Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 1 - 2026 - Pages 290-304

Impact of Nutritional Copper Sulfate on The Performance, Carcass Traits and Blood Constituents of Leghorn Chicks

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تأثير كبريتات النحاس الغذائية على الأداء وخصائص الذبيحة ومكونات الدم لدى فراخ الليجهورن

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Received: 19-01-2026; Accepted: 21-03-2026; Published: 11-04-2026

Abstract:
The purpose of this study was to evaluate the effects of adding copper sulphate to a diet high in plant proteins (PP) on broiler chickens' performance. 300 unsexed 1-day-old Leghorn commercial broilers were randomly assigned to 4 treat groups with equal average live body weights (LBW). Each group consisted of 75 chicks separated into 5 replicates of 15 chicks each and housed in similar conditions. Two different basal diets were used: one containing animal protein (AP) for the 1st treat group (T1) and another containing (PP) for the 2nd treat group (T2). The 3rd and 4th treat groups (T3 and T4) received the (PP) diet with the addition of copper sulfate at 150 and 300 ppm/kg, respectively. The study lasted for forty-two days, and all diets were expressed to chance the alimentary supplies of the broilers at each stage of growth based on the strain sequence recommendations.
The results of the study visibly showed that adding copper sulfate to the PP diet significantly increased broiler BW and BW gain at 3Wks of age related to those fed the (PP-diet) without copper sulfate or the AP-diet. By the completion of the trial at 6Wks of age, chickens fed the (PP-diet) with 300 ppm/kg of copper sulfate had the highest BW and BWG compared to the further treats. Supplementing broiler (PP-diets) with copper through the developing and final periods and throughout the entire experimental period improved FCR significantly associated to those fed the (PP-diet) without copper supplementation.
Both doses of copper sulfate supplementation significantly increased the relation weights of the eviscerated carcass, bursa of Fabricius, spleen, and pancreas in the plant protein diet group ($P \leq 0.01$). Relative weights of abdominal fat separated were meaningfully ($P \leq 0.01$) decreased for the broiler fed (PP-diet). T3 and T4 comparing with those fed AP-diet or PP-diet, (T1 and T2). Chemical structure of chick's meat specified that Copper supplementation to plant protein diet (T3 and T4) significantly ($P \leq 0.01$) decreased (EE %) matching with those fed Animal protein diet or Plant protein diet while; the (CP %) had the conflicting trend. Addition of copper sulfate to broiler Plant protein diet significantly ($P \leq 0.01$) decline plasma total cholesterol, total lipid concentrations and broiler meat total cholesterol. Supplementation of Cu to Plant protein diet significantly ($P \leq 0.01$) increased digestibility coefficient values of crude protein, ether extract, crude fiber and nitrogen free extract comparing with the digestibility values for the broiler fed Plant protein diet. Incorporation of copper in the broiler Plant protein diet at the highest level (T4, 300 ppm/kg) was superior for maximized the net return, economic efficiency (1.373) and relative economic efficiency (103.32%) comparing with the other treatments.

In summary, the study unequivocally showed that adding copper sulphate to broiler plant feeds has a significant impact in enhancing broiler performance, blood lipid profiles, and economic efficiency.

Keywords: Copper, Performance, Carcass Traits, Blood Component, Chicks.

الملخص:
هدفت هذه الدراسة إلى تقييم تأثير إضافة كبريتات النحاس إلى علف غني بالبروتينات النباتية على أداء دجاج التسمين. تم توزيع 300 دجاجة تسمين تجارية من سلالة ليغورن، غير محددة الجنس، عمرها يوم واحد، عشوائيًا على 4 مجموعات علاجية متساوية في متوسط وزن الجسم الحي. تتكون كل مجموعة من 75 كتكوتًا، موزعة على 5 مكررات، كل مكرر يحتوي على 15 كتكوتًا، وتم إيواؤها في ظروف متشابهة. استُخدم نوعان مختلفان من العلف الأساسي: أحدهما يحتوي على بروتين حيواني للمجموعة الأولى(T1) ، والآخر يحتوي على بروتين نباتي للمجموعة الثانية .(T2) تلقت المجموعتان الثالثة والرابعة (T3) و (T4العلف النباتي مع إضافة كبريتات النحاس بتركيز 150 و300 جزء في المليون/كجم على التوالي. استمرت الدراسة لمدة 42 يومًا، وتم تعديل جميع العلف لتغيير الإمدادات الغذائية لدجاج التسمين في كل مرحلة من مراحل النمو بناءً على توصيات تسلسل السلالة.
أظهرت نتائج الدراسة بوضوح أن إضافة كبريتات النحاس إلى علف البروتين النباتي (PP) زادت بشكل ملحوظ من وزن الجسم ومعدل زيادة الوزن لدى دجاج التسمين عند عمر 3 أسابيع، مقارنةً بالدجاج الذي تغذى على علف البروتين النباتي (PP)بدون كبريتات النحاس أو علف البروتين الحيواني .(AP) عند انتهاء التجربة في عمر 6 أسابيع، سجل الدجاج الذي تغذى على علف البروتين النباتي (PP) مع 300 جزء في المليون/كجم من كبريتات النحاس أعلى وزن للجسم ومعدل زيادة وزن مقارنةً بالمجموعات الأخرى. كما أدى تزويد دجاج التسمين (PP) بالنحاس خلال فترتي النمو والنمو، وطوال فترة التجربة بأكملها، إلى تحسين معامل تحويل العلف (FCR) بشكل ملحوظ، مقارنةً بالدجاج الذي تغذى على علف البروتين النباتي (PP) بدون إضافة النحاس.
أدت كلتا جرعتي إضافة كبريتات النحاس إلى زيادة ملحوظة في الوزن النسبي للذبيحة بعد إزالة الأحشاء، وجراب فابريسيوس، والطحال، والبنكرياس في مجموعة علف البروتين النباتي .(P ≤ 0.01) انخفضت الأوزان النسبية للدهون البطنية المفصولة بشكل ملحوظ (P ≤ 0.01) لدى دجاج التسمين الذي تغذى على نظام غذائي نباتي (PP-diet) في المجموعتين T3 وT4، مقارنةً بالدجاج الذي تغذى على نظام غذائي حيواني (AP-diet) أو نظام غذائي نباتي (PP-diet) في المجموعتين T1 و .T2أظهر التركيب الكيميائي للحم الدجاج أن إضافة النحاس إلى النظام الغذائي النباتي (T3) و (T4 أدت إلى انخفاض ملحوظ (P ≤ 0.01) في نسبة الطاقة الخام(EE%) ، لتكون مماثلة لتلك التي لوحظت لدى الدجاج الذي تغذى على نظام غذائي نباتي أو نظام غذائي حيواني، بينما كان اتجاه نسبة البروتين الخام (CP%) مختلفًا. أدت إضافة كبريتات النحاس إلى النظام الغذائي النباتي لدجاج التسمين إلى انخفاض ملحوظ (P ≤ 0.01) في مستوى الكوليسترول الكلي في البلازما، وتركيز الدهون الكلية، ومستوى الكوليسترول الكلي في لحم الدجاج. كما أدت إضافة النحاس إلى النظام الغذائي النباتي إلى زيادة ملحوظة (P ≤ 0.01) في قيم معامل هضم البروتين الخام، ومستخلص الإيثر، والألياف الخام، والمستخلص الخالي من النيتروجين، مقارنةً بقيم هضم البروتين الخام لدى الدجاج الذي تغذى على النظام الغذائي النباتي.
أظهرت الدراسة أن إضافة النحاس إلى علف البروتين النباتي للدجاج اللاحم بأعلى مستوىT4) ، 300 جزء في المليون/كجم (كانت الأفضل من حيث تحقيق أعلى عائد صافٍ، وكفاءة اقتصادية (1.373)، وكفاءة اقتصادية نسبية (103.32%) مقارنةً بالمعاملات الأخرى.
باختصار، أثبتت الدراسة بشكل قاطع أن إضافة كبريتات النحاس إلى علف البروتين النباتي للدجاج اللاحم لها تأثير كبير في تحسين أداء الدجاج، ومستويات الدهون في الدم، والكفاءة الاقتصادية.

الكلمات المفتاحية: النحاس، الأداء، صفات الذبيحة، مكونات الدم، الكتاكيت.

Introduction

Copper sulfate is a vital nutrient for animals, necessary for various physiological functions. It is commonly added to the feed of rabbits and poultry to promote growth and prevent gastrointestinal diseases. El Sabry et al (2021) and Braude (1967) reported that copper sulfate supplementation improved growing rate and competence of feed utilization while it reduced mortality and morbidity of enteritis in swine. King (1975); Omole (1977) and Forouzandeh et al (2021) found that growth rate significantly ($P \leq 0.05$) increased in rabbits when fed 200 ppm copper as copper sulfate and high dose of dicopper oxide (150 mg Cu/kg) was able to increase the growth performance of broiler chickens. However, feed efficiency insignificantly increased. Lebas et al. (1986); Liang et al. (1988) and Hamdi et al (2018) observed that increment copper (4-100 mg Cu/Kg feed) improved growth rate, feed efficiency and carcass yield, While, it reduced incidence of diarrhea in rabbits. Bassuny (1991) noted that a

supplement of copper sulfate to the diet increased nutrient digestibility, daily gain and feed intake and improved feed efficiency. The growth depression caused by high levels of copper was observed to occur between 500 and 1000 ppm (Grobner et al., 1986). The study investigated the impact of copper supplementation on tissue, kidney, and liver copper levels. It was found that while copper did not accumulate in the meat, concentrations in the liver and kidney increased with higher dietary copper levels. Additionally, the addition of copper sulfate led to improvements in body weight, daily gain, feed intake, and feed conversion (Ayyat, 1994; Zaki El-Din, 1995; Ayyat et al., 1995; Abo El-Ezz et al., 1996; Onifade and Abu, 1998). However, further research is needed to determine the optimal level of copper in the diets of growing rabbits.
The impartial of this experiment was to study the effects of feeding different levels of copper sulfate on growth performance, nutrient digestibility, carcass traits, some blood components, tissue copper concentration and economical efficiency of growing chicks from 1-6 weeks of age.

Materials and Methods
The present study was conducted at the Poultry Research Unit, Agriculture research center, in order to investigate the influence of different dietary copper levels on growth performance, mortality rate, digestion coefficients, carcass traits, some blood components, copper content of tissue and economic efficiency of growing broilers.
300 unsexed 1d-old Leghorn commercial broilers were wing-banded, weighed, and randomly distributed into 4 experimental groups. Each group consisted of 75 chicks divided into five replicates of 15 chicks each. The chicks were raised under similar hygienic, environmental, and managerial conditions in floor pens (1.5 m X 2 m) during the starting, growing, and finishing periods (0-3, 3-5, and 5-6 weeks of age, respectively).

Table1: Conformation and the nutritional value of the experimental diets (Kg/ 100 Kg).

	Starter Diets 0-3Wks		Grower Diets 3-5 Wks		Finisher Diets 5-6 Wks	
	A	B	A	B	A	B
Yellow corn	63.3	57.02	69.1	62.64	76.2	67.42
Wheat bran	2.2	----	2.3	0.8	----	2.2
Soybean meal (48%)	15.2	31.3	10.0	26.1	6	15
Corn gluten (60%)	13.	4.6	12.00	3.4	11.35	8
Fish meal (72%)	0.8	----	0.8	----	0.800	----
Meat meal (50%)	2.5	----	2.5	----	2.5	----
Calcium Carbonate	1.1	1.5	1.3	1.4	1.2	1.7
Dicalcium Phosphate	1.	1.7	1.0	1.7	0.9	1.6
Premix*	0.3	0.3	0.3	0.3	0.3	0.3
Soy oil	----	3.0	----	3.0	----	3.0
Table Salt (Na Cl)	0.23	0.30	0.24	0.30	0.25	0.30
D L.Methionine	0.010	0.120	0.040	0.15	0.040	0.1
L. Lysine	0.35	0.050	0.310	0.100	0.350	0.270
Tetracycline	0.01	0.010	0.010	0.010	0.010	0.010
Coxistate	0.100	0.100	0.100	0.100	0.100	0.100
Total (Kg)	100.	100	100	100	100	100
Chemical analysis (%)						
CP	22.7	22.6	20	20	18	18
ME k cal/ kg	3061	3064	3105	3109	3201	3200
EE	3.4	5.6	3.6	5.8	3.7	6.1
CF	2.75	3.1	2.55	2.95	2.19	2.66

Di-Ca	1.00	1.00	1.00	1.00	0.96	0.96
Phosphorus	0.46	0.46	0.45	0.45	0.42	0.42
Lysine	1.02	1.05	0.99	0.98	0.92	0.92
Methionine+cysteine	0.82	0.82	0.79	0.78	0.75	0.74

A=Animal diet; B= Plant diet; * Premix contain : Vitamins and minerals. A, 1200 IU; D. 3000 IU; E, 100 IU; C, 3 mg; K, 4 mg; B1, 3 mg; B2, 3 mg; B6, 5 mg; B12, 0.03 mg; Bantothinic acid, 15 mg; Folic acid, 2 mg; Biotin, 0.20 mg; Cobalt, 0.05 mg; Copper, 10 mg; Iodin, 50 mg; Manganese, 90 mg; Selenium, 0.20 mg and Zinc, 70 mg.

Two different basal diets were used: one containing fish and meat meal (Animal protein diet) for the first treatment group (T1) and another containing soybean and corn gluten meal as a protein source (Plant protein diet) for the second treatment group (T2). The third and fourth treatment groups (T3 and T4) were fed the plant protein diet with the addition of copper sulfate at 150 and 300 ppm ($CuSO_4$, $5H_2O$) for each treatment, respectively. ll All food preparations were designed to be isocaloric and isonitrogenous during each experimental phase, in accordance with the recommendations

The experimental treatments and diets were as follows:

T1	T2	T3	T4
Fed Animal protein diet	Fed plant protein diet		
Negative control	Positive control	+150 ppm $CuSO_4$, $5H_2O$ /kg.	+300 ppm $CuSO_4$, $5H_2O$ /kg.

Birds were provided with continuous access to feed and water, and were subjected to constant illumination throughout the trial.

Traits studied

Weekly measures of body weight (BW) and feed intake (FI) were conducted, concluding with final assessments at 42 days of age. Body weight growth (BWG) and feed conversion ratio (FCR) were computed at each interval. At the conclusion of the experiment, input-output analysis data were used to calculate economic efficiency (EE) and relative economic efficiency (REE).

Slaughter test

Ten chicks from each treatment group—one male and one female from each replicate—were randomly selected and put to death at the end of the six-week trial period. Carcass trait data were determined as a percentage of live body weight. Skinless-boneless combined samples from breast and thigh muscles were subjected to chemical analysis for crude protein (CP), ether extract (EE), and ash following AOAC (1995) guidelines, with results reported on a dry matter basis.

_Blood constituents

Each grill had two blood samples taken at the time of slaughter, one in test tubes that had been heparinised and another that had not. To separate the plasma or serum, the samples were centrifuged for 15 minutes at 3500 rpm. Total protein (Peters, 1968), total cholesterol (Ellefson and Caraway, 1976), total lipids (Bucolo and David, 1973), creatinine (Husdan and Rapaport, 1968), and the activity of the transaminase enzymes ALT and AST (Reitman and Frankel, 1957) were all measured using plasma samples. The techniques of Folch et al. (1957) and Charles and Richmond (1974) were used to extract and measure the cholesterol levels in skinless-boneless pooled samples from breast and thigh muscles. Malondialdehyde was detected in serum samples using commercial kits from Bio-Diagnosis Co., Cairo, Egypt, and the methods described in Yagi (1984).

Nutrients digestibility

At the end of experiment, five chicks per treatment group (one mail from each replicate) were randomly taken to evaluate the digestibility percentages of nutrients for the experimental diets. The procedure described by Jakobsen et al. (1960) was used for determination fecal protein from excreta samples. Digestion coefficients of dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE) and nitrogen free extract (NFE) were calculated (Fraps ,1946).

Economic Effectiveness

By dividing the income (worth of live body weight) by the cost of feed spent during the study period, the economic efficiency (EE) of each trial diet was calculated. The cost of each kilogram of the experimental diets was based on the market prices of the ingredients at the time of the experiment (November 2026). The cost of $CuSO_4$, $5H_2O$ was estimated at 120 LE/kg.

Statistical analysis

The General Linear Model of SAS (1996) was used to analyse the gathered data. Duncan's multiple range test was used to identify differences between treatment means (Duncan, 1955).
One way analysis model:

$$X_{ij} = \mu + T_i + e_{ij}$$

Where: X_{ij} = the individual observation.
μ = the overall mean.
T_i = Treatments (i = 1, 2, 3 and 4).
e_{ij} = Experimental error.

RESULTS AND DISCUSSION

Growth performance

The consequences from Figure 1 and 2 indicated a significant ($P<0.01$) impact on body weight (BW) amongst the various treatments at the conclusion of the experimental periods. Additionally, there was a significant ($P<0.01$) effect on (BWG) through the initial period (0 – 3 Wks of age) and for the average of the entire test (0 - 6 Wks of age).

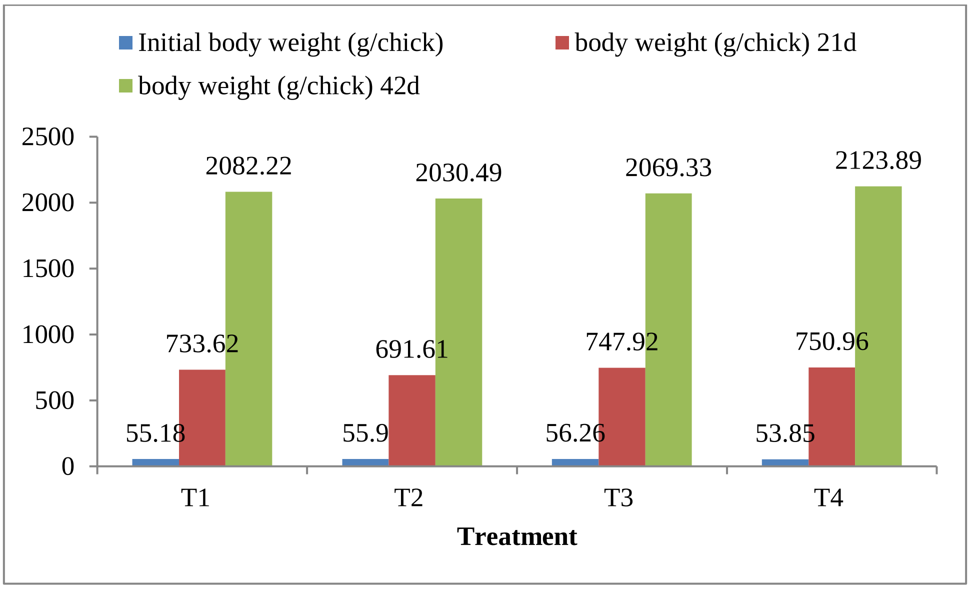

Figure 1: Influence of copper sulfate supplementation on broiler body weight.

The results clearly showed that the BW and BWG of the chicks fed the T3 and T4 diets exceeded those fed the T2 or T1 diets at the conclusion of the starting period (3 weeks of age). Chicks fed the T2 diet had the lowest BW and BWG (691.61 and 635.71 g) at the afromention period (3 weeks of age). The BW and BWG of broilers fed the T1 diet, however, were considerably higher than those fed the T2 diet over the same time period (three weeks of age). On the other hand, during the growing and finishing stage (3–6 weeks of age), BWG for all treatments was comparable and unaffected by copper supplementation. Chicks fed the (T4) diet had the highest BW and BWG (2123.89 and 2070.04 g, respectively) at the end of the experiment (6 weeks of age) when compared to the other treatments. While broilers fed the (T3) diet (150 ppm/kg diet) were comparable to those fed the diet (T1), chicks fed the (T2) diet had the lowest BW and BWG (2030.49 and 1974.54 g, respectively). According to earlier research by Khaled (2001), Arafa et al. (2001), Abou El-Wava (2003), and Macelline et al. (2020), which found comparable growth performance in broilers on both types of diets, there were no significant differences in final BW and BWG between broilers fed animal protein diets and those fed plant protein diets at the end of the 6-week experimental period.

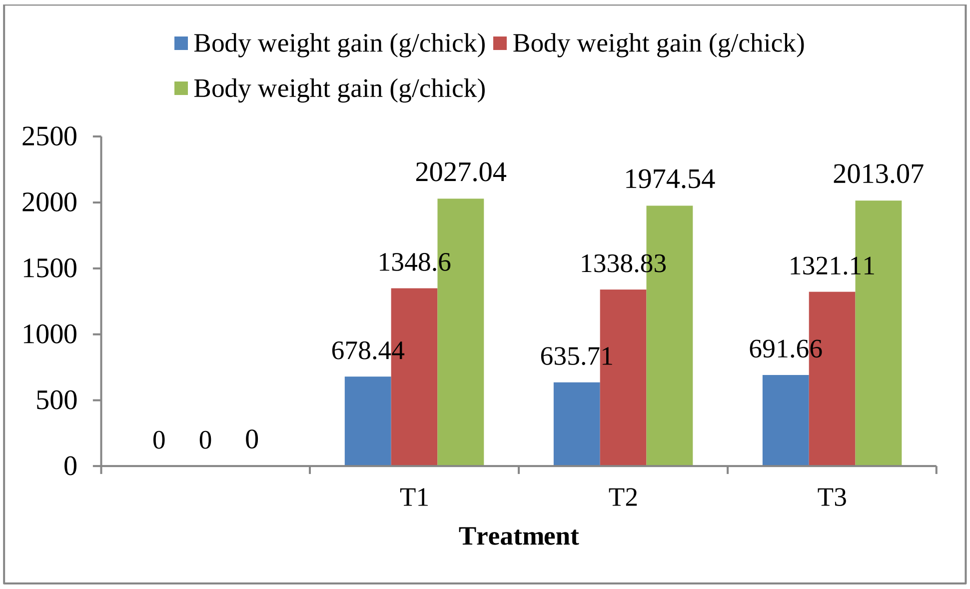

Figure 2: Addition of copper sulfate to the broiler diet resulted in increased body weight gain (BWG),

Additionally, the increase in BW and BWG in broilers fed animal protein diets compared to those fed plant protein diets during the growing period (0-3 Wks) aligns with findings from Herstad (1981) and Abdel-Salam et al. (1985) who observed improved body weight in chicks fed diets containing fish meal. The supplementation of $CuSO_4 \cdot 5H_2O$ had a positive impact on growth performance, highlighting its importance in the early stages of broiler growth. Additionally, this enhancement may be attributed to the fact that copper is a component of various metalloenzymes, including cytochrome oxidase, which plays a role in cellular respiration and could contribute to the growth-promoting abilities of copper. Our findings are consistent with those of Engy Abd Elsalam (2016), who noted that adding dietary copper improved the performance of chicks fed a sulfur amino acid (SAA)-deficient purified diet.
However, the improvement in BW and BWG during the first period caused by the addition of Cu at the highest level (T4, 300 ppm/kg diet) was consistent with the findings of Reham Ali (2018), who found that adding dietary copper sulphate increased Japanese quail body weight gain during the starter phase (1 to 3 weeks), but did not affect body weight gain during the grower phase (3 to 6 weeks). The insignificant effect of Cu addition at both levels during 3 – 6 Wks of age on broiler BWG agreement with the result of many researchers.

Feed intake and feed conversion:

Figure 3 illustrates that at the beginning period (0–3 weeks of age), there was no discernible difference in feed intake (FI) between broiler treatment groups fed animal or plant diets with or without Cu supplementation. However, during the growing period (0-3 Wks of age) and finishing period (3-6 Wks of age), as well as for the entire experimental period (0-6 Wks of age) (T4 and T5) expended the lowest amount of feed significantly (P<0.01) compared to those fed Animal protein diet (T1). Conversely, the broiler groups fed Plant protein diet (T2) used up the highest quantity of feed compared to the other treatments, but this was statistically equivalent to those fed (T1) diet, as shown in figure 3.

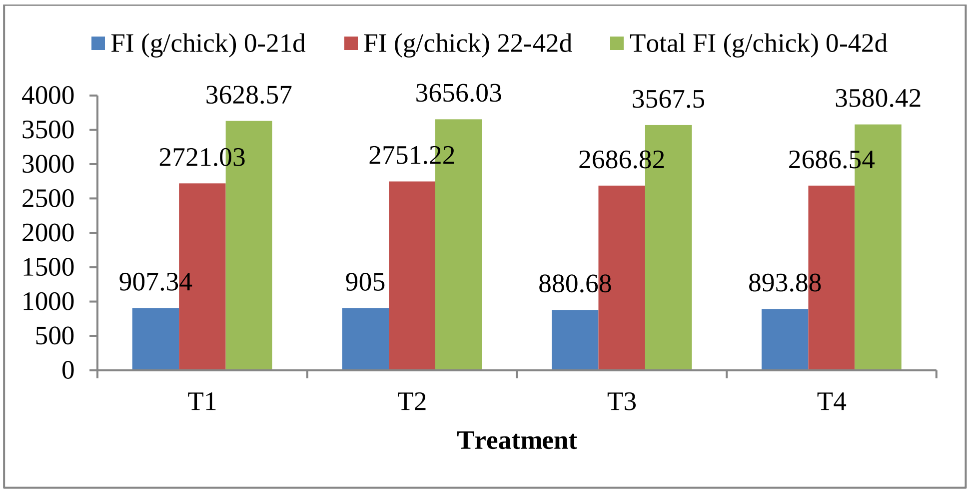

Figure 3: Effect of copper supplementation on broiler feed intake (FI).

Supplementation of broiler (PP-diet) T4 and T5 with copper sulfate during the starting (0-3 Wks of age), growing and finishing periods (3-6 Wks of age), and throughout the experimental period (0-6 Wks of age) significantly improved FCR compared to those fed PP-diet and had the best FCR according to Table 2. However, the results specified that the FCR for broilers fed T3 and T4 diet was statistically equal to those fed an animal protein diet (T1) throughout the mentioned periods. Broilers fed the greatest level of copper sulphate (T4) had the best FCR (1.73) among the treatment groups during the growth and finishing phases (3–6 weeks of age), although those fed the animal protein diet (T1) were statistically equal to those fed the T3 diet.

In general, the worst FCR was recorded for broilers fed a plant protein diet (T2) throughout the experimental periods according to Table 2.

These results contract with the observation of These results were in arrangement with Lebas et al. (1986) and Liang et al. (1988), who found that extra copper (4-100 mg/Kg feed) improved development and feed adeptness in rabbits.

Table 2: Feed conversion ratio (FCR) is affected by copper sulphate addition.

Treatments	FCR(g feed/g Gain) 0-3Wks	FCR(g feed/g Gain) 3-6Wks	Total FCR(g feed/g Gain) 0-6wks
T1	1.34^{ab}	2.03^{ab}	1.80^{ab}
T2	1.38^{a}	2.08^{a}	1.85^{a}
T3	1.27^{b}	2.04^{ab}	1.77^{ab}
T4	1.28^{b}	1.96^{b}	1.73^{b}
SEM	0.06	0.09	0.07
P-value	0.05	0.01	0.05

Means within the same column with different superscript are significantly different.

Also Dove and Hayden (1991) found highly significant increase in growth rate, feed intake and feed efficiency of weanling swine with Cu supplemented diet. Bassuny (1991), Zaki El-Din (1995), Abo El-Ezz et al. (1996), Ayyat et al. (1997) and Onifade and Abu (1998) reported that copper supplementation improved daily improvement, feed consumption and feed efficiency in rabbits. Das, et al (2010) supplementing broiler chickens with more Cu-salt than necessary may enhance performance and nutrient utilization, even when fed a high-energy finisher diet. Cu-proteinate demonstrated superior show and nutrient utilization associated to $CuSO_4$.

Carcass traits

The results from Tables 3 and 4 demonstrate the impact of Copper sulfate supplementation in a plant protein diet on various chick carcass characters (stated as g/100 g of live body weight) at the conclusion of the 6-Week experiment. Eviscerated carcass relative weights were generally significantly higher (P≤0.05) for broilers fed a Plant protein diet, with or without copper sulfate supplementation, compared to those fed an Animal protein diet (T1), as shown in Table 3.

Table 3: Effect of copper sulphate supplementation on the percentages of crude protein and ether extract in the relative weights of the carcass, giblets, abdominal fat, and poultry meat.

Treats	Carcass	Giblets	Abdominal Fat	Chicks meat analysis	
				CP %	EE %
T1	67.73^c	5.53	29.78^a	21.85^c	3.89^a
T2	69.68^b	5.12	27.60^a	21.90^c	3.40^b
T3	72.19^a	5.46	17.15^b	22.19^b	3.19^c
T4	72.47^a	5.64	18.88^b	22.95^a	3.09^c
SEM	1.18	0.31	7.76	0.28	0.06
P-value	0.05	0.877	0.05	0.05	0.05

Means within the same column with different superscript are significantly different.

Conversely, the inclusion of both copper doses in the plant protein diet notably boosted the relative eviscerated carcass weights from 69.68 g/100g LBW (T2) to 72.19 and 72.47 g/100g LBW (T3 and T4, respectively) (P ≤0.05). The greatest relative eviscerated carcass weight (72.47 g/100g LBW) was recorded in broilers given the T4 diet, whereas the least (67.73 g/100g LBW) was noted in broilers on the T1 diet (Table 3). No notable variations were observed in the relative weights of total giblets (heart, gizzard, and liver) among the treatments. The relative weights of separated abdominal fat were notably lower for broilers consuming the T3 and T4 diets (17.15 and 18.88 g/100g LBW, respectively) in comparison to those on the T1 and T2 diets (29.78 and 27.60 g/100g LBW, respectively) (Table 3).

The chemical makeup of chick meat revealed that incorporating copper sulfate into the diet (T3 and T4) resulted in a notable rise in crude protein percentage when compared to the (T1 and T2) diet. The greatest crude protein percentage (22.95%) was observed in broilers receiving the (T4, 300 ppm/kg diet), whereas the lowest percentages were seen in those on the (T1 and T2) diets at 21.85% and 21.95%, respectively. Overall, the fat content (EE) in the meat was notably reduced in broilers that received the (T2, T3, or T4) diets compared to those on the (T1) diet

Additionally, adding both levels of copper sulfate (150 and 300 ppm/kg of feed) to the (T3 and T4) diets significantly reduced the fat content in broiler meat compared to those fed the (T2) or (T1) diets Table (3). Similar results were obtained by Abdel-Rahman and Zanaty (1993), Zanaty and Ahmed (2000) and Zanaty (2002) who found that the increases in hot carcass weight with increased body size. Furthermore, the decrease in full alimentary tract percentage was significantly associated ($P \leq 0.05$) with the increase of dressing % of the experimental groups. This results confirms those found by Zhang et al. (1992), El-Maghawry et al. (1993), El-Hindawy et al. (1994) and El-Adawy and Borhami (1999) who showed increase in the alimentary tract % with the decrease in carcass percentage.

Decreasing the relative weight of abdominal fat and the ether extract content of meat for the broiler fed Plant protein diet supplemented with Cu may be due to Cu play an important role in energy and lipid metabolism. These finding were on line with the Fouad et al. (2014) they reported that, copper insufficiency results in reduced infants bile acid secretion and fat absorption, all of which can be reversed by supplementing the diet with copper sulfate. Results reported herein are in agreement with King (1975), Bassuny (1991) and Zaki El-Din (1995).

The bursa of Fabricius, spleen, and pancreas exhibited a notable rise in relative weights ($P \leq 0.05$) when both concentrations of copper sulfate were included in the broiler plant protein diet, in comparison to the weights of chicks on an animal protein diet or a plant protein diet (Table 4). The Copper sulfate treatment seemed to promote the growth and development of lymphoid organs, bursa, and spleen, possibly boosting the immune system. The bursa of Fabricius is essential for the development and maturation of B-lymphocytes.

Our results align with Abo-Talib et al. (2024), who reported that the bursa of Fabricius had a greater relative weight in the group given dietary copper sulfate than in the control group ($P \leq 0.05$).

Table 4: Supplementation of copper sulfate affects the comparative weights of the bursa, spleen, and pancreas.

Treatments	Bursa	Spleen	Pancreas
T1	0.086^{b}	0.192^{bc}	0.204^{b}
T2	0.085^{b}	0.175^{c}	0.209^{b}
T3	0.094^{a}	0.206^{a}	0.241^{a}
T4	0.096^{a}	0.208^{a}	0.251^{a}
SEM	0.02	0.04	0.01
P-value	0.05	0.05	0.05

Means within the same column with different superscript are significantly different.

Blood constituents

The findings in Table 5 and Figure 4 indicate that adding copper to the broiler plant protein diet resulted in a notable reduction ($P \leq 0.01$) in plasma total cholesterol and lipid levels.

Table 5: Impact of copper sulfate addition on plasma total cholesterol, lipids, protein, and serum malondialdehyde levels.

Items	Treatments				SEM	P-value
	T1	T2	T3	T4		
T. Ch. (mg/dl)	86.41^{a}	83.39^{b}	81.99^{c}	80.08^{c}	0.22	0.01
T. Lip (mg/dl)	4.322^{a}	3.965^{b}	3.748^{c}	3.701^{c}	0.13	0.05
T. Protein (g/dl)	5.46	5.24	5.20	5.23	0.40	0.776
MDA (mg/ml)	5.29^{a}	4.14^{b}	3.91^{c}	3.77^{d}	0.07	0.05

Means within the same column with different superscript are significantly different.
T.Ch= total cholesterol; T. Lip= Total lipids; T. Protein=Total protein; MDA= malondialdehyde.

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Also, the concentration of total broiler meat cholesterol was significantly (P≤ 0.01) decreased for the chicks fed Plant protein diet with or without Copper sulfate supplementation comparing with those fed Animal protein diet (T1). The amounts of ALT and AST, as well as total protein and transaminase enzyme activity, did not substantially differ between treatments.

The serum malondialdehyde (MDA) level, which indicates oxidative stress caused by all oxidative factors, notably dropped (P ≤ 0.01) with elevated copper sulfate supplementation in the plant protein diet.

The uppermost serum MDA concentration was observed in broilers fed the animal protein diet, while the lowermost concentration was found in broilers fed the maximum level of copper sulfate (T4) diet. Copper supplementation has been shown to reduce lipid synthesis, particularly cholesterol and triglycerides, and enhance fat oxidation by regulating the activity of ATPase copper transporting beta (ATP7B). Fu et al. (2024) reported a significant increase in total cholesterol levels in rats fed a cholesterol diet, which was reduced by the addition of copper sulfate. Abaza (2009) noted that supplementing with copper sulfate in the diet led to decreased levels of serum triglycerides and total cholesterol.

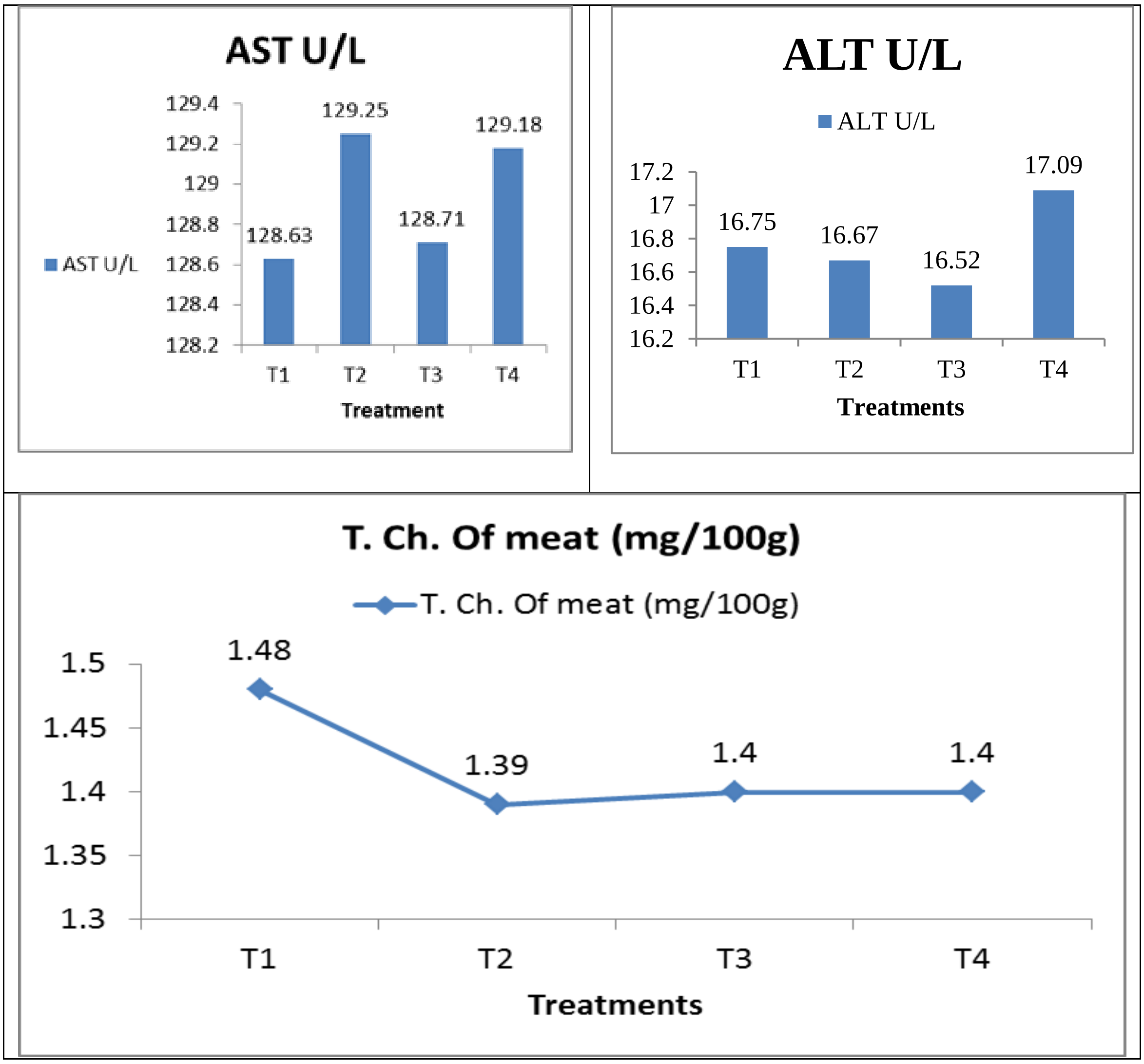

Figure 4: Impact of copper sulfate addition on plasma transaminase enzyme levels (AST and ALT) and the total cholesterol levels in broiler meat

Nutrient digestibility

Table (6) presents the impact of feeding broilers different diets on the percentage of nutrient digestibility.

Table 6: Influence of copper sulphate supplementation on the digestibility coefficients of broilers for dry matter, crude protein, ether extract, crude fibre, and nitrogen-free extract percentages.

Items	Treats				SEM	P-value
	T1	T2	T3	T4		
DM%	84.48^{a}	81.39^{b}	83.39^{a}	82.41^{ab}	0.46	0.05
CP%	86.91^{b}	82.15^{c}	90.23^{a}	90.88^{a}	0.3	0.05
EE%	72.39^{c}	70.07^{d}	73.63^{b}	74.85^{a}	0.24	0.05
CF%	42.76^{c}	40.44^{d}	44.21^{b}	48.03^{a}	0.49	0.05
NFE%	73.46^{a}	69.69^{c}	72.83^{b}	73.94^{a}	0.21	0.05

Means within the same column with different superscript are significantly different

The addition of copper sulphate to a plant protein diet markedly enhanced the digestibility percentages of CP), (EE), (CF), and (NFE) in comparison to the digestibility values of broilers on a diet devoid of copper sulphate supplementation. The digestibility percentages of (DM) for broilers fed the plant protein diet addition with both doses of copper (T3 and T4) were ($P<0.05$) higher than the DM digestibility for broilers fed the (PP-diet T2) and almost equal to the DM digestibility for broilers fed the (AA-diet T1). Additionally, the digestibility percentages of CP for broilers fed the T3 and T4 diets were ($P<0.05$) upper than the CP digestibility for broilers fed the animal protein diet (T1) or the plant protein diet (T2). The digestibility (%) of EE, CF, and NFE were markedly elevated for broilers consuming the T4 diet, whereas the lowest (%) were recorded for those on the (PP- diet T2). The enhancement in digestibility (%) for all nutrients correlated with an increase in body weight and body weight gain, as well as an improvement in feed utilisation, which elevated the feed conversion ratio for broilers consuming the T3 and T4 diets. The improvement in nutrient digestibility may be qualified to the beneficial part of copper sulfate in lipid metabolism and the enhancement of pancreatic function, as demonstrated in previous studies (Espinosa and Stein 2021). The results align with previous research by Fekete et al. (1988), Bassuny (1991), Zaki El-Din (1995), and Ayyat et al. (1995), which indicated enhanced nutritional digestibility and nutritive value due to $CuSO_4$ treatment.

Economic Efficiency

Table 7 displays the economic efficiency (EE) and relative economic efficiency (RFE) of various formulated diets. The findings suggest that higher levels of copper sulfate in broiler diets lead to increased net return, EE, and RFE. The inclusion of copper sulfate at the highest level (T4, 300 ppm/kg) in the broiler plant diet proved to be the most effective in maximizing net return, EE (1.373), and RFE (103.32%) compared to other treatments.

Table (7): Feed EE of the 4 dietary treatment

Items	T1	T2	T3	T4
Average feed intake, Kg/chick/6Wks.(a)	3.63	3.66	3.57	3.58
TFC by LE (b)*	9.84	9.84	9.70	9.85
BW (6Wks) kg (c)	2.082	2.030	2.069	2.124
Market Price/kg LBW , LE (d)	11.00	11.00	11.00	11.00
Total revenue (c x d = e)	22.90	22.3	22.76	23.36
Net revenue (e – b = f)	13.07	12.5	13.06	13.52

FEE (EE) (f/e)	1.33	1.27	1.35	1.37
RFEE (REE)**%	100	95.6	101.3	103.3

*TFC=Total feed costs were estimated by calculate the accumulation of the feed cost weekly.
FEE=Feed Economical efficiency
** RFEE =Relative feed economical efficiency (REE) % for plant diets were assuming that relative EE of animal diet (T1) =100 %.

Conclusion

As mentioned earlier, copper is a conditionally important mineral, the dietary requirements of poultry seem poorly understood Understanding copper sulfate vitamin is important to reduce or eliminate animal feed requirements in poultry feed, a by-product of restrained feed of international supply Dietary studies have been intensified that copper-intensive supplementation has a wide place in improving cattle performance, optimizing blood lipid profiles and increasing economic efficiency of cattle fed plant protein diets.

References

1. Abaza, I. (2009): Effects of Copper Sulfate on Productive, Reproductive Performance and Blood Constituents of Laying Japanese Quail Fed Optimal and Sub-Optimal Protein. https://doi.org/10.3923/IJPS.2009.80.89.
2. Abdel-Rahman, K. M. and Ahmed, B. M. (1985). Effect of digestibility, N-balance, microbial activity and carcass characteristics of rabbit. 1th Science Symp. Evaluation of Economic Studies on Local Strains of Poultry. Alexandria University, 23 - 24 March.
3. Abdel-Salam, F.E., Aboul-Seoude, A.A. and Radwan, M.A.H. (1985). Effect of liver meal as an animal protein source an feeding growing chicks. Annals of Agric. Sci. Moshtohor, 23:265.
4. Alnakaa, A. B., Altaib, M. O., & Abomhara, M. A. (2025). Effects on early-phase White Leghorn performance of switching from sesame meal (Sesamum indicum) to soybean meal level enhanced with enzymes. Bani Waleed University Journal of Humanities and Applied Sciences, 10(1), 253-267.
5. Abo El-Ezz, Z. R.; Salem, M. H.; Hassan, G. A.; El-Komy, A. and Abd El-moula, E. (1996). Effect of different levels of copper sulfate supplementation on some physical traits of rabbits. Egyptian Poultry Science Journal, 16 (1): 11 - 29.
6. Abo-Talib, K.A.; Al-Gamal, M.A.; Abbas, W.A. and El-Shafei, A.A. (2024): Effect of different litter materials on the productive and physiological performance of broiler chickens. Egyptian J. Nutrition and Feeds (2024), 27 (3):403-414.
7. Abou El-Wava, S. (2003). Total versus digestible protein and amino acids in formulated broiler diets containing plant or animal protein sources. Egypt. Poult. Sci. 23:581-600.
8. Abdul Majid AlFatyouri Lameen, & Amna Ali Alhadad. (2026). Olive cake's (OC) effects on broiler chickens' hematological parameters and growth performance. Bani Waleed University Journal of Humanities and Applied Sciences, 11(1), 131-144. https://doi.org/10.58916/jhas.v11i1.1082.
9. AOAC (1995). Association of Official Analytical Chemists. Official Methods of Analysis. 16th Edition, Washington, D. C., USA.
10. Arafa, S.A., Abdalla, A.G. and Abdel-Latif, K.O. (2001). Influence of feeding all vegetable protein versus animal protein diets on performance, carcass characteristics and immune response of broiler chicks reared in hot climate. Egypt. J. Nut. And Feeds 4:991-1003.
11. Altwoate, A. O., Alnakaa, A. B., Abomhara, M. A., & Altaib, M. O. (2024). Utilizing Date Seed Waste Meal as an Alternative Feed for Pullets. African Journal of Advanced Pure and Applied Sciences, 232-244.

12. Ayyat, M. S. (1994). Effect of different levels of dietary and copper on growth performance in rabbits. Egyptian Journal of Rabbit Science, 4 (1): 83 - 92.
13. Ayyat, M. S.; Gabr, H. A.; Marai, I. F. M.; Abdel-Monem, U.M.; Gaafary, M. N.; Tawfeek, M. I. And El-Rajim, M. I. (1997). Alleviation of heat-stressed growing rabbits by using some chemical growth enhancers, under subtropical Egyptian conditions. International Conference on Animal, Poultry and Rabbit Production and Health, Cairo, Egypt, 637 - 651.
14. Ayyat, M. S.; Marai, I. F. M. and Alazab, A. M. (1995). Copper-Protein nutrition of New Zealand White rabbits under Egyptian conditions. World Rabbit Science, 3 (3): 113 - 118.
15. Bassuny, S. M. (1991). Effect of copper sulfate supplement on rabbit performance under Egyptian conditions. Journal of Applied Rabbit Research, 14: 93 - 97.
16. Braude, R. (1967). Copper as stimulant in pig feeding. World Review Animal Food. 3: 69 - 76.
17. Bucolo, G. ,and David, H. (1973). Quantitative determination of serum triglycerides by the use of the enzyme .Clin.Chem., 19:475.
18. Charles, C.A. and Richmond, W. (1974). Enzymatic determination of total cholesterol. CDlin. Chem. 20:470-475.
19. Das, T. K. , Mondal, M. K. , Biswas, P., Bairagi, B. and Samanta, C. C. (2010): Influence of Level of Dietary Inorganic and Organic Copper and Energy Level on the Performance and Nutrient Utilization of Broiler Chickens. Asian-Aust. J. Anim. Sci. Vol. 23, No. 1 : 82 – 89.
20. Dove, C. R. and Hayden, K. D. (1991). The effect of copper addition to diets with various iron levels on the performance and hematology of weanling swine. Journal of Animal Science, 69: 2013 - 2020.
21. Duncan,D.B. (1955). Multiple range and multiple F tests. Biometrics, 11:1-42.
22. El Sabry, M. I. ; · Farid K. R.; Stino; Wafaa A. Abd El-Ghany (2021): Copper benefts and risks for poultry, livestock, and fsh production. Tropical Animal Health and Production (2021) 53:487 https://doi.org/10.1007/s11250-021-02915-9.
23. El-Adawy, M. M. and Borhami, B. E. (1999). Leaf protein concentrate of water hyacinth and berseem in feeding of New Zealand rabbits. Egyptian Journal of Rabbit Science, 9 (2): 197 - 214.
24. El-Hindawy, M. M.; Yamani, K. A. O.; Tawfeek, M. I. and Kashaba, B. M. (1994). Performance of weanling rabbits as affected by energy level and inclusion of biobiotics in the diet. Proceeding of the first International Conference on Rabbit Production in Hot Climates, Cairo, Egypt, 157-188.
25. Ellefson, R. D., and W.T. Caraway (1976). Fundamental of clinical chemistry .Ed Tietz NW, p 506
26. El-Maghawry, A. M.; Tawfeek. M. I. And Habeeb, A. A. (1993). Growth, liver and kidney functions and carcass traits of rabbits as affected by supplementation with Bospro under conditions of Egypt. Egyptian Journal of Rabbit Science, 3 (1): 1 - 11.
27. Engy Y. Abd ElsalamP P, A.I. AttiaP P, Z.A. IbrahimP P, D.E. Abou-KassemP P and A.M. Abo-Taleb (2016): Growth performance and some blood parameters of growing japanese quail as affected by dietary total sulphur amino acids levels and copper supplementation Zagazig J. Agric. Res., Vol. 43 No. (2) pp (481-497).
28. Espinosa CD, Stein HH. (2021): Digestibility and metabolism of copper in diets for pigs and influence of dietary copper on growth performance, intestinal health, and overall immune status: a review. J Anim Sci Biotechnol. 2021 Jan 11;12(1):13. doi: 10.1186/s40104-020-00533-3. PMID: 33431053; PMCID: PMC7798237.
29. Fekete,S.; Gippert, T.; Hullar, I. and Szilagyi, M. (1988). Effect of dietary copper sulfate concentration on digestion, growth rate and some blood parameters of broiler

rabbits. 4th Congress of the World Rabbit Science Association, Budapest, Hungary, 198 - 205.
30. Folch, J., Lees, M.E. and Stanley, G.H.S. (1957). A simple method for the isolation and purification of total lipids from animal tissues. J. Bio. Chem. 226: 407-409.
31. Forouzandeh A, Blavi L, Abdelli N, Melo-Duran D, Vidal A, Rodríguez M, Monteiro ANTR, Pérez JF, Darwich L, Solà-Oriol D. (2021): Effects of dicopper oxide and copper sulfate on growth performance and gut microbiota in broilers. Poult Sci. 2021 Aug;100(8):101224. doi: 10.1016/j.psj.2021.101224. Epub 2021 Apr 27. PMID: 34157560; PMCID: PMC8237351.
32. Fouad AM, El-Senousey HK. (2014): Nutritional factors affecting abdominal fat deposition in poultry: a review. Asian-Australas J Anim Sci. 2014 Jul;27(7):1057-68. doi: 10.5713/ajas.2013.13702.
33. Fraps , G.S.(1946). Relation of the protein, fat and energy of ration to the composition of chickens . Poult. Sci., 25: 421- 424.
34. Fu , Y.; Yang, J. ; Chen 1 J.and Li J. Y. (2024):The role and molecular mechanisms of copper in regulating animal lipid metabolism. Anim. Feed Sci. 2024;33(4):401-415.
35. Grobner, M. A.; Cheeke, P. R. and Patton, N. M. (1986). Effect of dietary copper and oxytetracycline on growth and mortality of weanling rabbits. Journal of Applied Rabbit Research, 9: 46 - 53.
36. Hamdi M., Solà D., Franco R., Durosoy S., Roméo A., Pérez J.F. (2018): Including copper sulphate or dicopper oxide in the diet of broiler chickens affects performance and copper content in the liver. Anim. Feed Sci. Technol. 2018;237:89–97.
37. Herstad, O. (1981). Herring meal, meat and bone meal and payzone in feed for chicks. Nutr. Abst. And Rev. 51:403.
38. Husdan, H. and Rapaport, A. (1968). Estimation of creatinine by the Jaffa reaction. Clin. Chem. 14:222-228.
39. Jakobsen, P.E., Kirston, S.G. and Nielsen, H. (1960) .Digestibility trails with poultry. 322 bretning fra foprsgs labratriet udgivest statens .Husdybug sudvalg kobenhann.
40. Khaled, O. (2001) Effect of various protein containing diets on performance and immunity of broiler chicks. Poultry Middle East and North Africa, 160:10.
41. King, J. O. L. (1975). The feeding of copper sulfate to growing rabbits. British Veterinary Journal, 131: 70 - 75.
42. Lebas, F. P.; Rouvier, R. and Rochambeau, H. De. (1986). Rabbit husbandry, health and production. FAO Animal Production and Health. Series No. 21.
43. Liang, Q. Z.; Ren, K. L. and Hang, J. Z. (1988). The effect of compound additive on the growth, feed efficiency and diarrhea of rabbit. 4th Congress of the World Rabbit Science Association, Budapest, Hungary, 224 - 231.
44. Macelline SP, Wickramasuriya SS, Cho HM, Kim E, Shin TK, Hong JS, Kim JC, Pluske JR, Choi HJ, Hong YG, Heo JM. (2020): Broilers fed a low protein diet supplemented with synthetic amino acids maintained growth performance and retained intestinal integrity while reducing nitrogen excretion when raised under poor sanitary conditions. Poult Sci. 2020 Feb;99(2):949-958.
45. Omole, T. A. (1977). Influence of levels of dietary protein and supplementary copper on the performance of growing rabbits. British Veterinary Journal, 133: 593 - 599.
46. Onifade, A. A. and Abu, O. A. (1998). Productive response of rabbits to supplemental copper in a diet based on tropical feedstuffs. Journal of Applied Animal Research, 13 (1 - 2): 129-135.
47. Peters, T. (1968). Determination of total protein in serum. Clinical Chemistry, 14:1147.

48. Reham A. M. Ali (2018): Antioxidant Responses of Japanese Quail to Dietary Copper Supplementation. J. Animal and Poultry Prod., Mansoura Univ., Vol.9 (12): 489 – 495.
49. Reitman, S., and Frankel, S. (1957). Coloric determination of GOT or GPT activity. Am. J. Clin. Path., 28-56.
50. SAS Institute. (1996). SAS/STAT User's Guide, Version 6. 5th ed. SAS Inst. Inc., Cary, NC.
51. Yagi, K. (1984). Assay for blood plasma or serum. Methods Enzyme. 105:328-331.
52. Zaki El-Din Manal (1995).Effect of copper sulfate supplementation on growth rate, nutrient digestibility and cecum, colon microorganisms of rabbits. Egyptian Poultry Science Journal, 15: 327 -349.
53. Zanaty, G. A. (1993). Carbohydrate and energy utilization by rabbits. Ph. D. Thesis. Minufiya University. Shebin El-Kom, Egypt.
54. Zanaty, G. A. (2002). The use of biogen as a naTurinal growth promoter for growing New Zealand White rabbits. 3th Scientific Conference on Rabbit Production in Hot Climates, Hurghada, Egypt, 507 - 523.
55. Zanaty, G. A. and Ahmed, B. M. (2000). Effect of different dietary protein sources and levels on growth performance, nutrient utilization and carcass characteristics of growing New Zealand White (NZW) rabbits. Egyptian Journal of Rabbit Science, 10 (2): 265 - 280.
56. Zhang, Y.; Hou, R.; Wang, C.; Dai, G.; Ma, G. and Gao, P. (1992). Effects of microbial feed additive on performance of meat rabbits. Journal of Applied Rabbit Research, 15: 1278 - 1282.