Dietary Supplementation of Baker's Yeast (*Saccharomyces cerevisiae*) Modulates Hemato-Biochemical Responses and Plasma Lipid Profile in Juvenile Common Carp (*Cyprinus carpio* L.)

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Abstract

A 60-day feeding trial was conducted to evaluate the effects of dietary baker's yeast (*Saccharomyces cerevisiae*) supplementation on plasma biochemical parameters and lipid profiles in juvenile common carp (*Cyprinus carpio* L.). Four isonitrogenous and isolipidic formulated diets containing varying inclusion levels of S. cerevisiae (Control [C]: 0 %, T1: 0.5 %, T2: 1.0 % and T3: 1.5 %) were administered to juvenile fish (initial mean weight 11.95 ± 1.55 g). Dietary yeast inclusion significantly improved plasma protein profiles in a dose-dependent manner. Total protein levels increased progressively from 3.66 ± 0.00 mg/100 mL in the control to 4.72 ± 0.02 mg/100 mL in T3 ($p < 0.05$). Plasma albumin concentrations peaked at 2.85 ± 0.00 mg/100 mL in T3, differing significantly from control and lower inclusion levels. Plasma globulin concentration was highest in T3 (1.87 ± 0.02 mg/100 mL ($p<0.05$). Concurrently, dietary yeast exerted a potent hypolipidemic effect. Plasma total cholesterol dropped from 267.00 ± 0.00 mg/100 mL (Control) to 164.00 ± 0.00 mg/100 mL (T3), and triglycerides decreased from 139.00 ± 2.82 mg/100 mL to 64.11 ± 0.04 mg/100 mL ($p<0.05$). Plasma lipoproteins followed a distinct declining trend, with low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL) concentrations decreasing by 44.7 % and 61.9 % in T3 compared to control, respectively. These findings demonstrate that dietary supplementation of S. cerevisiae at 1.5 % optimizes protein synthesis, enhances immune-related globulin fractions, and effectively modulates plasma lipid balance in *C. carpio* juvenile culture.

Key words: Saccharomyces cerevisiae, Common carp, Plasma biochemistry, Lipid profile, Probiotics.

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Introduction

Aquaculture continues to expand as a critical global sector for high-quality animal protein production, essential for ensuring food security for an estimated global population reaching 9.7 billion by 2050 (Paul *et al.*, 2022), To meet rising consumer demands, intensive culture systems such as recirculating aquaculture loops, floating net cages, and high-density earthen ponds have been widely adopted (FAO, 2024). However, high stocking densities and environmental fluctuations frequently induce chronic physiological stress, compromised mucosal and systemic immunity, and heightened vulnerability to opportunistic pathogens (Al-Janabi *et al.*, 2022). Historically, synthetic antibiotics and chemical chemotherapeutants were employed to manage disease outbreaks; however, their excessive use has resulted in antimicrobial resistance, residual accumulation in aquatic products, and environmental degradation (Das *et al.*, 2026). Consequently, contemporary aquafeed formulation focuses on functional dietary supplements (Qaddoori *et al.*, 2023; Alkinani *et al.*, 2026) including probiotics and prebiotics, to foster metabolic resilience and health (Vieira *et al.*, 2018; JaliI *et al.*, 2025). These include bacterial genera such as *Lactobacillus* (Al-Noor *et al.*, 2023) and yeast genera such as *Saccharomyces*, which have been recognized as probiotics that contribute to supporting fish health (Al-Janabi *et al.*, 2021; Qaddoori *et al.*, 2022). Baker's yeast, *Saccharomyces cerevisiae*, is considered a beneficial microorganism and an important source of single-cell protein. It also possesses immunomodulatory properties due to its content of glycoproteins and β-glucans (Rhema and Al-Noor, 2022). Dietary inclusion of *S. cerevisiae* has been shown to enhance gut digestive enzyme activities, stimulate intestinal mucosal integrity, and modulate systemic immune indices across diverse finfish species (Aderolu *et al.*, 2011 ; Hoseinifar *et al.*, 2014). Furthermore, yeast cell wall components interact directly with hepatic lipid metabolic pathways and enterocyte absorption mechanisms, exerting hypocholesterolemic and lipid-lowering effects (Chen *et al.*, 2014; Waldemar *et al.*, 2017). Common carp (*Cyprinus carpio* L.) is one of the most widely cultivated freshwater teleosts globally, accounting for a substantial proportion of inland aquaculture production. While the growth-promoting and immunostimulatory properties of probiotics have been widely reported, detailed systemic assessments regarding how specific inclusion levels of whole *S. cerevisiae* influence comprehensive blood biochemical profiles and lipid transport dynamics in juvenile *C. carpio* remain under reported. Plasma biochemical parameters, including total protein, albumin, globulin, and circulating lipid fractions (cholesterol, triglycerides, and lipophilic carriers), serve as sensitive physiological indicators of metabolic state, nutritional adequacy, and hepatic health (Huang *et al.*, 2008; Taati *et al.*, 2011). Therefore, this study aimed to investigate the dose-dependent effects of dietary *S. cerevisiae* supplementation on plasma protein balance and lipid parameters in juvenile common carp, establishing optimal inclusion levels for commercial feed formulations.

Materials And Methods

Yeast Activation and Experimental Diet Preparation

Commercial dried baker's yeast (*Saccharomyces cerevisiae*, Turkish origin) was obtained from local vendors in Basrah, Iraq. Prior to feed incorporation, the yeast was activated for each specific treatment level (0.5 %, 1.0 % and 1.5 % w/w) by dissolving the required yeast biomass in warm distilled water (50 mL, 35 °C) containing 1.0 g sucrose as an energy substrate. The mixture was incubated for 10 min to rehydrate and reactivate the cells. Four experimental diets were formulated to be equal in protein and lipid content (isoproteic and isolipidic): a basal control diet without yeast (C / T0: 0%), and three test diets supplemented with activated S. cerevisiae at 0.5 % (T1), 1.0 % (T2), and 1.5 % (T3). Macro-ingredients (fish meal, soybean meal, yellow corn, wheat bran, and wheat flour) were ground, sieved through a 2.0-mm mesh, and thoroughly homogenized. Hot distilled water (100 mL per 250 g dry mixture) was incorporated to form a uniform dough. The mixture was heated to 80 °C, allowed to cool to ambient temperature, and supplemented with vitamin and mineral premixes, commercial vegetable oil, and the respective yeast activations. The complete dough was incubated at 28 °C for 4 h to allow fermentation and microfloral development. Subsequently, the dough was pelleted using a laboratory meat grinder equipped with a 4.0-mm die. The resulting pellets were air-dried at ambient room temperature (25 °C) for 48 h with periodic turning, packaged in airtight polyethylene containers, and stored at 4 °C until feeding.

Table 1. Ingredient composition (%) of the experimental diets supplemented with *Saccharomyces cerevisiae*.

	Feed ingredients	Control (0%)	T1 (0.5 %)	T2 (1 %)	T3 (1.5 %)
1	Fish meal	23	23	23	23
2	Soybean meal	20	20	20	20
3	Yellow corn	15	15	15	15
4	Wheat bran	20	19.5	19	18.5
5	Wheat flour	18	18	18	18
6	Premix	2	2	2	2
7	Vegetable oil	2	2	2	2
8	*S. cerevisiae*	0	0.5	1	1.5
	Total	100	100	100	100

Experimental Fish Rearing Conditions and Design

A total of 150 healthy juvenile common carp (*C. carpio*) were obtained from the Aquaculture Unit in Al-Hartha District, University of Basrah, Iraq. Fish (initial individual body weight: 11.95 ± 1.55 g total length: 9.45 ± 0.85 cm) were bathed in a 3 % sodium chloride (NaCl) solution for 10 s to eliminate potential ectoparasites and external pathogens prior to stocking (Muhaisin, 1983). Fish were held in 60-L glass aquaria

previously sanitized with 200 ppm sodium hypochlorite (Herwig, 1979). The experiment was carried out using a completely randomized design consisting of four treatments with three replicate aquaria per treatment (10 fish per aquarium, 30 fish per treatment). Aquaria were continuously aerated via air stones connected to central air pumps to maintain dissolved oxygen near saturation (> 6.0 mg/L). Water temperature was maintained at 25 ± 2 °C using thermostatic heaters. Fish were acclimated to laboratory conditions for 10 days and fed a commercial control diet. Following acclimation, fish were fed their respective experimental diets at a rate of 3% body weight daily, split into two equal feedings (09:00 and 15:00 h) for 60 consecutive days.

Blood Sampling and Plasma Biochemical Analyses

At the end of the 60-day trial, three fish were randomly selected from each replicate aquarium (n = 9 per treatment). Fish were anesthetized, and blood samples were collected via caudal venipuncture using sterile 5-mL syringes pre-coated with K-EDTA anticoagulant (Matar, 2000). Blood samples were transferred to chilled tubes, mixed gently, and centrifuged at 3,000 × g for 15 min at 4 °C to separate plasma. Aliquots were stored at -20 °C until analytical determination. Plasma total protein and albumin concentrations were measured spectrophotometrically using commercial diagnostic assays (Randox Laboratories, Crumlin, UK) according to the manufacturer's protocols at wavelengths of 546 nm and 630 nm, respectively. Plasma globulin concentration was calculated by subtracting albumin from total protein (Wolf and Darlington, 1971):

- **Total protein concentration (mg/100 mL) = (Sample absorbance/Standard absorbance) × 6**
- **Albumin concentration (mg/100 mL) = (Sample absorbance / Standard absorbance) × 4.5**
- **Globulin (mg/100 mL) = Total Protein (mg/100 mL) – Albumin (mg/100 mL)**

Plasma total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL) concentrations were determined using enzymatic colorimetric diagnostic kits (Biomaghreb, Tunis, Tunisia) at specific absorption peaks (500–505 nm). Very-low-density lipoprotein cholesterol (VLDL) and low-density lipoprotein cholesterol (LDL) were calculated using standard biochemical formulas (Arun *et al.*, 2006; Taherpour *et al.*, 2009):

- **Total cholesterol concentration (mg/100 mL) = (Sample absorbance/ Standard absorbance) × 200**
- **Triglyceride concentration (mg/100 mL) = (Sample absorbance/ Standard absorbance) × 200**
- **HDL concentration (mg/100 mL) = (Sample absorbance/ Standard absorbance) × 200**
- **VLDL (mg/100 mL) = Triglycerides/ 5**
- **LDL (mg/100 mL) = Total Cholesterol – (HDL + VLDL)**

Statistical Analysis

All experimental data were analyzed using IBM SPSS Statistics for Windows (Version 26.0, IBM Corp., Armonk, NY, USA). Replicate aquarium means (n = 3 independent batches per treatment) were subjected to one-way Analysis of Variance (ANOVA). Data normality and homogeneity of variance were verified using Shapiro–Wilk and Levene tests, respectively. Differences between treatment means were evaluated using Tukey's Honestly Significant Difference (HSD) post-hoc test. Statistical significance was established at ($P<0.05$) and results are presented as mean ± standard error (SE).

Results

Plasma Protein Profiles

Dietary inclusion of *S. cerevisiae* significantly enhanced plasma protein metabolites in juvenile common carp in a concentration-dependent manner (Table 2). Total protein levels increased progressively with yeast supplementation, reaching a maximum of 4.72 ± 0.02 mg/100 mL in fish fed 1.5 % yeast (T3), which was significantly higher ($P<0.05$) than the control group (3.66 ± 0.00 mg/100 mL), T1 (3.87 ± 0.04 mg/100 mL), and T2 (4.34 ± 0.00 mg/100 mL). Plasma albumin concentration exhibited a similar rising pattern, with the unsupplemented control recording the lowest concentration (2.12 ± 0.01 mg/100 mL). Albumin significantly increased in T2 (2.70 ± 0.07 mg/100 mL) and T3 (2.85 ± 0.00 mg/100 mL) compared to T0 and T1 ($P<0.05$) although no significant statistical difference was observed between T2 and T3. Plasma globulin concentration was significantly elevated in T3 (1.87 ± 0.02 mg/100 mL ($P<0.05$) compared to the other treatments, whereas T0, T1, and T2 exhibited similar intermediate values (1.54, 1.64 and 1.64 mg/100 mL respectively).

Table 2. Plasma total protein, albumin, and globulin concentrations (mg/100 mL) in juvenile *Cyprinus carpio* fed diets containing varying levels of *Saccharomyces cerevisiae*

Parameter (mg/100 mL)	Control (0%)	T1 (0.5 %)	T2 (1 %)	T3 (1.5 %)
Total protein	3.66^{d}±0.00	3.87^{c}±0.04	4.34^{b}±0.00	4.72^{a}±0.02
Albumin	2.12^{d}±0.01	2.23^{c}±0.00	2.70^{ba}±0.07	2.85^{a}±0.00
Globulin	1.54^{b}±0.01	1.64^{b}±0.01	1.64^{b}±0.07	1.87^{a}±0.02

- **Values are presented as Mean ± SE (n = 3 independent replicate batches). Means within the same row carrying different superscript letters differ significantly ($P<0.05$, Tukey's HSD)**

Plasma Lipid Profile and Lipoproteins

Supplementation with *S. cerevisiae* exerted a pronounced, dose-dependent hypolipidemic effect on juvenile common carp (Table 3). Plasma total cholesterol

concentrations declined sharply with increasing yeast inclusion, dropping from 267.00 ± 0.00 mg/100 mL in the control to 213.00 ± 0.56 mg/100 mL in T1, 185.00 ± 0.00 mg/100 mL in T2, and reaching a minimum of 164.00 ± 0.00 mg/100 mL in T3 ($P<0.05$ across all treatments). Similarly, plasma triglyceride levels showed a progressive reduction from 139.00 ± 2.82 mg/100 mL in To down to 64.11 ± 0.04 mg/100 mL in T3 ($P<0.05$). Circulating lipoprotein fractions demonstrated significant alterations in response to dietary probiotic inclusion (Table 3). High-density lipoprotein (HDL) levels decreased systematically from 114.31 ± 1.40 mg/100 mL in control fish to 71.22 ± 0.00 mg/100 mL in T3 ($P<0.05$). Low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL) levels were highest in the unsupplemented control group (113.44 ± 0.00 mg/100 mL and 26.64 ± 0.33 mg/100 mL, respectively) and decreased significantly with yeast addition, reaching their lowest values in T3 (62.70 ± 0.04 mg/100 mL and 10.14 ± 0.00 mg/100 mL, representing reductions of 44.7 % and 61.9 % respectively).

Table 3. Plasma lipid parameters and lipoprotein fractions (mg/100 mL) in juvenile *Cyprinus carpio* fed diets containing varying levels of *Saccharomyces cerevisiae*.

Parameter (mg/100 mL)	Control (0%)	T1 (0.5%)	T2 (1.0%)	T3 (1.5%)
Total Cholesterol (TC)	267^{a}±0.00	213^{b}±0.56	185^{c}±0.00	164^{d}±0.00
Triglycerides (TG)	139^{a}±2.82	95.24^{b}±0.00	73.67^{c}±0.00	64.11^{d}±0.04
HDL Cholesterol	114.31^{a}±1.40	95.60^{b}±0.42	83.17^{c}±0.04	^{d}±0.0071.22
LDL Cholesterol	113.44^{a}±0.00	89.51^{b}±0.02	68.10^{c}±0.00	62.70^{d}±0.04
VLDL Cholesterol	26.64^{a}±0.33	18.77^{b}±0.02	15.32^{c}±0.01	10.14^{d}±0.00

- **Values are presented as Mean ± SE (n = 3 independent replicate batches). Means within the same row carrying different superscript letters differ significantly ($P<0.05$, Tukey's HSD).**

Discussion

Blood plasma biochemical evaluation provides valuable diagnostic insights into the physiological condition, hepatic metabolic activity, and nutritional state of teleost fish (Huang *et al.*, 2008). In the present study, dietary inclusion of *S. cerevisiae* significantly increased plasma total protein, albumin, and globulin levels in juvenile *C. carpio*, with maximum values recorded at the 1.5% inclusion level. These findings reflect enhanced hepatic protein synthesis and improved nutrient assimilation, likely driven by yeast-derived digestive enzyme stimulation and high-quality single-cell protein bio-availability (Agboola *et al.*, 2021; Pereira *et al.*, 2022). Plasma albumin plays a crucial role in maintaining oncotic pressure and transporting fatty acids and metabolites, while the globulin fraction contains essential immunoglobulins and acute-phase proteins (Wolf and

Darlington, 1971; Hoseinifar *et al*., 2014). The significant elevation in plasma globulin observed in T3 (1.87 mg/100 mL) suggests enhanced non-specific humoral immune capacity, which could be attributed to immunostimulatory yeast cell wall constituents such as β-glucans and mannan-oligosaccharides (Ringo *et al*., 2014). Similar plasma protein enhancements have been documented in juvenile *C. carpio* fed oligosaccharide prebiotics (Momeni-Moghaddam *et al*., 2015) and in *Labeo rohita* fed yeast extract (Andrews *et al*., 2009). A very important finding of this trial is the pronounced hypolipidemic effect of *S. cerevisiae* on circulating lipids and lipoproteins. Plasma total cholesterol and triglycerides decreased markedly with increasing yeast inclusion, dropping by 38.6% and 53.9% in T3 relative to control, respectively. Several physiological mechanisms may explain this lipid-lowering dynamic. First, Patrakar *et al*. (2012) indicated that metabolic metabolites produced during intestinal yeast fermentation, alongside prebiotic yeast wall polysaccharides, can inhibit hepatic 3-hydroxy-3-methylglutaryl-CoA reductase (HMGCR), the rate-limiting enzyme in cholesterol biosynthesis. Second, yeast cell wall components bind intestinal bile acids, promoting their fecal excretion and forcing the liver to utilize circulating cholesterol pools for de novo bile acid synthesis as mentioned by Waldemar *et al*. (2017). Finally, short-chain fatty acids (SCFAs) generated by probiotic gut microbiota fermentation can suppress hepatic lipogenesis and downregulate fatty acid synthase pathways (Chen *et al*., 2014). The concomitant reductions in LDL and VLDL fractions further highlight the metabolic benefits of *S. cerevisiae* supplementation. Elevated LDL and VLDL levels are associated with excessive lipid deposition, arterial oxidative stress, and hepatic steatosis in cultured fish species (Hermier, 1997; Safoura *et al*., 2010). By reducing atherogenic LDL and VLDL fractions, dietary *S. cerevisiae* may protect hepatic tissue against lipid overload and fatty liver syndrome. Although plasma HDL levels decreased alongside total cholesterol, the overall TC/HDL ratio improved favorably. Similar reductions in circulating lipids following yeast and probiotic administration have been reported in *C. carpio* by Eleraky *et al*. (2014) and *Clarias gariepinus* by Aderolu *et al*. (2011) and Turan *et al*. (2016). Overall, 1.5% supplementation of *S. cerevisiae* into diets for juvenile common carp optimizes plasma protein reserves, enhances immunoglobulins, and regulates lipid homeostasis.

Conclusion

In conclusion, dietary inclusion of baker's yeast (*Saccharomyces cerevisiae*) at a level of 1.5% (T3) significantly improved the physiological and metabolic profile of juvenile common carp (*Cyprinus carpio* L.). Supplementation enhanced plasma total protein, albumin, and globulin fractions, indicating superior nutrient utilization and boosted humoral immune potential. Similarly, *S. cerevisiae* exerted strong hypolipidemic actions by significantly lowering plasma cholesterol, triglycerides, LDL, and VLDL concentrations. These results demonstrate that *S. cerevisiae* is an effective functional aquafeed additive that promotes metabolic health and lipid homeostasis in common carp

culture. Further research is recommended to evaluate long-term health dynamics and pathogen challenge resistance under commercial intensive farming conditions.

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الإضافة العلفية لخميرة الخبز (*Saccharomyces cerevisiae*) تعدل الأستجابات الكيموحيوية الدمية وصورة دهون البلازما في يافعات الكارب الشائع (*Cyprinus carpio*)

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المستخلص

أجريت تجربة تغذية مدتها 60 يوما لتقييم آثار إضافة خميرة الخبز (*Saccharomyces cerevisiae*) إلى العلائق على المؤشرات الكيموحيوية في البلازما وصورة الدهون لدى يافعات أسماك الكارب الشائع (*Cyprinus carpio*). قدمت أربعة علائق مركبة تحتوي على مستويات متفاوتة من خميرة *S. cerevisiae* هي المجموعة الضابطة C 0 %، T1 0.5 %، T2 1 % و T3 1.5 %، للأسماك الصغيرة (متوسط الوزن الأولي 11.95 ± 1.55 غم). أدت أضافة الخميرة في العلائق الى تحسن ملحوظ في صور البروتين في البلازما بطريقة تعتمد على الجرعة. أرتفعت مستويات البروتين الكلي تدريجياً من 3.66 ± 0.00 ملغم/100 مل في المجموعة الضابطة الى 4.72 ± 0.02 ملغم/100 مل في T3 ($p<0.05$). بلغت تراكيز الألبومين في البلازما ذروتها عند 2.85 ± 0.00 ملغم/100 مل في المجموعة T3، مما يختلف معنوياً عن المجموعة الضابطة والمستويات الأقل من الخميرة. وكان تركيز الكلوبيولين في البلازما أعلى في المجموعة T3 (0.02 ± 1.87) ملغم/100 مل ($p<0.05$). وفي الوقت نفسه، أحدثت الخميرة العلفية تأثيراً قوياً في خفض نسبة الدهون في الدم. أنخفض الكوليسترول الكلي في البلازما من 267.00 ± 0.00 ملغم/100 مل (المجموعة الضابطة) الى 164.00 ± 0.00 ملغم/100 مل (T3)، وأنخفضت الدهون الثلاثية من 139.00 ± 2.82 ملغم/100 مل الى 64.11 ± 0.04 ملغم/100 مل ($p<0.05$) واتبعت البروتينات الدهنية في البلازما أتجاهاً تنازلياً واضحاً، إذ انخفضت تراكيز البروتين الدهني منخفض الكثافة (LDL) والبروتين الدهني منخفض الكثافة جداً (VLDL) بنسبة 44.7 % و 61.9 % في المجموعة T3 مقارنةً بالمجموعة الضابطة، على التوالي. وتُظهر هذه النتائج أن الإضافة العلفية من *S. cerevisiae* بنسبة 1.5 % أثرت إيجابياً على تخليق البروتينات في البلازما، وأجزاء الكلوبيولين وتوازن دهون البلازما عند تربية صغار الكارب الشائع *C. carpio*.

الكلمات المفتاحية: *Saccharomyces cerevisiae* ، الكارب الشائع، الكيمياء الحيوية للبلازما، صورة الدهون، إضافة الخميرة