Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(5): 107 – 121 (2025)
www.ejabf.journals.ekb.eg


# Synergistic Effects of Elevated Water Temperatures and Dietary Dried Yeast on the Growth Performance and Fed Utilization of the Nile Tilapia (*Oreochromis niloticus*)

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## ARTICLE INFO

**Article History:**
Received: June 7, 2025
Accepted: Aug. 15, 2025
Online: Sep. 6, 2025

**Keywords**:
The Nile tilapia (*Oreochromis niloticus*),
Dried yeast supplementation,
Growth performance,
Feed utilization,
Elevated water temperature

## ABSTRACT

This study evaluated the effect of dietary dried yeast supplementation on growth performance, feed utilization, body composition, energy retention (%), and protein productive value (PPV%) of the Nile tilapia (*Oreochromis niloticus*) fries reared at different water temperatures. A total of 180 fries (initial mean weight 146.17 ± 0.845 g/tank; 10 fish per tank; individual initial weight 14.617 g/fish) were randomly distributed into 18 aquaria. Diets were formulated to be isocaloric and isonitrogenous, with dried yeast added at 1.2% (12 g/kg) in groups G4–G6 for 75 days. Water temperatures were maintained at 28 °C (G1, G4), 31 °C (G2, G5), and 34 °C (G3, G6) during the last 15 days of the trial. Fish fed yeast-supplemented diets exhibited higher final body weight, body weight gain, daily growth rate, specific and relative growth rates, feed intake, and protein intake compared with control groups. Feed conversion ratio (FCR) and protein efficiency ratio (PER) were significantly improved ($P < 0.05$). Proximate body composition, including crude protein, ether extract, and gross energy, was significantly influenced by yeast supplementation. Both energy retention (%) and PPV% increased significantly in yeast-fed groups. Economic evaluation indicated net improvements in feeding cost (%) of 0.00, 7.90, 0.48, 22.24, 23.24, and 24.53 for groups G1–G6, respectively. In conclusion, supplementation of dried yeast in diets of Nile tilapia fries under elevated water temperature regimes enhanced growth performance, improved nutrient utilization, reduced feed cost, and increased resilience to thermal stress. These findings support the use of dried yeast as a functional feed additive, contributing to more sustainable aquaculture practices.

## INTRODUCTION

Global climate change has become one of the most pressing environmental challenges of the modern era, with rising global mean temperatures leading to severe consequences for aquatic ecosystems. **Tandong *et al.* (2011)** reported that increasing global temperatures have accelerated glacier retreat, contributing to altered hydrological cycles and changes in freshwater availability. In the tropics, **Roberts (1987)** emphasized that recognition of the negative ecological impacts of water resource development has drawn attention to the environmental consequences of water impoundments **(Madkour *et al.*, 2024)**. These impacts vary widely depending on local ecological characteristics and seasonal temperature patterns.

In aquaculture systems, water temperature is a critical factor influencing the physiology, metabolism, and health of cultured species, particularly in warm-water fish such as the Nile tilapia (*Oreochromis niloticus*). The interplay of environmental conditions and genetic factors regulates animal growth performance **(El-Wardany *et al.*, 2016)**. Several environmental factors interact to affect fish health and performance, with temperature often being the most influential. **Marquitak (2004)** and **Claireaux *et al.* (2007)** observed that fluctuations in temperature, water quality parameters (e.g., ammonia and nitrite concentrations), and management practices can act as stressors predisposing fish to bacterial infections such as *Aeromonas hydrophila*. High mortality events in fish are frequently linked to oxygen depletion, particularly in summer, either as a result of increased solar heating or elevated oxygen demand for the degradation of organic matter. Warm water accelerates decomposition processes, further exacerbating oxygen depletion risks. **(Winckler and Fidhiany, 1996; Wendelaar Bonga, 1997)** noted that stress responses in fish are highly variable and adaptive, reflecting the wide ecological diversity of aquatic habitats. Stress can be detected through behavioral alterations (e.g., abnormal swimming), physiological disruptions, weight loss, and mortality, which collectively serve as indicators of environmental suitability for cultured fish.

The Nile tilapia is among the most widely cultured freshwater fish species worldwide due to its fast growth, adaptability, and high tolerance to environmental stressors **(El-Nadi *et al.*, 2025a, 2025b)**. However, elevated water temperatures, combined with intensive aquaculture practices, may reduce productivity and compromise fish welfare. This has increased the demand for dietary interventions that can mitigate stress, enhance growth performance, and improve feed efficiency in tilapia farming.

In this context, functional feed additives such as yeast have gained increasing attention in aquaculture. **Glencross *et al.* (2020)** noted that the use of yeast in fish nutrition is not new, with research dating back to the 1980s, though its significance has grown substantially in modern aquaculture biotechnology. **Abdel-Tawwab *et al.* (2020)** further suggested that yeast represents an environmentally sustainable and economically viable alternative to fishmeal, reducing dependency on finite marine resources. Yeast is considered a high-quality protein source, rich in essential amino acids and vitamins. According to **Bertolo *et al.* (2019)**, yeast biomass is protein-rich, non-toxic, and can be cultivated on diverse substrates, while **Huyben *et al.* (2018)** reported that yeast provides vital nutrients, including lysine, sulfur-containing amino acids, vitamin B-complex, and folic acid. These properties highlight yeast as both a nutritional and functional ingredient in aquafeeds.

Several studies have demonstrated the positive impacts of yeast inclusion in fish diets **(Abozaid *et al.*, 2024; Ghaly *et al.*, 2024)**. For instance, **Ozório *et al.* (2012)** reported that a 15% dietary inclusion of yeast improved the growth performance of tilapia without compromising product quality. Replacement of 10% fishmeal with brewer's yeast (*Saccharomyces cerevisiae*) enhanced nitrogen retention and protein efficiency ratio, though results on growth performance were mixed. In another study, **Ozório *et al*. (2012)** observed that dietary yeast could significantly increase body weight when incorporated at higher inclusion levels, with growth improved by as much as 20% when fishmeal was replaced by up to 40% yeast. Similarly, **Rad *et al.* (2012)** noted that dietary supplementation with *S. cerevisiae* at 1 g/kg diet improved growth, feed utilization, and body composition of *O. niloticus* fingerlings. **Banu *et al.* (2020)** further demonstrated that dried yeast is highly palatable for tilapia juveniles, supporting growth without negatively affecting body composition.

In addition to nutritional benefits, yeast also functions as a probiotic in aquafeeds. **Chowdhury and Roy (2020)** described *S. cerevisiae* as one of the most commonly used probiotic organisms in aquaculture, enhancing feed utilization and fish productivity. Studies by **Kesarcodi-Watson *et al.* (2008)**, **Pooramini *et al.* (2009)** and **Abozaid *et al.* (2024)** confirmed that yeast supplementation can improve fish performance and feed efficiency when acting as a probiotic. Importantly, the increasing use of antibiotics in aquaculture, as discussed by **(Smith *et al.*, 2003; Sørum, 2006)**, has raised concerns about resistance and sustainability, further promoting interest in yeast as a safe and natural alternative to antibiotics. **Mahdy *et al.* (2022)** added that yeast can improve not only growth performance and disease resistance but also water quality and microbial community diversity, thus contributing to more sustainable aquaculture practices.

Given these observations, yeast supplementation appears to offer multiple benefits in tilapia aquaculture, particularly under environmental stress conditions such as elevated water temperatures. However, while several studies have addressed yeast's role in fish growth and feed efficiency, limited information is available regarding its combined effects on growth performance, feed utilization, body composition, protein productive value (PPV%), energy retention, and economic outcomes under varying thermal conditions. Therefore, the present study was designed to investigate the impact of dried yeast supplementation on the Nile tilapia (*O. niloticus*) fries reared under normal (28 °C) and elevated temperatures (31 °C and 34 °C). The study focused on growth performance, feed utilization, body composition, energy retention (%), PPV%, and the economic efficiency of feeding strategies, with the aim of providing insights into the potential application of dried yeast as a functional and sustainable feed additive under changing environmental conditions.

## MATERIALS AND METHODS

This study aimed to investigate the impact of dried yeast supplementation on growth performance, feed utilization, body composition, energy retention (%), and protein productive value (PPV%) of the Nile tilapia (*Oreochromis niloticus*) fries under normal conditions (28 °C) and two elevated water temperatures (31 °C and 34 °C).

The trial was conducted at the Fish Experimental Laboratory, Animal Production Department, Biological Agriculture Research Institute, National Research Centre (NRC), Cairo, Egypt, in cooperation with the Cell Biology Department, Biotechnology Research Institute, NRC, Cairo, Egypt.

**Experimental unit**

A total of 180 Nile tilapia fries were acclimated before the experiment and then randomly distributed into 18 glass aquaria (80 × 40 × 30 cm; 60 L capacity each), at a stocking density of 10 fish per aquarium. The initial mean body weight was 146.17 ± 0.85 g/tank (14.617 g/fish). Experimental fish were obtained from the Abbassa Fish Hatchery, Sharkia Governorate, Egypt.

Prior to the feeding trial, all fish were kept in dechlorinated tap water and adapted to a control diet for two weeks. Dried yeast was incorporated into the experimental diet at 1.2% (12 g/kg diet).

**Experimental design and diets**

The experiment was conducted using six treatment groups to examine the combined effects of dietary yeast supplementation and water temperature:

- **G1 (Control, 28 °C):** Basal diet without dried yeast, maintained at 28 °C
- **G2 (Control, 31 °C):** Basal diet without dried yeast, maintained at 31 °C
- **G3 (Control, 34 °C):** Basal diet without dried yeast, maintained at 34 °C
- **G4 (Yeast, 28 °C):** Diet supplemented with 1.2% dried yeast, maintained at 28 °C
- **G5 (Yeast, 31 °C):** Diet supplemented with 1.2% dried yeast, maintained at 31 °C
- **G6 (Yeast, 34 °C):** Diet supplemented with 1.2% dried yeast, maintained at 34 °C

The feeding trial lasted 75 days (April–June 2024). During the first 60 days, all groups were maintained at their designated target temperatures. In the final 15 days, water temperatures were gradually adjusted to 28 °C (G1, G4), 31 °C (G2, G5), and 34 °C (G3, G6) using thermostatically controlled heaters and sensors for the elevated-temperature treatments, while the control groups remained at 28 °C under room temperature conditions.

The proximate composition and formulation of the experimental diets are presented in Table (1).

**Table 1.** Composition of the different experimental diets

| **Item** | **Experimental diets** | | **Price of tone LE** |
|---|---|---|---|
| | **$D_1$ Fed to $G_1$, $G_2$ and $G_3$ Basal diet** | **$D_2$ Fed to $G_4$, $G_5$ and $G_6$ Tested diet** | |
| ***Composition of tested diets*** | | | |
| Protein concentration (56%) | 17.00 | 17.00 | 25000 |
| Soybean meal (44%) | 40.00 | 40.00 | 33000 |
| Ground Yellow corn (8%) | 28.00 | 28.00 | 12500 |
| Wheat bran (13%) | 10.00 | 8.80 | 9800 |
| Vegetable oil | 3.00 | 3.00 | 50000 |
| Vitamin and Minerals mixture* | 2.00 | 2.00 | 80000 |
| Dried yeast | 00.00 | 01.20 | 15000 |
| Price of ton fed (LE) | 25030 | 26712 | ---- |
| Price of kg fed (LE) | 25.030 | 26.712 | ---- |

*Vitamin and Minerals mixture: contained Vit. A (E672) (IU) 876.19, Vit. D3 (IU) 1141.39, Vit. E 114.30, Vit. K3 7.55, Vit. B1 13.71, Vit. B2 11.44, Vit. B6 15.33, Vit. B12 0.03, Niacin 60.96, Calpan 30.48, Folic Acid 3.04, Biotin 0.37, Vit. C 11.44, Selenium 0.27, Manganese 19.04, Iron 9.15, Iodine 0.77, Zinc 76.19, Copper 3.04, Cobalt 0.37, Choline Chloride 457.14, and Antioxidant 95.23 (Vit. vitamin; IU international unit).
Price of tone LE according to 2024.

***Parameters of growth performance***

**Body weight gain** (BWG) = Final weight - Initial weight.

**Survival rate** (SR %) = Number of fish at final / Number of fish at start x100.

**Specific growth rate (SGR) =**

[In final weight (g) - In initial weight (g)] / Experimental days *100

***Calculation of feed conversion ratio (FCR)***

**FCR =** total dry matter intake, (TDMI), g / total body weight gain (TBWG), g.

***Calculation of crude protein efficiency ratio (CPER)***

**PER**= total body weight gain (TBWG), g / total crude protein intake (TCPI), g.

***Feed efficiency***

**Feed efficiency** (FE %) = [weight gain (g) / feed intake (g)]

**Protein productive value** (PPV %) = [$PR_1$– $PR_0$ / PI] 100.

Where: $PR_1$ = is the total fish body protein at the end of the experiment.

$PR_0$ = is the total fish body protein at the start of the experiment. PI = Protein intake.

**Energy retention percentages (ER %)**

The energy retention percentage was calculated according the following equation:

Energy retention (ER %) = E-$E_0$ / $E_F$ X 100

Where: E= the energy in fish carcass (kcal) at the end of the experiment.

$E_0$= the energy in fish carcass (kcal) at the start of the experiment.

$E_F$ = the energy (kcal) in feed intake.

**Body composition**

In the beginning 10 fish used meanwhile, at the end 5 fish from each treatment were randomly chosen to determine their whole-body composition.

### Analytical procedures
Analysis of tested diets and fish body composition were analyzed according to **AOAC (2016)**.

### Calculated data
The gross energy (kcal/kg DM) of the experimental diets and the body composition of the tested fish groups were calculated following **(Blaxter, 1968; MacRae & Lobley, 2003)**, using the caloric values of 5.65 kcal/g for crude protein (CP), 9.40 kcal/g for ether extract (EE), and 4.15 kcal/g for crude fiber (CF) and nitrogen-free extract (NFE).

Metabolizable energy (ME) was calculated according to **NRC (2011)**, using conversion values of 4.50 kcal/g for protein, 8.15 kcal/g for fat, and 3.49 kcal/g for carbohydrate. The protein-to-energy ratio (mg CP/kcal ME) was also determined following **NRC (2011)**.

### Statistical analysis
All collected data were subjected to one-way analysis of variance (ANOVA) using SPSS software **(SPSS, 2020)**. Differences among treatment means were tested using Duncan's Multiple Range Test **(Duncan, 1955)**. Statistical significance was accepted at $P < 0.05$.

## RESULTS

### Chemical analysis of different experimental diets
Table (2) shows the proximate composition and energy content of the experimental diets. The crude protein content of the two diets was 30.15 and 30.80%, while gross energy values were 4559 and 4543 kcal/kg DM, respectively. Metabolizable energy (ME) was estimated at 353.94 and 351.37 kcal/kg DM, and the protein-to-energy ratios were 85.18 and 87.66 mg CP/kcal ME. These values fall within the recommended nutritional requirements for the Nile tilapia, indicating that the experimental diets were both iso-caloric and iso-nitrogenous, and therefore nutritionally comparable.

**Table 2.** Chemical analysis of different experimental diets

| Item | Experimental diets | |
|---|---|---|
| | $D_1$ Fed to $G_1$, $G_2$ and $G_3$ | $D_2$ Fed to $G_4$, $G_5$ and $G_6$ |
| **Moisture** | 8.15 | 9.48 |
| **Dry matter (DM)** | 91.85 | 90.52 |
| ***Chemical analysis on DM basis*** | | |
| **Organic matter (OM)** | 93.66 | 93.14 |
| **Crude protein (CP)** | 30.15 | 30.80 |
| **Crude fiber (CF)** | 6.55 | 6.85 |
| **Ether extract (EE)** | 4.18 | 4.10 |
| **Nitrogen free extract (NFE)** | 52.78 | 51.39 |

| | | |
|---|---|---|
| **Ash** | 6.34 | 6.86 |
| **Gross energy kcal/ kg DM** | 4559 | 4543 |
| **Gross energy cal/ g DM** | 4.559 | 4.543 |
| **Metabolizable energy kcal/ kg DM** | 353.94 | 351.37 |
| **Protein energy ratio (mg CP/ Kcal ME)** | 85.18 | 87.66 |

Gross energy (kcal/ kg DM) was calculated according to (Blaxter1968; MacRae and Lobley 2003). Where, each g CP = 5.65 Kcal, g EE = 9.40 kcal and g CF and NFE = 4.15 Kcal.

## Growth and survival ratio

As presented in Table (3), the inclusion of dried yeast in the diet significantly (P < 0.05) enhanced final weight (FW), total body weight gain (TBWG), average daily gain (ADG), specific growth rate (SGR), and relative growth rate (RGR) in fish groups receiving 12 g/kg dried yeast (G4, G5, and G6) at all tested water temperatures (28 °C, 31 °C, and 34 °C), compared with their respective control groups (G1, G2, and G3) that did not receive dried yeast.

Among all treatments, fish in group G6 (yeast-supplemented diet at 34 °C) recorded the highest values of FW, TBWG, ADG, SGR, and RGR compared with the other five groups (G1–G5). Notably, group G5 (yeast at 31 °C) exhibited a mortality rate of 0%, whereas the other groups (G1, G2, G3, G4, and G6) showed measurable mortality.

**Table 3.** Growth performance, specific growth rate and survival ratio of the Nile tilapia *(O. niloticus)* fed diets contained dried yeast and reared in different water temperature

| Item | Experimental groups | | | | | | SEM | Sign. *P*<0.05 |
|---|---|---|---|---|---|---|---|---|
| | Fish fed basal diet and reared in water temperature at | | | Fish fed diet contained 12 g dried yeast/kg diet and reared in water temperature at | | | | |
| | (28°C) | (31°C) | (34°C) | (28°C) | (31°C) | (34°C) | | |
| | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $G_5$ | $G_6$ | | |
| **Number of fish** | 30 | 30 | 30 | 30 | 30 | 30 | - | - |
| **IW, g** | 145 | 152 | 144 | 145 | 145 | 146 | 0.845 | NS |
| **FW, g** | $367^{d}$ | $360^{e}$ | $363^{de}$ | $469^{c}$ | $475^{b}$ | $489^{a}$ | 13.96 | * |
| **TBWG, g** | $222^{c}$ | $208^{d}$ | $219^{c}$ | $324^{b}$ | $330^{b}$ | $343^{a}$ | 14.19 | * |
| ***Duration experimental*** | | | | | 75 days | | | |
| **ADG, g** | $2.96^{c}$ | $2.77^{d}$ | $2.92^{c}$ | $4.32^{b}$ | $4.40^{b}$ | $4.57^{a}$ | 0.189 | * |
| **SGR** | $0.72^{c}$ | $0.68^{d}$ | $0.72^{c}$ | $0.91^{b}$ | $0.92^{ab}$ | $0.94^{a}$ | 0.027 | * |
| **RGR** | $1.50^{c}$ | $1.35^{d}$ | $1.50^{c}$ | $2.20^{b}$ | $2.25^{b}$ | $2.35^{a}$ | 0.101 | * |
| **Starter number** | 30 | 30 | 30 | 30 | 30 | 30 | - | - |
| **End number of** | 30 | 30 | 30 | 30 | 28 | 30 | - | - |
| **SR %** | 100 | 100 | 100 | 100 | 93.33 | 100 | - | - |
| **Dead number** | Zero | Zero | Zero | Zero | 2 | Zero | - | - |
| **Mortality rate %** | Zero | Zero | Zero | Zero | 6.67 | Zero | - | - |

a, b, c, d and e: Means in the same row having different superscripts differ significantly (*P* < 0.05). SEM: Standard error of the mean, NS: Not significant, *: Significant at (*P* < 0.05). IW: Initial weight, g. FW: Final weight, g, TBWG: Total body weight gain, g, Average daily gain, g (ADG). SGR: Specific growth rate, RGR: Relative growth rate, SR: Survival ratio.

## Feed utilization

As shown in Table (4), feed intake (FI) and crude protein intake (CPI) were higher in groups fed diets supplemented with dried yeast (G4, G5, and G6) compared with their respective controls at the same water temperatures (G1, G2, and G3). The highest FI (656.05 g) and CPI (206.06 g) were recorded in fish from G6. Feed conversion ratio (FCR) was significantly ($P$ < 0.05) improved in yeast-supplemented groups (G4–G6) compared with non-supplemented groups (G1–G3). Similarly, the protein efficiency ratio (PER) was significantly ($P$ < 0.05) higher in yeast-fed groups across all tested temperature conditions.

**Table 4.** Feed utilization of the Nile tilapia *(O. niloticus)* fed diets contained dried yeast and reared in different water temperature

| Item | Experimental groups | | | | | | SEM | Sign. $P$<0.05 |
|---|---|---|---|---|---|---|---|---|
| | Fish fed basal diet and reared in water temperature at | | | Fish fed diet contained 12 g dried yeast/kg diet and reared in water temperature at | | | | |
| | (28°C) | (31°C) | (34°C) | (28°C) | (31°C) | (34°C) | | |
| | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $G_5$ | $G_6$ | | |
| TBW, g | $222^c$ | $208^d$ | $219^c$ | $324^b$ | $330^b$ | $343^a$ | 14.19 | * |
| FI, g | $551.46^{cd}$ | $557.34^c$ | $546.42^d$ | $637.14^b$ | $642.18^b$ | $656.05^a$ | 11.48 | * |
| FCR | $2.484^b$ | $2.680^c$ | $2.495^b$ | $1.966^a$ | $1.946^a$ | $1.913^a$ | 0.076 | * |
| FCP % | 30.15 | 30.15 | 30.15 | 30.80 | 30.80 | 30.80 | - | - |
| CPI, g | $166.27^{cd}$ | $168.04^c$ | $164.75^d$ | $196.24^b$ | $197.79^b$ | $202.06^a$ | 3.963 | * |
| PER | $1.335^c$ | $1.238^d$ | $1.329^c$ | $1.651^b$ | $1.668a^b$ | $1.698^a$ | 0.046 | * |

a, b, c and d: Means in the same row having different superscripts differ significantly ($P$ < 0.05), SEM: Standard error of the mean, NS: Not significant,*: Significant at ($P$ < 0.05), BWG: Total body weight gain,FI: Feed intake, FCR: Feed conversion ratio, FCP%: Feed crude protein percentages, CPI: Crude protein intake, PER: Protein efficiency ratio.

## Whole-body composition

Results in Table (5) show that the inclusion of dried yeast in the diets significantly ($P$ < 0.05) affected the proximate composition of Nile tilapia. Yeast supplementation was associated with reductions in organic matter (OM), crude protein (CP), ether extract (EE), and gross energy, while ash content increased significantly. Among treatments, the highest dry matter (DM) was observed in G6 (28.06%), OM in G2 (88.62%), CP in G3 (62.39%), EE in G2 (31.90%), ash in G5 (19.94%), and gross energy in G2 (6.20 kcal/g DM).

**Table 5.** Fish body composition of initial and different experimental groups that fed diets contained dried yeast and reared in different water temperature

| Item | Fish body omposition of initial fish | Experimental groups | | | | | | SEM | Sign. $P$<0.05 |
|---|---|---|---|---|---|---|---|---|---|
| | | Fish fed basal diet and reared in water temperature at | | | Fish fed diet contained 12 g dried yeast/kg diet and reared in water temperature at | | | | |
| | | (28°C) | (31°C) | (34°C) | (28°C) | (31°C) | (34°C) | | |
| | | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $G_5$ | $G_6$ | | |
| Moistue | 80.73 | $73.68^d$ | $73.10^e$ | $73.80^c$ | $74.32^b$ | $76.96^a$ | $71.94^f$ | 0.371 | * |
| DM | 19.27 | $26.32^c$ | $26.90^b$ | $26.20^d$ | $25.68^e$ | $23.04^f$ | $28.06^a$ | 0.371 | * |
| ***Chemical analysis on DM basis*** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **OM** | 81.61 | 87.92$^{b}$ | 88.62$^{a}$ | 87.71$^{c}$ | 84.24$^{d}$ | 80.06$^{f}$ | 82.39$^{e}$ | 0.772 | * |
| **CP** | 65.25 | 60.71$^{b}$ | 56.72$^{e}$ | 62.39$^{a}$ | 60.07$^{c}$ | 59.52$^{d}$ | 53.36$^{f}$ | 0.718 | * |
| **EE** | 16.36 | 27.21$^{c}$ | 31.90$^{a}$ | 25.32$^{d}$ | 24.17$^{e}$ | 20.54$^{f}$ | 29.03$^{b}$ | 0.876 | * |
| **Ash** | 18.39 | 12.08$^{e}$ | 11.38$^{f}$ | 12.29$^{d}$ | 15.76$^{c}$ | 19.94$^{a}$ | 17.61$^{b}$ | 0.771 | * |
| **GE1** | 522.45 | 598.79$^{b}$ | 620.33$^{a}$ | 590.51$^{c}$ | 566.59$^{e}$ | 529.36$^{f}$ | 574.37$^{d}$ | 6.908 | * |
| **GE2** | 5.2245 | 5.9879$^{b}$ | 6.2033$^{a}$ | 5.9051$^{c}$ | 5.6659$^{e}$ | 5.2936$^{f}$ | 5.7437$^{d}$ | 0.069 | * |

a, b, c, d, e and f: Means in the same row having different superscripts differ significantly (*P* < 0.05). SEM: Standard error of the mean, NS: Not significant,*: Significant at (*P* < 0.05), DM: Dry matter OM: Organic matter, CP: Crude protein, EE: Ether extract, GE1: Gross energy kcal/100g.GE2: Gross energy cal/g DM.

## Energy retention and protein productive value

As shown in Table (6), both energy retention (ER%) and protein productive value (PPV%) were significantly (*P* < 0.05) influenced by dietary treatments. Fish in the yeast-supplemented groups (G4, G5, and G6) exhibited higher ER% values (65.60, 60.20, and 68.66%, respectively) compared with their corresponding control groups (57.28, 56.63, and 55.88% for G1, G2, and G3, respectively). Similarly, PPV% improved in yeast-fed groups, reaching 95.35%, 95.11%, and 81.99% in G4, G5, and G6, compared with 77.10%, 62.49%, and 80.44% in G1, G2, and G3, respectively.

**Table 6.** Energy retention (ER) and protein productive value (PPV) % of different groups that fed diets contained dried yeast and reared in different water temperature

| **Item** | **Experimental groups** | | | | | | **SEM** | **Sign. *P*<0.05** |
|---|---|---|---|---|---|---|---|---|
| | **Fish fed basal diet and reared in water temperature at** | | | **Fish fed diet contained 12 g dried yeast/kg diet and reared in water temperature at** | | | | |
| | **(28°C)** | **(31°C)** | **(34°C)** | **(28°C)** | **(31°C)** | **(34°C)** | | |
| | **$G_1$** | **$G_2$** | **$G_3$** | **$G_4$** | **$G_5$** | **$G_6$** | | |
| **IW** | 145 | 152 | 144 | 145 | 145 | 146 | 0.845 | NS |
| **FW** | 367$^{d}$ | 360$^{e}$ | 363$^{de}$ | 469$^{c}$ | 475$^{b}$ | 489$^{a}$ | 13.96 | * |
| ***Calculation the energy retention*** | | | | | | | | |
| **ECFBW** | 5.9879$^{b}$ | 6.2033$^{a}$ | 5.9051$^{c}$ | 5.669$^{e}$ | 5.9236$^{f}$ | 5.7437$^{d}$ | 0.069 | * |
| **TEEBF** | 2198$^{e}$ | 2233$^{d}$ | 2144$^{f}$ | 2657$^{b}$ | 2514$^{c}$ | 2809$^{a}$ | 60.869 | * |
| **ECIBF** | 5.2245 | | | | | | - | - |
| **TESBF** | 758$^{b}$ | 794$^{a}$ | 752$^{b}$ | 758$^{b}$ | 758$^{b}$ | 763$^{b}$ | 4.531 | * |
| **ERBF** | 1440$^{d}$ | 1439$^{d}$ | 1392$^{e}$ | 1899$^{b}$ | 1756$^{c}$ | 2046$^{a}$ | 61.52 | * |
| **EFI** | 4.559 | | | 4.543 | | | - | - |
| **QFI** | 551.46$^{cd}$ | 557.34$^{c}$ | 546.42$^{d}$ | 637.14$^{b}$ | 642.18$^{b}$ | 656.05$^{a}$ | 11.476 | * |
| **TEFI** | 2514$^{cd}$ | 2541$^{c}$ | 2491$^{d}$ | 2895$^{b}$ | 2917$^{b}$ | 2980$^{a}$ | 51.065 | * |
| **ER%** | 57.28$^{d}$ | 56.63$^{d}$ | 55.88$^{d}$ | 65.60$^{b}$ | 60.20$^{c}$ | 68.66$^{a}$ | 1.181 | |
| ***Calculation the protein productive value (PPV) %*** | | | | | | | | |
| **CPFB%** | 60.71$^{b}$ | 56.72$^{e}$ | 62.39$^{a}$ | 60.07$^{c}$ | 59.52$^{d}$ | 53.36$^{f}$ | 0.718 | * |
| **$PR_1$** | 222.81$^{d}$ | 204.19$^{e}$ | 226.48$^{c}$ | 281.73$^{a}$ | 282.72$^{a}$ | 260.93$^{b}$ | 7.360 | * |
| **CPIBC%** | 65.25 | | | | | | - | - |
| **$PR_2$** | 94.61$^{b}$ | 99.18$^{a}$ | 93.96$^{b}$ | 94.61$^{b}$ | 94.61$^{b}$ | 95.27$^{b}$ | 0.564 | * |
| **$PR_3$** | 128.20$^{d}$ | 105.01$^{e}$ | 132.52$^{c}$ | 187.12$^{a}$ | 188.11$^{a}$ | 165.66$^{b}$ | 7.601 | * |
| **CPFE%** | 30.15 | | | 30.80 | | | - | - |
| **TPI** | 166.27$^{cd}$ | 168.04$^{c}$ | 164.75$^{d}$ | 196.24$^{b}$ | 197.79$^{b}$ | 202.06$^{a}$ | 3.96 | * |
| **PPV%** | 77.10$^{c}$ | 62.49$^{d}$ | 80.44$^{b}$ | 95.35$^{a}$ | 95.11$^{a}$ | 81.99$^{b}$ | 2.740 | * |

a, b, c, d, e and f: Means in the same row having different superscripts differ significantly (*P* < 0.05). SEM: Standard error of the mean., NS: Not significant.

*: Significant at (*P* < 0.05). IW: Initial weight, g. FW: Final weight, g. ECFBW: Energy content in final body fish (cal / g). TEEBF: Total energy at the end in body fish (E), Energy content in initial body fish (cal / g), TESBF: Total energy at the start in body fish ($E_0$), Energy retained in body fish ($E-E_0$), EFI: Energy of the feed intake (Cal / g feed). Quantity of feed intake. TEFI: Total energy of feed intake (EF), ER%:

Energy retention (ER) % CPFBC%: Crude protein % in final body fish, $PR_1$: Total protein at the end in body fish, CPIBFC%: Crude protein % in initial body fish. $PR_2$: Total protein at the start in body fish PR3: Protein Energy retained in body fish ($PR_3$) = ($PR_1$ – $PR_2$) CPFI: Crude protein in feed intake (CP %), TPI: Total protein intake, g, PPV%: Protein productive value.

## Economic evaluation

Economic analysis (Table 7) showed that the inclusion of dried yeast slightly increased the cost of feed formulation, from 25.03 LE/kg in the control diets (G1–G3) to 26.71 LE/kg in the supplemented diets (G4–G6). Despite this increase, feed cost efficiency (%) improved markedly in yeast-fed groups, reaching 22.24%, 23.24%, and 24.53% for G4, G5, and G6, respectively, compared with 0.0%, 7.90%, and 0.48% in the control groups (G1, G2, and G3).

**Table 7.** Economical evaluation of different experimental groups that fed diets contained dried yeast and reared in different water temperature

| Item | Experimental groups | | | | | |
|---|---|---|---|---|---|---|
| | Fish fed basal diet and reared in water temperature at | | | Fish fed diet contained 12 g dried yeast/kg diet and reared in water temperature at | | |
| | (28°C) | (31°C) | (34°C) | (28°C) | (31°C) | (34°C) |
| | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $G_5$ | $G_6$ |
| **Costing of kg feed (LE)** | 25.030 | 25.030 | 25.030 | 26.712 | 26.712 | 26.712 |
| **Relative to control (%)** | 100 | 100 | 100 | 106.72 | 106.72 | 106.72 |
| **Feed conversion ratio (FCR)** | 2.484 | 2.680 | 2.495 | 1.966 | 1.946 | 1.913 |
| **Feeding cost (LE) per (Kg weight gain)** | 62.17 | 67.08 | 62.450 | 52.52 | 51.98 | 51.10 |
| **Relative to control (%)** | 100 | 107.90 | 100.45 | 84.48 | 83.48 | 82.19 |
| **Net improving in feeding cost (%)** | Zero | 7.90 | 0.48 | 22.24 | 23.24 | 24.53 |

Diet formulation calculated according to the local prices at year 2024 as presented in Table (1).
Feed cost (L.E) FCR×FI. Cost per Kg diet.

# DISCUSSION

The present study demonstrated that dietary supplementation with dried yeast exerted positive effects on growth performance, feed utilization, body composition, nutrient retention, and economic efficiency of the Nile tilapia (*Oreochromis niloticus*) fries reared under different water temperatures. These findings indicate that dried yeast can function not only as a nutrient source but also as a functional feed additive that enhances fish resilience to thermal stress.

Fish fed yeast-supplemented diets exhibited superior growth indices, including FW, BWG, ADG, and SGR, alongside higher survival compared with unsupplemented groups. The positive response was most pronounced at 34 °C, suggesting that yeast supplementation can partially counteract the adverse impacts of thermal stress. The underlying mechanisms may involve yeast-derived bioactive compounds such as β-glucans, mannan oligosaccharides, nucleotides, and vitamins, which are reported to enhance gut integrity, improve immune competence, and reduce oxidative stress **(Li & Gatlin, 2006; Tovar-Ramírez *et al.*, 2010)**. Similar improvements in tilapia growth and survival with yeast supplementation have been documented by **(Goda *et al.*, 2012; Sutthi & Thaimuangphol, 2020; El-Nadi *et al.*, 2024)**. In contrast, some studies have reported marginal effects depending on yeast strain or inclusion level **(Ozório *et al.*, 2012)**, highlighting the importance of optimizing dosage and dietary context.

Feed utilization parameters were markedly improved in yeast-fed groups, as reflected by higher feed intake (FI), crude protein intake (CPI), and protein efficiency ratio (PER), coupled with reduced feed conversion ratio (FCR). These findings suggest that yeast supplementation enhances nutrient digestibility and assimilation. Previous studies have shown that yeast can stimulate digestive enzyme secretion, improve villi morphology, and modulate gut microbiota composition, thereby facilitating superior nutrient absorption **(Lara-Flores *et al.*, 2003; Diab *et al.*, 2006)**. Our results agree with **Abozaid *et al.* (2024)**, who reported improved FCR and PER in Nile tilapia with yeast supplementation. However, **Ozório *et al.* (2012)** observed no significant effect on FI, which may reflect differences in experimental conditions and basal diet composition.

Yeast inclusion significantly altered body composition, particularly by increasing ash content while decreasing crude protein, lipid, and energy deposition. The elevation in ash may indicate enhanced mineral deposition, potentially linked to improved nutrient transport and metabolism stimulated by yeast bioactives. Reduced carcass protein and lipid suggest more efficient nutrient utilization for metabolic and growth processes rather than storage. Similar results were obtained by **Abozaid *et al.* (2024)**. On the other hand, **Goda *et al.* (2012)** found no effect on moisture, suggesting that responses may be context-dependent. These findings underscore that yeast supplementation not only promotes growth but also influences nutrient partitioning.

The significant increases in ER% and PPV% in yeast-fed groups confirm that dietary yeast improves the efficiency of nutrient utilization. Nucleotides derived from yeast are known to support protein and nucleic acid synthesis, while mannan oligosaccharides modulate gut health, collectively enhancing energy metabolism and protein retention **(Li & Gatlin, 2006)**. Similar improvements in PPV were reported in tilapia by **Abo-State *et al.* (2021)** and in other aquaculture species supplemented with nucleotides or yeast derivatives **(Abozaid *et al.*, 2024; Ghaly *et al.*, 2024)**. The elevated PPV in the current study suggests that yeast enhances nitrogen retention and minimizes losses, which is particularly valuable under thermal stress conditions that usually impair protein metabolism.

Although yeast supplementation slightly increased feed cost per kilogram, the net economic return improved due to higher growth rates and superior feed efficiency. This aligns with the findings of **Pooramini *et al.* (2009)** and **Goda *et al.* (2012)**, who reported that probiotic or yeast supplementation reduced production costs by improving nutrient utilization and reducing mortality. The current results highlight that the benefits of yeast are not only biological but also economic, thereby reinforcing its application as a sustainable strategy in commercial tilapia farming.

Collectively, the results indicate that dried yeast can serve as a valuable dietary additive for the Nile tilapia culture under variable temperature regimes. Beyond growth and feed utilization, yeast improves nutrient retention and enhances economic profitability, both of which are critical for sustainable aquaculture. Considering the challenges posed by climate change and rising water temperatures, functional feed additives like yeast may play a key role in enhancing fish resilience and ensuring stable production. Future research should investigate optimal inclusion levels, long-term effects, and interactions with other dietary components to maximize benefits.

## CONCLUSION

The present study demonstrated that dietary inclusion of dried yeast in Nile tilapia diets significantly enhanced growth performance, feed utilization, nutrient retention, and economic efficiency, particularly under elevated water temperatures. Yeast supplementation improved survival, feed conversion, protein efficiency, and energy retention, while positively influencing body composition through greater mineral deposition. Although feed costs increased slightly, the overall economic return was substantially improved, confirming the cost-effectiveness of yeast incorporation. These findings indicate that dried yeast is not only a valuable protein and energy source but also a functional feed additive that enhances resilience to thermal stress, promotes nutrient utilization, and supports sustainable aquaculture practices. Future research should focus on optimizing inclusion levels, exploring synergistic effects with other additives, and assessing long-term impacts on fish health and production.

**Acknowledgements**

The authors express their appreciation to laboratory team for comprehensive effort that resulted in significant improvement of this study.

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