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Nutritional Influence of the Cinnamon (*Cinnamomum zeylanicum*) Meal (and/or) Water Extract on the Productivity, Biochemical Parameters, and Economic Assessment of the Nile Tilapia

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ABSTRACT

This research examined the impact of incorporating cinnamon meal (CM), water cinnamon extract (CEX), and its combination on fish productivities, blood parameters and economic outcomes over 56 days. Five groups of fish were fed different diets: a control diet (D1), 1% cinnamon meal (D2), 1% water cinnamon extract (D3), combinations of 0.5% CM and 0.5% WCEX (D4), and 1% CM and 1% WCEX (D5). All diets were iso-caloric and iso-nitrogenous. Significant improvements in growth performances and feed utilization parameters were observed ($P<0.05$) in D5 (1% CM and 1% WCEX) compared to control or other treatments, with 100% survival in the D2, D4, and D5 groups, compared to 93.33% in D1 and D3. Feed conversion ratio improved with cinnamon-treated diets, and serum protein and globulin levels increased significantly, while cholesterol levels decreased. Body composition analysis showed a significant reduction in OM and CP, while DM, EE, ash, and GE content increased. The economic return improved in cinnamon-treated groups, though the percentage of profitable value decreased slightly. Diet costs were reduced, and net improvement over the control ranged from 2.32 to 8.82%. In conclusion, adding cinnamon meal and/or cinnamon water extract to fish diets impacted growth and feed efficiency positively, without negative effects.

INTRODUCTION

The rapid advancement of aquaculture sector to intensive, high density regimes has inevitably resulted in posing an extended and increased pressure on aquaculture operations, largely due to using high levels of fat and excessively feeding systems which was contributed to various prevalent health concerns, including hepatic-steatosis **(Zhang**

***et al*., 2011)**, inflammation **(Chen *et al*., 2016)**, lipo-toxicity **(Chitraju *et al*., 2017)**, mitochondria damages at the ultra structural level **(Cao *et al*., 2019)**, and hepatobiliary disorders **(Li *et al*., 2024)**. Consequently, a profound effect has been recorded on general health and fish productivity, posing a serious obstacle in the aquaculture sustainability's sector and welfare and threatening productivity performance. It is worth noting that the Nile tilapia is a widely favored species in aquaculture due to its favorable growth characteristics and high market value **(Abdel-Tawwab *et al*., 2018; Abdellah *et al*., 2024)**. According to **Pridgeon and Klesius (2011)**, while intensive aquaculture systems are efficient, they can expose fish to stress resulting from poor water quality and hypoxia. This stress may impair their immune systems and increase their susceptibility to diseases, such as those caused by the Gram-negative bacterium *Aeromonas hydrophila*, leading to economic losses in both marine and freshwater environments. **Alderman and Hastings (1998)** and **Teuber (2001)** noted that using antibiotics for disease prevention can lead to developing the antibiotic resistant bacteria. Consequently, there has been growing attention toward finding cost-effective and environmentally friendly feed additives as alternatives to traditional antibiotics. **Abdel-Tawwab (2012)**, **Van Doan *et al.* (2017)**, and **Abozaied *et al*. (2024a, b)** emphasized the need to improve feed quality with additives to enhance tilapia productivity. Numerous studies have explored the use of various medicinal herbs to provide therapeutic benefits with minimal negative effects **(Dügenci *et al*., 2003; Citarasu, 2010; Harikrishnan *et al.*, 2011)**. Recent research has increasingly focused on medicinal plants as feed additives to boost productivity and immune response **(Reverter *et al.*, 2014; Awad & Awaad, 2017; Hoseinifar *et al.*, 2020; Abdel-Latif *et al.*, 2022; Hamed *et al.*, 2022)**.

Cinnamon, known for its wide range of biological activities, contains numerous bioactive compounds such as essential oils and polyphenols **(Kwon *et al.*, 2009; Gruenwald *et al.*, 2010)**. These compounds act as scavengers of reactive oxygen and nitrogen species and redox-active metals **(Rice-Evans *et al.*, 1997; Łuczaj *et al.*, 2009)**. Cinnamon has been well-documented for its anti-inflammatory **(Lee *et al.*, 2005)**, antimicrobial **(Matan *et al.*, 2006)**, and antioxidant **(Shan *et al.*, 2009)** effects. Its potential to enhance fish productivity and resistance to bacterial infections has been recognized **(Ahmad *et al.*, 2011; Setiawati *et al.*, 2016; Sivagurunathan & Innocent, 2017)**. Additionally, **Hamed *et al*. (2022)** suggested that cinnamon could serve as an immune stimulant to mitigate toxicities.

Cinnamon powder is also known for its anti-flatulent properties **(Nabavi *et al.*, 2015)**. Many bioactive substances such as cinnamic aldehyde exhibit strong antioxidant activities by scavenging free radicals **(Lee *et al.*, 2005; Łuczaj *et al.*, 2009; Shan *et al.*, 2009; Ahmadifar *et al.*, 2021)**. Several investigations have demonstrated that dietary cinnamon positively impacts the performance, antioxidant levels, and resistance to bacterial infections in aquatic species **(Ahmad *et al.*, 2011; Sivagurunathan & Innocent, 2017; Begum *et al.*, 2018)**.

Our investigation aimed to explore the effects of incorporating cinnamon meal and/or cinnamon extract in water on productivity, biochemical parameters, and economic viability in the Nile tilapia.

MATERIALS AND METHODS

Our study was conducted in Fish Lab. of Biological Agriculture Research Institute, National Research Center.

Experimental units

One hundred fifty Nile tilapia fingerlings, with an average initial weight of 14.4 ± 0.602 g, were acclimated and then randomly assigned to experimental aquariums. The fish were distributed among 15 aquariums, each housing 10 fish (80 × 40 × 30cm, 60-liter capacity).

Experimental diets

Five different diets were prepared, each containing 30% crude protein, as outlined below:

D1: Control diet without cinnamon.
D2: Containing 1% cinnamon meal (CM).
D3: Containing 1% water cinnamon extract (WCEX).
D4: Containing 0.5% CM + 0.5% WCEX.
D5: Containing 1% CM + 1% WCEX.

The feeding trial lasted for 56 days from mid-March to mid-May 2024. The composition of the different experimental rations is detailed in Table (1).

Table 1. Composition of the different experimental rations

Item	Experimental diets					Price of tone LE
	Control	1% CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX	
	D_1	D_2	D_3	D_4	D_5	
Composition of tested diets						
Cinnamon meal (CM)	0	1	0	0.5	1	3000
Water cinnamon extract (WCEX)	0	0	1	0.5	1	500
Soybean meal (44%)	40	40	40	40	40	33000
Protein concentration (56%)	17	17	17	17	17	25000
Yellow corn (8%)	28	28	28	28	28	12500
Wheat bran (13%)	10	9	9	9	8	14500
Vegetable oil	3	3	3	3	3	50000
Salt (sodium chloride)	1	1	1	1	1	5000
Vitamin and Minerals	1	1	1	1	1	40000
Price of ton fed (LE)	24350	24235	24210	24223	24095	---
Price of kg fed (LE)	24.350	24.235	24.210	24.223	24.095	---

CM: Cinnamon meal. WCEX: Water cinnamon extract

Growth performance parameters

BWG = Final weight - Initial weight

SR % = (N at the end / N at the beginning) × 100

N: Number of fish

SGR = [(ln final weight (g) - ln initial weight (g)) / Number of days] × 100

FCR = Total dry matter intake (TDMI, g) / Total body weight gain (TBWG, g)

Protein efficiency ratio, PER = TBWG, g / TCPI, g

Feed efficiency, FE % = (Weight gain (g) / Feed intake (g)) × 100

Protein productive value, PPV % = [(PR1 - PR0) / PI] × 100

Energy retention, ER %:

ER % = [(E - E0) / EF] × 100

Blood sampling

After anesthetizing fish with clove oil (0.5ml/ l), samples were taken from the caudal vein using 3ml syringe and allowed to be clotted at room temperature for fifteen minutes. Blood samples were centrifuged at 3000rpm/ 15min, then the serum was separated, collected, and kept at -20°C before being subjected to biochemical assays.

Body composition

Initially, 15 fish were used for body composition. When the study ended, 6 fingerlings from each treatment group were used for body composition analysis.

Analytical procedures

Testing either diets or fish body composition were conducted according to **AOAC (2016)** methods.

Biochemical assays

Aspartate aminotransferase (AST) **(Reitman & Frankel, 1957)**, serum total proteins **(Cannon *et al*., 1974)**, cholesterol **(Ellefson & Caraway, 1976)**, globulin, alanine aminotransferase (ALT), glucose **(Caraway & Watts, 1987)**, albumin, uric acid and creatinine **(Tietz, 1990)** were determined. Each biochemical parameter was colorimetrically analyzed in accordance with the manufacturer's instructions.

Calculated data

Gross energy for the experimental diets and fish body composition was calculated based on the studies of **Blaxter (1968)** and **MacRae and Lobley (2003)**, using the following values: 5.65 kcal/g for protein, 9.40kcal/ g for ether extract, and 4.15kcal/ g for crude fiber and nitrogen-free extract.

The metabolizable energy (ME) was determined according to **NRC (2011)**, with values of 4.50kcal/ g for protein, 8.15kcal/ g for fat, and 3.49kcal/ g for carbohydrates. In addition, the protein energy ratio was calculated according to **NRC (2011)**.

Statistical analysis

Data were analyzed using one-way (ANOVA) with **SPSS (2020)**. **Duncan (1955)** test was used to differentiate between means.

RESULTS

Chemical analysis of the experimental diets

Chemical analysis results, detailed in Table (2), show that the CP content across of five rations ranged from 30.18 to 30.51%. Gross energy (GE) values varied between 4512 and 4562kcal/ kg, while metabolizable energy (ME) ranged from 353.75 to 359.23kcal/ kg. Additionally, the protein energy ratio was between 84.93 and 85.42mg CP/kcal ME. These values are deemed appropriate for meeting the nutritional requirements of the Nile tilapia. Moreover, all diets were comparable in terms of caloric and nitrogen contents.

Table 2. Chemical analysis of different experimental diets

Item	Experimental diets				
	Control	1% CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX
	D_1	D_2	D_3	D_4	D_5
Moisture	6.59	7.50	7.32	7.27	7.04
Dry matter	93.41	92.50	92.68	92.73	92.96
Chemical analysis on DM basis					
Organic matter	94.11	94.00	93.85	93.79	93.68
Crude protein	30.51	30.18	30.26	30.22	30.34
Crude fiber	5.07	5.22	5.18	5.64	5.40
Ether extract	3.79	3.48	3.89	3.35	3.22
Nitrogen free extract	54.74	55.12	54.52	54.58	54.72
Ash	5.89	6.00	6.15	6.21	6.32
Gross energy kcal/ kg DM	4562	4536	4553	4521	4512
Metabolizable energy(ME) kcal/ kg DM	359.23	356.54	358.15	353.78	353.75
Protein energy ratio(PER) (mg CP/ Kcal ME)	84.93	84.65	84.49	85.42	85.77

CM: Cinnamon meal. WCEX: Water cinnamon extract, GE: calculated according to **Blaxter (1968)** and **MacRae and Lobley (2003)**
ME and PER calculated according to **NRC (2011)**.

Growth and survival ratio

The results presented in Table (3) reveal that feeding the Nile tilapia on diets containing cinnamon meal (CM), water cinnamon extract (WCEX), or their combination (D2, D3, D4, and D5) led to significant improvements in FW, TBWG, and ADG compared to the control diet (D1). Additionally, SGR were enhanced in all groups, except for those fed with D3, relative to the control. The survival rates were 100% in D2, D4, and D5 groups, whereas the survival was 93.33% for D1 and D3 groups. Similarly, the mortality rate was zero in D2, D4, and D5 groups, compared to 6.67% n D1 and D3 groups. Overall, the inclusion of cinnamon meal, water cinnamon extract, or their combination in the diets had a significant impact on these productivities and survival parameters.

Table 3. Growth performance, specific growth rate and survival ratio of different experimental groups

Item	Experimental diets					SEM	Sign. P<0.05
	Control	1% CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX		
	D_1	D_2	D_3	D_4	D_5		
Number of fish	30	30	30	30	30	-	-
IW/10 fish	143	146	142	143	146	0.602	NS
FW/10 fish	349^{c}	366^{b}	362^{b}	368^{b}	390^{a}	3.717	*
Total body weight gain, g (TBWG)	206^{c}	220^{b}	220^{b}	225^{b}	244^{a}	3.544	*
Duration experimental period	56 days						
Average daily gain, g (ADG)	3.68^{c}	3.93^{b}	3.93^{b}	4.02^{b}	4.36^{a}	0.063	*
Specific growth rate (SGR)	1.45^{c}	1.51^{bc}	1.20^{d}	1.57^{b}	1.67^{a}	0.044	*
N at the starter	45	45	45	45	45	-	-
N at the end	42	45	42	45	45	-	-
Survival ratio	93.33	100	93.33	100	100	-	-
Number of dead fish	3	Zero	3	Zero	Zero	-	-
Mortality rate percentages	6.67	Zero	6.67	Zero	Zero	-	-

CM: Cinnamon meal. WCEX: Water cinnamon extract.

Feed utilization

The recorded results in Table (4) indicate that the inclusion of cinnamon meal (CM), water cinnamon extract (WCEX), and their combinations in D2, D3, D4, and D5 groups led to significant improvements in FCR compared to the basal diet (D1). Additionally, the treatments exhibited a significant increase in the feed intake (FI) across the experimental groups, with recorded values of 532.14, 553.72, 540.64, 548, and 572.88g for D1, D2, D3, D4, and D5, respectively.

Similarly, the crude protein intake (CPI) was significantly higher in D2, D3, D4, and D5 groups compared to the basal diet, with corresponding values of 162.36, 167.11, 163.60, 165.89, and 173.81g for the respective diets.

Table 4. Feed utilization of the different experimental groups

Item	Experimental diets					SEM	Sign. *P*<0.05
	Control	1% CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX		
	D_1	D_2	D_3	D_4	D_5		
Total body weight gain, g (TBWG)	206^{c}	220^{b}	220^{b}	225^{b}	244^{a}	3.544	*
Feed intake (FI), g	532.14^{d}	553.72^{b}	540.64^{c}	548^{b}	572.88^{a}	3.790	*
Feed conversion ratio (FCR)	2.58^{c}	2.52^{bc}	2.46^{abc}	2.44^{ab}	2.35^{a}	0.025	*
Feed crude protein %	30.51	30.18	30.26	30.22	30.34	-	-
Crude protein intake (CPI), g	162.36^{b}	167.11^{b}	163.60^{b}	165.89^{b}	173.81^{a}	1.273	*
Protein efficiency ratio (PER)	1.269^{c}	$1.316b^{c}$	1.345^{abc}	1.356^{ab}	1.404^{a}	0.015	*

CM: Cinnamon meal.
WCEX: Water cinnamon extract.

Biochemical parameters

Table (5) shows that protein serum and globulin levels increased significantly in all groups receiving cinnamon treatments compared to the basal diet (D1), with the highest values recorded in fish fed diet D5 (5.54 and 4.21g/ dl, respectively). Albumin levels significantly decreased in D3 group but significantly increased ($P < 0.05$) in groups receiving diets D4 and D5, which combined cinnamon meal and water cinnamon extract. The highest alanine aminotransferase (ALT) level in D2 group was 86.8 units/l, while the highest aspartate aminotransferase (AST) level in D4 group was 247.0 units/l. Uric acid and creatinine levels were significantly higher in fish fed diets D4 and D3, respectively. Additionally, dietary treatments led to a significant increase in glucose levels compared to the basal diet (D1), while cholesterol levels decreased in groups receiving cinnamon meal, water cinnamon extract, or their combination (D2, D3, D4, and D5) compared to the basal diet (D1). Remarkably, the lowest cholesterol value was recorded in D3 group.

Table 5. Biochemical parameters of the different experimental groups

Item	Experimental diets					SEM	Sign. P<0.05
	Control	1 % CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX		
	D_1	D_2	D_3	D_4	D_5		
Total Protein (g/dl)	2.98^{c}	4.11^{b}	3.96^{b}	5.22^{a}	5.54^{a}	0.18	*
Albumin (g/dl)	1.11^{c}	1.03^{cd}	0.85^{d}	1.62^{a}	1.33^{b}	0.07	*
Globulin (g/dl)	1.87^{c}	3.07^{b}	3.11^{b}	3.60^{b}	4.21^{a}	0.15	*
A:G ratio	0.59^{a}	0.34^{b}	0.27^{c}	0.45^{ab}	0.32^{b}	0.09	*
ALT (Unit/l)	74.72^{ab}	86.84^{a}	74.75^{ab}	68.76^{b}	70.41^{b}	4.08	*
AST (Unit/l)	235.7^{ab}	237.5^{ab}	199.0^{b}	247.0^{a}	213.2^{ab}	11.71	*
Uric acid (mg/dl)	3.66^{b}	5.84^{b}	5.71^{b}	10.22^{a}	4.92^{b}	1.10	*
Creatinine (mg/dl)	7.39^{b}	3.19^{c}	10.19^{a}	7.45^{b}	7.11^{b}	0.53	*
Glucose (mg/dl)	16.53^{c}	35.92^{ab}	21.65^{bc}	48.90^{a}	42.35^{a}	5.35	*
Cholesterol (mg/dl)	149.7^{a}	131.4^{ab}	94.41^{b}	128.4^{ab}	120.5^{ab}	14.62	*

CM: Cinnamon meal. WCEX: Water cinnamon extract.

Fish body composition

In Table (6), the results show that the Nile tilapia fed diets incorporating cinnamon meal (CM), water cinnamon extract (WCEX), or their combination experienced a significant reduction in the body composition regarding the organic matter (OM) and crude protein (CP) compared to the basal diet group. Conversely, the dry matter (DM), ether extract (EE), ash, and gross energy content were significantly higher in these groups relative to the control.

Table 6. Fish body composition of initial and different experimental groups fed tested diets

Item	Body composition of initial fish	Experimental diets					SEM	Sign. P<0.05
		Control	1 % CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX		
		D_1	D_2	D_3	D_4	D_5		
Moisture	75.41	75.92[b]	71.74[d]	76.26[a]	69.25[e]	72.26[c]	0.711	*
Dry matter	24.59	24.08[d]	28.26[b]	23.74[e]	30.75[a]	27.74[c]	0.711	*
		Chemical analysis on DM basis						
Organic matter	85.23	86.14[a]	84.49[c]	83.69[d]	84.77[b]	83.62[d]	0.246	*
Crude protein	61.23	65.17[a]	60.10[c]	61.30[b]	58.55[d]	57.50[e]	0.714	*
Ether extract	24.00	20.97[d]	24.39[b]	22.29[c]	26.22[a]	26.10[a]	0.554	*
Ash	14.77	13.86[d]	15.51[b]	16.31[a]	15.23[c]	16.38[a]	0.246	*
Gross energy kcal/ 100g	571.55	565.33[c]	568.83[b]	556.81[d]	577.28[a]	570.40[b]	1.802	*
Gross energy cal/ g DM	5.7155	5.6533[c]	5.6883[b]	5.5681[d]	5.7728[a]	5.7040[b]	0.018	*

CM: Cinnamon meal, WCEX: Water cinnamon extract

Energy retention (ER)% and protein productive value (PPV)%

In Table (7), the data presented indicate that the inclusion of cinnamon meal (CM), water cinnamon extract (WCEX), or their combination in the diets of the Nile tilapia led to an increase in the energy retention percentage (ER%) compared to the control (D1). Specifically, ER% values improved by 4.35, 2.71, 10.61, and 13.02% in D2, D3, D4, and D5 groups, relative to the basal diet group. Conversely, the protein productive value (PPV%) decreased with the inclusion of these additives, with reductions of 9.31, 4.25, 10.50, and 9.95% for diets D2, D3, D4, and D5 compared to the basal diet group (D1).

Table 7. Energy retention and protein productive value % of different experimental groups

Item	Experimental diets					SEM	Sign. P<0.05
	Control	1 % CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX		
	D_1	D_2	D_3	D_4	D_5		
IW/10 fish	143	146	142	143	146	0.602	NS
FW/10 fish	349^{c}	366^{b}	362^{b}	368^{b}	390^{a}	3.717	*
Calculation the energy retention							
Energy content in final body fish (cal / g)	5.6533^{c}	5.6883^{b}	5.5681^{d}	5.7728^{a}	5.7028^{b}	0.018	*
Total energy at the end in body fish (E)	1973^{c}	2082^{b}	2016^{c}	2124^{b}	2225^{a}	24.11	*
Energy content in initial body fish (cal / g)	**5.7155**						
Total energy at the start in body fish (E_0)	817^{ab}	834^{a}	812^{b}	817^{ab}	834^{a}	3.394	*
Energy retained in body fish ($E-E_0$)	1156^{d}	1248^{c}	1204^{cd}	1307^{b}	1391^{a}	22.98	*
Energy of the feed intake (Cal / g feed)	4.562	4.536	4.553	4.521	4.512	-	-
Quantity of feed intake	532.14^{d}	553.72^{b}	540.64^{c}	548.94^{b}	572.88^{a}	3.79	*
Total energy of feed intake (EF)	2428^{d}	3512^{b}	2462^{cd}	2482^{bc}	2585^{a}	14.83	*
Energy retention (ER)%	47.61^{b}	49.68^{b}	48.90^{b}	52.66^{b}	53.81^{a}	0.675	*
Calculation the protein productive value (PPV) %							
CP in final body	65.17^{a}	60.10^{c}	61.30^{b}	58.55^{d}	57.50^{e}	0.714	*
CP at the end (PR_1)	227.44^{a}	219.97^{bc}	221.91^{abc}	215.46^{c}	224.25^{ab}	1.320	*
CP % in initial body	**61.23**						
CP at the start in body fish (PR_2)	87.56^{ab}	89.40^{a}	86.95^{b}	87.56^{ab}	89.40^{a}	0.369	*
Protein Energy retained in body (PR_3) = ($PR_1 - PR_2$)	139.88^{a}	130.57^{b}	134.96^{ab}	127.90^{b}	134.85^{ab}	1.420	*
CP in feed intake	30.51	30.18	30.26	30.22	30.34	-	-
PI, g	162.36^{b}	167.11^{b}	163.60^{b}	165.89^{b}	173.81^{a}	1.273	*
PPV %	86.15^{a}	78.13^{b}	82.49^{ab}	77.10^{b}	77.58^{b}	1.121	*

CM: Cinnamon meal, WCEX: Water cinnamon extract.

Economic evaluation

Table (8) shows that the cost of feed formulation decreased upon incorporating cinnamon meal (CM), water cinnamon extract (WCEX), or their combination into the Nile tilapia diets. The cost per kilogram of feed reduced from 24.350 LE in the control diet (D1) to 24.235 LE, 24.210 LE, 24.223 LE, and 24.095 LE for rations, D2, D3, D4, and D5, respectively. Additionally, the net improvement in cost efficiency was 2.32, 4.62, 5.40, and 8.82% for groups of D2, D3, D4, and D5, which is higher compared to the basal diet (D1), without cinnamon meal or water extract.

Table 8. Economical evaluation of different experimental groups

Item	Tested diets				
	Control	1 % CM	1% WCEX	0.5% CM + 0.5% WCEX	1% CM + 1% WCEX
	D_1	D_2	D_3	D_4	D_5
Costing of kg feed (LE)	24.350	24.235	24.210	24.223	24.095
Relative to control (%)	100	99.53	99.43	99.48	98.95
Feed conversion ratio (FCR)	2.58	2.52	2.46	2.44	2.35
Feeding cost (LE) per (Kg weight gain)	62.82	61.07	59.56	59.10	56.62
Relative to control (%)	100	97.21	94.81	94.08	90.13
Net improvement in feeding cost (%)	Zero	2.32	4.62	5.40	8.82

CM: Cinnamon meal. WCEX: Water cinnamon extract, LE.: Egyptian pound
Diet formulation calculated according to the local prices in 2024, as presented in Table (1).
Feed cost (L.E) FCR×FI. Cost per Kg diet.

DISCUSSION

The study results recorded significant improvements in productivity and survival rates of fish fed rations with cinnamon meal (CM), water cinnamon extract (WCEX), or a combination of both. FW, TBWG, and ADG were improved in the treated groups compared to the control, with a specific growth rate (SGR) showing improvement in all, except for the D3 group. Fish in the D2, D4, and D5 groups achieved a 100% survival rate (SR), while D1 and D3 recorded a slightly lower SR value of 93.33%. Similarly, the mortality rate was zero for D2, D4, and D5, with D1 and D3 showing a mortality rate of 6.67%. Feed utilization, as FCR and FI, significantly enhanced in the treated groups, given that D5 group recorded the highest FI (572.88g). The current results align with those of **Abdel-Tawwab *et al*. (2018)**, who reported an improved performance with cinnamon nanoparticle supplementation in the Nile tilapia. Other studies supported these findings, recording the cinnamon's positive effects on the productivity of various fish species. The biochemical findings of this study complement the previous set of findings since they reveal a rise in the serum total protein and globulin in all groups that received cinnamon treatment. High protein and globulin values indicated the positive effect of cinnamon on fish immunological state, especially that of D5 group. Such observations were reported in the study of **Aly *et al.* (2023)**, who found that feeding the Nile tilapia with cinnamon and garlic increased both specific and non-specific immunity in fish suffering from fungal infections. Previous studies have also highlighted the protective role of natural plants in aquaculture and their positive effects on protein and globulin levels **(Abbas *et al*., 2019a, b; Awad *et al*., 2024)**.

The non-significant changes in alanine aminotransferase (ALT) and aspartate aminotransferase (AST) values in most cinnamon-treated groups indicate the safety of cinnamon for liver tissue, subsequently unaffecting liver function. Additionally, non-significant changes in the uric acid and creatinine levels suggest a normal kidney function, except for the increased values in groups D3 and D4, which may be attributed to high protein concentrations.

Regarding glucose levels, cinnamon is known for its anti-diabetic effects; however, this study observed an increase in glucose levels, possibly due to the stress associated with introducing an unfamiliar food. Exposure to external stressors can induce the secretion of catecholamines and cortisol, which increases glucose production to meet energy demands during stress **(Authman *et al.*, 2021)**.

Body composition analysis showed a significant decrease in crude protein content, while increases were detected in the dry matter (DM), ether extract (EE), ash, and gross energy (GE) of the cinnamon-treated fish compared to the basal diet group (D1). Cinnamon may have activated insulin-like growth factors, enhancing protein and collagen biosynthesis. However, results from other studies on cinnamon's effects on the body composition varied, reflecting differences in species and experimental conditions.

Energy retention (ER%) and protein productive value (PPV%) were positively influenced by the inclusion of cinnamon, as noted in previous studies. Economic evaluations also revealed that the inclusion of cinnamon meal (CM) and water cinnamon extract (WCEX) in rations improved the economic efficiency, aligning with the findings of **Goda *et al.* (2012)** regarding the cost-effectiveness of using natural additives in aquaculture.

CONCLUSION

Cinnamon, whether used as a meal or extract, can significantly enhance growth, feed utilization, immune response, and economic efficiency in aquaculture, making it a promising additive for improving fish health and productivity. The data suggest that the inclusion of cinnamon meal, water cinnamon extract, and their combination in fish diets does not negatively affect growth productivity or feed utilization, while also improving energy retention and protein productive value. Furthermore, cinnamon increases serum total protein and globulin levels while decreasing serum cholesterol. Additionally, it leads to a reduction in net feeding costs.

REFERENCES

Abbas, W.T; Authman, M.M.N; Darwish, D.A; Kenawy, A.M; Abumourad, I.M.K. and Ibrahim, T.B. (2019a). Cadmium toxicity-induced oxidative stress and genotoxic effects on Nile tilapia (*Oreochromis niloticus* L.) fish: The protective role of fenugreek (*Trigonella foenum-graecum*) seeds. Egypt. J. Aquat. Res., 23(5 (Special Issue)), 193-215.

Abbas, W.T.; Ibrahim, T.B.E.; Elgendy, M.Y. and Zaher, M.F.A. (2019b). Effect of Curcumin on Iron Toxicity and Bacterial Infection in Catfish (*Clariasgariepinus*). PJBS, 22 (11), 510-517.

Abdellah, K.M.; Said, M. M. and Elkady, E.M. (2024). Commercial Probiotic Usage to Improve Semi-Intensive Tilapia Production System Under Egyptian Conditions. Egyptian Journal of Aquatic Biology & Fisheries, 28(5): 1039 – 1058

Abdel-Latif, H.M.R.; Abdel-Daim, M.M.; Shukry, M.; Nowosad, J. and Kucharczyk, D. (2022). Benefits and applications of *Moringa oleifera* as a plant protein source in Aqua feed: a review. Aquac. 547: 737369.

Abdel-Tawwab, M. (2012). The use of American ginseng (*Panax quinquefolium*) in practical diets for Nile tilapia (*Oreochromis niloticus*): growth performance and challenge with Aeromonas hydrophila, J. Appl. Aquac., 24: 66-76.

Abdel-Tawwab, M.; Samir, F.; Asmaa, S. Abd El-Naby, M. and Monier, N. (2018). Antioxidative and immunostimulatory effect of dietary cinnamonnano particles on the performance of Nile tilapia, *Oreochromis niloticus* (L.) and its susceptibility to hypoxia stress and Aeromonas hydrophila infection. Fish Shellfish Immunol., 74: 19-25.

Abozaid, H.; Elnadi, A.S.M.; Aboelhassan, D.M.; El-Nomeary Y. A.A.; Omer, H.A.A. and Abbas, W.T. (2024b). Using the dried yeast (*Saccharomyces cerevisiae*) as a growth promoter in the Nile tilapia (*Oreochromis niloticus*) diets. Egypt. J. Aquatic Biol. Fish., 28 (2): 699 -716.

Abozaid, H.; Elnadi, A.S.M.; Mansour, H.; Aboelhassan, D.M.; Awad, E.; El-Nomeary, Y.A.A.; Omar, H.A.A.; Abbas, W.T. and Farag, I.M. (2024a). Nutritional Effect of Using a Bioactive Mixture (Lemon, Onion and Garlic) on Growth Performances, Feed Utilization, Immune Status and Gene Expression of Nile tilapia (*Oreochromis niloticus*). Egypt. J. Vet. Sci., 55 (6): 1669-1684.

Ahmad, M.H.; El Mesallamy, A.M.D.; Samir, F. and Zahran, F. (2011). Effect of cinnamon (*Cinnamomum zeylanicum*) on growth performance, feed utilization, whole-body composition, and resistance to Aeromonas hydrophila in Nile tilapia, J. Appl. Aquac., 23: 289-298.

Ahmadifar, E.; Yousefi, M.; Karimi, M. and Fadaei Raieni, R., *et al*. (2021). Benefits of dietary polyphenols and polyphenol-rich additives to aquatic animal health: an overview. Rev. Fish. Sci. Aquac., 29: 478-511.

Alderman, D.J. and Hastings, T.S. (1998). Antibiotic use in aquaculture: development of antibiotic resistance-potential for consumer health risks, Int. J. Food Sci. Technol., 33: 139-155.

Aly, S. M.; Elatta, M. A.; Nasr, A. A. and Fathi, M. (2023). Efficacy of garlic and cinnamon as an alternative to chemotherapeutic agents in controlling Saprolegnia infection in Nile tilapia. Aquaculture and Fisheries. In press. https://doi.org/10.1016/j.aaf.2023.07.010.

AOAC (**2016**). Official Methods of Analysis, 18*th* ed. Association of Official Analytical Chemists, Washington, DC, USA (2005). All content following this page was uploaded by Hayder N. Al-Mentafji on 02 February 2016.

Authman, M.M.; Abbas, W.T.; Abbas, H.H.; Kenawy, A.M.; Ibrahim, T.B. and Abd El-Hady, O.K. (2021). Ameliorative effect of the dietary Egyptian leek (*Allium ampeloprasum* L. var. Kurrat) on zinc toxicity of the African catfish, *Clarias gariepinus* (Burchell, 1822). Aqua Res., 52(11): 5656-5672.

Awad, E. and Awaad, A. (2017). Role of medicinal plants on growth performance and immune status in fish. Fish Shellfish Immunol., 67, 40-54.

Awad, E. S.; Abdelzaher, M.F.; Abbas, W.T.; Darwish, D.A.; Abdel-Monsef, M.; Younes, A.M. and Gaafar, A.Y. (2024). Effect of Beetroot (*Beta vulgaris* L.) Extract on Enhancing the Immune Status and Antioxidant Enzymes of the Nile tilapia (*Oreochromis niloticus*) Exposed to Lead. Egypt. J. Aquat. Res., 28(3): 439-459.

Begum, M.K.; Eshik, M.M.E.; Punom, N.J.; Abedin, M.M. and Rahman, M.S. (2018). Growth performances and bacterial load of *Heteropneustes fossilis* (Bloch, 1794) using cinnamon as feed supplement. Bangladesh J. Zool., 46 (2), 155–166.

Blaxter, K.L. (1968). The energy metabolism of ruminants. 2*nd*ed. Charles Thomas Publisher. Spring field. Illinois, USA**.**

Cannon, D.C.; Olitzky, I. and Inkpen, J.A. (1974). Proteins. In: Clinical Chemistry, principles and techniques, 2nd ed., R.J. Henery, D.C. Cannon, J.W. Wink Elman (eds.), Harper and Row New York, pp: 407-421.

Cao, X.F.; Dai, Y.J.; Liu, M.Y.; Yuan, X.Y.; Wang, C.C.; Huang, Y.Y. and Jiang, G.Z. (2019). High-fat diet induces aberrant hepatic lipid secretion in blunt snout bream by activating endoplasmic reticulum stress-associated IRE1/XBP1 pathway. Biochim. Et. Biophys. Acta (BBA). Mol. Cell Biol. Lipids 1864 (3), 213–223.

Caraway, W.T. and Watts N.B. (1987). Carbohydrates In: Fundamentals of clinical chemistry. 3ry ed. Edited by Tietz, N.W. Philadelphia, WB Saunders. P: 422-47.

Chen, Q. Q.; Liu, W. B.; Zhou, M.; Dai, Y.J.; Xu, C.; Tian, H.; Yand Xu, W.N. (2016). Effects of berberine on the growth and immune performance in response to ammonia stress and high-fat dietary in blunt snout bream *Megalobrama amblycephala*. Fish Shellfish Immunol., 55, 165–172.

Chitraju, C.; Mejhert, N.; Haas, J.T.; Diaz-Ramirez, L.G.; Grueter, C.A.; Imbriglio, J.E.; Pinto, S.; Koliwad, S.K.; Walther, T.C. and Farese Jr., R.V. (2017). Triglyceride synthesis by DGAT1 protects adipocytes from lipid-induced ER stress during lipolysis. e403 Cell Metab., 26 (2), 407–418.

Citarasu, T. (2010). Herbal Biomedicines: a New Opportunity for Aquaculture Industry, (2010), pp. 403-414, http://dx.doi.org/10.1007/s10499-009-9253-7.

Dügenci, S.K.; Arda, N. and Candan, A. (2003). Some medicinal plants as immunostimulant for fish, J. Ethnopharmacol. 88: 99-106.

Duncan, D.B. (1955). Multiple Rang and Multiple F-Test Biometrics, 11: 1-42.https://doi.org/10.2307/3001478https://www.jstor.org/stable/3001478 doi:10.2307/3001478

Ellefson, R.D. and Caraway, W.T. (1976). Fundamentals of clinical chemistry. Ed Tietz, N.W. Philadelphia, WB Saunders. p: 506.

Goda, A.M.A.; Mabrouk, H.A.H.; Wafa, M.A. and El-Afifi, TM. (2012). Effect ofusing Baker's yeast and exogenous digestive enzymes as growth promoters ongrowth, feed utilization and hematological indices of Nile tilapia, *Oreochromis niloticus* fingerlings. J. Agric. Sci. Technol., B2 (1B): 15-28.

Gruenwald, J.; Freder, J. and Armbruester, N. (2010). Cinnamon and health, Crit. Rev. Food Sci. Nutr., 50: 822-834.

Hamed, H.S.; Omaya, M.I. and Abdel-Tawwab, M. (2022). Modulatory effects of dietary cinnamon (*Cinnamomum zeylanicum*) against waterborne lead toxicity in Nile tilapia fingerlings: Growth performance, haemato-biochemical, innate immunity and hepatic antioxidant indices. Aqua Reports., 25: 101190.

Harikrishnan, R.; Balasundaram, C. and Heo, M.S. (2011). Impact of plant products on innate and adaptive immune system of cultured finfish and shellfish. Aquac., 317, 1–15.

Hoseinifar, S.H.; Sun, Y.Z.; Zhou, Z.; Van Doan, H.; Davies, S.J. and Harikrishnan, R. (2020). Boosting immune function and disease bio-control through environment-friendly and sustainable approaches in finfish aquaculture: herbal therapy scenarios. Rev. Fish. Sci. Aquac., 28, 303-321.

Kwon, H.K.; Jeon, W.K.; Hwang, J.S.; Lee C.G.; So, J.S.; Park, J.A.; Ko, B.S and Im, S.H. (2009). Cinnamon extract suppresses tumor progression by modulating angiogenesis and the effect or function of CD8+ T cells, Canc. Lett., 278: 174-182.

Lee, S.H.; Lee, S.Y.; Son, D.J.; Lee, H.; Yoo, H.S.; Song, S.; Oh, K.W.; Han, D.C.; Kwon, B.M. and Hong, J.T. (2005). Inhibitory effect of 2-hydroxycinnamaldehyde on nitric oxide production through inhibition of NF-κB activation in RAW 264.7 cells. Biochem. Pharm., 69: 791-799.

Li, Z.; Gao, Q.; Dong, S.; Dong, K.; Xu, Y.; Mei, Y. and Hou, Z. (2024). Effects of Chronic Stress from High Stocking Density in Mariculture: Evaluations of Growth Performance and Lipid Metabolism of Rainbow Trout (*Oncorhychus mykiss*). Biology, 13(4), 263.

Łuczaj, W.; Zapora, E.; Szczepański, M.; Wnuczko, K. and Skrzydlewska, E. (2009). Polyphenols action against oxidative stress formation in endothelial cells, Acta Pol. Pharm., 66: 617-624.

MacRae, **J. and Lobley, G.E. (2003).** Some factors which influence thermal energy losses during the metabolism of ruminants Quelques facteurs des pertes d'energie thermique liées au métabolisme des ruminants Einige Faktoren mit Einfluss auf die Wärmeenergieverluste während des Stoffwechsels bei Wiederkäuern. Livestock Production Science, 9(4): 447-45, July 1982, Accepted 16 December 1981, Available online 1 October 2003. https://doi.org/10.1016/0301-6226(82)90050-1.

Matan, N.; H. Rimkeeree, A.J.; Mawson, P.; Chompreeda, Haruthaithanasan, V. and Parker, M. (2006). Antimicrobial activity of cinnamon and clove oils under modified atmosphere conditions, Int. J. Food Microbiol., 107: 180-185.

Nabavi, S.F.; Lorenzo, D.i.; Izadi, A.; Sobarzo-S´anchez, M.; Daglia, E. and Nabavi, S.M.M. (2015). Antibacterial effects of cinnamon: from farm to food, cosmetic and pharmaceutical industries. Nutri., 7: 7729-7748.

NRC (2011). National Research Council. Nutrient Requirement of Fish. National Academy Press, Washington, DC, USA.

Pridgeon, J.W. and Klesius, P.H. (2011). Virulence of Aeromonas hydrophila to channel catfish Ictaluras punctatus fingerlings in the presence and absence of bacterial extra cellular products, Dis. Aquat. Org., 95: 209-215.

Reitman, S. and Frankel, S. (1957). Colorimetric determination of glutamic oxaloacetic and glutamic pyruvic transaminases, Am. J. Clin. Pathol., 28: 53-56.

Reverter, M.; Bontemps, N.; Lecchini, D.; Banaigs, B. and Sasal, P. (2014). Use of plant extracts in fish aquaculture as an alternative to chemotherapy: current status and future perspectives. Aqua., 433, 50-61.

Rice-Evans, C.; Miller, N. and Paganga, G. (1997). Antioxidant properties of phenolic compounds,Trends Plant Sci., 2: 152-159.

Setiawati, M.; Jusadi, D.; Laheng, S.; Suprayudi, A.M. and Vinasyiam, A. (2016). The enhancement of growth performance and feed efficiency of Asian catfish, *Pangasianodon hypophthalmus* fed on *Cinnamomum burmannii* leaf powder and extract as nutritional supplementation. Legis J. Bioflux Soc., 9 (6): 1301-1309.

Shan, B.; Cai, Y.Z.; Brooks, J.D. and Corke, H. (2009). Antibacterial and antioxidant effects of five spice and herb extracts as natural preservatives of raw pork, J. Sci. Food Agric., 89: 1879-1885.

Sivagurunathan, A. and Innocent, B.X. (2017). Immunomodulatory effect of dietary cinnamon in growth and haematology of tilapia challenged with Pseudomonas aeruginosa, Int. J. Pharm. Phytopharm. Res., 3: 277-280.

SPSS (2020). Statistical Package for Social Science (**Software version:** 22.0).

Teuber, **M.(2001)**. Veterinary use and antibiotic resistance, Curr. Opin. Microbiol., 4: 493-499.

Tietz, N.W. (1990). Clinical guide to laboratory tests. 2*nd*Ed. Philadelphia, WB Saunders, 566pp.

Van Doan, H.; Hoseinifar, S.H.; Dawood, M.A.O.; Chitmanat, C. and Ayyamath, K. (2017). Effects of Cordyceps militaris spent mushroom substrate and Lactobacillus plant arum on mucosal, serum immunology and growth performance of Nile tilapia (*Oreochromis niloticus*), Fish Shellfish Immunol., 70: 57- 94.

Zhang, K.; Wang, S.; Malhotra, J.; Hassler, J.R.; Back, S.H.; Wang, G.; Chang, L.; Xu, W.; Miao, H.; Leonardi, R.; Chen, Y.E.; Jackowski, S and Kaufman, R.J., 2011. The unfolded protein response transducer IRE1α prevents ER stress-induced hepatic steatosis. EMBO J. 30 (7), 1357–1375. https://doi.org/10.1038/ emboj. 2011.52.