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Performance characteristics and biochemical parameters of broiler birds injected with glucose and biogenic magnesium oxide nanoparticles

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Abstract

This study investigated the effect of injection of glucose and magnesium oxide nanoparticles (MgONPs) on performance (weight gain and feed conversion ratio) and biochemical parameters (superoxide dismutase –SOD, malondialdehyde – MDA, alkaline phosphatase – ALP, transaminases – alanine transaminase and aspartate aminotransferase) and catalase - CAT in broiler chicks. A total of 105 day-old broiler chicks were randomly distributed into seven treatments (T1 – T7) with three replicates of five birds per replicate. Each treatment group was subcutaneously injected at day old with the following: T1 (without injection - control group), T2 (0.5 mL deionized water - sham group), T3 (100 mg of glucose dissolved in 0.5 mL of deionized water), T4 (100 mg of glucose and 4 mg of magnesium sulphate each dissolved in 0.5 mL of deionized water), T5 (100 mg glucose and 4 mL magnesium oxide nanoparticles solution each dissolved in 0.5 mL of deionized water), T6 (4 mg of magnesium sulphate only dissolved in 0.5 mL of deionized water) and T7 (4 mL of magnesium oxide nanoparticles solution only in 0.5 mL of deionized water). The results of this study showed that in vivo administration of magnesium oxide nanoparticles (at day old) favoured the eventual feed conversion ratio and final weight gain (1.82, 40.10 g, respectively) of the broiler birds when compared with similar values for birds without the nanoparticle injection (2.37, 33.32 g, respectively). It equally revealed that administration of the nanoparticles singly or in addition to glucose posed no detrimental effect ($p>0.05$) on the tissue enzymes activities of the birds when compared with the control values. Administration and dosage of the nanoparticles have to be keenly monitored in order not to have a detrimental effect on the antioxidant enzymes parameters.

1. Introduction

Nanotechnology involves the multidisciplinary field of biotechnology that handles the understanding and control of matter at nanoscale, where an unusual phenomenon enables originative applications. Nanoparticles of both metallic and non-metallic origin have recently been investigated and developed for use in a variety of biochemical and therapeutic disciplines [1]. Biochemically significant metals create concern since they are in harmony with the living organism's system in terms of absorption, assimilation, excretion, and side effects. Several inorganic metals are available in the human body with a wide range of biological activity. Magnesium, chromium, manganese, iron, cobalt, copper, zinc, selenium, and molybdenum are some of these metals.

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These metals are produced in the form of nanoparticles using a variety of physical and chemical processes for biomedical and therapeutic purposes [2]. Glucose, a good source of energy as well as a metabolic intermediate of cells is the simplest form of carbohydrate [3]. It is the simplest source of energy for almost all organisms [4].

Recently, nanoparticles have attracted a great deal of attention in the poultry industry, particularly as it concerns their effect on tissue enzymes in a biological system. Due to increased exposure to stress, the environment, and unusual housing and management settings, farm animals typically have a greater need for minerals and vitamins than other animals [5,6]. However, information concerning the effect of Nano-Mg and glucose on tissue enzymes in broiler chicks is still scanty. Magnesium is involved in the metabolism of carbohydrates, lipids, proteins, and ATP in the mitochondria, which is why it was used in this study. High magnesium uptake has been proven to improve glucose stability [7]. Intracellular magnesium promotes glucose transport and oxidation within cells [7]. Since body magnesium is required in energy synthesis, inadequate magnesium intake may have a negative impact on energy metabolism. Magnesium is also a cofactor in over 300 enzyme activities involved in the degradative metabolism of food and the synthesis of new products [8]. Again, reactions that are catalyzed by hexokinase and phosphofructokinase require adenosine triphosphate and magnesium as cofactors [9]. Hence, the main objective of the present research was to investigate the effect of glucose cum magnesium oxide nanoparticles on performance and biochemical parameters in broiler chicks.

2. Materials and methods

2.1 Sample collection

2.1.1 Biogenic Synthesis of Magnesium Nanoparticles

The magnesium nanoparticle solution already synthesized and characterised was obtained from the Nanotechnology Research Group, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The nanoparticle was light in colour, has sizes of 50 to 150 nm with anisotropic structures of a rectangle, triangle and rhombus. It absorbed maximally at 226 nm.

2.1.2 Experimental birds

The experiment was conducted at the pullet section of Biochemistry and Nutrition Laboratory, Department of Chemical Sciences, Fountain University, Osogbo, Nigeria. A total of 105 one-day-old broiler chicks purchased from Zartech Hatchery Limited, Oluyole Estate, Ibadan, Oyo State, Nigeria were used for the research. The birds were housed in a well-ventilated and illuminated cage system. They were fed compounded diets that met up with the nutritional requirement of broilers as stipulated by [10].

2.1.3 Experimental design

The research consisted of seven dietary treatments, three replicates and five birds per replicate:

T1- Without injection (control group)

T2- Injected with 0.5 mL of deionized water (sham group)

T3- Injected with 100 mg of glucose dissolved in 0.5 mL of deionized water

T4- Injected with 100 mg of glucose and 4 mg of magnesium sulphate ($MgSO_4$) each dissolved in 0.5 mL of deionized water

T5- Injected with 100 mg glucose and 4 mg of magnesium oxide nanoparticles solution each in 0.5 mL of deionized water

T6- Injected with 4 mg of magnesium sulphate ($MgSO_4$) only, dissolved in 0.5 mL of deionized water

T7- Injected with 4 mg of magnesium oxide nanoparticles only in 0.5 mL of deionized water. Deionized water injections were employed as a sham control group to rule out any detrimental consequences induced by the stress of injection and handling.

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The procedural steps guiding the handling and management of birds as instructed by the law governing such in University of Ilorin were strictly adhered to. The birds' random blood sugar (RBS) were measured with a glucometer in the first, third and fifth week. Feed and water were supplied without restriction. Vaccinations and medications were administered as and when due. The birds were group brooded for a week and the study lasted for five weeks.

2.2 Gross composition of experimental diets

Table 1 shows the gross composition of experimental diets used for the research. The diets were compounded to meet the energy, protein and mineral requirements of the birds at the various facets of life (pre-starter, starter and finisher stages) as recommended by [10].

2.3 Blood collection and preparation of tissue homogenates

The birds were fasted overnight to empty the crop at the end of the fifth week, then two chicks per replicate were randomly picked and slaughtered for the purpose of the study. The chicks' jugular veins were cut using a sterilized scalpel blade and 10 mL of blood were collected into centrifuge tubes. Serum was later collected after centrifugation at 5000 rpm for ten minutes using a Bench Centrifuge (90-1, Gallenkomp, England) using Pasteur pipettes into Eppendorf tubes. The sera were kept frozen until needed for further analysis.

The de-feathered broiler chicks were dissected and the organs of interest (liver and kidney) were then removed. A portion of 0.5 g of the liver and kidney tissues were cleaned with tissue paper to remove debris, then homogenized in ice-cold 0.25 M sucrose solution. The resulting homogenates were centrifuged at 5000 rpm for 10 min at 4^0C to obtain clear supernatants, which were kept frozen for the biochemical analyses.

2.4 Determination of biochemical parameters

The biochemical parameters of the broiler chickens were determined by standard methods as described for alkaline phosphatase (ALP) [11], malondialdehyde (MDA) [12], superoxide dismutase (SOD) [13] and total protein [14].

2.5 Statistical analysis

All experimental data obtained were represented as means ± SEM (n = 6). Analysis of variance (ANOVA) was used to test for differences between means followed by Duncan's Multiple Range and Tukey's tests for significant differences between the means at $P<0.05$.

3. Results and Discussion

Nanotechnology's progress and the widening range of applications for its products raise severe safety issues. Their small size, shape, higher surface area to

Table 1: Gross composition (kg/100 kg) of experimental diets

Ingredients (kg)	Pre-starter (kg)	Starter (kg)	Finisher
Maize	50.26	55.51	66.113
Oil	0.43	0.50	1.816
Soybean meal	32.68	23.11	22.460
Wheat offals	13.65	17.52	5.000
Limestone	1.86	1.79	2.450
Dicalcium phosphate	0.31	0.44	1.126
Salt	0.34	0.32	0.353
Methionine	0.20	0.28	0.167
Lysine	0.01	0.28	0.265
Premix	0.26	0.25	0.250
Total	100.00	100.00	100.000

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Table 2: Performance characteristics of broiler birds on the various injectable materials

Treatments	FCR (%) Mean±SEM	FWG (g/bird/day) Mean±SEM
Control	2.37 ± 0.12 [a]	33.32 ± 3.69 [a c]
Sham	2.13 ± 0.07 [b]	35.33 ± 3.62 [bc]
Glucose (100 mg)	1.99 ± 0.19 [c]	35.17 ± 1.17 [bc]
Glucose (100 mg) + $MgSO_4$ (4 mg)	1.88 ± 0.11 [d]	36.62 ± 1.23 [bc]
Glucose (100 mg) + MgONPs (4 mL)	1.83 ± 0.12 [e]	38.34 ± 1.35[b]
$MgSO_4$ (4 mg)	1.88 ± 0.15 [d]	36.66 ± 1.33 [bc]
MgONPs (4 mL)	1.82 ± 0.07[e]	40.10 ± 2.23[a]

FCR – Feed conversion ratio, FWG – Final weight gain
N = 6. SEM – Standard Error of Mean
[abc and d]: are means within the same column but with different superscripts that are significantly different

volume ratio, optical, magnetic, electronic, and mechanical properties confer special abilities on them, including the ability to travel through the organism faster than other materials, allowing them to be distributed more easily in the internal environment [2,15,16].

Table 2 shows the feed conversion ratio (%) and the final weight gain (g/bird/day) of birds on the various injectable materials. When compared to other injectables, control included, birds injected with MgONPs plus glucose and MgONPs only, exhibited a statistically significant ($p<0.05$) increase in weight gain (38.34, 40.10 g/bird/day, respectively) and a statistically significant superior feed conversion ratio (1.83, 1.82%, respectively). Feed conversion ratio (FCR) is the ratio at which animals mostly can convert a kilogram of feed to a kilogram of meat [17]. The lesser the FCR, the better the result. This simply implies that the rate of converting feed to meat is faster. It has a direct link with weight gain in animals. Birds that have favourable FCR usually accumulate meat faster, and hence have the desired weight gain. FCR as well as the final weight gain in favour of birds injected with either MgONPs

Table 3: Serum alkaline phosphatase and transaminases activities of broiler birds on the various injectable materials

Treatments	Control	Sham	Glucose (100 mg)	Glucose (100 mg) + $MgSO_4$ (4 mg)	Glucose (100 mg) + MgONPs (4 mL)	$MgSO_4$ (4 mg)	MgONPs (4 mL)
ALP	54.29 ± 0.51[a]	53.98 ± 0.15[a]	54.35 ± 0.59[a]	53.90 ± 0.18[a]	53.93 ± 0.20[a]	54.24 ± 0.55[a]	54.21 ± 0.71[a]
AST	110.86 ± 1.82[c]	115.79 ± 0.76[b]	108.39 ± 1.18[c]	124.83 ± 2.44[a]	127.69 ± 1.20[a]	124. 97 ± 2.37[a]	114.00 ± 2.35[b]
ALT	33.74 ± 1.24[a]	35.29 ± 2.10[a]	34.54 ± 1.03[a]	33.43 ± 1.42[a]	33.65 ± 1.71[a]	35.09 ± 1.17[a]	33. 97 ± 0.99[a]

Results are mean ± standard eror of means of six determinations. Enzyme activities are expressed as UI mg^{-1} protein.
[ab and c]: are means within the same row but with different superscripts that are significantly different

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Table 4: Oxidative stress biomarkers and gamma glutamyl transpeptidase activities of the liver and kidney of broiler birds on the various injectable materials

Treatments	Control	Sham	Glucose (100 mg)	Glucose (100 mg) + $MgSO_4$ (4 mg)	Glucose (100 mg) + MgONPs (4mL)	$MgSO_4$ (4 mg) only	MgONPs (4 mL) only
LIVER ENZYMES ACTIVITIES (UI/mg protein)							
SOD	79.96 ± 0.54^{a}	80.14 ± 0.43^{a}	79.97 ± 0.31^{a}	80.26 ± 0.24^{a}	79.98 ± 0.13^{a}	80.20 ± 0.44^{a}	80.56 ± 0.43^{a}
CAT	75.24 ± 8.75^{a}	50.42 ± 6.36^{b}	51.39 ± 4.67^{b}	47.66 ± 5.54^{b}	57.78 ± 3.56^{b}	55.1± 9 5.22^{b}	54.99 ± 6.58^{b}
GGT	0.72 ± 0.02^{a}	0.25 ± 0.02^{c}	0.46 ± 0.03^{b}	0.24 ± 0.02^{c}	0.27 ± 0.02^{c}	0.46 ± 0.03^{b}	0.46 ± 0.02^{b}
KIDNEY ENZYMES ACTIVITIES (UI/mg protein)							
SOD	79.61 ± 0.39^{a}	79.97 ± 0.45^{a}	80.18 ± 0.53^{a}	79.89± 0.49^{a}	80.27 ± 0.36^{a}	79.93 ± 0.34^{a}	80.17 ± 0.55^{a}
CAT	55.03 ± 1.15^{a}	47.04 ± 1.33^{bc}	47.52 ± 1.46^{bc}	43.10 ± 0.86^{d}	43.10 ± 0.86^{d}	45.89 ± 1.18^{c}	49.10 ± 1.08^{b}
GGT	45.58 ± 0.89^{a}	43.62 ± 1.05^{b}	46.45 ± 1.50^{a}	44.69 ± 1.49^{ab}	43.30 ± 0.92^{b}	43.93 ± 1.11^{b}	44.20 ± 2.50^{ab}

Results are mean ± standard error of means of six determinations.
$^{abc\ and\ d}$: are means within the same row but with different superscripts that are significantly different

alone or in addition to glucose is following the report of Jankowski *et al*. [18] which reported that substituting MnO with Mn_2O_3 nanoparticles ($NanoMn_2O_3$) posed no deleterious effects on the growth performance of the turkeys but rather favoured ileal digestibility of manganese. It had earlier been reported that Mn nano as feed additives posed no negative effect on the body weight, feed intake and FCR of broiler chickens [19,20,21]. Contrarily, Yongbo *et al*. [22] reported a negative effect of Mn nano supplementation at 60 mg/kg on the final body weight and FCR in a Japanese quail study, but not on the feed intake. It should however be noted that administering extremely high doses of Mn (1500 mg/kg [23] and 1600 mg/kg and more [19] lowered body weight of the quail considerably.

3.1 Cellular enzymes of birds on the various injectables

The specific activities of ALP in the serum of birds exhibited no statistically significant (P>0.05) variations across all treatments when compared with the positive and negative control (those birds without injection and those injected with distilled water only– sham group, respectively). The aspartate aminotransferase (AST) enzyme activities of birds on the various injectables were comparable with those of the birds on the positive and the negative controls, suggesting intact membrane structures. There were no significant differences in the activities of the alanine transaminases amongst broiler birds on the various injectable materials (Table 3).

Measurement of enzyme activities is an important tool in assessing cellular toxicity that could have been caused by chemical compounds [24]. It could be used as a measure of tissue cellular damage by a chemical compound long before its effect will be visible through histological techniques [25].

Alkaline phosphatase has been severally used as a marker enzyme to ascertain the

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Table 5: Liver and kidney protein (mg ml^{-1}) contents of broiler birds on the various injectable materials.

Treatments	Control	Sham	Glucose (100 mg)	Glucose (100 mg) + $MgSO_4$ (4 mg)	Glucose (100 mg) + MgONP (4 mL)	$MgSO_4$ (4 mg) only	MgONP (4 mL) only
LIVER PROTEIN CONTENTS							
PRO	119.95 ± 0.16^a	120.05 ± 0.16^a	120.08 ± 0.17^a	120.07 ± 0.10^a	119.97± 0.86^a	119.91 ± 0.16^a	120.11 ± 0.16^a
KIDNEY PROTEIN CONTENTS							
PRO	119.92 ± 0.10^a	120.07 ± 0.18^a	119.85 ± 0.23^a	120.00 ± 0.16^a	119.93 ± 0.15^a	120.06 ± 0.09^a	120.11 ± 0.13^a

Results are mean ± standard error of means of six determinations. Protein contents are expressed as mg ml^{-1}.
^{a}: is a mean within the same row with same superscript that is not significantly different

integrity of plasma membrane as well as that of the endoplasmic reticulum [26]. Magnesium plays a vital role as a cofactor in alkaline phosphatase (ALP) and is required for the proper functioning of the enzyme. The absence of significant differences in the activity of alkaline phosphatase in the serum of broiler chickens may indicate that magnesium nanoparticles have no detrimental effects on the selected studied organ, hence ascertaining the integrity of the plasma membrane.

Enzymes that catalyse the transfer of an amino acids' amino group (-NH_2) to a carbonyl molecule, most commonly an alpha-keto acid, are known as aminotransferases. AST is mostly located in the liver, although it can also be found in the heart, skeletal muscle, kidneys, brain, and red blood cells [24]. Non-significant alanine transaminase values obtained for birds on the various injectables as compared with the birds on the control is an affirmation of the safety of usage of the MgONPs.

It was earlier reported that injection of broiler birds with CPHE-AgNPs at day old did not affect the aminotransferases activities (ALT & AST) of the birds [27]. Aspartate aminotransferase activities of birds on the various injectables on the other hand were significantly higher than what was obtainable for birds on both the positive and the negative control. Contrarily, Salau *et al.* [1] reported a significantly reduced serum AST in rats treated intraperitoneally with cocoa pod husk extract-mediated silver nanoparticles (CPHE-AgNPs).

The specific activity of the antioxidant enzymes; SOD, CAT and GGT in the liver and kidney of broiler chicks on various parenteral materials are shown in Table 4. The results revealed no statistically significant ($p>0.05$) changes in the SOD enzyme activity of the birds on the various parenteral treatments. Superoxide dismutase-SOD is generally considered a key enzyme in the regulation of intracellular concentration of superoxide radical (O_2^-) and peroxides which can react in the Haber-Weiss reaction to form hydroxyl radicals leading to lipid peroxidation [28]. SOD protects cells against damage caused by free radicals and hydro or lipoperoxides [29]. The observed consistency, without significant ($p>0.05$) difference in the activities of superoxide dismutase may suggest that magnesium nanoparticles administered do not affect or contribute to antioxidant status of cells.

Birds placed on the control diet (no injection) had higher statistically significant ($p<0.05$) liver catalase activities when compared with those of the birds on the injectable materials. Kidney catalase activities were also significantly ($p<0.05$) highest for birds on the control diets, followed by those of the birds on the MgONPs only. Catalase, a common enzyme found in nearly all living organisms exposed

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to oxygen, normally catalyzes the decomposition of hydrogen peroxide to water and oxygen. It is a very important enzyme in protecting the cell from oxidative damage by reactive oxygen species (ROS).

The enzyme is responsible for neutralization through decomposition of hydrogen peroxide, thereby maintaining an optimum level of the molecule in the cell which is also essential for cellular signaling processes. In mammalian tissues, the highest catalase concentration is found in the liver and the erythrocytes and lowest in the connective tissues [30]. The observed significantly ($p<0.05$) higher serum liver and kidney catalase activities of birds on the control diet when compared with the lower levels of the birds on the various injectables could indicate that the various treatments induce mild oxidative stress since SOD and MDA values were not affected.

Liver and kidney GGT were significantly ($p<0.05$) lower for the birds on the various injectable materials when compared with the corresponding values obtained for the birds on the control diet (no injection). Gamma-glutamyltransferase (GGT) is an enzyme present in the cell surface membrane of many tissues. GGT catalyzes the transfer of the gamma-glutamyl group of glutathione to peptides, amino acids, or water to form glutamate. The low GGT activities of birds on the various injectables as compared with those of the birds on the positive and negative controls could have resulted from leakage to serum or outright inhibition in the tissues. High levels of GGT in the blood may equally be a sign of liver disease or damage to the bile ducts [24,30].

Liver and kidney protein ($mgml^{-1}$) of broiler birds on the various injectable materials revealed no statistically significant ($p>0.05$) changes in the protein contents of the liver and kidney of the birds injected with the nanoparticles. when compared with those of the birds not on the nanoparticles; control groups, and sham groups respectively (Table 5).

Table 6: Liver and kidney malondialdehyde concentrations (nmol MDA/mg protein) of broiler birds on the various injectable materials

Treatments	Control	Sham	Glucose (100 mg)	Glucose (100 mg) + $MgSO_4$ (4 mg)	Glucose (100 mg) + MgONPs (4 mL)	$MgSO_4$ (4 mg) only	MgONPs (4 mL) only
Liver MDA	79.98 ± 0.17[a]	80.05 ± 0.64[a]	79.86 ± 0.21[a]	80.10 ± 0.60[a]	80.21 ± 0.51[a]	79.98 ± 0.08[a]	80.53 ± 0.26[a]
Kidney MDA	80.00 ± 0.52[a]	80.15 ± 0.42[a]	79.87 ± 0.38[a]	80.27 ± 0.55[a]	79.98 ± 0.13[a]	80.19 ± 0.44[a]	80.58 ± 0.26[a]

Results are mean ± standard error of means of six determinations. Malondialdehyde concentrations are expressed as nmol MDA/mg protein.
[a]: is a mean within the same row with same superscript that is not significantly different

Proteins are important dietary groups because they provide a significant but expensive source of energy, as well as vital amino acids, including lysine, tryptophan, methionine, leucine, isoleucine, and valine, which are required for human health but cannot be synthesized by the body. Many proteins are enzymes that aid in the speeding up of biological processes [10]. Magnesium had earlier been reported to protect against protein oxidation in the plasma and liver [31].

The protein concentrations in the liver and kidney of the broiler chickens injected with the MgONPs solution did not differ significantly ($p>0.05$) when compared with the values in the control and the sham group. The findings are comparable to those of Echeverry-Rendón *et al*. [32], who found that

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injecting surface-modified $Mg(OH)_2$ NPs into broiler chickens had no negative impact on protein content. This suggests that the injection of the MgONPs solution did not adversely affect the protein concentration in the liver and kidney of the broiler chicks.

Liver and kidney malondialdehyde concentrations (nmol MDA/mg protein) of broiler birds on the various injectable materials revealed no statistically significant ($p>0.05$) changes (Table 6). Malondialdehyde (MDA) is a lipid peroxidation end product that is commonly utilized as a marker of tissue damage [26]. The non-significant ($P>0.05$) effect in the concentrations of malondialdehyde observed, may suggest that magnesium nanoparticle does not induce obvious toxic effects such as lipid peroxidation in the liver and kidney of broiler chicks.

The blood glucose levels of experimental birds on the 1st, 3rd, and 5th weeks are shown in Table 7. In the first week, birds given the glucose (100 mg) and MgONPs (4 mL) injection had the greatest blood sugar level compared to the control, while birds in the negative control (sham group) had the lowest. At the third week, birds receiving MgONPs (4 mL) injection only, had the highest statistically significant blood sugar level, while birds receiving $MgSO_4$ (4 mg) injection only, had the lowest. At the fifth week, birds given only Glucose (100 mg) had the greatest statistically significant blood sugar level while birds given only $MgSO_4$ (4 mg) had the lowest.

Magnesium in the cell revitalizes glucose transport and the oxidation process [33]. Since body magnesium is required in energy synthesis, inadequate magnesium intake may have a negative impact on energy metabolism. It has been reported that even during fasting, broiler chickens, though have greater blood glucose levels than mammals, still do not incur diabetes. The rate-limiting stage in systemic glucose utilization is glucose absorption into the circulation, which is controlled by the membrane protein family of glucose transporters (GLUTs) [34].

There is a striking relationship between magnesium uptake and glucose stability. High magnesium uptake has been proven to improve glucose stability [7]. Higher statistically significant blood glucose level ($p< 0.05$) observed in those birds injected with either glucose or in addition with MgONPs over those not with the nanoparticle is an attestation of the fact that magnesium revitalizes intracellular glucose transport and its oxidation steps [33]. Contrary to this, another study [4] reported that Cu-NP supplementation induces a considerable

Table 7: Blood glucose level (mmol/L) of broiler birds on the various injectable materials

Treatments	1st WEEK Mean±SEM	3rd WEEK Mean±SEM	5th WEEK Mean±SEM
Control	149 ± 2.20^{d}	220 ± 1.23^{c}	227 ± 1.56^{bc}
Sham Group	141 ± 2.32^{e}	219 ± 1.45^{c}	220 ± 1.78^{c}
Glucose (100 mg)	181 ± 1.99^{bc}	221 ± 2.13^{c}	290 ± 1.56^{a}
Glucose (100 mg) + $MgSO_4$ (4 mg)	167 ± 1.23^{c}	229 ± 1.32^{b}	233 ± 4.21^{b}
Glucose (100 mg) + MgONPs (4 mL)	191 ± 1.87^{a}	237 ± 2.45^{ab}	241 ± 2.49^{ab}
$MgSO_4$ (4 mg)	190 ± 1.45^{a}	215 ± 3.23^{d}	213 ± 1.67^{d}
MgONPs (4 mL)	184 ± 2.11^{b}	240 ± 1.67^{a}	218 ± 1.98^{cd}

N = 6. SEM – Standard Error of Mean
abcd and e: are means within the same column but with different superscripts that are significantly different

reduction in glucose levels in fish when compared to $CuSO_4$.

Canli and Canli [35] also reported that 5 mg/kg of oxide Cu-NP reduced glucose, total cholesterol, and triglyceride levels in rats after oral administration as compared to the control. This could be due to cortisol-mediated gluconeogenesis, which causes hyperglycaemia [36]. The disparity could result from differences in NPs used, species of organisms used, etc.

4. Conclusion

Activities of the enzymes in the serum are reflective of the biochemical integrity of the state of the tissues. Magnesium oxide nanoparticles had no detrimental effect on the activities of ALP, ALT, AST and SOD, as well as levels of MDA and protein. It equally favoured final weight gain and the rate at which the birds were able to convert feed into meat. Hence, posed no health hazard on the final consumer of the meat. However, its usage in terms of quantity must be monitored in order not to have a detrimental effect on a few antioxidant enzyme parameters like catalase and gamma-glutamyl transferase.

Conflict of interest

Authors declared no conflict of interest. The study was self-sponsored with no grant obtained from any source.

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References

[1] Salau AK, Osineye SO, Lateef A, 2022. Nanotoxicological investigations of cocoa pod husk extract-mediated silver nanoparticles in selected tissues of albino rats. *Toxicology and Environmental Health Sciences* 14(2): 193-202. https://doi.org/10.1007/s13530-022-00129-6

[2] Lateef A, Ojo SA, Akinwale AS, Azeez L, Gueguim-Kana EB, Beukes LS, 2015. Biogenic synthesis of silver nanoparticles using cell-free extract of *Bacillus safensis* LAU 13: antimicrobial, free radical scavenging and larvicidal activities. *Biologia* 70(10):1295–1306

[3] Clark DL, Sokolof J, 1999. Basic Neurochemistry: Molecular, Cellular and Medical Aspects. Lippincott. pp. 637-670.

[4] El Basuini MF, El-Hais AM, Dawood MAO, Abou -Zeid AE-S, EL-Damrawy SZ, Khalafalla MME-S, Koshio S, Ishikawa M, Dossou S (2016). Effect of different levels of dietary copper nanoparticles and copper sulfate on growth performance, blood biochemical profiles, antioxidant status and immune response of red sea bream (*Pagrus major*). *Aquaculture* 455, 32–40.10.1016/ j.aquaculture.

[5] Collins NE, Moran ET, 1999. Influence of supplemental manganese and zinc on live performance and carcass quality of broilers. *J. Appl. Poult. Res*. 8, 222–227, https:// doi.org/10.1093/japr/8.2.222.

[6] Berta E, Andrasofszky E, Bersenyi E, Glavits A, Gaspardy A, Fekete SG, 2004. Effect of inorganic and organic manganese supplementation on the performance and tissue manganese content of broiler chicks. *Acta Vet. Hung.* 52, 199–209, https://doi.org/10.1556/AVet.52.2004.2.8.

[7] Song Y, Manson JE, Buring JE, Liu S, 2004. Dietary magnesium intake in relation to plasma insulin levels and risk of type 2 diabetes in women. *Diabetes Care*, **27**,59-65.

[8] Lukaski HC, 2000. Magnesium, zinc, and chromium nutriture and physical activity. *The American Journal of Clinical Nutrition*, **72**, 585-593.

[9] Nuviala RJ, Lapieza MG, Bernal E, 1999: Magnesium, zinc, and copper status in women involved in different sports. *Int. J. Sport-Nutr.* **9**, 295-309.

[10] AOAC, 2005. Official Methods of Analysis 18th edition. Association of Official Analytical Chemists. Washington, D.C-USA

[11] Wright PJ, Leathwood PD, Plummer DT (1972) Enzymes in rat urine: alkaline phosphatase, *Enzymologia*, 42: 317-327.

[12] Reilly CA and Aust SD. 1999. Measurement of lipid peroxidation. *Curr. Protoc. Toxicol*.

[13] Amiceralli F. 1999. Age dependent ultrastructural alterations and biochemical response of rat skeletal muscle after hypoxic or hyperoxic treatments. *Biochem Biophys. Acta*, 1453: 105-114.

[14] Dawnay AB, Hirst AD, Perry DE, Chambers RE, 1991. A critical assessment of current analytical methods for the routine assay of serum total protein and recommendations for their improvement. *Ann Clin Biochem.* 28(6):556-567. doi: 10.1177/000456329102800604.

[15] Oberdörster G, Oberdörster E, Oberdörster J, 2005. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. *Environ Health Perspect* 113(7):823–839

[16] Fard JK, Jafari S, Eghbal MA, 2015. A review of

molecular mechanisms involved in toxicity of nanoparticles. *Adv Pharma Bull* 5(4):447–454

[17] Ogunbode SM, Oladimeji RA, Salaudeen QO, Bello RA, Majolagbe HO, 2020. Antioxidant Parameters, Lipid Profiles and Performance Studies of Broiler Birds Fed Graded Level Taurine-Supplemented Diets. *Fountain Journal of Natural and Applied Sciences* 9(2): 10-21.

[18] Jankowski J, Ognik K, Stępniowska A, Zduńczyk Z, Kozłowski K, 2018. The effect of the source and doses of manganese on the performance, digestibility and distribution of selected minerals, redox, and immune status of turkeys. *Poult. Sci*. 98 (3), 1379-1389, http://dx.doi.org/10.3382/ps/pey467.

[19] Sunder GS, Kumar CV, Panda AK, Raju MVLN, Rao R, 2013. Effect of supplemental organic Zn and Mn on broiler performance, bone measures, tissue mineral uptake and immune response at 35 days of age. *Poult. Sci.* 3, 1–11, http://dx.doi.org/10.3923/crpsaj.2013.1.11.

[20] Lofti L, Zaghari M, Zeinoddii S, Shivazad M, 2014. Comparison of dietary nano and micro manganese on broiler performance. *Proceeding of the 5th International Conference on Nanotechnology*: Fundamentals and Applications. Prague, Czech Republic, 293.

[21] Ghosh A, Mandal GP, Roy A, Patra AK, 2016. Effects of supplementation of manganese with or without phytase on growth performance, carcass traits, muscle and tibia composition, and immunity in broiler chickens. *Livest. Sci*. 191, 80–85, https://doi.org/10.1016/j.livsci.2016.07.014.

[22] Yongbo S, Shixia G, Tianyao Y, Ying L, Yuxin Z, Yuting D, Juntao L, Liying Z, 2021, Effects of manganese hydroxychloride on growth performance, antioxidant capacity, tibia parameters and manganese deposition of broilers. *Animals 11*(12), 3470; https://doi.org/10.3390/ani11123470

[23] Miles RD, Henry PR, Sampath VC, Shivazd M, Comer CW, 2003. Relative bioavailability of novel amino acid chelates of manganese and copper for chicks. *J. Appl. Poult. Res*. 12, 417–423, https://doi.org/10.1093/japr/12.4.417.

[24] Yakubu MT, Bilbis LS, Lawal M, Akanji M A, 2003a. Evaluation of selected parameters of rat liver and kidney function following repeated administration of yohimbine. *Biokemistri*, 15(2): 50-56.

[25] Starikova AV, Skopenkova VV, Polikarpova AV, Reshetov DA, Vassilieva SG, Velyaev OA, Shmidt AA, Savchenko IM, Soldatov VO, Egorova TV, Bardina MV, 2022. Therapeutic potential of highly functional codon-optimized microutrophin for muscle-specific expression. *Scientific Reports*. 12 (1):848. doi: 10.1038/s41598-022-04892-x.

[26] Akanji MA, Yakubu MT, 2000. a- Tocopherol protects against metabisulphite-induced tissue damage in rats. *Nig. J. Biochem. Mol. Biol*. 15, 179 -183.

[27] Ogunbode SM, Salau AK, Azeez L, Osineye SO, Olaogun OO, Adebisi JO, Akinlade HO, Isa FO (2018) Carcass characteristics and selected tissue enzyme activities of birds injected with cocoa pod husk extract-mediated silver nanoparticles (CPHE-AgNPs) at day old. *Sci Focus* 23(2):81–90

[28] Prasad AA, Odu AA, 1998. Efficacy of procaine penicillin as growth promoter in broiler chicks fed low a high fiber diets in the Tropics. *Arch. Dezootec*., 47: 621 – 628.

[29] Suleyman K, Oruwari BM, Sese BT, Mgbere OO, 1995. The effect of whole palm kernel on broiler performance and production cost; energy-protein ratio. *International Journal of Animal Science* 10: 115-120.

[30] Salau AK, Yakubu MT, Oladiji AT, 2016. Effects of aqueous root bark extracts of *Anogeissus leiocarpus* (DC) *Terminalia avicennioides* on redox and haematological parameters of diethylnitrosamine-administered rats. *Iranian Journal of Toxicology* 10(1): 21-26.

[31] Mario E, Massimiliano P, 2019. Benefits of magnesium supplementation to broiler subjected to dietary and heat stress: Improved redox status, breast quality and decreased myopathy incidence. *Antioxidants*, 8(10), 56; https://doi.org/10.3390/antiox8100456.

[32] Echeverry-Rendón M, Stančič B, Muizer K, Duque V, Calderon DJ, Echeverria F, Harmsen MC, 2022. Cytotoxicity assessment of surface-modified magnesium hydroxide nanoparticles. *ACS Omega.* 7 (21):17528-17537. doi: 10.1021/acsomega.1c06515.

[33] Paolisso G, Scheen A, D'Onofrio F, Lefebvre, P. 1990. Magnesium and glucose homeostasis. *Diabetologia*, 33(9),511-514.

[34] Akiba Y, Chida Y, Takahashi T, Ohtomo Y, Sato K, Takahashi K, 1999. Persistent hypoglycemia induced by continuous insulin infusion in broiler chickens. *British Poultry Science.* 40(5), 701–705. https://doi.org/10.1080/00071669987124.

[35] Canli EG, Canli M, 2017. Effects of aluminum, copper, and titanium nanoparticles on some blood parameters in Wistar rats. *Turk. J. Zool.* 41(2), 259 –266.10.3906/zoo-1512-23

[36] Mommsen TP, Vijayan MM, Moon TW, 1999. Cortisol in teleosts: dynamics, mechanisms of action, and metabolic regulation. *Rev. Fish Biol. Fish*. 9(3), 211–268.10.1023/A:1008924418720