Fermentation of Soybean Meal to Improve Diet Formulation for Common Carp *Cyprinus carpio* L.

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Abstract

This investigation aimed to evaluate the chemo-biological fermentation of FSBM for partial substitution of SBM at ratios of (C 0%, T1 15%, T2 25%, and T3 35%) in diets formulated for common carp (*Cyprinus carpio* L.) juveniles. The FSBM contained 51.22% protein and 17 amino acids in varying proportions, including 10 essential amino acids, with Lysine having the highest value of 9.98 µg/100 µg protein. Growth parameters of the experimental fish were monitored for 56 days during which they were fed at 3% of their live body weight. Fish were weighed biweekly to adjust feed ration. Results showed that diet T2 had the highest values for initial weight, final weight, weight gain, relative growth rate, SGR, FCR and PER with values of 14.7 g, 31.4 g, 16.7 g, 113.6 %, 1.355%/day, 1.91 and 1.603 respectively. Control diet (C) achieved the lowest values with rates of 15.1, 25.9, 10.8, 71.5, 0.963, 2.83 and 1.078, respectively, with significant difference ($p \leq 0.05$) in comparison with other treatments. The highest total apparent digestibility coefficient 79.6 % was recorded in treatment T2 (25% supplementation), and the lowest recorded 75.7% with no supplementation treatment (control). The same trend was observed for the digestibility of protein, fat, ash and carbohydrate. From the results of Statistical analysis significant differences ($p \leq 0.05$) were revealed between supplementation treatments (T1, T2, and T3) when compared with control, except for fat and ash digestibility, where all treatments showed non-significant differences ($p \geq 0.05$). The results indicated that FSBM supplemented treatments (T1, T2, and T3) achieved better growth than control, where T2 diet clearly outperforming the other dietary treatments in measured nutrition and growth parameters.

Keywords: Fermented soybean meal, Feed formulation, Fish nutrition, *Cyprinus carpio* L.

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Introduction

The aquaculture sector is one of the fastest-growing sectors of animal production worldwide, with an average yearly growth rate of 10.3%. As the world's population continues to increase and other food sources decrease steadily, aquaculture is important in supplying protein-rich foods to assist in addressing the increasing nutritional demands (FAO, 2020). Aquaculture sustainability is highly reliant on the improvement of the feed production sector, which can represent about 50 – 80 % of the overall costs of fish production (Abdel-Latif *et al*., 2022). The majority of these costs could be attributed to the higher prices and decreasing supplies of fishmeal, which represents the primary feed ingredient in aquaculture diets (Qiu *et al*., 2023). At present, there are limited opportunities to sustainably increase fishmeal production, making its future use economically unfeasible (Al-Noor *et al*., 2023). To formulate commercially viable and nutritionally balanced diets, numerous studies in the fisheries sector have focused on developing the feeding industry through the use of unconventional and inexpensive feeds from alternative low-cost sources, thereby reducing manufacturing costs (Najim and Al-Tameemi, 2023). Plant proteins are considered the best alternatives to fishmeal (Abdul Kari*et al*., 2021). Soybean meal is a good substitute for fishmeal; however, it contains many antinutritional factors such as phytates, saponins, and anti-vitamins, which reduce the animal's ability to digest proteins and carbohydrates (Adeyemo and Onilude, 2013). Therefore, biological, physical or chemical methods should be applied to convert plant proteins into high-value-added nutritional products (Jassim *et al*., 2024). Some studies have indicated that microbial fermentation of plant proteins could improve amino acid availability and bioaccessibility, short-chain fatty acids, bioactive compounds and enzymes, thereby enhancing their nutritional quality (Rhema and Al-Noor, 2022). Fermentation can thus improve feed quality due to the ability of microorganisms to convert raw materials into value-added products or to enhance the nutritional properties, taste, and aroma of feeds (Yaqub *et al*., 2025). Furthermore, fermenting soybean meal promotes the growth of beneficial microorganisms such as *Lactobacillus* in fish intestinal microbiota, improving their ability to utilize feed, increasing the digestibility of otherwise indigestible nutrients, and reducing the toxicity of certain compounds in the diet (Phinyo *et al*., 2024). It also has positive effects against diseases and boosts immune responses, thereby supporting gut health, improving growth, and reducing stress (Siddik *et al*., 2024). Accordingly, the currentinvestigation aimed to evaluate fermented soybean meal as a dietary supplement on some of feeding and growth parameters in juvenile common carp (*Cyprinus carpio*).

Materials And Methods

Soybean Meal

Soybean meal (SBM) was purchased from local markets in Basrah City, Iraq, in a quantity of 10 kg during November 2024. The samples were allocated into polyethylene bags for transport to the Laboratory of Fish Technology, Department of Fisheries and

Marine Resources, at the College of Agriculture, University of Basrah, Iraq, to later testing and analysis.

Fermentation of Soybean Meal

A two-stage fermentation technique was employed. The first stage involved fermenting soybean meal using 30% (w/v) domestic date vinegar (4% acetic acid) with the mother at 37°C for 48 hours (Al-Kanaani, 2014). In the second stage, dry baker's yeast (*Saccharomyces cerevisiae*, of Turkish origin) obtained from local markets in Basrah City was used. The yeast was activated in the laboratory by mixing 3 g of each dry yeast and sugar with added warm water (6 ml), then the mixture was settled for 30 minutes. Subsequently, 40g of primarily fermented soybean meal was mixed with the yeast mixture in a lidded glass container, with a piece of cloth placed around the container's mouth. The mixture was then incubatedfor 48 hours at 28 °C. Fermentation process was terminated using heat at 60°C for 6 hoursin an electric oven. After fermentation termination, sample was oven-dried (105°C), finally ground and stored in plastic containers for subsequent analyses, according to (Chinma *et al*., 2014).

Chemical analysis of SBM and FSBM

Moisture determined by drying 5 g of sample at 105°C until constant weigh. The ash determined by incineration of 2–5 g sample in a muffle furnace at 525°C for 16 h. Crude protein content was determined using the semi-micro Kjeldahl method, applying a conversion factor of 6.25 Lipid content determination was applied using Soxhlet extraction according to the method of (AOAC, 2000).

Estimation of Amino Acids

Amino acid profiles of SBM and FSBM was determined according to Vidotti *et al.* (2003). It was analyzed on an ion exchange column with post-column ninhydrin derivatization, being detected by a Visible-UV Detector -6 Av uv -Spd Shimadzu within an automated system. High-performance liquid chromatography equipment, which was supplied and maintained by the Ministry of Science and Technology in Baghdad, Iraq, was used for this procedure.

Diet Formulation

Feed ingredients used to formulate experimental diets were purchased from local markets in Basrah City, Iraq (Table 1). Upon arrival at the laboratory, the ingredients were finely ground by an electric grinder and sifted through a 2 mm mesh sieve. The proportion of each feed ingredient was then determined, thoroughly mixed for homogeneity, and used to prepare four experimental diets: T1 containing 15% FSBM, T2 containing 25% FSBM, T3 containing 35% FSBM and a control diet (C) without FSBM inclusion. For each 250 g portion of the diet mixture, boiling water (approximately 100 mL) was added and mixed properly. The mixture was then heated (to approximately 80 °C) and permitted to cool gradually before vitamins and minerals were finally added. The resulting dough was mixed thoroughly again and then formed into pellets using a Braun meat mincer fitted with a 4 mm die. The pellets were then dried at ambient temperature for 48 hours in the laboratory with constant rotation to ensure the complete removal of moisture. The dried feed was stored in 1 kg plastic containers and kept refrigerated until use.

Fish and Experimental System

Juveniles of common carp (*Cyprinus carpio* L.) were used in this study. Fish were procured from the fish farm of Aquaculture Unit, College of Agriculture at University of Basrah, Iraq, during December 2024. The average weight of the fish was 14.66 ± 0.21 g. The experimental fish rearing system was designed using a closed recirculating system in the Aquaculture Laboratory belongs to Aquaculture Unit at College of Agriculture, University of Basrah. Upon experiment initiation, fish were distributed at a rate of eight fish per tank. Fish prior acclimation to experimental conditions proceeded for ten days during which they were fed at a standard diet.

Table 1. Experimental diet formulation and proximate analysis.

Ingredients	C	T1	T2	T3
Fish meal	30	28	21	14
SBM	15	0	0	0
FSBM	0	15	25	35
Whole Wheat flour	18	18	18	16
Whole barley flour	18	17	17	17
Wheat bran	17	20	17	16
Premix	2	2	2	2
Chemical analysis (%)				
Moisture	7.13±0.19	7.28±0.22	7.83±0.18	7.78±0.21
Crude protein	32.75±1.23	32.35±1.74	32.65±2.02	32.55±1.88
Crude lipid	6.11±1.48	6.01±1.28	5.98±1.33	5.89± 1.41
Carbohydrate	47.13±2.24	46.95±1.85	45.88±2.19	46.24±2.02
Ash	6.88±0.98	7.41±0.86	7.66±0.94	7.54±1.02
Gross energy (Kcal/100 g)	437.3±19.2	433.4±15.1	430.4±14.7	430.5±13.8

Feeding experiment

Fish growth

Feeding experiment continued for 56 days from January 7, 2025 toMarch5, 2025. During this period, the fish were fed 3% daily ration (of their body weight), divided in two meals (each meal amounting to 1.5% of their body weight) at 8 to 9 AM and 1 to 2 PM. Fish weights were measured every 14 days to adjust daily feed rationwhile 30% of water volume was changed simultaneously. Growth parameters i.e. Total weight gain (TWG) and daily weight gain (DWG) were calculated according to Sevier *et al*. (2000) as follows: TWG (g/fish) = Final weight – Initial weight; DWG (g/fish/day) = TWG / time (day). Relative growth rate (RGR) and specific growth rate (SGR) were calculated as:

RGR (%) = TWG/ Initial wt. × 100

SGR (%/day) = (ln final wt. – ln Initial wt.) / time (day) × 100

Feed conversion ratio (FCR), protein intake (PI) and protein efficiency ratio (PER) were calculated according to Tacon (1990) as follows:

FCR = Consumed feed (g)/ TWG (g) PI (g/fish) = Consumed feed (g) × Feed protein content (%);

PER (%) = TWG/ PI.

Feed apparent digestibility

Apparent total digestibility (TADC) and nutrient apparent digestibility coefficients (NADC) were determined using the indirect method outlined by Talbot (1985), with chromium oxide (Cr_2O_3) as the marker. The marker concentrations in the experimental diets and in the feces of fish collected were assayed spectrophotometrically at an absorbance of 350 nm as follows:

TADC (%) = 100 – [100 × (% marker in feed)/ (%marker in feces)

NADC = 100 – [100 × {(% marker in feed)/ (%marker in feces)}/ {(%marker in feces)/ (%marker in feed)}]

Statistical analysis

The growth trial was laid out in a completely randomized design (CRD) with four treatments, which were replicated three times. The same method was used to analyze all other growth and feeding traits. Differences among treatment means were separated using the least significant difference (LSD) test, and all statistical analyses were carried out using IBM SPSS Statistics version 26.0.

Results

Table (2) presents the chemical composition of raw and fermented soybean meals. Variations in chemical composition were sowed between the studied treatments. As for moisture content, the highest value of 7.97%was recorded for fermented soybean meal, which was appeared significantly higher ($p \leq 0.05$) than 5.89 % value of raw soybean meal. For crude protein, the highest value was observed in fermented soybean meal, with an average of 51.22%, whereasraw soybean meal showed the lowest value of 43.18%. Statistically significant differences ($p \leq 0.05$) were revealed between above levels. Differences in crude fat content were also appeared between raw and fermented soybean meals. Raw soybean meal recorded the highest fat content 2.17%, while the lowest value was found in fermented soybean meal 1.98%. However, these results were statistically non-significant ($p \geq 0.05$). Ash content was similar between raw and fermented soybean meal, with averages of 6.54% and 6.62%, respectively, which were statistically non-significant differences ($p \geq 0.05$). Regarding nitrogen-free extract (NFE), the results indicated that its proportion in raw soybean meal was higher than in fermented soybean meal, with averages of 32.21% and 24.22%, respectively. Statistically significant differences (p≤0.05) were revealed between these results.

Table 2. Proximate analysis of SBM and FSBM

Component	SBM	FSBM
Moisture	$5.89^{a} \pm 1.01$	$7.97^{b} \pm 1.06$
Protein	$43.18^{a} \pm 2.77$	$51.22^{b} \pm 3.28$
Fat	$2.17^{a} \pm 0.16$	$1.98^{a} \pm 0.12$
Ash	$6.54^{a} \pm 1.33$	$6.62^{a} \pm 1.28$
NFE	$42.22^{a} \pm 3.54$	$32.21^{b} \pm 3.10$

*Different superscripts within same row indicate significant differences at P< 0.05

Table 3. Amino acid profiles of SBM and FSBM

Amino acid	SBM	FSBM
Arginine	5.59	5.12
Histidine	2.64	2.45
Isoleucine	3.83	3.97
Leucine	5.66	7.58
Lysine	5.38	9.98
Methionine	1.23	1.21
Phenylalanine	5.78	4.89
Threonine	4.66	4.25
Tryptophan	1.76	2.41
Valine	4.28	4.71
Σ EAA	**40.81**	**46.57**
Σ NEAA	**55.08**	**49.11**

EAA, Essential amino acids; NEAA, Non-essential amino acids.

The results of amino acid compositionsanalyzed using HPLC for SBM and FSBM are presented in Table 3. The results indicated the presence of 10 essential amino acids in a balanced composition. Lysine had the highest value in FSBM, reaching 9.98 µg/100 µg protein, whereas Phenylalanine recorded the highest value in SBM at 5.78 µg/100 µg protein. Methionine was the lowest among the essential amino acids in both FSBM and SBM, with values of 1.21 and 1.23 µg/100 µg protein, respectively. The remaining essential amino acids varied in their proportions and concentrations between raw and fermented soybean meals. Overall, the total essential amino acids in FSBM reached 46.57 µg/100 µg protein, which was higher compared to 40.81 µg/100 µg protein in SBM. Conversely, non-essential amino acids were totaled 55.08 and 49.11 µg/100 µg protein for SBM and FSBM, respectively. The mean values of initial weight (IW, g), final weight (FW, g), weight gain (WG, g), relative growth rate (RGR, %), specific growth rate (SGR, %/day), feed conversion ratio (FCR), and protein efficiency ratio (PER) for common carp juveniles during the growth trial are presented in table 4. Diet T2 recorded the highest values for these parameters, with IW, FW, WG, RGR, SGR, FCR, and PER being 14.7 g, 31.4 g, 16.7 g, 113.6 %, 1.355%/day, 1.91 and 1.603 respectively. Conversely, lowest values were noted in control diet, with corresponding values of 15.1 g, 25.9 g, 10.8 g, 71.5%, 0.963%/day, 2.83, and 1.078, respectively, with significant differences ($p \leq 0.05$) revealed compared to the FSBM supplemented treatments (T1, T2, and T3).Inclusion of FSBMl in diets T1, T2, and T3 led to better growth parameters in comparison with control diet, with T2 showing clear superiority over all other dietary treatments in growth performance parameters.

Table 4. Feeding and growth efficiency parameters of *C. carpio* fish fed experimental diets

Parameter	C	T1	T2	T3
IW (g)	15.1^{a}	14.9^{a}	14.7^{a}	15.2^{a}
FW (g)	25.9^{a}	30.7^{b}	31.4^{b}	30.8^{b}
WG (g)	10.8^{a}	15.8^{b}	16.7^{b}	15.6^{b}
RGR (%)	71.5^{a}	106.0^{b}	113.6^{b}	102.6^{b}
SGR (%/day)	0.963^{a}	1.291^{b}	1.355^{b}	1.261^{b}
FCR	2.83^{a}	2.01^{b}	1.91^{b}	2.06^{b}
PER	1.078^{a}	1.541^{b}	1.603^{b}	1.493^{b}

*Different superscripts within same row indicatesignificant differences at ($p \leq 0.05$)

Total apparent digestibility coefficients and nutrients apparent digestibility in the experimental diets are shown in table 5which reflect FSBM inclusionin common carp diet. The highest total apparent digestibility was recorded in T2 diet (25% inclusion level) at 79.6%, whereas control diet (C, without FSBM) recorded lowest at 75.7%. The apparent digestibility values for diets T1 (15% inclusion) and T3 (35% inclusion) were 78.4% and 78.8%, respectively. Statistically significant differences ($p \leq 0.05$) were revealed between treatments T1, T2, and T3 compared to control (C). Regarding the apparent digestibility of protein, fat, ash, and carbohydrates, treatment T2 showed the highest values, followed by T3, then T1, and finally C. Statistically significant differences ($p \leq 0.05$) were indicated between T1, T2, and T3 compared to C, except for fat and ash digestibility, which revealednon-significant differences ($p \geq 0.05$).

Table 5. Nutrient apparent digestibility coefficients of trial diets

Nutrients	C	T1	T2	T3
Total digestibility	75.7^{a}	78.4^{b}	79.6^{b}	78.8^{b}
Protein	74.4^{a}	78.8^{b}	80.1^{b}	78.9^{b}
Lipid	78.4^{a}	78.2^{a}	79.9^{a}	78.7^{a}
Carbohydrate	71.3^{a}	75.9^{b}	76.8^{b}	76.1^{b}
Ash	78.8^{a}	80.5^{a}	81.4^{a}	81.3^{a}

*Different superscripts within same row indicate significant differences $P< 0.05$

Discussion

Chemical Composition

Variations in chemical composition between raw and fermented soybean meal (SBM and FSBM) can be attributed to the role of the fermentation process in enhancing the nutritional profile of the fermented treatment compared to the raw one. Hettiarachchy (2018) indicated that the protein level in raw grains relays primarily on the processing accuracy they undergo. The increase in protein content in fermented soybean meal could be ascribed to the action of microorganismswhich can produce many nutritional compounds, like protein, while consuming sugars during fermentation. For example, crude protein in FSBM increased from 43.44% to 67.5% compared to SBM (El-Dakar *et al.*, 2023). The results also showed differences in fat content between FSBM and SBM, which is explained by the fermentation process releasing the lipids contained in the substrate, leading to increased fatty acid contents (Kalpanadevi *et al.*, 2018). Simultaneously, lower carbohydrate levels were recorded in FSBM compared to SBM due to their consumption by various microorganisms during fermentation stages (Chinma *et al.*, 2014).

FSBM was also characterized by higher mineral contents such as calcium and phosphorus, which enhance its nutritional and health value compared to SBM. This increase in ash content is attributed to the fermentation process (Belewu and Sam, 2010). These findings agree with Xu *et al.* (2020), who confirmed that fermentation improves soluble protein content in acids and water, enhancing digestibility and nutritional value by providing essential amino acids, increasing small molecular proteins, and protease activity, thereby improving protein efficiency in animal muscle deposition. Similarly, Rostika and Safitri (2012) reported increases in nutrient values such as protein rising from 38.25% to 44.82%, alongside reductions in crude fiber and fat in fermented soybean meal.

These results also align with Pratiwy and Triyan (2022), who reported that FSBM can be used as a plant-based alternative to fishmeal due to its high protein content of up to 65.5% and many nutritional components such as vitamins, beta-glucans, mannooligosaccharides, organic acids, and antibiotics. Phinyo *et al.* (2024) noted that feeding five experimental diets containing FSBM to tilapia improved protein content while reducing fat and crude fiber levels. These findings were consistent with Pi *et al.* (2022), who showed increases in protein values of FSBM fermented microbially for 72 and 120 hours. Weng *et al.* (2023) found a 7.45% increase in protein content and a 48.66% reduction in phytic acid concentration and liver fat in *Micropterus salmoides* fed diets containing FSBM compared to those fed non-fermented soybean meal.

Amino Acids

The results showed a clear difference in essential amino acid contents as well as total non-essential amino acids between FSBM and SBM. This difference in amino acid availability largely depends on the nature and composition of the raw material and its processing method (Shapawi *et al.*, 2007). Well-balanced amino acids typically range between 25–50%, which gives fish proteins a good composition and high nutritional value. Fish proteins contain essential as well as non-essential amino acids, and their amino acid profiles depends mainly on diet so as seasonal changes, thus resulting in fish with very high nutritional or economic value (Ghaly *et al.*, 2013). Osibona *et al.* (2009) noted that balanced and abundant essential amino acids can be obtained by feeding fish on protein-rich diets and other nutritional supplements. Amino acids play an important role as sources of energy, building blocks for protein synthesis, and regulators of metabolic pathways, particularly essential amino acids which the body cannot synthesize and must obtain from the diet (Hamidoghli *et al.*, 2018). Levels of soybean proteins with molecular weights below 35 kDa and 10 kDa were reported higher in fermented soybean than non-fermented soybean, resulted inenhanced protein and amino acid contents (Yang *et al.*, 2020). Abdel-Aziz *et al.* (2020) in their study on the effect of microbial fermentation on soybean meal, reported similar amino acid values to the present study where they indicated a 60-fold increase in free amino acids representing nearly 26% of the total content of amino acids. These results are agreed with those reported by Guo *et al.* (2023), who explained that microbial fermentation of soybean meal can produce more important proteins and increase the content of essential amino acids while maintaining a good flavor, which aligns with the results of the current study and also the results of Mukherjee *et al.* (2016) and Dai *et al.* (2017).FSBM could be a good source of important amino acids that satisfy nutritional needs such as Asparagine 10.89%, Threonine 3.71%, serine 4%, Glucosamine 16.35%, Glycine 4.15%, Alanine 4.70%, Cysteine 1.40%, Lysine 8.08%, Tyrosine 4.60%, Valine 5.83% and Methionine 2.49%. Weng *et al.* (2023) indicated that replacing diets with FSBM positively affects the composition of gut microbiota and thus metabolic pathways, especially those related to the biosynthesis of amino acids and secondary plant metabolites. Hong *et al.* (2004) attributed the increase in amino acid and crude protein content to two factors: first, the growth and metabolism of microorganisms converting some solid carbon into carbon dioxide, which increased the relative crude protein content; second, microorganisms converting part of the inorganic nitrogen into amino acids, peptides and single-cell protein (SCP).

Growth Performance

Various studies have shown that the composition of dietary ingredients directly affects growth and production indicators, which helps determine the suitability of their use in fish nutrition based on the nutritional requirements of the cultured species to achieve high productivity at the lowest possible cost (Al-Noor *et al.*, 2025).The results indicated that treatment T2 exhibited superior feed conversion ratio (FCR), which may be attributed to the role of yeast as a probiotic that improves FCR by enhancing digestibility in the intestine, thereby increasing nutrient absorption and metabolism (Rhema and Al-Noor, 2022). Fermented soybean meal (FSBM) is a rich source of nutrients, especially carbohydrates and fats and serves as a good source of amino acids. It also contains enzyme inhibitors such as trypsin, lipase, and lectin along with bioactive compounds like tocotrienols, which possess antioxidant properties and promote digestive enzyme production and growth of beneficial gut microbiota, positively reflecting on fish growth and immunity parameters (Yang *et al*., 2022).The results align with El-Dakar *et al*. (2023), who studied fermentation of SBM by *Bacillus subtilis*and its influence on growth performance, histology and hematology of liver and intestines in Nile tilapia (*Oreochromis niloticus*), finding improved growth and nutrition parameters with diets containing FSBM. Noaman *et al*. (2015) reported that FSBM led to better growth and nutrition parametersin comparison with SBM, attributing that to improvement in palatability and digestibility due to reduced exposure to anti-nutritional factors in plant-origin proteins used in Nile tilapia feeds. Furthermore, FSBM can partially or fully replace fishmeal in feeds intended for Nile tilapia and other fish species in intensive aquaculture systems, enhancing growth performance and overall fish health (Picoli *et al*., 2024). Zhang *et al*. (2023) confirmed that replacing a portion of fishmeal with FSBM significantly improved growth performance in juvenile coho salmon (*Oncorhynchus kisutch*), with this substitution outperformed unfermented SBM. Similarly, Guo *et al*. (2023) evaluated the replacement of SBM, corn gluten meal (CGM) and fishmeal (FM) with FSBM in largemouth bass (*Micropterus salmoides*) diets, showing an 11.8% increase in weight compared to the control, with notable improvements in flesh quality, immune parameters, antioxidant activities, intestinal morphology and gut microbiota composition. Li *et al*. (2022) observed increases in feed intake (FI), weight gain (WG) and digestive enzyme activities when 378 g/kg of raw material was replaced by 360 g/kg of FSBM in diets of turbot (*Scophthalmus maximus* L.). The chemical composition of the yeasts and the presence of mono-, di-, and polysaccharides may have positively influenced growth and weight gain during fermentation with dry yeast, which can enhance immunity, improve fish health, and reduce stress, thus positively affecting growth (Agboola*et al*., 2021).Moreover, FSBM was used as a dietary supplement in tilapia diets, where it demonstrated inhibitory effects against the pathogenic bacterium *Aeromonas hydrophila*, suggesting that FSBM can be considered a valuable antibiotic agent for bacterial infection resistance and growth promotion, as evidenced by improved growth indices such as daily and total weight gain, relative growth rate, and specific growth rate (Phinyo *et al*., 2024).This effect is partly due to fermentation processes which significantly reduced the anti-nutritional effects of non-starch polysaccharides like pectin, cellulose and phytate. These compounds can negatively interfere with nutrient digestion by forming hydrogen bonds and protein-carbohydrate complexes, their breakdown during treatment makes them more digestible, positively affecting growth parameters (Zhao *et al*., 2022). Simultaneously, the possibility of using FSBM as a fishmeal replacement in diets of African catfish (*Clarias gariepinus*) was also demonstrated by Zakaria *et al*. (2022). Fish fed diets with a 40% substitution showed the highest growth rate, significantly increased white blood cell counts (WBC) and notable improvements serum protein and lipid profile characteristics compared to other treatments, contributing to better fish growth performance and enhanced health status.

Digestibility

Total apparent and nutrient digestibility coefficients of tested diets at the current study showed that diet T2 was superior. Zakaria *et al*. (2022) reported that replacing fishmeal (FM) with FSBM positively affected liver tissue characteristics, including vacuoles, nuclei, red blood cells, and intestinal microbiota analysis, showing that the abundance of *Akkermansia muciniphila*was significantly increased in fish, indicating good health status. This also enhances the activity of enzymes such as phytase and phosphatase, increasing nutrient digestibility (Olukomaiya *et al*., 2020). Additionally, Li *et al*. (2020) observed increased digestive enzyme activity and intestinal health in fish fed diets containing FSBM. These findings are consistent with Zhang *et al*. (2023), who recorded elevated activities of digestive enzymes (pepsin, trypsin, alpha-amylase, lipase) and liver enzymes (SOD, catalase, alkaline phosphatase) in coho salmon (*Oncorhynchus kisutch*) juveniles fed four diets with partial replacement of fishmeal by FSBM. Malik and Javed (2021) noted increased enzymatic activity in FSBM, including the production of digestive proteases and cellulolytic enzymes such as FPase and CMCase, capable of degrading various biomass materials like corn stalks, rice husks, wheat branand sugarcane residues. These enzymes which are produced by gut bacteria, can also break down anti-nutritional factors (Hortillosa *et al*., 2022; Zhao *et al*., 2022).Higher apparent total digestibility and nutrient digestibility coefficients in T2 diet could be ascribed to the effect of FSBM which fermented with different microorganisms, and could positively contributed to increased protein and fat digestibility by providing sufficient energy in the diet to support protein and fat digestion processes (Dai *et al*., 2017). This supports previous studies that probiotics in fish diets, including bakery yeast, could inhibits anti-digestive factors in feed ingredients, thereby increasing nutrient digestibility compared to the control diet without additives (Rhema and Al-Noor, 2022). Previously, Wang *et al*. (2021) indicated that FSBM fermentation could encourage the growth of *Proteobacteria* phylum, which is anabundant bacterium in solid-state fermentations (SSF) of SBM. These bacilli play important roles in fermentation of foods, reducing plant sensitivity, increasing pathogen inhibition and decreasing contamination of various feed materials with mycotoxins (Xu *et al*., 2020).Additionally, it was confirmed by Nguyen *et al*. (2023) that diets containing FSBM were highly efficient for red tilapia where fermentation with *Bacillus subtilis* improved digestive tract function, increased feed utilization efficiency, and enhanced growth performance in fish relying on soybean protein as the main dietary protein source. In conclusion, the current investigation showed very promising results to use FSBM as sustainable alternative in formulating diets for the common carp in juvenile common carp under the conditions of the present study. When more extended suitably, the results of the present experiment could contribute significantly in improving aquafeed economics which is vital part for aquaculture sector viability and sustainability especially in developing countries.

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تخمير عليقة فول الصويا لتحسين تركيبة النظام الغذائي لسمك الكارب الشائع *Cyprinus carpio* L.

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المستخلص

هدفت الدراسة الى تقييم التخمير الكيموحيوي لكسبة فول الصويا المخمرة (FSBM) كبديل جزئي لكسبة فول الصويا التقليدية (SBM) بنسب (C 0 %، T1 15%، T2 25% و T3 35%) في علائق أسماك الكارب الشائع *Cyprinus carpio* L.، أحتوت FSBM على بروتين 51.22 % و 17 حامض أميني متباينة في نسب تواجدها 10 منها أساسية حيث أمتلك الحامض الأميني اللايسين أعلى قيمة 9.98 ميكروغرام/100 ميكروغرام بروتين، تم متابعة معايير النمو لأسماك التجربة لمدة 56 يوم غذيت خلالها عن نسبة 3 % من وزن الكتلة الحية للأسماك، تم وزن الأسماك كل أسبوعين لتعديل كمية العلف، سجلت النتائج أمتلاك عليقة T2 أعلى المعدلات IW (g)، FW (g)، WG (g)، RGR (%)، SGR (%/day)، FCR و PER فكانت القيم14.7 غم، 31.4 غم، 16.7 غم، 113.6 %، 1.355 %/يوم، 1.91 و 1.603 على التوالي. في المقابل، سجلت المعاملة الضابطة (C) أدنى القيم، والتي بلغت 15.1 غم، 25.9 غم، 10.8 غم، 71.5 %، 0.963 %/يوم، 2.83، و1.078 على التوالي وبفارق معنوي ($p \leq 0.05$) عن بقية المعاملات T1، T2 و T3، أظهرت النتائج الى أن أعلى معامل هضم أجمالي بلغت 79.6 % في المعاملة T2 (نسبة أضافة 25 %) وأقلها كانت 75.7 % في عليقة C (بدون أضافة)، وكذلك الحال لقابلية هضم البروتين والدهن والرماد والكاربوهيدرات وبينت نتائج التحليل الأحصائي فروقاً معنوية ($p \leq 0.05$) بين معاملات T1، T2 و T3 ومعاملة C ما عدا هضم الدهن والرماد والتي أثبتت النتائج الأحصائية عدم وجود فروق معنوية ($p \geq 0.05$) بين المعاملات. وقد أظهرت النتائج أن عملية الأضافة في الأنظمة الغذائية T1 و T2 و T3 أعطت نمو أفضل مقارنة بالنظام الغذائي الضابط حيث تفوق نظام T2 على الكل الأنظمة الغذائية الأخرى من حيث المؤشرات الغذائية ومعايير النمو بشكل واضح.

الكلمات المفتاحية: كسبة فول الصويا المخمرة، تركيب العلائق، تغذية الأسماك، أسماك الكارب الشائع.