

## Using *Artemia Parthenogenetica* Powder in Broiler Diets on Some Physiological and Oxidation Indicators

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### Abstract

This study aimed to partial replacement of artemia powder with different protein concentrate levels in broiler diets on selected physiological and oxidation indicators. Two hundred and forty, one-day-old Ross 308 chicks were distributed to four levels of Artemia powder replacement: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%). Results of Statistical analysis showed no significant changes in most blood physiological indicators at 21 days of age across all treatments. However, albumin levels decreased in T3, while globulin decreased in T4 -compared to T1. Blood urea levels significantly increased with higher replacement, with T3 and T4 showing the highest values at 21 days. At 35 days of age, T2, T3, and T4 demonstrated clear positive changes in several biochemical indicators. Replacement resulted in a significant decrease in some lipid profile and protein levels at 35 days compared to T1, while no changes were observed in cholesterol, glucose, albumin, globulin ratio, uric acid, urea, creatinine, aspartate aminotransferase, or alanine aminotransferase. Additionally, a significant increase was observed in high-density lipoprotein levels and alkaline phosphatase activity. There was a substantial rise in certain oxidative stress markers, specifically glutathione, superoxide dismutase, and glutathione peroxidase, with no differences in catalase and malondialdehyde at 35 days. Furthermore, intestinal villus length was unaffected by replacement, while crypt depth significantly increased with supplementation at the end of the experiment. The results indicate that partial replacement of Artemia powder up to a level of 1.5% can be used as a safe food substitute, with potential biochemical and physiological benefits.

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### Introduction

In commercial broiler production, proteins are essential macronutrients that have a significant impact on feed costs, growth performance, and production efficiency. Proper protein mixtures and sufficient amounts of amino acids are necessary to maintain optimal performance, as contemporary broiler chickens grow faster and utilize feed more efficiently (Beski *et al.*, 2015). Given the changing trends in poultry nutrition, a comprehensive study of alternative protein sources is necessary to address sustainability concerns and cost limitations associated with conventional ingredients (Al-Khalafah and Al-Nasser, 2023; Al-Baidhani *et al.*, 2025). Recent studies have explored into a variety of protein alternatives, such as plant-

based concentrates, poultry byproducts, and aquatic sources, to improve amino acid balance while preserving high nutritional value (Al-Azzawi and Bandr, 2023; Spínola *et al.*, 2024).

The crustacean species *Artemia parthenogenetica*, also known as brine shrimp, is found in more than 500 tropical and subtropical saline waters worldwide (Anand *et al.*, 2024). These organisms are two different species: *Artemia urmiana* and *Artemia parthenogenetica*, and are promising as a possible replacement protein source for poultry diets due to their remarkable nutritional value (Gharibi *et al.*, 2021). The high protein content of artemia (40-60%) of its dry weight is comparable to that of conventional animal protein sources, highly varied levels of highly unsaturated fatty acid content (HUFA) are among the other nutritional components (Salman *et al.*, 2020). Additionally, it contains a lot of vital amino acids that improve immunity and health, which lowers the prevalence of disease (Peykaran *et al.*, 2014; Hamdan *et al.*, 2016). *Artemia* gives poultry with between (2131 and 3500) kcal of energy and has a protein digestibility coefficient of about 92%, it also contains essential minerals that the body needs to function correctly (Madkour *et al.*, 2022).

Furthermore, assessing the physiological reactions of poultry is essential to guaranteeing the safe addition of these substitute protein sources to poultry diets, the viability of these replacements can be positively indicated by tracking physiological markers like growth performance, immunological response, and general health (Abdel-Wareth *et al.*, 2024). This method ensures that the switch to alternative sources is safe and efficient for poultry production by highlighting the nutritional advantages of alternative proteins and assisting in the identification of any possible negative effects. Knowing the levels of lipids such as cholesterol, triglycerides, and lipoproteins, including high-density lipoprotein (HDL), very-low-density lipoprotein (VLDL), and low-density lipoprotein (LDL) in the blood can give a picture of what the effect of inclusion of *Artemia* powder on serum lipid profiles when using it as a viable protein source (Cheng *et al.*, 2020). In order to build trust in the use of innovative ingredients and eventually support a more sustainable and profitable poultry industry, such evaluations are crucial (Khan *et al.*, 2023), and determine whether varying amounts of *Artemia* can be used as a substitute for protein concentrate in broiler diets (Cheng *et al.*, 2020; Oke *et al.*, 2024). Thus, this study intends to ascertain the best amount to use, assess the effects of the supplement on different body functions, oxidation indicators, and intestinal structure,

## **Materials and Methods**

### **Ethics Approval**

The scientific ethical committee of the Animal Production Department, College of Agricultural Engineering Sciences, University of Baghdad, approved this study and gave the Ethical Number (108/2025). All applicable national and international guidelines for the care and use of animals were followed.

### **Experiment Design**

This study was conducted at the Poultry Farm, a part of the Department of Animal Production, College of Agriculture Engineering Sciences, University of Baghdad on Abu Ghraib, from April 15, 2024, to May 20, 2024. Two hundred and forty, one-day-old Ross308

chicks weighing an average of 38.72 g were used. The chicks were divided up randomly into four groups, each with three replicates (20 birds each replicate). The chicks were fed diets that included different levels of artemia powder as a partial substitute for protein concentrate:

**T1:** 0 (%) replacement of artemia powder (Control Group without any substitute).

**T2:** 0.5 (%) replacement of artemia powder with protein concentrate.

**T3:** 1 (%) replacement of artemia powder with protein concentrate.

**T4:** 1.5 (%) replacement of artemia powder with protein concentrate.

Chemical Analysis, Amino and fatty acids of Artemia Powder were determined in the laboratories of the Ministry of Science and Technology, Baghdad were present in Table 1.

**Table 1. Chemical Analysis of Artemia Powder**

Chemical Composition	
Crude Protein (%)	33.2
Moisture (%)	4.44
Ash (%)	3.5
Crude Fiber (%)	6.5
Ether Extract (%)	3.1
Metabolizable Energy (kcal/kg)	2804
Methionine (%)	0.286
Lysine (%)	0.746
Calcium (%)	0.198
Available Phosphorus (%)	0.41
Palmitic Acid (Gmg <sup>-1</sup> )	15.93
Linoleic Acid (G mg <sup>-1</sup> )	18.86
Linolenic Acid (G mg <sup>-1</sup> )	32.74

Three different diets were used based on the age of the birds (Table 2): the starter diet for days 1-10, the grower diet for days 11-22, and the finisher diet for days 23-35, all diets formulated were Balanced energy and protein according to the Ross 308 (Aviagen, 2022) Manual.

**Table 2. Percentage of Feed Compound of Diets and their chemical analysis composition**

Ingredients	T1	T2	T3	T4
Maize	48	48	48	48.5
Wheat	9.7	9.5	9.4	8.55
Soybean meal 48 (%)	33	33.1	33.15	33.4
Protein concentrate	5	4.5	4	3.5
Artemia powder	0	0.5	1	1.5
Plant oil	2	2	2	2
Limestone	1.2	1.2	1.2	1.15
Salts	0.2	0.2	0.2	0.2

<b>Di calcium phosphate (DCP)</b>	0.7	0.8	0.85	1
<b>Vitamin</b>	0.2	0.2	0.2	0.2
<b>Totals</b>	100	100	100	100
<b>Chemical Analysis</b>				
<b>Crude protein (%)</b>	23.08	23.00	23.02	23.03
<b>Energy (kilo calorie/ kg diet)</b>	3002.20	3002.41	3000.87	3001.19
<b>Methionine +cysteine (%)</b>	0.50	0.50	0.50	0.50
<b>Lysine (%)</b>	1.38	1.35	1.33	1.32
<b>Calcium (%)</b>	0.96	0.96	0.96	0.96
<b>Available phosphorus (%)</b>	0.46	0.46	0.467	0.47

All chicks *ad libitum* feed and water along all experiment period. The chicks were housed under continuous light, with a one-hour breaks in lighting each day to allow for the electric current to be turned off. The heating was controlled by a gas incubator.

Blood samples were collected at 21 and 35 days of age via the wing vein and then dispensed in test tubes; serums were collected and analyzed after the centrifuge was complete and transferred to a new clean tube for measure glucose, total protein, albumin, lipid profile, AST, ALT, ALP, Uric acid, Urea and creatinine, the analyses were measure by commercial ready use kit Manufactured by BIOLABO (French) using chemistry analyzer manufactured by XIAN YIMA (Joody *et al.*, 2018). In addition, CAT, Malondialdehyde (MDA), GSH, SOD, and GPX, according to the method Weydert and Cullen (2010). Histological examinations were conducted following the guidelines provided by Bancroft and Marilyn (2008).

### Statistical analysis

The data of the experiment were analyzed using the complete random design (CRD) using the ready-made statistical program SAS (SAS, 2012). Also, the significant differences between the means were compared using Duncan's polynomial test (Duncan, 1955) at a significance level of 5%.

### Results and Discussion

The presented results in Table 3 indicate a clear fluctuation in lipid profile values; however, these variables were numerically in the first twenty-one days compared to the last fifteen days of the chick's life, which showed statistical significance. The cholesterol homeostasis appeared throughout the experiment contrary to the other values of lipid profile, which may be attributed to the body's Self-Regulation of Cholesterol by the liver, which adjusts its cholesterol production (increase or decrease) based on dietary intake; thus, the body was still able to maintain in the normal levels compared to control groups (Trapani *et al.*, 2012; Desert *et al.*, 2018), Added artemia powder does not increase cholesterol intake due to its low fat content, including cholesterol and unsaturated fatty acids. However, it notably increases HDL (good cholesterol) and decreases LDL (bad cholesterol) levels, which transport cholesterol in the bloodstream. This improvement in lipoproteins is attributed to Artemia's unique

biochemical composition, including essential fatty acids (omega-3 and omega-6), astaxanthin, carotenoids, and chitin (Peykaran et al., 2014; De Carvalho and Caramujo, 2017; Elbahnasy and Elshopakey, 2024), which collectively enhance lipid transport efficiency, modulate hepatic lipid metabolism, and upregulate genes involved in cholesterol efflux pathways. The ATP-binding cassette transporter A1 (ABCA1) gene, responsible for transporting cholesterol back to the liver for excretion or recycling, is key in reverse cholesterol transport, removing excess cholesterol from peripheral tissues and reducing serum cholesterol levels (Pizzini *et al.*, 2017). Studies showed carotenoids in artemia improve ABCA1 gene expression, increasing HDL levels while decreasing intracellular cholesterol pools and reducing LDL production (Wang *et al.*, 2024). Additionally, omega-3 fatty acids and chitin in artemia powder activate important enzymes for lipid metabolism (LCAT, LPL, CYP7A1, and HL) (Kasbi *et al.*, 2013). Enhanced LCAT and LPL activity supports HDL synthesis and triglyceride clearance, while CYP7A1 regulates cholesterol conversion into bile acids in the liver, promoting cholesterol elimination and lowering serum LDL concentrations (Chen *et al.*, 2021).

**Table 3. Effect of different levels of Artemia Powder in broiler diets on serum lipid profiles in 21 and 35 days of age (Mean  $\pm$  standard error)**

Age	Parameters	T1	T2	T3	T4	Significant level
21 days	Cholesterol (mg/dl)	101.90 $\pm$ 15.07	96.13 $\pm$ 16.29	92.71 $\pm$ 3.72	98.48 $\pm$ 15.46	N.S
	Triglyceride (mg/dl)	69.61 $\pm$ 6.92	78.02 $\pm$ 11.67	73.49 $\pm$ 9.62	87.07 $\pm$ 9.65	N.S
	HDL (mg/dl)	43.46 $\pm$ 0.79	41.13 $\pm$ 12.16	51.83 $\pm$ 10.29	54.07 $\pm$ 2.87	N.S
	VLDL (mg/dl)	13.92 $\pm$ 1.38	15.60 $\pm$ 2.33	14.69 $\pm$ 1.92	17.41 $\pm$ 1.93	N.S
	LDL (mg/dl)	44.52 $\pm$ 13.92	39.40 $\pm$ 19.15	26.18 $\pm$ 12.54	30.59 $\pm$ 12.55	N.S
35 days	Cholesterol (mg/dl)	93.71 $\pm$ 7.77	82.87 $\pm$ 15.65	83.79 $\pm$ 10.42	58.96 $\pm$ 6.80	N.S
	Triglyceride (mg/dl)	114.05 $\pm$ 14.05 a	57.83 $\pm$ 11.19 b	51.80 $\pm$ 6.70 b	41.36 $\pm$ 3.13 b	*
	HDL (mg/dl)	41.71 $\pm$ 16.89 a	62.84 $\pm$ 3.27 b	52.92 $\pm$ 0.66 a	51.24 $\pm$ 10.89 a	*
	VLDL (mg/dl)	22.81 $\pm$ 2.81 a	11.56 $\pm$ 1.93 b	10.36 $\pm$ 1.38 b	8.27 $\pm$ 2.33 b	*
	LDL (mg/dl)	29.19 $\pm$ 10.57 a	19.77 $\pm$ 12.55 b	21.26 $\pm$ 13.92 a	20.34 $\pm$ 19.15 b	*

Levels of substitute protein concentrate with Artemia Powder: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%).

Different letters within the same row indicate significant differences according to Duncan's multiple range test 5 %. NS: means -there are no significant differences between the treatments.

The absence of an effect on blood sugar levels was due to the low carbohydrate content of artemia, which consequently does not directly impact blood sugar levels. In addition, essential fatty acids in their composition, such as omega-3, may play an important role in

maintaining stable glucose levels in the blood, as noticeable in Table 4. The reduction in blood proteins, including albumin and globulin levels, was noted on day 21 of treatment four, along with continued decline on day 35. However, these decreases are not significant in some proteins, which may be attributed to the substantial substitution of protein concentrate in the diet with *Artemia* that reduced the total protein available for absorption and utilization by the bird. Also, *Artemia* has a lower protein content compared to other protein sources or may lack sufficient amounts of essential amino acids such as lysine and methionine (Piotrowska *et al.*, 2011), furthermore, certain compounds in *Artemia*, such as chitin, may influence protein digestion and absorption, which subsequently impacts blood protein levels, as noted in Table 5. Inspection levels of albumin, globulin, and (A/G) ratio is essential and could open several avenues for inquiry because it could reflect specific physiological and metabolic changes. Albumin plays a role in transport and osmotic regulation, while globulins are related to immunity and metabolism. A decreased ratio, as noticed in our result, could indicate over-supplementation, nutrient imbalances, or changes in immune response (improvements in health, such as reduced infection or stress, or a lack of stimulation for globulin production) as a result of additive, also may suggest an *Artemia* powder needed for supplementation to improve nutritional value without upsetting metabolic balance and ensuring get the desired adequate immune stimulation (Tóthová *et al.*, 2019).

**Table 4. Effect of different levels of Artemia powder in broiler diets on some biochemical parameters in 21 and 35 days of age (Mean  $\pm$  standard error)**

Age	Parameters	T1	T2	T3	T4	Significant level
21 days	Glucose (mg/dl)	190.10 $\pm$ 7.77	188.24 $\pm$ 4.84	198.49 $\pm$ 18.67	219.45 $\pm$ 14.81	N.S
	Protein (g/dl)	3.55 $\pm$ 0.12	3.72 $\pm$ 0.11	3.51 $\pm$ 0.27	3.05 $\pm$ 0.32	N.S
	Albumin (g/dl)	1.82 $\pm$ 0.08 a	1.64 $\pm$ 0.09 ab	1.49 $\pm$ 0.07 b	1.73 $\pm$ 0.08 ab	*
	Globulin (g/dl)	1.74 $\pm$ 0.17 ab	2.09 $\pm$ 0.20 a	2.02 $\pm$ 0.26 ab	1.32 $\pm$ 0.26 b	*
	Albu/Globu	1.08 $\pm$ 0.13 ab	0.82 $\pm$ 0.12 b	0.77 $\pm$ 0.11 B	1.52 $\pm$ 0.36 a	*
35 days	Glucose (mg/dl)	145.59 $\pm$ 48.61	156.64 $\pm$ 19.61	147.68 $\pm$ 7.33	151.38 $\pm$ 15.09	N.S
	Protein (g/dl)	3.24 $\pm$ 0.34 a	2.66 $\pm$ 0.12 ab	2.82 $\pm$ 0.15 ab	2.48 $\pm$ 0.08 b	*
	Albumin (g/dl)	1.72 $\pm$ 0.18	1.58 $\pm$ 0.18	1.44 $\pm$ 0.15	1.36 $\pm$ 0.04	N.S
	Globulin (g/dl)	1.52 $\pm$ 0.27	1.07 $\pm$ 0.15	1.38 $\pm$ 0.30	1.11 $\pm$ 0.08	N.S
	Albu/Globu	1.19 $\pm$ 0.20	1.57 $\pm$ 0.35	1.21 $\pm$ 0.38	1.23 $\pm$ 0.10	N.S

Levels of substitute protein concentrate with *Artemia* Powder: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%).

Different letters within the same row indicate significant differences according to Duncan's multiple range test 5%. NS: means -there are no significant differences between the treatments.

The increase in urea concentration observed on day 21 (Table 5), correlating with higher levels of added Artemia, suggests that the additional protein source contributed to increased protein breakdown and availability. Also, the numerical increase observed in our experiment, along with the decline in blood protein levels as Artemia concentration increased, potentially reflects increased liver and kidney activity where nitrogen is converted into urea to be excreted via the kidneys, that could serve as clear evidence supporting our hypothesis, There are potential challenges in absorption and utilization of artemia powder, resulting in elevated urea production as a byproduct of protein degradation. In other words, the higher Artemia concentration stimulated protein metabolism, specifically the process of nitrogen elimination resulting from protein breakdown.

**Table 5. Effect of different levels of Artemia Powder in broiler diets on uric acid, urea, creatinine, Aspartate transferase (AST), Alanine transaminase (ALT) and Alkaline Phosphatase (ALP) in 21 days of age (Mean  $\pm$  standard error)**

Age	Parameters	T1	T2	T3	T4	Significant level
21 days	Uric acid (mg/dl)	4.19 $\pm$ 0.14	4.29 $\pm$ 0.09	4.22 $\pm$ 0.34	4.64 $\pm$ 0.17	N.S
	Urea (mg/dl)	8.71 $\pm$ 2.97 C	8.97 $\pm$ 0.53 BC	17.56 $\pm$ 0.88 AB	18.34 $\pm$ 0.9 A	*
	Creatinine (mg/dl)	2.71 $\pm$ 0.30	2.19 $\pm$ 0.09	2.04 $\pm$ 0.03	2.01 $\pm$ 0.05	N.S
	AST (U/L)	36.07 $\pm$ 3.95 AB	14.25 $\pm$ 1.02 B	26.18 $\pm$ 9.34 AB	45.09 $\pm$ 6.66 A	N.S
	ALT (U/L)	13.86 $\pm$ 3.52	7.27 $\pm$ 1.77	18.62 $\pm$ 5.66	13.38 $\pm$ 1.90	N.S
	ALP (U/L)	8.42 $\pm$ 1.10	7.79 $\pm$ 0.95	3.57 $\pm$ 0.30	4.40 $\pm$ 4.80	N.S
35 days	Uric acid (mg/dl)	3.94 $\pm$ 0.66	3.44 $\pm$ 0.50	3.44 $\pm$ 0.48	3.23 $\pm$ 0.57	N.S
	Urea (mg/dl)	11.13 $\pm$ 2.97	8.97 $\pm$ 0.53	7.42 $\pm$ 0.88	9.78 $\pm$ 0.90	N.S
	Creatinine (mg/dl)	0.76 $\pm$ 0.30	0.37 $\pm$ 0.09	0.36 $\pm$ 0.03	0.40 $\pm$ 0.05	N.S
	AST (U/L)	11.63 $\pm$ 3.95	7.37 $\pm$ 1.02	21.52 $\pm$ 9.34	25.79 $\pm$ 6.66	N.S
	ALT (U/L)	12.60 $\pm$ 3.52	7.56 $\pm$ 1.77	17.25 $\pm$ 5.66	12.41 $\pm$ 1.90	N.S
	ALP (U/L)	2.44 $\pm$ 1.10 B	3.21 $\pm$ 0.95 B	1.52 $\pm$ 0.30 B	12.53 $\pm$ 4.80 A	*

Levels of substitute protein concentrate with Artemia powder: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%).

Different letters within the same row indicate significant differences according to Duncan's multiple range test 5%. NS: means there are no significant differences between the treatments.

The inclusion of Artemia powder in broiler diets enhances the antioxidant defense system by increasing the activity of key enzymes such as GPX, GSH, and SOD at certain additive

levels, as demonstrated in the data presented in Table 6, in the fourth treatment, CAT values decreased relatively, while GPX levels increased, and MDA levels remained within normal ranges. Reduction in Catalase (CAT) levels may occur due to excessive oxidative stress and elevated reactive oxygen species (ROS) levels because of inappropriate Artemia powder levels, which can consume CAT faster than it is produced. These results can be attributed to the rich antioxidant profile of Artemia, which includes carotenoids, omega-3 fatty acids, selenium, and essential minerals. Carotenoids, such as Astaxanthin, are powerful antioxidants that reduce the CAT enzyme and increase GPX activity, which relies on glutathione to remove peroxides (Hosseindoust *et al.*, 2020; Zhu *et al.*, 2021). These peroxides may increase with the rise in unsaturated fatty acids due to the higher concentration of added Artemia. Some treatments also showed increased glutathione levels, which may correlate with the rise in the amino acid leucine from artemia, which is essential for its synthesis and regeneration. Regarding the increase in Superoxide Dismutase (SOD), that indicates the body has a greater capacity to remove superoxide free radicals. SOD converts these harmful radicals into less toxic molecules, such as hydrogen peroxide. This hydrogen peroxide is then detoxified more effectively by enzymes like Glutathione Peroxidase (GPX) and Catalase (CAT). These components generally work together to reduce oxidative stress and improve overall health in broilers. The observed changes in our results suggest that Artemia supplementation may enhance the defense mechanisms against free radicals simultaneously, indicating a relatively low level of oxidative stress due to improved nutrition that needs more study until used as a certified protein source.

**Table 6. Effect of different levels of Artemia powder in broiler diets on parameters of oxidative status in 35 days of age (Mean  $\pm$  standard error)**

Groups	35 days				
	CAT (U/mL)	MDA nmol/ml	GSH (mmol/L)	SOD (U/L)	GPX ( $\mu$ mol/min/ml)
T1	1.53 $\pm$ 0.28	6.55 $\pm$ 0.90	6.61 $\pm$ 1.94 AB	14.55 $\pm$ 1.54 C	26.30 $\pm$ 7.11 AB
T2	1.38 $\pm$ 0.06	6.41 $\pm$ 0.38	11.52 $\pm$ 1.76 A	30.82 $\pm$ 0.90 AB	20.76 $\pm$ 2.52 AB
T3	1.62 $\pm$ 0.22	6.27 $\pm$ 1.42	7.35 $\pm$ 1.53 AB	42.07 $\pm$ 4.05 A	13.06 $\pm$ 0.52 B
T4	1.04 $\pm$ 0.18	5.64 $\pm$ 0.63	5.14 $\pm$ 0.42 B	24.52 $\pm$ 7.09 BC	35.73 $\pm$ 5.76 A
Significant level	N.S	N.S	*	*	*

Levels of substitute protein concentrate with Artemia Powder: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%).

Different letters within the same column indicate significant differences according to Duncan's multiple range test 5%. NS: means there are no significant differences between the treatments.

The histological examination of the intestines reveals an improvement in crypt depth with no significant differences in villus length due to Artemia powder addition Table 7. This effect may be attributed to the stimulation of intestinal cell growth and regeneration, which occur through the activation of cell division in the basal layer of the intestine; this reaction leads to an increase in the number of new cells in the intestinal crypts and consequently, an increase in crypt depth (Eyng *et al.*, 2014). Furthermore, Artemia contains several bioactive compounds capable of stimulating the production of IGF-1 (Insulin-like Growth Factor-1). These components include essential amino acids such as Arginine, Leucine, and Glycine, as well as bioactive peptides like Proline-rich Peptides (PRPs), which play a role in enhancing the growth of intestinal epithelial cells and directly stimulating IGF-1 production (Lednev *et al.*, 2020; Wolfarth *et al.*, 2020).

Additionally, the polyunsaturated fatty acids (PUFAs) found in Artemia, such as DHA (Docosahexaenoic Acid) and EPA (Eicosapentaenoic Acid), play a crucial role in stimulating the gene expression of IGF-1, either by activating hormone receptors in the intestine or by enhancing the regeneration and growth process (Shahnazi *et al.*, 2015). IGF-1 primarily stimulates cell division and regeneration in the crypt region, leading to an increase in crypt depth but not necessarily villus elongation (Zhou *et al.*, 2018). Villus length may remain unchanged due to the dynamic balance between villus growth on one hand and erosion on the other (Parker *et al.*, 2017). When Artemia powder is added, there may be stimulation of new cell formation at the base of the intestine, increasing crypt depth. However, at the same time, there may be a constant rate of villus erosion due to the natural flow of epithelial cells through the intestinal renewal cycle (Kai, 2021; Parker *et al.*, 2017).

**Table 7. Effect of different levels of Artemia powder in broiler diets on histological parameters in 35 days of age (Mean  $\pm$  standard error)**

Groups	35 days	
	Villi (Mm)	Crypt Depth (Mm)
T1	352.2 $\pm$ 3.35	7.79 $\pm$ 1.00 b
T2	366.6 $\pm$ 3.67	10.36 $\pm$ 0.55 a
T3	357.6 $\pm$ 3.22	9.76 $\pm$ 0.80 ab
T4	386.9 $\pm$ 1.83	10.65 $\pm$ 0.40 a
Significant level	N.S	*

Levels of substitute protein concentrate with Artemia Powder: T1 (0%), T2 (0.5%), T3 (1%), and T4 (1.5%).

Different letters within the same column indicate significant differences according to Duncan's multiple range test 5%. NS: means -there are no significant differences between the treatments.

## Conclusions

We conclude from this study that Artemia powder can be used in broiler feed at levels ranging from 0.5, 1 and 1.5% as an alternative to protein concentrate without any negative effects on physiological characteristics, while noting an improvement in the antioxidant

defense system by activating some important enzymes like GPX, GSH, and SOD at certain additive levels, which leads to improvement in the overall health condition.

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### **Conflict of interests**

The authors of this work declare no conflicts of interest. All authors have reviewed and consented to the content of the manuscript, disclose no financial interests, and certify that this contribution constitutes original work not under review by other periodicals.

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### **Author Contribution**

The first and second authors wrote the original draft of the manuscript. The third and fourth authors were responsible for data collection and data analysis. The fifth and sixth authors reviewed and edited the manuscript. All authors have read and agreed to the submission of the manuscript to the journal.

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