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Research Article

Effects of Different Dietary Fat Sources on Oxidative Stress Parameters in Broiler Chickens

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ABSTRACT

Introduction: Certain types of dietary fats may elevate the generation of free radicals, resulting in oxidative stress and potential cellular damage. The present study aimed to investigate the impact of high-energy diets derived from various fat sources on broiler chicken welfare and production.

Materials and methods: A total of 216-day-old unsexed Arbor Acre broiler chickens were assigned to four treatment groups. The groups, including control, beef tallow (high energy diet animal source, HEDAS), palm oil (high energy diet plant source, HEDPS), and low energy diet (LED), each consisting of three replicates with 18 birds, were investigated in a completely randomized design over 42 days.

Results: According to the results, the HEDPS group had the highest live weight, while the HEDAS group indicated the highest dressing percentage. Significant differences were noted in alanine transaminase and alanine phosphatase in the treatment group compared to the control group. Cholesterol levels were significantly high in the HEDAS group and LDL levels were the lowest compared to the control group. The HEDAS group also exhibited the highest triglyceride level compared to other treatments. The HDL levels were higher in the LED and HEDPS groups compared to the HEDAS group. The VLDL concentration was significantly higher in the HEDAS group in comparison with other groups.

Conclusion: The HEDPS diet positively affected serum biochemistry and carcass characteristics, highlighting its potential in broiler chicken welfare and production.

1. Introduction

The dietary supply of fat and oils with an energy value of more than twice compared to carbohydrates and proteins, is commonplace in modern poultry production[1]. Besides supplying energy, lipids also improve the absorption of fat-soluble vitamins, diminish feed dustiness and improve its palatability, decrease feed intake, and improve feed efficiency[2]. Stress in broiler chicken production arises from environmental, nutritional, and managerial issues, adversely affecting their performance, health, and overall production. The imbalance between free radicals and the cell's antioxidant defenses could lead to oxidative stress, causing cellular damage. Free radicals, such as superoxide (O2) trigger chain reactions that damage cellular components, including DNA, proteins, lipoproteins, and other structures[3]. These alterations can disrupt the function and biological structure of cellular molecules, leading to various complications, including metabolic dysfunction and cell death[4,5]. Oxidative stress causes significant biological damage in birds, caused by increased metabolic rate in the mitochondria of cells. Weakness in the antioxidant defenses in cells increases the production of free radicals under physiological oxygen metabolism[1]. Reactive oxygen species and reactive nitrogen species, needed in small quantities for cellular signaling during homeostasis, can lead to oxidative stress when excessively produced[2]. The oxidative reactions (superoxide dismutase, catalase, and glutathione peroxidase) oxidize molecules and those oxidized molecules attract electrons from neighboring molecules triggering a chain of unending reactions causing massive tissue damage in the living organism. Furthermore,

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reactive oxygen species adversely affect the expression of enzymes involved in essential processes, such as inflammatory reactions, defense mechanisms, and detoxification, which can lead to the failure of cell defense mechanisms against oxidants[6-8].

Fat metabolism and deposition in poultry are affected by dietary fat sources and quality[9]. Oxidative stress is one of the significant challenges in poultry production, and these oxidative reactions are responsible for rancidity in processed poultry products by inducing lipid oxidation[10,11]. Poultry productivity may decline through oxidative reactions that potentially damage intestinal epithelia by producing free radicals[12,13]. Therefore, there is a need to elucidate the effect of different dietary fat sources and how they cause oxidative stress in broiler chickens.

2. Materials and Methods

2.1. Ethical approval

The animal wellbeing and management practices were approved by the research project committee of the Department of Animal Production and Health, Federal University Wukari, Nigeria, following the regulations of the Nigerian Institute of Animal Science (NIAS).

2.2. Experimental site

The present study was conducted at the Teaching and Research Farm of the Department of Animal Production and Health, Faculty of Agriculture and Life Sciences, Federal University Wukari Taraba State, Nigeria. The farm is located at Latitude 7° 11' North and longitude 9° 14' East at an elevation of 364m above sea level.

2.3. Experimental animals, design and management

Two hundred- and sixteen-day-old unsexed *Arbor acre* broiler chickens were purchased from FIDAN Hatchery Ibadan, Oyo State, Nigeria. The chicks were randomly divided into four treatment groups. Each treatment was replicated three times with eighteen birds per replicate in a completely randomized design. The chickens were raised in a deep litter system in a 2m x 2 m pen size. Feed and water were served *ad* libitum during the experimental period. The feed intake and weight gain were recorded weekly and average weight gain per chicken was taken for the period of the experiment. The collected data was used to calculate the final weight gain, average daily weight gain, average daily feed intake, and feed conversion ratio for the beginning and ending phases, respectively, at the end of the 42 days.

2.4. Experimental diets

Four experimental diets were formulated according to the NRC[7] (Tables 1 and 2). The treatment diets included 0% fat (control), 3.0% Beef tallow (HEDAS), 3.0% palm oil (HEDPS), and low energy diet (LED).

2.5. Carcass evaluation

At the end of the feeding trial phase, four chickens were randomly selected from each treatment group representing the average weight of the replicates and for carcass analysis. The chickens fasted overnight while accessing the provided *ad-libitum* water freely. The selected ones were weighed to obtain live body weight before slaughtering by severing the jugular vein using a sharp knife and allowed to bleed completely. To facilitate de-feathering, the slaughtered chickens were dipped in hot water, dressing, and evisceration. The head, neck, shank, and viscera were removed to get the dressed weight while dressing percentage was calculated using the following formula[48].

$$\text{Dressing percentage (\%)} = \frac{\text{Dressed weight}}{\text{Live weight}} \times 100$$

Prime cut parts weight, such as back, neck, breast, wings, thighs, drumsticks, and internal organs weight, including heart, liver, full and empty gizzard, spleen, kidney, lungs, intestinal weight, and abdominal fat were measured and expressed as a percentage of live weight.

2.6. Blood analyses

Blood samples were collected from four chickens per

Table 1. Ingredient composition and calculated analysis of broiler chicken starter diets

Ingredients	Control	LED	HEDAS	HEDPS
Maize	55.00	49.00	52.00	52.00
Maize offal	2.00	6.00	2.00	2.00
Rice offal	-	2.00	-	-
Soya bean meal	36.00	36.00	36.00	36.00
Fish meal	2.00	2.00	2.00	2.00
Limestone	1.00	1.00	1.00	1.00
Beef Tallow	-	-	3.00	-
Palm oil	-	-	-	3.00
Bone meal	3.00	3.00	3.00	3.00
Salt	0.3	0.3	0.3	0.3
Premix*	0.3	0.3	0.3	0.3
Lysine	0.2	0.2	0.2	0.2
Methionine	0.2	0.2	0.2	0.2
Total	100	100	100	100
Calculated analysis				
Crude protein	22.90	22.38	22.38	22.38
Ether extract	4.73	9.91	9.91	9.91
Crude fiber	4.43	4.30	4.30	4.30
Calcium	1.32	1.32	1.32	1.32
Phosphorus	0.57	0.57	0.57	0.57
Ca:P	2.30	2.30	2.30	2.30
Lysine	1.45	1.45	1.45	1.45
Meth + Cysteine	0.89	0.87	0.87	0.87
ME (Kcal/kg)	2871	2780	2910	2900

*To provide per kg of feed: Vitamin A: 8,500,000 IU; Vitamin D3 1,500,000 IU; Vitamin E 10,000mg; Vitamin K3 1,500mg; Vitamin B1 1,600mg; Vitamin B2 4,000mg; Niacin 20,000mg; Pantothenic acid 5,000mg; Vitamin B6 1,500mg; Vitamin B12 10.0 mg; Folic acid 500mg; Biotin H2 750mg; Choline chloride 175,000mg; Cobalt 200mg; Copper3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganese 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1,250mg at inclusion rate 2.5kg per ton of feed. Kingzyme®: Xylanase, Beta-Glucanase, Mannanase, and Cellulase enzymes, LED: Low energy diet, high, HEDAS: High energy diet animal source, HEDPS: High energy diet plant source, and ME: Metabolizable energy.

Table 2. Ingredient composition and calculated analysis of broiler chicken finisher diets

Ingredients	Control	LED	HEDAS	HEDPS
Maize	64.00	40.00	61.00	61.00
Soya bean meal	31.00	31.00	31.00	31.00
Maize offal	-	19.00	-	-
Rice offal	-	5.00	-	-
Limestone	1.00	1.00	1.00	1.00
Beef tallow	-	-	3.00	-
Palm oil	-	-	-	3.00
Bone meal	3.00	3.00	3.00	3.00
Salt	0.3	0.3	0.3	0.3
Premix*	0.3	0.3	0.3	0.3
Lysine	0.2	0.2	0.2	0.2
Methionine	0.2	0.2	0.2	0.2
Total	100	100	100	100
Calculated analysis				
Crude protein	20.05	19.51	19.51	19.51
Ether extract	4.51	9.91	9.91	9.91
Crude fiber	3.98	3.85	3.85	3.85
Calcium	1.21	1.21	1.21	1.21
Phosphorus	0.51	0.50	0.50	0.50
Ca: P	2.40	2.40	2.40	2.40
Lysine	1.23	1.22	1.22	1.22
Meth + Cysteine	0.80	0.78	0.78	0.78
ME (Kcal/kg)	2900	2870	2920	2930

*To provide per kg of feed: Vitamin A: 8,500,000 IU; Vitamin D3 1,500,000 IU; Vitamin E 10,000mg; Vitamin K3 1,500mg; Vitamin B1 1,600mg; Vitamin B2 4,000mg; Niacin 20,000mg; Pantothenic acid 5,000mg; Vitamin B6 1,500mg; Vitamin B12 10.0 mg; Folic acid 500mg; Biotin H2 750mg; Choline chloride 175,000mg; Cobalt 200mg; Copper 3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganese 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1,250mg at inclusion rate 2.5kg per ton of feed. Kingzyme®: Xylanase, Beta-Glucanase, Mannanase, and Cellulase enzymes blend, LED: Low energy diet, High HEDAS: High energy diet animal source, HEDPS: High energy diet plant source and ME: Metabolizable energy.

treatment for hematological, biochemical, and antioxidant analyses. According to the described methods by the Association of analytical chemists[14], 5 ml of blood was collected by severing the jugular vein into labeled sterile universal bottles with and without ethylene-diaminetetraacetic acid. The blood samples were used to determine the hematological and biochemical/antioxidant components, respectively. The biochemical indices measured were cholesterol, lipid fractions (High-density lipoprotein, Low-density lipoprotein, very low-density lipoprotein, Triglycerides), total protein (TP), albumin, globulin, urea, creatinine, and glucose. Antioxidant indices (MDA, SOD, and CAT) were also measured using commercial kits (Kiazist, Hamedan, Iran).

2.7. Statistical analysis

The data set generated was subjected to Analysis of Variance (ANOVA) using JMP Statistical Package, version 16.0. Differences among means were compared using Tukey's Honest Significant Difference (HSD) at a 5% probability level.

3. Results

3.1. Carcass characteristics

As can be seen in Table 3, the results of the carcass characteristics of broiler chickens fed with different dietary fat sources are represented. The dressed weight of the chcikens was significant, with the LED group having the highest live weight compared to the other treatment groups ($p < 0.05$). The LED group however had the lowest ($p < 0.05$) dressed weight compared to the other treatment groups which were similar ($p > 0.05$). Birds in the HEDAS group gave the highest ($p < 0.05$) dressing percentage compared to the LED and HEDPS groups which were similar ($p > 0.05$). While back cut was significant with the HEDAS group having the lowest back percentage compared with the other treatment groups ($p < 0.05$). Other carcass cut parts were similar across the treatment groups ($p > 0.05$). Except for liver weight where the HEDAS and HEDPS were similar to the control group, other organ weights were similar across all the treatment groups ($p > 0.05$).

3.2. Serum biochemistry

The result of the serum biochemistry of broiler chickens fed with different dietary fat sources is presented in Table 4. The birds on LED showed higher ALT levels compared to the HEDAS group which gave the least ($p < 0.05$). Alanine phosphatase (ALP) was also significant with the control, observed to be higher than other groups ($p < 0.05$). Birds in the HEDAS group gave higher ($p < 0.05$) cholesterol levels compared to the other treatment groups with the HEDPS chickens giving the lowest cholesterol levels. Triglyceride

Table 3. Carcass characteristics of broiler chickens fed with different dietary fat sources

Parameters	Control	LED	HEDAS	HEDPS	SD	P-value
Live weight (gr)	996.50^{d}	1468.50^{a}	1004.25^{c}	1402.50^{b}	18.76	0.0001
Dressed weight (g/bird)	755.75^{a}	964.25^{b}	785.75^{a}	785.50^{a}	21.71	0.0001
Dressing (%)	70.01^{b}	56.50^{c}	78.85^{a}	55.28^{c}	1.10	0.0001
Drumstick (%)	108.00	124.50	96.25	112.00	5.85	0.4297
Breast (%)	198.25	173.50	166.00	200.25	14.13	0.7720
Wings (%)	90.00	135.00	105.25	88.75	7.29	0.1433
Back (%)	142.25^{ab}	180.75^{a}	117.50^{b}	141.00^{ab}	6.34	0.0288
Thigh (%)	116.25	134.00	102.00	119.00	4.26	0.1222
Neck (%)	5.27	5.28	5.54	4.05	0.47	0.1738
Liver (%)	2.22^{a}	1.78^{b}	2.46^{a}	2.20^{a}	0.24	0.0034
Spleen (%)	0.38	0.39	0.40	0.40	0.05	0.9776
Gizzard (%)	2.17	2.17	2.18	2.10	0.25	0.0462

^{a,b,c} Means on the same row with different superscripts are significantly different ($p < 0.05$); SD: Standard deviation. HEDAS: High energy diet animal sources, HEDPS: High energy diet plant source, LED: Low Energy diet.

Table 4. Serum biochemistry of broiler chickens fed different dietary fat sources

Parameters	Control	LED	HEDAS	HEDPS	SD	P-value
Glucose (mg/dl)	90.57	92.76	105.98	97.45	2.53	0.8503
AST (U/L)	61.50	56.75	71.75	72.00	6.46	0.2940
ALT (U/L)	19.00^{c}	28.00^{a}	18.25^{d}	22.25^{b}	1.07	0.0001
ALP (U/L)	42.99^{a}	23.02^{d}	27.19^{c}	32.54^{b}	1.85	0.0001
Total Protein(g/dl)	4.02	38.78	40.34	38.78	0.88	0.1778
Albumins (g/dl)	25.34	24.30	22.64	22.92	1.41	0.5167
Globulin (g/dl)	15.69	14.65	17.70	14.65	1.51	0.4645
Urea (mg/dl)	41.11	37.97	40.04	38.34	3.91	0.9332
Creatinine(mmol/l)	0.33	0.29	0.31	0.37	0.03	0.2837
Cholesterol (mg/dl)	115.73^{b}	114.03^{bc}	123.90^{a}	109.58^{c}	1.16	0.0001
Triglyceride (mg/dl)	90.57^{b}	92.76^{b}	105.96^{a}	97.45^{ab}	2.53	0.0049
HDL (mg/dl)	60.90^{c}	63.94^{a}	57.77^{d}	62.60^{b}	0.63	0.0005
LDL (mg/dl)	34.27^{b}	30.63^{c}	38.32^{a}	27.53^{d}	1.18	0.0002
VLDL (mg/dl)	17.76^{d}	19.32^{b}	21.59^{a}	19.24^{c}	0.84	0.0003
MDA (µmol/mg)	1.13	1.35	1.44	1.47	0.18	0.5600
SOD (U/mol)	23.45	24.56	21.31	22.59	2.92	0.8799
Catalase(U/mg)	12.41	12.38	13.25	11.34	1.46	0.8344

^{a,b,c,d} Means on the same row with different superscripts are significantly different ($p < 0.05$); SD: Standard deviation; AST: Aspartate aminotransferase; ALT: Alanine transaminase; ALP: Alkaline phosphatase; LDL: Low-density lipoprotein; HDL: High-density lipoprotein; VLDLP: Very low-density lipoprotein, MDA: Malonaldehyde, SOD: Superoxide dismutase, CAT: Catalase.

levels were also significant with HEDAS birds having the highest triglyceride levels and being comparable to the HEPDS group ($p < 0.05$).

HDL levels were significant across the treatment groups with the LED and HEDPS groups having the highest HDL levels and the HEDAS chickens having the lowest HDL ($p < 0.05$). Dietary fat sources also influenced LDL concentration, with chickens in the HEDAS group having the highest LDL with the HEDPS having the lowest ($p < 0.05$). The VLDL was significant with HEDAS chickens having higher VLDL levels compared to the other treatment groups ($p < 0.05$). All other serum indices measured remained similar across the treatment groups. All measured antioxidant parameters (MDA, SOD, and Catalase) were similar for all treatment groups ($p > 0.05$).

4. Discussion

4.1. Carcass characteristics

Carcass characteristics in broiler chickens are influenced by dietary fat supplementations[15-18]. The obtained results of the present study agreed with Bobadoye et al.[19], who found that the inclusion of palm oil in the diet of broilers would promote fat deposition in broiler carcasses. The liver is the main site of lipogenesis in broilers and synthesized over 90% fatty acids[20] hence the higher liver weights observed in the control and high-fat diets relative to the LED group.

The findings of this study are also in line with results obtained by Shahryar et al.[21], who fed 3.0% canola oil and observed significant effects on the carcass characteristics of broiler chickens. Nobakht et al.[22] found no influence of different dietary vegetable oils on the yield of carcass, breast, and thigh. Similarly, Anjum et al.[23] did not observe differences in carcass dressing percentage and organ weights in broiler chickens fed diets with oxidized soybean oil.

4.2. Serum biochemical indices

Higher values in blood glucose have been reported by Choi et al.[24], Jambocus et al.[25], Bortolin et al.[26], and Lee et al.[27,] in groups that consumed an obesogenic diet (tallow). The accumulation of fatty acids in other organs, such as the liver, can also lead to insulin resistance and hyperglycemia since saturated fatty acids interfere with the activity of insulin receptors and glucose transporters[28]. Functions of synthesis of proteins in the liver of broilers are reflected by total protein and serum concentrations of albumin, which may be associated with animal growth and physiological status[29]. In the present study, the concentrations of albumin, globulin, and total protein, remained unaffected indicating the different dietary fat sources did not adversely influence these indices of broilers[30].

High levels of AST in the serum indicate liver damage caused by oxidative stress[31] which was not observed in the current study. Reduced ALT activity suggests a decrease in energy demand, metabolic pathways, and amino acids. However, in previous studies, an increase in the activity of ALT in the LED group was recorded indicating that there was an increased demand for energy due to tissue impairment[32-34]. The evaluation of liver dysfunction and oxidative stress in avian species commonly involves the measurement of enzyme levels, particularly AST and ALT[35]. The increase in AST and ALT levels indicates liver injury, certain inflammatory conditions, or damage to liver cells[32,33]. The amino-transferases (alanine and aspartate) function as links between carbohydrate and protein metabolism by the interconversion of strategic compounds like α - ketoglutarate and alanine to pyruvic acid and glutamic acid respectively, a process known as transamination[36]. An unusual elevation in the serum levels of AST and ALT may indicate potential liver injury[37]. The lower liver weight obtained in the LED group, compared to other treatment groups supported the findings.

The measurement of total cholesterol serum concentration is utilized to evaluate the lipid profile of

avian species[30]. Animal fats, including beef tallow, compared with plant sources, such as palm oil with high amounts of unsaturated fatty acids, often contain high saturated fatty acids, which can raise serum cholesterol levels. This is in line with Duraisamy et al.[38], who fed beef tallow and sunflower oil to broiler chickens. The inclusion of unsaturated fats in the diet positively modifies the fatty acid composition of broiler muscle[39], leading to a reduction in cholesterol levels in the meat[39], which in turn offers health advantages to consumers. Previous studies reported an increase in the serum concentration of triglycerides in diet-induced obesity models[40,42]. Oxidative stress induced by heat or lipids has been shown to increase serum levels of triglycerides and VLDL, as well as the mRNA expression levels of genes related to fatty acid synthase[43].

According to Zhang et al.[44], HEDPS in birds increased the serum levels of HDL. Ge et al.[45] reported that the decreased serum LDL concentration in broilers is affected by high dietary energy. It was confirmed by Zhao and Kim[46] that the serum levels of LDL in broiler chickens increased after feeding them a fat-rich diet. These differences may be related to the type of dietary lipids that are supplemented. It has been shown that palm oil increases the levels of HDL and reduces the levels of LDL in the blood[47].

5. Conclusion

The present study highlighted that various dietary fat sources significantly affect the carcass characteristics and serum biochemical indices of broiler chickens. High-energy diets, particularly those derived from plant sources like palm oil, positively impact live weight and serum biochemistry, enhancing overall production performance and health. Animal fats, such as beef tallow, increase levels of cholesterol, triglycerides, and LDL, which are indicators of metabolic stress. Conversely, plant-based fats, particularly palm oil, promote healthier lipid profiles with higher HDL and lower LDL levels, thus suggesting beneficial effects for both animal welfare and product quality. Further studies need to be conducted to evaluate the recommended level of different fat sources in the broiler chicken diets.

Declarations

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Nwuku Jivini Aji contributed to data collection and literature review. Obun Cletus Otu wrote the original draft. Ademu Lawrence designed the methodology and managed the analyses of the study. All authors read and approved the final draft of the manuscript.

Authors' relationships and activities

All authors disclose any personal and financial relationships with other people or organizations.

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Availability of data and materials

The original contributions presented in the study are included in the article/supplementary material. For inquiries, please contact the corresponding author/s.

Ethical considerations

All authors have reviewed the manuscripts for ethical concerns, such as plagiarism, consent to publish, misconduct, data fabrication and falsification, double publishing and submission, and redundancy.

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