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Effects of Dietary Sesame Oil Supplementation on Growth Performance, Feed Utilization, and Fillet Quality in Nile Tilapia

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Abstract

Sesame oil is an ideal lipid source replacing the fish oil in fish diet thanks to its fatty acid profile and sensory characteristics. This study was conducted to evaluate the impacts of dietary sesame oil supplementation on growth, feed utilization, and fillet quality of Nile tilapia in growth-out stage. The basal feed for tilapia was supplemented with sesame oil at ratios of 0, 10, 20, and 40 g kg^{-1} corresponding to AS0, AS10, AS20, and AS40 treatments. Fish (~80g) were fed to apparent satiation for 6 weeks. Fish were weighed periodically to monitor the growth rate. At the end of the experiment, fish were dissected to collect the fillet and measure the intestinal indicators; the number of fish and amount of consumed feed served to calculate the survival rate, feed conversion ratio, and protein efficiency rate. Fillet samples were then used to analyze the fatty acid composition, chemical composition, physicochemical indicators, and sensory characteristics. The results showed that the highest value of fish growth and feed utilization were found in AS20. The sesame oil levels did not modify the intestinal parameters but changed the hardness and lightness of fish fillet. The sensory parameters including aroma and sweetness were highest in AS20 and AS40. The significant differences were recorded in total lipid and fatty acid level in fish fillet. In conclusion, the supplementation of sesame oil at 20 g kg^{-1} diet brings the benefits in fish growth and fillet quality of Nile tilapia in growth-out stage from 80 to 300 g/fish.

Keywords

Sesame oil, Nile tilapia, fillet quality

Introduction

Nile tilapia (*Oreochromis niloticus*) is an important freshwater fish species that provides a large quantity for global consumption. Previous studies have shown that Nile tilapia can use plant-derived oils replacing fish oil in diet without any negative effects on fish growth, feed efficiency and immune response (Abdelhamid *et al.*,

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2024). The influences were mostly recorded in quality and nutritional composition in fish tissues (Mai *et al.*, 2022).

As the economics fish species, tilapia farming is also facing to many problems such as intensive farming pressures, environmental sustainability, or feed cost concerns. Protein and lipid are key energy sources in aquatic feed, with increasing dietary lipid use for efficient energy conversion. (Fan *et al*., 2021; Meng *et al*., 2023). Most previous studies show that increasing the fat content in fish diets improved growth performance, but very high level of lipid content in fish feed also leads to the negative effects on fish health and flesh quality (Fan *et al.*, 2021; Yoo *et al.*, 2022).

Fish oil is a traditional feed lipid but scarce and costly. Research focuses on alternatives, with terrestrial vegetable oils offering a sustainable, affordable substitute for aquaculture. Among them, sesame oil contains high content of n-6 polyunsaturated fatty acids (PUFA), linoleic acid, reported to have positive effects on muscle quality (Markworth *et al.*, 2018) and fish immune status (Nguyen *et al.*, 2021). In addition, several previous studies also demonstrated that sesame oil contains sesamine, a bioactive compound which has a positive effect on the biosynthesis of highly unsaturated fatty acids (HUFA) (Zajic *et al.*, 2016). Several studies have proven that using sesame oil to replace fish oil did not affect the growth, feed efficiency, and health status of omnivorous fish such as tilapia (Nakharuthai *et al.*, 2020), common carp (Mai *et al.*, 2022; Nguyen *et al.*, 2022). Köse & Yildiz (2013) reported that nutritional quality of the whole fish and liver in rainbow trout, in particular DHA level. However, data on the optimal level of sesame oil in fish and influence of its dietary level on fish flesh quality are still limited. Investigating sesame oil as a fish oil alternative enhances feed sustainability, improves fillet quality, reduces reliance on marine resources, and lowers costs. Compared to soybean oil and sunflower oil, sesame oil is less competitive in price. However, compared to fish oil, it has significant potential to enhance the sensory qualities of aquatic products and improve fish health. Consequently, the current study was conducted to assess the influence of ratio of dietary supplementation of sesame oil on growth performance, feed utilization, and fillet quality in Nile tilapia.

Materials and Methods

Experimental diet

The ingredients in the experimental diets were similar and only differed in the dietary lipid levels. In particular, protein levels ranged from 27.91 to 28.62%; ash levels from 10.95 to 12.31%; fiber levels from 3.78 to 3.94%. The sesame oil was cold-pressed in the laboratory and supplemented in diet at 0, 10, 20, 40 g kg^{-1}, corresponding to AS0, AS10, AS20 and AS40. The fat contents in experimental diets are 3.18; 3.98; 5.89 and 7.86%, respectively. After pelleting, the feed was subjected to quality inspection, packaged, and stored. The feed pellets were characterized as floating pellets with a size of 2mm. The experimental feed were homogenized and the lipids were extracted with chloroform/methanol (2:1, v:v) according to the methods published in by Folch *et al.* (1957). The proportions of important fatty acids in experimental diets are presented in **Table 1**.

Fish

Nile tilapia (~80g) were collected, acclimated for 14 days with commercial feed, and healthy individuals were selected for experimentation.

Experimental design

Healthy fish (77.8-82.0g) were randomly allocated (20 fish/cage, 3 cages/group) in 1m × 1m × 1.2m cages within a pond of 1500m², 2m deep, continuously aerated (1 aerated rocks/m^2). Fish were fed experimental diets (AS0, AS10, AS20, AS40) to satiation twice daily for six weeks. Feed consumption per cage was recorded daily. Fish are weighed every 2 weeks to monitor the growth rate. Environmental parameters such as temperature (28-32°C), pH (7.5-8), O_2 (6.5-8.5 mg L^{-1}), NO_2 (<0.05 mg L^{-1}), and NH_3/NH_4^+ (<0.05 mg L^{-1}) were maintained suitable for Nile tilapia.

Table 1. Nutritional content and fatty acid composition in experimental feed

Variable	Experimental diet			
	AS0	AS10	AS20	AS40
Dried matter	89.98	90.13	90.54	91.01
Protein	27.92	28.62	28.23	27.91
Lipid	3.18	3.98	5.89	7.86
Ash	12.31	11.45	11.21	10.95
Fiber	3.78	3.90	3.89	3.94
Fatty acid				
SFA	48.89	45.31	41.23	37.15
MUFA	32.99	33.85	34.18	34.50
PUFA	18.12	20.84	24.60	28.36
HUFA	0.72	0.87	0.79	0.71
Oleic acid, OA	25.67	26.79	27.98	29.17
Linoleic acid, LA	15.22	17.99	22.14	26.28
α-Linolenic, ALA	1.72	1.46	1.27	1.08
Arachidonic acid, ARA	0.24	0.19	0.17	0.15
Eicosapentaenoic acid, EPA	0.07	0.20	0.13	0.06
Docosahexaenonic acid, DHA	0.12	0.32	0.21	0.10
Σ n-3	2.29	2.33	1.93	1.52
Σ n-6	15.83	18.51	22.68	26.84

Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. The content of biochemical composition and fatty acids were analyzed in experimental feed.

Sample collection and analysis

Sample collection

After six weeks of feeding trial, dorsal muscles were analyzed for fillet quality, and visceral tissues were measured for intestinal indices. For experimental diet, samples were randomly collected from six different points within the same experimental diet. The collected samples were then pooled into a single composite sample for fatty acid analysis.

Fillet physicochemical properties

Shear force (g) was analyzed using food texture analyzer TA-XT plus (USA). Shear force was measured on 3cm × 2cm × 1.5cm fillet samples using Warner-Bratzler probes, ensuring vertical blade alignment with muscle fibers. Samples from each experimental group were treated as replicates.

pH value of fish fillet: fillet samples were stored at 4^{o}C and measured at the time of slaughter according to TCVN 4835:2002 standard. The samples of each experimental group were considered as replicates (n = 9).

Moisture (%) (AOAC 2001.11): The initial moisture of fish fillets was determined by drying the sample at 105°C with infrared rays to a constant weight using a fast moisture analyzer MA 35 Sartorius-Germany.

Drip loss (DL) on thawing was determined based on a method adapted from (Campanone *et al.*, 2002), where DL was expressed as: DL (%) = 100 × (W0 – WF)/WF. Where, W0 is the sample weight before the freezing and WF is the sample weight after thawing. Fillet samples were thawed in a cold room (4°C) for 24h.

Sensory assessment

The sensory assessment was conducted following the method of Hugo *et al.* (2009) and adapted to the tilapia. A 10-member untrained panel (ages 22-38) scored chewiness, fatness, aroma, sweetness, and color (0-4) (**Table 2**) after

Table 2. Scoring scale for sensory indices in experimental fish fillets

Parameters	Score			
	4	3	2	1
Chewiness	very chewy	chewy	less chewy	not chewy
Fatness	very fat	fat	low fat	not fat
Aroma	very aromatic	aromatic	less aromatic	not aromatic
Sweetness	very sweet	sweet	less sweet	not sweet
Color	very white	white	dark	very dark

tasting three cooked fillet samples in a sensory panel room. Tasting of fillet samples was conducted at room temperature in individual booths under red light. Bottled water at room temperature was provided for respondents between samples.

Biochemical composition in fish fillet and experimental feed

Homogenized samples of fish fillet and experimental feed were analyzed for dry matter (DM), crude protein, crude lipid, and ash content were analyzed according to routinely analytical procedures (AOAC 930.15, 920.39, 2009.01, and 942.05, respectively). DM was measured by drying at a temperature of 105°C for 24h, ash content by incineration at a temperature of 550°C for 12h, and crude protein content (N x 6.25) by the Kjeldhal method procedures. Total lipids of the carp muscle content (%) were extracted and quantified using the Soxhlet method with diethyl ether as the extraction solvent. The samples of each experimental treatment (n = 9) were considered as replicates.

Fatty acid analysis

Total lipids were extracted with a mixture of chloroform/methanol/water (2: 2: 1.8; v: v: v) according to a method of Bligh & Dyer (1959) for fish fillets (9 fish per treatments), and chloroform/methanol (2:1, v:v) according to Folch *et al.* (1957) for experimental feed (1 pooled sample per diet), respectively. The extracted lipids were converted to fatty acid methyl esters through methylation and were then separated by gas chromatography (GC) and quantified according to Nguyen *et al.* (2019). Results were expressed as % fatty acids in sample.

Data analysis

The husbandry parameters and intestinal indices were calculated as follows

Daily weight gain (DWG, g/fish/day) = (FBW – IBW)/T

Specific growth rate (SGR, %/fish/day) = 100 × (Ln (FBW) – Ln (IBW))/T

Where FBW, IBW are final and initial body weight, T is numbers of days

Feed conversion ratio (FCR) = Total consumed feed / total fish body weight gain

Weight gain (WG, %) = 100 × (Final body weight – Initial body weight)/Initial body weight

Survival rate (%) = 100 × Final fish numbers/Initial fish numbers

Gastro-somatic index (GaSI, %) = 100 × Gut weight/fish body weight

Visceral somatic index (VSI, %) = 100 × Visceral weight/fish body weight

Hepatosomatic index (HSI, %) = 100 × liver weight/fish body weight

Statistical analysis

Data are expressed as mean ± SD, analyzed with STATISTICA 10.0 software, using one-way ANOVA analysis method and *LSD* tool to compare means between experimental treatments at P <0.05. In which, the number of cages (n = 3) are considered the replicates for husbandry parameters;

and number of samples (n = 9) is considered repetitions for others studied variables.

Results

Husbandry and intestinal parameters

The initial average weights of experimental fish were similar (P >0.05) ranging from 77.8 to 82.0 g/fish; after 6 weeks experiment, there was a clear difference between the treatments (P <0.05). Accordingly, the highest values of FBW and DWG were obtained in fish fed AS40 diet (297.5 ± 8.0 g $fish^{-1}$). The lowest value was found in the control treatment without sesame oil supplementation, AS0 (250.3 ± 4.8 g $fish^{-1}$). However, regarding the values of SGR and WG, the AS20 and AS40 were similar and higher than AS0 (P <0.05).

In the present experiment, FCR values range from 0.9 to 1.0 and these values in sesame oil-supplemented diets were lower than control (**Table 3**, P <0.05); in which, the experimental group fed on the AS20 and AS40 induced the value of FCR lower than AS10. Similar to FCR, protein efficiency ratio (PER) in fish fed sesame oil-supplemented diets were also better than AS0 (P <0.05); among them, the highest value of PER belonged to AS20.

In contrast with husbandry parameters, no significant differences were observed in intestinal indices including VSI, GSI, and GaSI after 6 weeks of feeding trial. These obtained results demonstrated that the supplemented ratios did not influence the fish intestinal morphology (P >0.05).

Physicochemical indicators in fish fillet

The results of physicochemical parameters of experimental fish fillets were shown in the Table 4. The significant differences were recorded in fish fillet shear force and lightness (L) while other parameters were not influenced by dietary supplementation ratios of sesame oil. The shear force reflects the hardness of fish fillet. The results presented in **Table 4** demonstrated that the hardness of experimental fish fillet increased with sesame oil level in diet (P <0.05). However, no differences were found in the hardness between AS20 and AS40 (P >0.05). Similarly, the lightness values of fish fillets were affected by supplemented level of sesame oil in feed diet, increasing from 50.2 (AS0) to 53.0 (AS40).

Sensory indicators in fish fillet

Sensory indices of fish fillets were evaluated through scoring by an evaluation jury and the results were presented in the **Table 5**.

The obtained results showed that the supplemented levels of sesame oil in the diet did

Table 3. Growth, feed utilization, survival rate, and intestinal indices of fish fed the diet supplemented with various ratios of sesame oil for 6 weeks

Variables	Experimental groups			
	AS0	AS10	AS20	AS40
IBW (g $fish^{-1}$)	77.8^{a} ± 1.0	77.8^{a} ± 3.1	82.0^{a} ± 2.4	80.1^{a} ± 5.2
FBW (g $fish^{-1}$)	250.3^{a} ± 14.8	269.0^{b} ± 14.8	285.0^{bc} ± 12.0	297.5^{c} ± 8.1
DWG (g/fish/day)	4.1^{a} ± 0.3	4.5^{ab} ± 0.4	4.8^{bc} ± 0.3	5.1^{c} ± 0.1
SGR (%/fish/day)	2.1^{a} ± 0.1	2.2^{ab} ± 0.2	2.2^{b} ± 0.1	2.3^{b} ± 0.1
WG (%)	222.0^{a} ± 14.5	245.7^{ab} ± 32.9	247.5^{b} ± 24.8	270.3^{b} ± 14.0
FCR	1.015^{c} ± 0.009	0.976^{b} ± 0.000	0.940^{a} ± 0.018	0.937^{a} ± 0.008
PER	3.5^{a} ± 0.0	3.8^{b} ± 0.0	4.0^{c} ± 0.1	3.8^{b} ± 0.0
Survival rate (%)	100	100	100	100
VSI (%)	7.7^{a} ± 2.1	6.6^{a} ± 1.3	6.1^{a} ± 0.3	6.2^{a} ± 1.3
HSI (%)	1.3^{a} ± 0.3	1.7^{a} ± 0.2	1.7^{a} ± 0.4	1.6^{a} ± 0.6
GaSI (%)	3.6^{a} ± 1.1	3.5^{a} ± 1.1	2.7^{a} ± 0.7	3.1^{a} ± 0.4

Note: AS0, AS10, AS20, AS40: experimental diets supplemented with sesame oil at 0, 10, 20, 40 g kg^{-1} of feed. IBW: initial body weight; FBW: final body weight; DWG: daily weight gain; SGR: specific growth rate; WG: weight gain; FCR: feed conversion ratio; PER: protein efficiency ratio; VSI: visceral somatic index, HSI: hepatic somatic index, GaSI: Gastro-somatic index Data was presented as mean ± SD. The values with the same letters denote the non-significant difference (P <0.05).

Table 4. Physicochemical variables in fish fillet after 6 weeks of experiment

Variable	Experimental treatments			
	AS0	AS10	AS20	AS40
Shear force (g)	$2162.1^{a} \pm 110.6$	$2505.9^{b} \pm 178.6$	$2830.1^{c} \pm 139.2$	$2771.0^{c} \pm 194.0$
Moisture (%)	$77.8^{a} \pm 2.3$	$78.6^{a} \pm 0.6$	$76.4^{a} \pm 1.7$	$77.9^{a} \pm 0.9$
pH	$6.5^{a} \pm 0.0$	$6.4^{a} \pm 0.3$	$6.4^{a} \pm 0.1$	$6.5^{a} \pm 0.2$
Color				
L	$50.2^{a} \pm 2.2$	$51.9^{ab} \pm 0.9$	$51.5^{ab} \pm 1.6$	$53.0^{b} \pm 0.5$
a	$-6.0^{a} \pm 1.2$	$-6.2^{a} \pm 1.1$	$-5.6^{a} \pm 0.7$	$-6.3^{a} \pm 0.8$
b	$-2.4^{a} \pm 3.2$	$-3.4^{a} \pm 1.7$	$-3.7^{a} \pm 1.4$	$-2.9^{a} \pm 1.3$
Drip loss (%)	$4.0^{a} \pm 0.5$	$3.8^{a} \pm 0.8$	$3.5^{a} \pm 1.2$	$3.8^{a} \pm 2.4$

Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at 0, 10, 20, 40 g kg^{-1} of feed. Lightness (L): values range from black to white, coding from 0 to 100; redness (a): values range from negative to positive coding from green to red; yellowness (b): values range from negative to positive, coding from blue to yellow. Data was presented as mean ± SD. The values with the same letters denote the non-significant difference (P <0.05).

Table 5. Sensory indices of experimental fish fillet after 6 weeks of rearing

Variables	Experimental treatments			
	AS0	AS10	AS20	AS40
Chewiness	$2.3^{a} \pm 0.3$	$1.9^{a} \pm 0.9$	$2.4^{a} \pm 0.2$	$2.5^{a} \pm 0.3$
Fatness	$2.3^{a} \pm 0.3$	$2.3^{a} \pm 0.9$	$2.5^{a} \pm 0.2$	$2.5^{a} \pm 0.2$
Aroma	$2.3^{a} \pm 0.4$	$2.4^{ab} \pm 0.9$	$2.8^{b} \pm 0.1$	$2.8^{b} \pm 0.1$
Sweetness	$2.3^{a} \pm 0.2$	$2.6^{ab} \pm 1.0$	$3.0^{b} \pm 0.2$	$3.1^{b} \pm 0.2$
Color	$2.8^{a} \pm 0.2$	$2.2^{a} \pm 0.9$	$2.6^{a} \pm 0.2$	$2.9^{a} \pm 0.2$

Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. Data was presented as mean ± SD. The values with the same letters denote the non-significant difference (P <0.05).

not affect the chewiness, fatness, and color. Experimental fillets were less tough (ranging from 1.9 to 2.5), low in fat (2.3 to 2.5), quite aromatic (2.3 to 2.8), slightly sweet to moderately sweet (2.3 to 3.1), and quite white (2.2 to 2.9). The significant difference was found in the aroma and sweetness parameters of fish fillets (P <0.05) and the highest values belonged to the fillets of AS20 and AS40 groups. This shows that dietary supplementation from 20 g kg^{-1} diets of sesame oil has an impact on these two indicators.

Nutritional composition in experimental fish fillet

Most of the chemical composition parameters were similar across treatments, with key differences observed in total lipid content and fatty acid profiles.

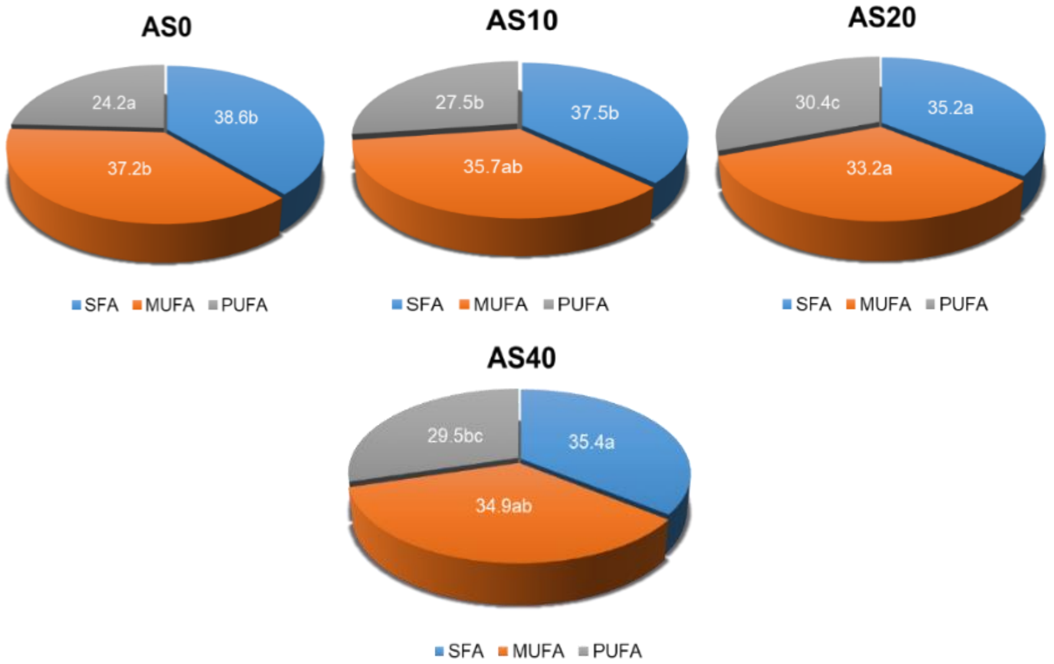
Results on the chemical composition of experimental fish fillets were presented in the **Table 6**. Specifically, crude protein (ranging from 85.0 to 86.1%), dry matter (20.8 to 21.5%), and ash (5.5 to 5.6%) parameters did not differ between experimental groups (P >0.05) despite dietary modifications. The significant impact of dietary level of sesame oil was observed in total lipid content where total lipid content in fillets from the AS40 group was similar to AS20, but both were significantly higher than those in AS0 and AS10 (P <0.05).

The proportion of the main fatty acid groups including saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA) were presented in the **Figure 1**. Specifically, the SFA proportions were higher in AS0 and AS10 compared to AS20 and AS40 (P <0.05).

Table 6. Chemical composition in fillets of fish fed on the experimental diets for weeks

Variables	Experimental groups			
	AS0	AS10	AS20	AS40
Dry matter, %	$20.9^{a} \pm 0.4$	$20.8^{a} \pm 0.5$	$21.0^{a} \pm 0.3$	$21.5^{a} \pm 0.4$
Crude protein, %	$86.7^{a} \pm 2.9$	$86.2^{a} \pm 1.5$	$86.1^{a} \pm 0.6$	$85.0^{a} \pm 2.9$
Total lipid, %	$2.7^{a} \pm 0.6$	$2.4^{a} \pm 0.6$	$3.2^{ab} \pm 0.6$	$4.0^{b} \pm 0.5$
Ash, %	$5.6^{a} \pm 0.2$	$5.5^{a} \pm 0.2$	$5.6^{a} \pm 0.1$	$5.6^{a} \pm 0.1$

Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. Data was presented as mean ± SD. The values with the same letters denote the non-significant difference (P <0.05).



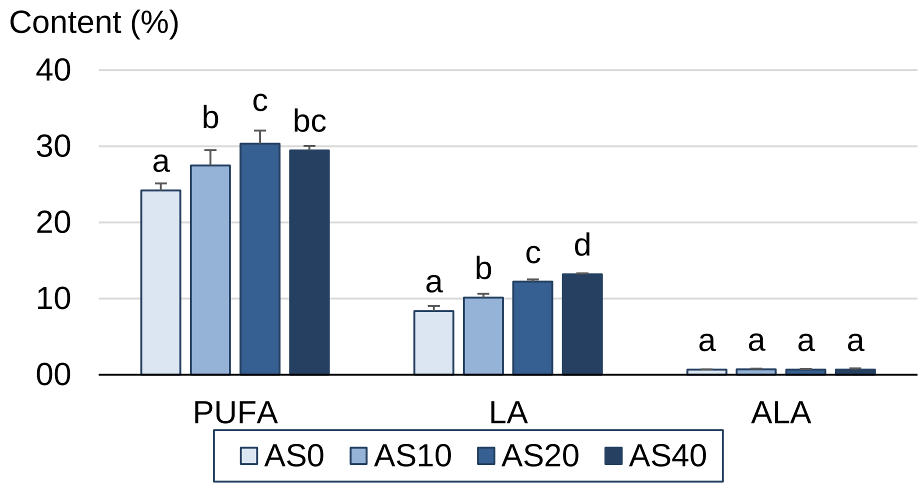
Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. SFA: saturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: Polyunsaturated fatty acid. The values with the same letters in a fatty acid group denote the non-significant difference (P <0.05).

Figure 1. Proportion of main fatty acid groups in fillets of fish fed on the experimental diets for 6 weeks

Similarly, the MUFA proportion in AS0 was higher than AS20. On the other hand, the proportion of the PUFA was recorded highest in AS20 and AS40, following in AS10, and the lowest value was found in AS0.

Regarding the results of important fatty acids in PUFA group measured in fish fillet (**Figure 2**), the contents of linoleic acid (LA) increased with the sesame oil contents supplemented in the diets (*P* <0.05). Expressly, the highest LA content was recorded in AS40 group (13.2%), following in AS20 (12.2%) and AS10 treatments (10.1%), and the lowest value observed in AS0 (8.4%). Unlike LA, the contents of linolenic acid (ALA) were very low and did not differ among experimental groups (*P* >0.05).

Concerning the highly unsaturated fatty acid (HUFA) content (**Figure 3**), fish fed with AS20 contained the higher content of HUFA in fillet (18.1%) than other experimental groups (*P* <0.05). The results of contents of important HUFAs such as arachidonic acid (ARA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) showed that the influence of supplemented ratios of sesame oil in diet was found in ARA and DHA contents. Specifically, the supplementation of sesame oil induced a higher content of ARA in fish fed on



Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. Data was presented as mean ± SD. The values with the same letters in each fatty acid group denote the non-significant difference (P <0.05).

Figure 2. Polyunsaturated fatty acid (PUFA), linoleic (LA), and α-linolenic acid (ALA) in fillets of fish fed on the experimental diets after 6 weeks

the AS20 (4.3%) compared to AS0 (3.3%), and no significant differences were recorded among sesame oil-fed groups. Contrarily, fish fed AS40 diet displayed the lowest content of DHA (2.9%) compared to other treatments (P <0.05).

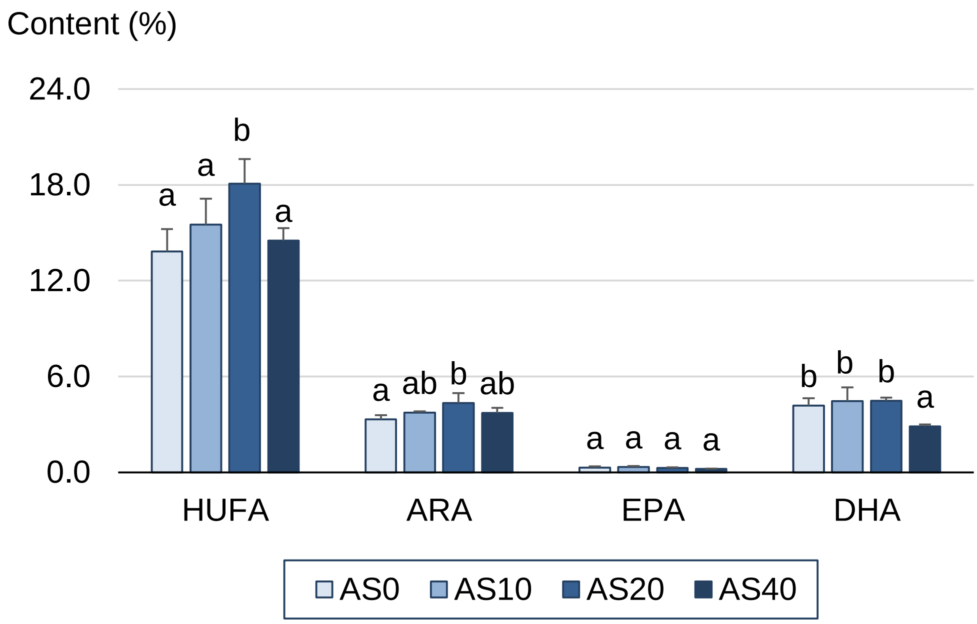
Discussions

Influence of sesame oil supplementation in diet on fish growth, feed utilization, and intestinal indices

Increased levels of sesame oil in the diet led to significant improvements in growth performance, as evidenced by higher final body weight (FBW), daily weight gain (DWG), specific growth rate (SGR), and overall weight gain (WG). In aquaculture feed, lipid is the main energy source. This study examined how varying fat levels, specifically sesame oil, affected fish growth and final weight.. Recent studies have demonstrated that ARA supplementation can influence various physiological functions in fish, including enhancing the availability of circulating glucose and proteins, thereby improving growth performance and feed utilization (Ma *et al.*, 2018). In the present study, sesame oil, which is rich in LA, a precursor of ARA was used, and the tissue composition of fish fed a sesame oil-enriched diet had a high ARA content (Mai *et al.*, 2022). The previous studies demonstrated that the fish get the highest growth rate with the optimal lipid level in diet (Abdel-Ghany *et al.*, 2021; Godoy *et al.*, 2019) suggesting that the sesame oil supplemented at 20 g kg^{-1} diet (AS20 group) was the optimal level in term of fish growth performance. Interestingly, the optimal growth rate in a previous study on tilapia was achieved when corn oil (Abdel-Ghany *et al.*, 2021) and soybean oil (Godoy *et al.*, 2019) were included at higher levels than in this study (85 g kg^{-1} and 30 g kg^{-1}, respectively).

Sesame oil supplementation improved feed utilization. AS20 showed the best FCR and PER, with other supplemented groups outperforming AS0, likely due to efficient sesame oil digestion in Nile tilapia. As other aquatic animals, Nile tilapia can explore the lipid source to convert into the energy more than hydrocarbon source. Previous study demonstrated that Nile tilapia can use the lipid level until 6% in diet in the growth out stage (Godoy *et al.*, 2019). In the current experiment, the optimal level of sesame oil supplementation for feed utilization was 20 g kg^{-1} of diet equivalent to 5.8% total lipid as similar with the results reported in Abdel-Ghany *et al.* (2021).

Sesame oil supplementation did not affect survival or intestinal indices, indicating no adverse health effects. Usually, lipid content of whole-body and hepatopancreas or liver



Note: AS0, AS10, AS20, AS40: diets supplemented with sesame oil at ratios of 0, 10, 20, 40 g kg^{-1} of feed. Data was presented as mean ± SD. The values with the same letters in each fatty acid group denote the non-significant difference (P <0.05).

Figure 3. Highly unsaturated fatty acid (HUFA), arachidonic acid (ARA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) levels in fillets of fish fed on the experimental diets after 6 weeks

increased in fish as dietary lipid levels increased (Zhou *et al.*, 2024). In this study, sesame oil supplementation increased fillet growth without affecting intestinal indices or causing fat accumulation.

Influence of dietary supplementation of sesame oil on fillet nutritional and sensory parameters

The supplementation of sesame oil induced the modifications in lipid level and fatty acid profile, and sensory indicators in Nile tilapia fillet. A diet enriched in linoleic acid in sesame oil may lead to high rates of ARA accumulation in omnivorous fish species such as tilapia (Nguyen *et al.*, 2022; 2020). In the body, ARA is a precursor to synthesize a number of cytokines involved in the immune system as well as other physiological activities including prostaglandins (PG). *In vitro* studies with muscle cells indicate that PGF2α stimulates protein synthesis and the growth of skeletal muscle fiber (De Souza *et al.*, 2016). These arguments explain the higher shear force for fish fillets using AS20 and AS40 feed compared to other experimental groups. Muscle firmness can enhance the value of fish fillets in some markets in the world.

In the current study, muscle color was assessed by brightness (L), redness (a) and yellowness (b). The dietary lipid content affects the absorption, transport, and deposition of pigments in fish cells (Qiufen *et al.*, 2012). Almost of farmed fish species require fat-soluble carotenoids to express body color (Lin *et al.*, 2024). Fish could not synthesize the carotenoids and must absorb them from feed source. Lipid deficiency not only affects the growth performance but also affects the absorption of pigment substances (Borel *et al.*, 2023). Lipid content in the feed of not less than 5% showed good pigment absorption in several fish species such as catfish, eel, loach, and ornamental fish (Qiufen *et al.*, 2012). In the current study, the natural color of muscle fish (redness and yellowness) was not affected by the level of sesame oil supplementation. Research on rainbow trout also found that the yellowness of fish fillet was not affected by the lipid ratio in the feed ranging from 6.6 to 29.4% (Meng *et al.*, 2023). Fillet brightness differed significantly, with AS40 showing the highest due to sesame oil color. As tilapia is white-fleshed, high brightness is desirable for processed products like surimi.

Fatty acid composition of fish tissues reflects that one in the diet (Mai *et al.*, 2022; Nguyen *et al.*, 2021; 2019); however, the supplementation of sesame oil at 20 g kg^{-1} diet induced the proportion of fatty acid groups more equivalent than other treatments, higher value in PUFA, HUFAs, and ARA levels compared to AS0 and AS10. The obtained results may be explained by the bioconversion capacity of PUFA precursors to HUFA in Nile tilapia as the other omnivorous fish (Nguyen *et al.*, 2022). In this case, linoleic acid enriched in sesame oil was converted to ARA. PUFAs and HUFAs are considered the essential mediators for improving and maintaining human health; however, only the cardiac effect has been extensively documented (Sokoła-Wysoczanska *et al.*, 2018). The beneficial effects of n-3 and n-6 HUFA like DHA and ARA were also demonstrated for human health as well as aquatic animals (Nguyen *et al.*, 2023). The highest value of PUFAs and HUFAs were found in AS20-fed fish suggesting that the fillet issue from this treatment may give the positive influence on fish immune response and consumers.

The relationship between lipid composition and fish flesh quality, especially aroma and flavor, is understudied. High fish oil or meal levels cause off-flavors, and dietary lipid sources influence sensory characteristics.. Hugo *et al.* (2009) was also reported that high oleic sunflower seed oil induced the chicken meat more preferred than fish oil-fed ones. Similarly, the flavour of rainbow trout Oncorhynchus mykiss fed the dietary sesame oil was also higher than control (Hematzadeh & Jalali, 2017). The basal diet lacked sesame oil but contained fish meal (5-10% fish oil), enhancing aroma and sweetness in AS20 and AS40 higher than AS0.

Conclusions

In conclusion, sesame oil supplementation did not affect survival or intestinal indices in Nile tilapia but improved growth, feed utilization, and fillet quality. The optimal level was 20 g kg^{-1} diet. These findings support cost-effective, nutritionally enhanced feed formulations, promoting sustainable aquaculture and higher market value. Further research on larger fish (500-800g) is recommended to refine commercial production strategies.

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