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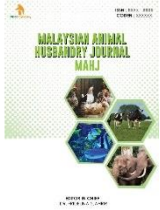

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RESEARCH ARTICLE

PERFORMANCE OF BROILER CHICKENS FED DIETS SUPPLEMENTED WITH *CARICA PAPAYA, OCIMUM GRATISSIUM* AND *BRYOPHYLLUM PINNATUM* LEAFMEALS

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ABSTRACT

This study evaluated the influence of dietary supplementation with *Carica papaya* leaf meal (CPLM), *Ocimum gratissimum* leaf meal (OGLM), and *Bryophyllum pinnatum* leaf meal (BPLM) on the growth performance and physiological responses of broiler chickens. A standard basal diet was divided into four treatments: diet 1 served as the control, while diets 2, 3, and 4 were each supplemented with 0.2% of CPLM, OGLM, and BPLM, respectively. One hundred and twelve day old broiler chicks were randomly assigned to the four experimental diets (28 birds per diet), 7 birds per replicate using a Completely Randomized Design. At the conclusion of the feeding period, birds fed the CPLM-supplemented diet showed significantly greater body weight gain and improved feed conversion ratio ($p < 0.05$) compared to those on the control, OGLM, and BPLM supplemented diets. Birds fed the BPLM-supplemented diet exhibited higher ($p < 0.05$) white blood cell, granulocyte, and lymphocyte counts than those in other groups. In addition, serum cholesterol and glucose levels were notably reduced ($p < 0.05$) in the BPLM group relative to the control. Antioxidant enzyme activities, specifically glutathione peroxidase and catalase, were significantly elevated ($p < 0.05$) in the OGLM-fed group. Furthermore, birds fed any of the supplemented diets (CPLM, OGLM, BPLM) had lower levels of serum protein oxidation and thiobarbituric acid ($p < 0.05$) compared to the control. These findings suggest that 0.2% dietary supplementation of CPLM enhances growth performance, while all the phytogenic leaf meals at 0.2% contribute to reduced oxidative stress in broiler chickens.

KEYWORDS

Broiler; performance; serum metabolites; antioxidant status; herbs

1. INTRODUCTION

In recent years, there has been growing interest in phytogenic plants as feed additives due to their ability to lower bacterial load and enhance digestive secretions, contributing to improved animal health and productivity (Reisinger et al., 2011). These plants are rich in bioactive constituents such as allicin, thymol, carvacrol, anethole, and allyl-isothiocyanate, which have demonstrated potential in promoting poultry growth and supporting immune function (Hippenstiel et al., 2011). As the livestock industry seeks safer, more natural alternatives to antibiotic growth promoters, phytogenic feed additives (PFAs) have gained popularity for their health-promoting properties and lower risk of contributing to antimicrobial resistance. Phytogenics encompass a broad and diverse category of plant-based feed supplements derived from various plant parts, including leaves, roots, tubers, and fruits of herbs and spices. These additives are typically administered in dried, powdered, extract, or essential oil form. Their application in swine and poultry diets has shown promise, particularly in enhancing growth performance and immune responses (Jamroz et al., 2006). Also referred to as phytochemicals, botanicals, or plant secondary metabolites, phytogenics include a wide range of compounds with reported therapeutic and performance-enhancing effects (Bravo et al., 2014; Pirgozliev et al., 2015). One of the key advantages of using these substances in poultry diets is their ability to mitigate the risk of antibiotic-resistant pathogens, a growing concern in animal agriculture. Although the health benefits of phytogenic compounds are well-recognized, the exact biological mechanisms through which they act are not yet fully understood (Karadas et al., 2014; Pirgozliev et al., 2015).

Phytogenic feed additives are incorporated into animal diets with the goal of improving performance metrics such as growth rate, feed efficiency, and immune health. These non-antibiotic growth promoters, sourced from aromatic plants, are rich in bioactive substances with antimicrobial, antiviral, and antioxidant properties (Bölükbaşi et al., 2009). Their inclusion in feed can enhance nutrient digestion, improve absorption, and reduce pathogenic load in the gastrointestinal tract (Athanasiadou et al., 2007).

Carica papaya (commonly known as pawpaw), a member of the Caricaceae family, is recognized for its high nutritional value, especially in its leaves, which are often incorporated into food products like flour and tea to boost their nutrient content (Santana et al., 2019). The leaves are an excellent source of vitamin C, which plays a critical role in collagen synthesis and wound healing (Ahlwat et al., 2019). In addition, *C. papaya* is rich in antioxidants such as vitamins A and E, flavonoids, and various minerals including magnesium, potassium, and calcium (Amin et al., 2019). Its seeds also contain compounds like glucosinolates, benzyl isothiocyanate, tocopherols, β-cryptoxanthin, and carotenoids, which are known for their antioxidant and disease-preventing properties, including anti-cancer and anti-cataract effects (Amin et al., 2019; Santana et al., 2019).

Ocimum gratissimum contains a diverse range of phenolic compounds and flavonoids, such as rosmarinic acid, gallic acid, caffeic acid, and quercetin derivatives, as well as triterpenoids like ursolic and oleanolic acids. These constituents have been shown to possess strong antioxidant and anti-inflammatory activities (Casanova et al., 2014; Venuprasad et al., 2014; Ajayi et al., 2019; Irondi et al., 2016; Dzoyem et al., 2021).

Similarly, phytochemical evaluations of *Bryophyllum pinnatum* leaf meal

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have confirmed the presence of key secondary metabolites including flavonoids, phenols, and terpenoids. These compounds contribute to its medicinal potential, particularly its antioxidant and anti-inflammatory effects. Flavonoids, being water-soluble antioxidants, help to neutralize free radicals and protect cells from oxidative damage, while phenolic compounds are known for their pain-relieving and immune-stimulating properties (Okwu, 2004). The phytochemical richness of *B. pinnatum* underscores its potential as a functional feed additive in poultry nutrition.

2. Materials and Methods

2.1 Location and experimental site

The study was carried out at the Poultry Unit of Teaching and Research farm Department of Agricultural Technology, The Federal Polytechnic Ado Ekiti, Ekiti state, Nigeria. The state is located in South Western part of the country, Ekiti state covers a land area of 6353km square (2453sqmi) with a population estimated in 2005 to be 2737,186.

2.2 Site preparation

The poultry house was thoroughly washed, fumigated with disinfectant. The poultry house was allowed to stay and dried for two weeks before the arrival of the experimental birds, proper weeding of the surrounding was carried out to prevent predators and pests.

2.3 Experimental animals

A total number of one hundred and twelve (112) birds of commercial breed was used in this experiment. There were 4 treatments and 4 replicates per treatment. Seven (7) birds were allotted per replicates amounting (24) birds per treatment. Normal medications and vaccinations were given to the experimental birds.

2.4 Test ingredients

The *Carica papaya* leafmeal (CPLM), *Ocimum gratissimum* leaf meal (OGLM), *Bryophyllum pinnatum leafmeal* (BPLM) used in this study were harvested within the premises of The Federal Polytechnic Ado Ekiti, they were air-dried for 24 days in order to reduce the moisture content. They were milled into fine particles and used to formulate the diets.

2.5 Management of experimental birds

A total of 112 day-old Cobb-500 broiler chicks were used for this study. The birds were sourced from a reputable commercial hatchery. Upon arrival, they were brooded for a period of two weeks to allow for acclimatization. During this phase, electric bulbs were used to provide both heat and lighting within the pen. Adequate space and ventilation were ensured in the brooding area, and the pen was lined with polythene sheets to retain warmth and offer protection against predators and harsh weather conditions. After the acclimatization period, the birds were introduced to the experimental diets. Standard poultry management practices were followed throughout the trial. All necessary vaccinations and medications were administered as required. Feed and clean drinking water were made available to the birds at all times (ad libitum) during the course of the experiment.

2.6 Experimental diets

The composition of experimental diets were presented in table below. The basal diets were formulated for broiler starter (0-28) days and finisher phase (29-56) days. The basal diets were divided into 4 diets.

Diet 1: Control diet (without supplements)

Diet 2: Contained 0.2% of *Carica papaya* leaf meal.

Diet 3: Contained 0.2% of *Ocimum gratissimum* leaf meal.

Diet 4: Contained 0.2% of *Bryophyllum pinnatum* leaf meal.

Table 1: Composition of experimental diet (%) for broiler starter and finisher

Ingredients	Starter	Finisher
Maize	51.00	60.00
Soybean cake	23.00	15.00
Groundnut cake	16.00	16.00
Fish meal	2.00	2.00
Bone meal	4.00	3.00
Limestone	2.00	2.00
Broiler premix	0.25	0.25
Methionine	0.25	0.25
Lysine	0.25	0.25
Common salt Oil	0.25 1.00	0.25 1.00
Total	100.00	100.00
Calculated composition		
Metabolizable energy (kcal/kg)	2938.00	2984.70
Crude protein (g/100g)	24.68	20.31
Crude fibre (g/100g) Average calcium	2.56 2.35	2.85 1.99
Average phosphorus	0.84	0.65
Lysine	1.33	1.27
Methionine	0.60	0.58

3. Data Collection

Birds in each treatment group were weighed weekly to monitor growth performance, while daily feed intake was recorded. The evaluated performance parameters included initial body weight, final live weight, total feed intake, average daily feed intake, and average daily weight gain. Weight gain was calculated by subtracting the initial body weight from the final live weight. The feed conversion ratio (FCR) was determined by dividing the total feed intake by the birds' total weight gain.

At the conclusion of the feeding trial, birds were randomly chosen from each replicate for blood sample collection. Using a 5 ml syringe, blood was drawn from the jugular vein located in the neck region. Samples intended for hematological analysis were transferred into sterile bottles containing Ethylene Diamine Tetra-Acetic Acid (EDTA) as an anticoagulant, following the method of Ritchie et al. (1994). Additional blood samples were collected into plain tubes for the analysis of serum metabolites—including creatinine, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), cholesterol, and glucose—as well as serum antioxidant enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase, protein oxidation, and thiobarbituric acid reactive substances (TBARS). Serum metabolite levels were measured using a Reflectron Plus 8C79 analyzer (Roche Diagnostics, GombH Mannheim, Germany). The activities of glutathione peroxidase and superoxide dismutase were assessed using the protocols described by Rotruck et al. (1973) and Aebi (1974), respectively.

After slaughter, the live, dressed, and internal organ weights of the birds were measured using a precision scale. Dressed weight and internal organ weights were expressed as percentages of the live body weight.

3.1 Analysis of data

The model: $Dny = \mu+\alpha\eta+\beta\eta\gamma$, was used in this experiment, where Dny= any of the response variables; n= the overall mean; $\alpha\eta$= effect of the *nth* treatment (*D*=diets 1,2,3,4 and 5); and $\beta\eta\gamma$ = random error due to experimentation. Data were exposed to one-way ANOVA using SPSS version 20. The differences among the means were determined (P<0.05) by Duncan multiple range test of SPSS.

4. Results

Table 2 shows the impact of CPLM, OGLM, and BPLM supplementation on the growth performance of broiler chickens. Birds fed the control, OGLM, and BPLM diets recorded body weight gains of 50.95 g, 49.89 g, and 49.99 g, respectively, with no significant differences among them (P>0.05). However, these values were significantly lower (P<0.05) compared to the 58.39 g weight gain observed in birds receiving the CPLM-supplemented diet. The feed conversion ratio (FCR) was also significantly improved (lower) in the CPLM group at 1.52, compared to the control and other treatment groups. In contrast, there were no significant differences (P>0.05) in final live weight or feed intake among the different dietary treatments.

Table 2: Effect of CPLM, OGLM and BPLM supplementation on growth performance of broiler chickens

Parameters	Treatment groups (%)				SEM	*p* -value
	Control	CPLM	OGLM	BPLM		
Initial weight (g)	38.80	38.88	38.97	38.97	0.04	0.60
Final live-weight(g)	2905.38	2865.31	2841.13	2914.68	13.32	0.17
Bodyweight gain (g)	50.95^{b}	58.39^{a}	49.89^{b}	49.99^{b}	1.67	0.01
Feed intake (b/g/d)	87.46	86.96	89.90	88.61	0.50	0.16
Feed conversion ratio	1.72^{b}	1.52^{c}	1.80^{a}	1.77^{ab}	0.03	0.09

^{a,b,c} means in the same row with different superscripts are significantly (P<0.05) different; SEM: standard error of mean, *Carica papaya* leafmeal (CPLM) ; *Ocimum gratissimum* leaf meal (OGLM); *Bryophyllum pinnatum* leafmeal (BPLM).

The effects of CPLM, OGLM, and BPLM supplementation on the hematological parameters of broiler chickens are summarized in Table 3. There were no significant differences (P>0.05) in mean cell volume, mean corpuscular hemoglobin, hemoglobin concentration, or monocyte counts among the different phytogenic-supplemented diets. However, packed cell volume (PCV) was significantly higher (P<0.05) in birds fed the BPLM diet (36.33%) compared to those receiving the control, CPLM, and OGLM diets, which recorded PCV values of 34.00%, 33.00%, and 31.67%, respectively. Red blood cell (RBC) count and mean corpuscular hemoglobin concentration (MCHC) were significantly lower (P<0.05) in birds fed OGLM compared to the control, CPLM, and BPLM groups, which did not differ significantly from each other (P>0.05). Additionally, white blood cell (WBC), granulocyte, and lymphocyte counts were significantly elevated (P<0.05) in birds supplemented with BPLM compared to those on the control, CPLM, and OGLM diets. Overall, hemoglobin, mean cell volume, mean corpuscular hemoglobin, and monocyte levels were not significantly affected (P>0.05) by the phytogenic supplements.

Table 3: Effect of CPLM, OGLM and BPLM supplementation on hematological indices of broiler chickens

Parameters	Treatment groups (%)				SEM	*p* –value
	Control	CPLM	OGLM	BPLM		
Packed cell volume (%)	34.00^{ab}	33.00^{b}	31.67^{b}	36.33^{a}	0.67	0.03
Red blood cell ($\times10^{12}$/L)	3.07^{a}	3.07^{a}	2.77^{b}	3.03^{a}	0.05	0.07
Haemoglobin (g/dl)	10.99	11.18	11.00	11.07	0.04	0.35
MCHC (%)	33.29^{a}	33.22^{a}	32.62^{b}	33.29^{a}	0.11	0.05
MCV (fl)	110.00	109.67	109.67	109.67	0.13	0.80
MCH (pg)	36.34	36.18	36.45	36.30	0.07	0.64
WBC ($\times10^{12}$/L)	2.67^{b}	2.85^{ab}	2.73^{b}	2.93^{a}	0.01	0.04
Granulocytes ($\times10^{12}$/L)	0.62^{b}	0.57^{b}	0.60^{b}	0.72^{a}	0.02	0.03
Lymphocytes ($\times10^{12}$/L)	1.94^{c}	2.39^{b}	2.38^{b}	2.53^{a}	0.07	0.01
Monocytes ($\times10^{12}$/L)	0.06	0.06	0.05	0.06	0.01	0.16

^{a,b,c} means in the same row with different superscripts are significantly (P<0.05) different; SEM: standard error of mean, *Carica papaya* leafmeal (CPLM) ; *Ocimum gratissimum* leaf meal (OGLM); *Bryophyllum pinnatum* leafmeal (BPLM). MCHC-Mean cell haemaglobin concentration; MCV-Mean cell volume ; MCH- Mean cell haemoglobin.

The impact of CPLM, OGLM, and BPLM supplementation on serum metabolites in broiler chickens is shown in Table 4. Birds receiving the BPLM diet exhibited significantly higher alkaline phosphatase levels (54.33 IU/L) compared to those fed the control, CPLM, and OGLM diets, which had values of 54.30 IU/L, 51.67 IU/L, and 53.33 IU/L, respectively (P<0.05). Cholesterol concentrations were significantly lower (P<0.05) in birds fed the OGLM diet (5.00 mmol/L) relative to the control, CPLM, and BPLM groups, which recorded values of 6.03 mmol/L, 5.53 mmol/L, and 5.50 mmol/L, respectively. Additionally, glucose levels in birds fed BPLM were significantly (P<0.05) reduced compared to those in the control, CPLM, and OGLM groups, with the latter two showing no significant difference between each other (P>0.05). No significant effects were observed on creatinine, urea, aspartate aminotransferase (AST), or alanine aminotransferase (ALT) due to the phytogenic feed additives.

Table 4: Effect of CPLM, OGLM and BPLM supplementation on serum metabolites of broiler chickens

Parameters	Treatment groups (%)				SEM	*p* –value
	Control	CPLM	OGLM	BPLM		
Creatinine (mmol/l)	39.20	39.59	39.81	39.74	0.13	0.43
Urea (mmol/l)	6.83	6.83	6.85	6.85	0.01	0.83
AST (IU/L)	10.70	10.85	10.67	10.52	0.10	0.92
ALT (IU/L)	12.47	12.10	12.27	12.17	0.08	0.46
ALP (IU/L)	54.30^{a}	51.67^{b}	53.33^{ab}	54.33^{a}	0.45	0.10
Cholesterol (mmol/l)	6.03^{a}	5.53^{b}	5.00^{c}	5.50^{b}	0.12	0.02
Glucose (mg/dl)	21.33^{a}	18.67^{b}	18.67^{b}	17.00^{c}	0.50	0.01

a,b,c means in the same row with different superscripts are significantly (P<0.05) different; SEM: standard error of mean, *Carica papaya* leafmeal (CPLM) ; *Ocimum gratissimum* leaf meal (OGLM); *Bryophyllum pinnatum* leafmeal (BPLM). AST- Aspartate aminotransferase; ALT- Alanine aminotransferase; ALP- Alkaline phosphatase

Table 5 illustrates the effects of CPLM, OGLM, and BPLM supplementation on serum antioxidant activities in broiler chickens. Birds fed the *Ocimum gratissimum* leaf meal (OGLM) diet showed significantly higher (P<0.05) levels of serum glutathione peroxidase and catalase compared to those on the control, CPLM, and BPLM diets. Additionally, protein oxidation was significantly reduced (P<0.05) in the OGLM group relative to the other dietary treatments. Conversely, thiobarbituric acid (TBA) levels were significantly lower (P<0.05) in birds supplemented with BPLM compared to those receiving the control, CPLM, and OGLM diets.

Table 5: Effect of CPLM, OGLM and BPLM supplementation on serum antioxidant activity of broiler chickens

Parameters	Treatment groups (%)				SEM	*p* -value
	Control	CPLM	OGLM	BPLM		
SOD (%)	76.46	77.09	76.42	76.54	0.23	0.76
GPx (mg.mL^{-1})	181.12^{d}	186.59^{c}	195.69^{a}	190.63^{b}	1.62	0.01
Catalase (U.ml^{-1})	21.03^{d}	24.98^{c}	29.53^{a}	28.04^{b}	0.99	0.01
Protein oxidation	76.78^{a}	64.67^{b}	52.86^{d}	60.69^{c}	2.63	0.10
TBA	4.07^{a}	2.82^{b}	2.33^{bc}	1.83^{c}	0.27	0.10

a,b,c means in the same row with different superscripts are significantly (P<0.05) different; SEM: standard error of mean, *Carica papaya* leafmeal (CPLM) ; *Ocimum gratissimum* leaf meal (OGLM); *Bryophyllum pinnatum* leafmeal (BPLM), SOD- Superoxide dismutase; GPx- Glutathione peroxidase; TBA- Thiobarbituric acid.

5. Discussion

The enhanced body weight gain (BWG) and improved feed conversion ratio (FCR) observed in birds fed diets supplemented with CPLM may be attributed to the bioactive components present in CPLM. Phytochemicals with antimicrobial and antioxidant properties, as reported, likely contributed to these improvements in BWG and FCR (Negi, 2012; Valenzuela–Grijalva et al., 2017). Additionally, phytochemicals in CPLM are known to exert anabolic effects and influence metabolic pathways that promote muscle growth, as described (Devi et al., 2015; Gonzales-Rios et al., 2016). The findings of this study clearly demonstrate the positive impact of the tested phytogenic feed additives (PFAs) on broiler growth performance.

However, these results contrast with those who found that phytogenic additives reduced feed intake with minimal effects on weight gain, leading to enhanced FCR (Windisch et al., 2008). The inclusion of CPLM might have altered diet palatability, possibly due to the pungent nature of certain phytogenic compounds, which could reduce feed intake (Brenes and Roura, 2010). The current findings align with in that PFAs can improve FCR by reducing feed intake without significantly affecting BWG or final body weight (Windisch et al., 2008). These results also support previous work, who reported improvements in BWG and FCR following PFA supplementation without impacting feed consumption (Mountzouris et al., 2011).

Hematological parameters are reliable indicators of an animal's physiological condition (Khan and Zafar, 2005). In this study, supplementation with CPLM and BPLM increased packed cell volume (PCV), possibly by stimulating red blood cell production. Similar increases in PCV and red blood cell counts have been observed with CPLM and BPLM extracts and leaf meals compared to control and OGLM diets (Ekpo et al., 2021). The highest mean corpuscular hemoglobin concentration (MCHC) values were recorded in birds fed control and BPLM diets, followed by CPLM, with the lowest observed in the OGLM group. While this finding agrees with ranges reported, it differs from, who reported higher MCHC values in White Leghorn layers, potentially due to sex-related differences (Addass et al., 2012; Adeyemo and Sani, 2013; Najib and Al-Aqil, 2015).

Variations in white blood cell counts and differentials across dietary treatments may indicate immunomodulatory effects of the phytogenic supplements, as noted by (Oloruntola et al., 2016). White blood cells play a vital role in immune defense, and the elevated white blood cell, granulocyte, and lymphocyte counts in birds fed BPLM suggest a beneficial immunomodulatory response, consistent with findings by (Hang and Lee, 2018). Phytochemicals such as flavonoids and carotenoids have been shown to enhance immune function by stimulating lymphocytes, monocytes, granulocytes, and immunoglobulin production (Alipour et al., 2015). BPLM's immunomodulatory and anti-inflammatory properties may contribute to the observed increase in white blood cell levels, possibly through downregulation of inflammatory mediators and improved immune response (Ekpo et al., 2021).

The observed reduction in cholesterol levels may result from phytochemical metabolites like saponins and phenols, which interfere with intestinal cholesterol absorption through chemical interactions in the gut (Oloruntola et al., 2018a). Similarly, the decreased glucose levels in birds fed BPLM suggest its inhibitory effect on serum glucose elevation, likely due to its diverse phytochemical composition. Herbal supplements in this study also demonstrated strong antioxidant potential, which is important for mitigating oxidative stress (Gupta et al., 2006).

Glutathione peroxidase and catalase are key antioxidant enzymes that protect against oxidative damage (Afolabi and Oloyede, 2014). The increased glutathione peroxidase and catalase activities observed in birds fed OGLM highlight the antioxidant capacity of this phytogenic additive and its potential to enhance the birds' oxidative status. The elevated antioxidant activities in birds receiving CPLM, OGLM, and BPLM may be attributed to their polyphenolic content, such as flavonoids and phenolic acids (Goyal and Brahma, 2014). According to Dhama et al. (2015), active compounds in OGLM exert potent antioxidant effects by scavenging free radicals and boosting catalase and glutathione peroxidase activities.

In addition, OGLM supplementation reduced thiobarbituric acid (TBA) levels and protein oxidation in broiler chickens. These antioxidant effects may have contributed to the improved performance observed in birds fed phytogenic additives compared to the control group. TBA is commonly used to assess lipid peroxidation by measuring compounds such as malondialdehyde (MDA) in biological samples (Dasgupta and Klein, 2014). Lipid peroxidation results from oxidative stress degrading cellular lipids, particularly in tissues like the liver, and indicates oxidative damage. Protein oxidation can cause protein fragmentation, polymerization, and aggregation, reducing protein functionality and nutritional value (Bekhit et al., 2013). Phytogenic compounds possess antioxidant properties that help protect cells from lipid peroxidation induced by oxidative stress (Windisch et al., 2008).

Superoxide dismutase (SOD) is an enzyme that protect against oxidative stress (Young and Woodside, 2001). The study found that the Superoxide dismutase (SOD) of birds fed phytogenic supplement in this present study were not affected, which contradict the result of Hashemi and Davoodi, (2010) revealing the antioxidant and anti-stress properties of these phytogenic. Goya's and Bralima, (2014) reported the higher antioxidant activities observed in birds fed phytogenic supplements could be attributed to the photogenic' polyphenolic contents (Flavonoids or Phenolic acids) (Goya's and Bralima, 2014).

6. Conclusions

CPLM, OGLM, and BPLM contain phytochemicals that offer health benefits and exhibit antioxidant activity. Supplementing the diet with 0.2% CPLM enhanced body weight gain and improved feed conversion ratio in broiler chickens. Additionally, these herbal supplements demonstrated immunomodulatory effects and contributed to lowering cholesterol levels in the birds. At the same supplementation level (0.2%), CPLM, OGLM, and BPLM also decreased serum protein oxidation and thiobarbituric acid concentrations, indicating reduced oxidative stress.

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