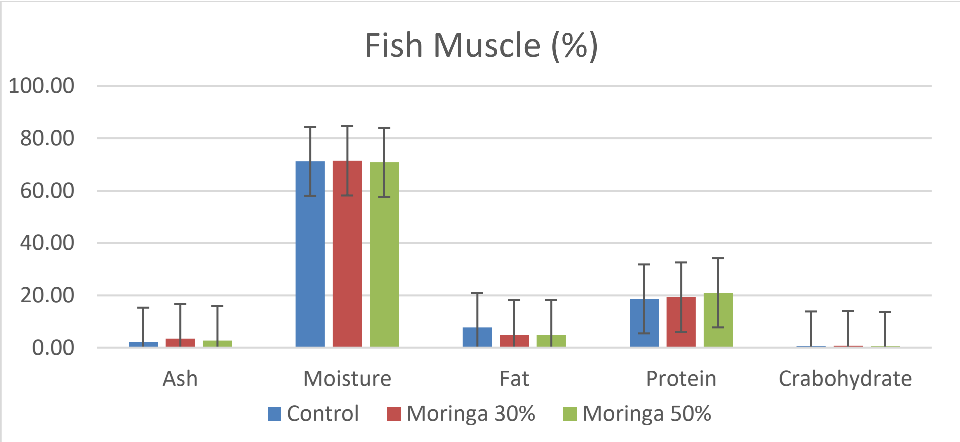

Figure 1. Proximate chemical composition of fish muscle fed with different levels of Moringa (30% and 50%) compared to the control group.

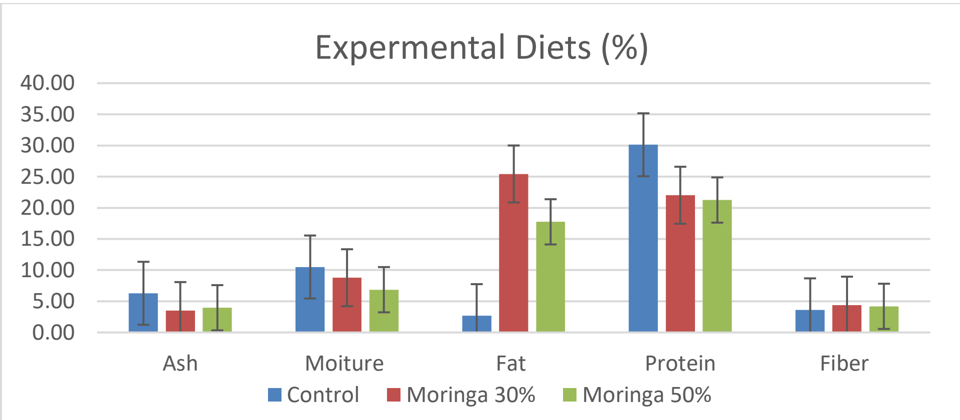

Figure 2. Proximate chemical composition of experimental diets with different levels of Moringa (30% and 50%) compared to the control.

Discussion

The present findings demonstrate that dietary inclusion of *Moringa oleifera* at levels of 30% and 50% did not significantly affect the proximate chemical composition of Nile tilapia muscle. This stability in muscle composition, despite noticeable variations in diet formulation, may reflect the ability of *Oreochromis niloticus* to regulate nutrient utilization and maintain homeostasis in tissue composition. Similar observations have been reported in previous studies, where dietary modifications did not always translate into significant changes in fish muscle composition, particularly when protein and energy requirements were adequately met [21-30]. The slight increase in protein content observed in the Moringa-treated groups, although not statistically significant, may be attributed to the relatively high protein and amino acid content of *Moringa oleifera* leaves.

Moringa is known to contain essential amino acids and bioactive compounds that can enhance nutrient absorption and protein metabolism, which may explain the trend toward improved protein deposition in fish muscle. These findings are consistent with reports suggesting that plant-based feed additives can contribute to improved growth performance and muscle quality in fish [31-40]. The reduction in fat content in the

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Moringa-fed groups, although not significant, may be linked to the presence of bioactive compounds such as flavonoids and phenolics in Moringa, which have been reported to influence lipid metabolism. These compounds may enhance lipid utilization or reduce lipid accumulation in fish tissues, resulting in lower fat deposition. Additionally, the relatively stable moisture content across all groups indicates that dietary Moringa inclusion had minimal impact on water retention and overall muscle structure [41-46].
In contrast, the proximate composition of the experimental diets showed highly significant differences with increasing levels of Moringa inclusion. The observed decrease in protein content in the Moringa-based diets may be due to the replacement of higher-protein conventional feed ingredients with Moringa leaf powder, which, although rich in nutrients, may have lower crude protein concentration compared to formulated feed components. Conversely, the marked increase in fat content in the treated diets may be attributed to the inherent lipid content of Moringa leaves or changes in formulation balance. The increase in crude fiber content in Moringa-supplemented diets is expected, as plant-based materials such as Moringa leaves are known to contain higher fiber levels compared to conventional feed ingredients. This increase in fiber may influence digestibility and nutrient absorption, although Nile tilapia are generally capable of utilizing moderate levels of dietary fiber [47-50]. The decrease in moisture and ash content in the treated diets further reflects compositional changes associated with the inclusion of plant material.
Overall, the results suggest that while *Moringa oleifera* inclusion significantly alters the nutritional profile of formulated diets, these changes do not necessarily translate into significant modifications in fish muscle composition [51,52]. This highlights the adaptability of Nile tilapia to dietary variations and supports the potential use of Moringa as an alternative feed ingredient in aquaculture without compromising muscle quality [53,54].

Conclusion

In conclusion, the inclusion of *Moringa oleifera* at 30% and 50% levels significantly altered the proximate composition of the experimental diets, particularly by decreasing protein and moisture contents and increasing fat and fiber levels. However, these dietary changes did not result in significant differences in the proximate chemical composition of Nile tilapia (*Oreochromis niloticus*) muscle. These findings indicate that Moringa can be incorporated into fish diets at relatively high levels without adversely affecting muscle nutritional quality, supporting its potential as a sustainable alternative feed ingredient in aquaculture.

Conflict of interest. Nil

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