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Effect of Phytogenic Supplementation on the Carcass Characteristics of Broiler Chickens Exposed to Heat Stress

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Abstract

PHYTOGENICS are known to mitigate the negative effects of high temperatures on livestock, by enhancing their antioxidant capacity, improving gut health, and modulating the immune system. High temperature affects production performance of broiler chickens; hence this can be mitigated by using phytogenics. This study evaluated the effect of three phytogenic supplements (*A. digitata*, *C. annuum*, and *L. javanica)* on heat-stressed broiler chickens reared under the deep litter system in a 6-week trial. A total of 144 one-day-old Cobb 500 broilers were used in the experiment. The birds were assigned to four treatments [i.e., *C. annum, L. javanica, A. digitata, and control (untreated tap water*)] in a Completely Randomised Design and each treatment (36 birds) was replicated three times. Results showed that phytogenic supplementation caused an increase ($p<0.05$) in carcass weight and yield, dressing out percentage, and wholesale cuts weight for birds supplemented with *C. annuum* followed by *A. digitata* compared with the control group. Broilers supplemented with *L. javanica* had significantly ($p<0.05$) lower carcass and wholesale cut weight but significantly ($p<0.05$) higher dressing out percentage and wholesale cut yield than the control group. Birds supplemented with *C. annuum* had significantly lower abdominal fat than other treatment groups. Supplementation of *C. annuum* and *A. digitata* improved carcass weight and yield.

Keywords: Broilers, Carcass characteristics, Cobb 500, heat stress, phytogenic supplements.

Introduction

Poultry plays an important role in the livelihoods of households, contributing substantially to the economies of developing countries including Botswana. Chickens are particularly susceptible to heat stress as they lack sweat glands and have a feather covering, which prevents them from dissipating heat from the body [1]. For instance, heat stress affects feed intake leading to reduced performance of poultry enterprises, thus making it a major challenge in poultry production in sub-tropical and tropical climates. According to [2], a decline in feed utilisation efficiency is the major cause of poor growth performance in hot climates. The chickens' health and performance are negatively impacted by physiological problems that result from heat stress such as respiratory alkalosis, endocrine issues, systemic immunological dysregulation, and electrolyte imbalance [3]. Furthermore, such stress has detrimental effects on intestinal immunity, antioxidant capacity, and altered intestinal shape [4]. When broiler chickens experience heat stress, their feed intake decreases, thus leading to impaired feed conversion efficiency and reduced growth rates. Heat stress affects carcass quality, mainly colour, and weight, thus leading to the final product becoming less desirable to consumers [5].

Mitigating heat stress is important as high temperatures and humidity can decrease carcass weight, thereby affecting broiler chickens' profitability [6]. Therefore, implementing effective strategies to mitigate heat stress in broiler chickens is crucial to improving the industry's overall performance and profitability.

Various studies have shown that phytogenic supplements can enhance the carcass characteristics of broiler chickens exposed to high temperatures, allowing the broiler chicken industry to maintain high standards and meet consumer demands even under hyperthermia [7,8]. Selenium and vitamins E and C are also known to enhance the production performance of broilers [1]. For instance, phytogenics are plant-derived substances containing varied biologically active compounds, including essential oils, herbs, and spices, used primarily as

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feed additives or supplements in animal nutrition [9]. Phytogenic supplements can improve carcass weight and maintain carcass colour by reducing oxidative stress and enhancing nutrient absorption. Information on the use of phytogenics to combat the effects of heat stress in broiler chickens is limited. Therefore, this study assessed the effects of *Lippia javanica, Adansonia digitata*, and *Capsicum annuum* supplemented in drinking water on the carcass characteristics of broiler chickens exposed to high ambient temperatures and reared under an intensive system in an open-sided house. It was hypothesized that phytogenic supplementation would not significantly affect carcass characteristics of broilers.

Material and Methods

Ethical considerations

The management and care of the broiler chickens followed the Animal Ethics Committee accepted standards for animal welfare and ethics (Ethics Number BUAN-ACUC-2024-06) of the Botswana University of Agriculture and Natural Resources (BUAN).

Experimental site

Birds were reared at the BUAN Broiler Production Unit, Sebele Content Farm from November to December 2023. Broiler chickens were reared on deep litter in an open-sided house. The farm is located at coordinates 24°34'54.41" S 25°58'14.64" E, about 15 km north of Gaborone and has an elevation of 978 m [10]. The average temperatures of the coldest month (July) and warmest month (January of 2022) are 13.5 °C and 26°C, respectively [10]. Carcass characterisation was performed at the BUAN Meat Science Laboratory in the Department of Animal Sciences.

Experimental design and broiler management

A Completely Randomised Design was used to allocate 144 one-day-old Cobb 500 broiler chicks to four treatments (i.e., *C. annum, L. javanica, A. digitata, and control (untreated tap water*). Untreated tap water was used as the control and three other treatments *(C. annum, L. javanica, A. digitata)* were added to the drinking water at 10 g/L. Each treatment had three replicate pens holding 12 chicks each as an experimental unit. Broilers were fed a starter diet for 14 days, a grower diet from 15-28 days, and a finisher diet from day 29 to slaughter (i.e., day 43). The nutritional composition of the poultry diets is shown in Table 1. Feed and water were supplied *ad libitum* throughout the experimental period.

One hundred and forty-four (144) Cobb 500 one-day-old broiler chicks were obtained from a broiler chick distributor in Gaborone and reared for 6 weeks under deep litter with high cyclic temperature (33-40 °C) during the day. A week before the arrival of chicks, the housing unit, feeders, and drinkers were cleaned thoroughly and disinfected using Virukill (which contains didecyldimethylammonium chloride as an active ingredient). Sunflower husks were spread on the floor and used as bedding material. Each pen measuring 3 m^2 was equipped with a drinker and a feeder. Upon arrival, chicks were acclimatised to the environment for a week. Feed and water were supplied *ad libitum* for six weeks. Broilers were fed a commercial starter diet for 14 days, a grower diet from 15 to 28 days of age, and a finisher diet from day 29 to slaughter point (i.e., day 43). Thereafter, chicks were weighed using an electronic scale sensitive to 0.001g (Adam, Gauteng Province, South Africa) and balanced for weight across treatments. Thereafter, chicks were introduced to the five treatments. The body weight of the chicks was measured weekly while feed intake was measured daily. Birds were subjected to a 22-hour light schedule throughout the rearing period to encourage feed intake [11].

Slaughter procedure

At the end of 6 weeks, feed, and water were withdrawn for 12 hours before slaughter to reduce the amount of gastro-internal content of the chickens and lessen the chance of contaminating carcasses with digesta and faeces. All the birds were weighed (pre-slaughter weight / live body weight) before being transported to the BUAN slaughterhouse, where they were humanely sacrificed by cutting the neck and severing both carotid arteries and jugular veins without decapitating the head and allowed to bleed for 3 minutes. The carcasses were then scalded at 55-60 ^{o}C in a water bath for 30 seconds before being de-feathered in a rotary drum picker [12]. Thereafter, birds were plucked after which their heads, necks, and feet were severed from the carcasses. The carcasses were then taken to BUAN Meat Science Laboratory for carcass characterisation.

Seventy-two broiler chicken carcasses were randomly selected (i.e., 18 from each treatment) for carcass evaluation. Carcasses were weighed after de-feathering, before the removal of internal organs [5]. Thereafter, internal organs including the liver, heart, pancreas, spleen, gizzards, and abdominal fat pad were individually removed and weighed after disembowelment. To obtain the actual weight of the gizzard, the gizzards were firstly emptied before weighing to remove the feed content. The dressed weight of each bird was recorded, and the dressing out percentage was calculated by determining the proportion of dressed weight and visceral organ weights to live weight [13]. Carcass yield was then calculated by determining the proportion of dressed carcass weight to live weight [5]. Thereafter, the cold dressed weights were determined at 24 hr. *post-mortem* after chilling at 4 °C [5]. After obtaining the cold dressed weight, the carcasses were dissected to

obtain wholesale cuts including drumsticks, thighs, backs, wings, and breasts, which were individually weighed to determine part yield [14]. The abdominal fat depot beneath the skin and around the internal organs in the abdominal cavity was carefully removed from the carcass using a sharp knife and weighed using an electronic weighing scale sensitive to 0.001 g. The formulae below were used to calculate carcass yield percentage, dressing out percentage, and wholesale cuts yield.

Carcass yield (%) = (dressed weight/live weight) * 100. (1)

Dressing out (%) = (dressed weight + the visceral organ weights) / LBW * 100 (2)

Wholesale cut yield (%) = Cut weight/carcass weight * 100 (3)

Statistical analysis

Data on carcass characteristics and visceral organ parameters were analysed using analysis of variance (ANOVA) using the Mixed Model (Proc Mixed) Procedures of Statistical Analysis System (SAS) version 9.4, [15] to determine the effect of supplementary treatments on carcass characteristics of broiler chickens. The mixed procedures determined the means, least-square means, and standard errors at a significant level of 0.05 (5%). The reported results were least square means separated using the LSD test to identify significant differences among treatment means. The statistical model used was as follows:

$$Y_{ijk} = \mu_i + D_j + F_k + \varepsilon_{ijk}$$

where Y_{ijk}= the response variable (Carcass characteristics)

μ_i = Overall mean

D_j= the j^{th} treatment effect (control, *L. javanica, A. digitata, C. annuum*)

F_k = the k^{th} replicate effect

ε_{ijk}= the error term.

Results

Carcass traits and yield

Data on the live weight, dressed weight, cold carcass weight, dressing out percentage, and carcass yield percentage are presented in Table 1. Phytogenic supplementation significantly affected carcass traits and yield. The highest live weight was achieved in birds supplemented with 10 g/L of *C. annuum* and *A. digitata*, whereas the birds supplemented with *L. javanica* (10 g/L) and the control group had the lowest live weights. In the present study, birds supplemented with *C. annuum* had a significantly ($p<0.05$) higher dressed weight and cold carcass weight followed by those on *A. digitata and L. javanica* and the control group. Birds supplemented with *C. annuum* had a higher dressing out percentage than the control. The birds on *C. annuum* had a non-significant ($P>0.05$) dressing out percentage with those on *A. digitata* and *L. Javanica* and did not significantly differ ($p>0.05$) from the control. Birds supplemented with *A. Digitata* and *C. Annum* and the control group had significantly ($p<0.05$) lower carcass yield percentages than those on *L. javanica*.

Carcass wholesale cuts and parts yield

As shown in Table 3, phytogenic supplements significantly ($p<0.05$) affected carcass wholesale cut weight and yield of heat-stressed broiler chickens. Broilers supplemented with *C. Annum* had higher ($p<0.05$) thigh and wing weights than the control and *L. javanica.* However, broilers supplemented with *A. digitata* did not differ significantly ($p>0.05$) from those supplemented with *C. annum* and control regarding thigh and wing weights. Significantly ($p<0.05$) lower breast weight was observed on broilers supplemented with *L. javanica* and the control compared to those on *C. annum.* Back weight was highest on broilers supplemented with *C. annum* followed by *A. digitata, L. javanica,* and the control group. The drumstick weight was higher on broiler chickens supplemented with C. *annum* than in the control group. However, broilers supplemented with *L. javanica* and *A. digitata* did not differ ($P>0.05$) from those supplemented with *C. Annum* for drumstick weights. Broilers on phytogenic supplementation had significantly ($p<0.05$) lower breast muscles, thigh, and drumstick yield percentages than the control.

Visceral organs

According to Table 4, phytogenic supplementations did not significantly ($p>0.05$) affect the weight of the liver, heart, gizzard, and spleen but affected significantly ($p<0.05$) abdominal fat weight. Broiler chickens in the control group, *L. javanica, and A. digitata* had higher ($p<0.05$) abdominal fat compared to those on *C. annum*

Discussion

Carcass traits and yield

In this study, broilers supplemented with *C. annuum* and *A. digitata* had the highest live weight. These results indicate a potentially positive impact of *C. annuum* and *A. digitata* on growth rates under heat-stress conditions. The bioactive compounds such as vitamin C, selenium, carotenoids, and capsaicinoids found in *C. annuum* and *A. digitata* could have mitigated the negative effects of stress by promoting antioxidant activity, reducing inflammation, and enhancing immune function. The current results agree with [16] and [17], who reported improved live weight in broiler chickens supplemented with *C. annuum* and *piper nigrum*. In another study,[18] in Nigeria supplemented broiler chicken diets with *A. digitata* leaf meal using five levels (i.e., 0.00%, 0.025%, 0.05%, 0.075%, and

0.10%) and concluded that *A. digitata* leaf meal could help to ameliorate heat stress. The improved dressed weight and cold carcass weight on broiler chickens supplemented with *C. annuum* implies that supplementing *C. annuum* and *A. digitata* improved ($p<0.05$) the edible parts, which could be due to the antioxidant and ascorbic acid that reduce the effect of heat stress and improve nutrient absorption. The current results agree with [17] and [19], who reported a significant increase in broiler carcass weight supplemented with *C. annuum* and *A. digitata*. Supplementation with *C. annuum* improved the absolute carcass weight and the efficiency of converting live weight to dressed weight, as indicated by the highest dressing out percentage. Carcass yield in poultry is a reliable indicator of the quality of the diet. In this study, *A. digitata* and *C. Annuum* seemed to contain quality nutrients like the control diets. This is shown by the improved carcass yield of broilers when supplemented with *A. digitata* and *C. annuum* via drinking water. Lower carcass yield in broilers supplemented with *L. javanica* indicates that *L. javanica* did not compromise carcass yield. The findings of this study are consistent with the results of [13] and [4], who reported reduced carcass weight in broilers fed the diet supplemented with *L. javanica*. This could be due to high fibre contents in *L. javanica* that hinder digestion and nutrient assimilation dynamics leading to low carcass yield. It can be deduced from the study results that incorporating *A. digitata* and *C. annuum* into heat-stressed broiler chicken diets may enhance the dressed weight and carcass yield.

The present study recorded higher thigh and wing weights in groups supplemented with the *A. digitata* and *C. Annuum* than those reported in the previous studies. The authors [13 and 20] supplemented broiler chickens with *L. javanica*, and *A. digitata* and found that drumstick and thigh had lower weights of 97 and 110 g, respectively at 6 weeks of age. Similarly, [21] reported drumstick and thigh weights of 100.6 ± 11.1 g and 112.7 ± 15.5 g respectively in broiler chickens supplemented with *A. digitata* fruit meal during the same period. Furthermore, [5] supplemented Koekoek chickens with *L. javanica* and obtained an average breast weight of 147.23 ± 1.69 g, a value lower than the one reported in the present study (Table 3). The differences in weight may be due to how the phytogenic supplements were delivered to birds. In the current study, phytogenic supplements were delivered via drinking water and feed in other studies. The breast muscle is the most economically valuable in modern broiler production [22]. Higher breast, thigh, and drumstick yield percentages of broiler chickens supplemented with phytogenics plants in the present study indicate that phytogenic supplements support breast muscle development when delivered via water. This could be attributable to the bioactive compounds such as quercetin, which are responsible for fat reduction, muscle growth and anti-oxidation [23]. This finding agrees with [4], [24] and [25], who reported efficient use of the phytogenic supplementation in poultry production, which in turn yielded greater carcass weight and quality. In this study, broiler chickens supplemented with *C. annuum* had the highest thigh weight (129.67±3.00), breast weight (16878.33±1.33), back weight (164.67±1.83), wing weight (95.00±1.70), and drumstick weight (117.33±2.75), followed by *A. digitata*, control, and *L. javanica*. In other related studies by [26] and [27], it was reported that the weight of wholesale/carcass cuts of broiler chickens was significantly better when a diet supplemented with *C. annuum* at 0.5 g/100 g of feed was used compared to a control diet.

The comparable liver, heart, gizzard, and spleen weights in this study imply that the phytogenic supplements did not affect the internal organs of broiler chickens. This was unexpected, as fibre and phytochemicals in phytogenic plants are associated with significant changes in the structure and morphology of the gut as an adaptive mechanism to accommodate the fibre and phytochemicals [28]. This clearly shows that these phytogenic plants had anti-nutritional contents below the threshold of broiler chickens. The current results agree with [29] who found a non-significant effect of dietary inclusion of red chilli pepper (*C. annuum*) on the weight of internal organs of broiler chickens. Similarly, [30] found a non-significant effect of red and black pepper powder on the weight of carcasses and organs of broiler chickens. Broilers supplemented with *C. annuum* had lower abdominal fat weight suggesting that C. *annuum* had reduced the activity of 6-phosphogluconate dehydrogenase, and fatty acid synthase enzymes which are linked to hepatic lipogenesis[31], which is a good property as far as consumers are concerned. Also, *C. annum* contains capsaicinoids (capsaicin, nonivamide, piperine, homodihydrocapsaicin, dihydrocapsaicin, nordihydrocapsaicin, and homocapsaicin) which are known to increase metabolic rate, enhance fat oxidation, and reduce adipogenesis, leading to decreased fat deposition in the abdominal region. A similar pattern has been reported by [17] and [32] in broiler chickens.

Conclusion

Supplementation with *C. annum* and *A. Digitata* affected the carcass characteristics of heat-stressed broiler chickens. *C. annuum* displayed greater effectiveness than other phytogenic supplements on carcass traits and yield. The study revealed further that phytogenic supplements rich in vitamin C and antioxidants improved the carcass weight and yield of heat-stressed broiler chickens, thus alleviating the consequences of heat stress. It is recommended that further studies be conducted to explore the diverse impacts of adding *C. annuum* to poultry diets,

especially focusing on its potential for immuno-modulation and anti-inflammatory properties.

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Declaration of Conflict of Interest

The authors declared no conflict of interest.

TABLE 1. Nutrition composition of Irvine's broiler diets from day 0 to slaughter age

Composition (g/kg)	Starter feed	Grower feed	Finisher feed
Protein	200	180	160
Total Lysine	12	10	9
Moisture	120	120	120
Fat	10	10	10
Fibre	50	60	70
Calcium	8 -12	7 -12	6 - 12
Phosphate	6	5.5	5

Source: agrifeed.co.bw

TABLE 2. Means and standard errors of the phytogenic supplements effect on carcass dressed weight and yield of heat-stressed broiler chickens at 6 weeks

Parameter	Treatment			
	Control	*L. javanica*	*A. digitata*	*C. annuum*
Live weight (g)	2105.67±30.57 ^{b}	2035.67±30.57 ^{b}	2219.33±30.57 ^{a}	2291.00±30.57 ^{a}
Dressed weight (g)	1823.67±33.37 ^{c}	1818.33±33.37 ^{c}	1979.00±33.37 ^{b}	2113.33±33.37 ^{a}
Cold carcass weight (g)	1478.33±39.95 ^{c}	1387.67±39.95 ^{c}	1621.33±39.95 ^{b}	1801.67±39.95 ^{a}
Dressing out %	86.57±1.08 ^{b}	89.30±1.08 ^{ab}	89.57±1.08 ^{ab}	92.30±1.08 ^{a}
Carcass yield %	70.03±1.71 ^{a}	63.17±1.71 ^{b}	73.03±1.71 ^{a}	74.33±1.71 ^{a}

$^{a, b, c, d}$ Means with different superscripts in the same row are significantly different)

TABLE 3. Means and standard errors of the phytogenic supplements effect on wholesale cuts weight and yield of heat-stressed broiler chickens at 6 weeks of age

Parameter	Treatment				SL
	Control	*L. javanica*	*A. digitata*	*C. annuum*	
Thigh weight (g)	115.00±3.00 ^{b}	112.00±3.00 ^{b}	120.00±3.00 $^{a b}$	129.67±3.00 ^{a}	*
Breast weight (g)	160.33±1.33 ^{c}	156.33±1.33 ^{c}	168.33±1.33 ^{b}	178.33±1.33 ^{a}	*
Back weight (g)	144.67±1.83 ^{c}	119.67±1.83 ^{d}	158.00±1.83 ^{b}	164.67±1.83 ^{a}	*
Wing weight (g)	87.50±1.70 ^{b}	86.00±1.70 ^{b}	89.67±1.70 $^{a b}$	95.00±1.70 ^{a}	*
Drumstick weight (g)	104.00±2.75 ^{b}	109.33±2.75 $^{a b}$	113.33±2.75 $^{a b}$	117.33±2.75 ^{a}	*
Breast muscle yield (%)	10.85±0.40 ^{a}	12.15±0.40 ^{b}	13.00±0.40 ^{b}	12.93±0.40 ^{b}	*
Thigh yield (%)	7.58.89±0.36 ^{a}	8.94±0.36 ^{b}	9.25±0.36 ^{b}	9.52±0.36 ^{b}	*
Drumstick yield (%)	7.04±0.37 ^{a}	8.49±0.37 ^{b}	8.53±0.37 ^{b}	8.60±0.37 ^{b}	*

$^{a, b, c, d}$ Means with different superscripts in the same row are significantly different); SL: Significance level Significant* (P<0.05, Non-significant (NS-P>0.05)

TABLE 4. Means and standard errors of phytogenic supplements effect on internal organs of heat-stressed broiler chickens at 6 weeks

Parameter	Treatment				SL
	Control	*L. javanica*	*A. digitata*	*C. annuum*	
Liver weight (g)	39.00±3.04 [a]	40.67±3.04 [a]	45.67±3.04 [a]	46.67±3.04 [a]	NS
Heart weight (g)	9.70±0.45 [a]	9.73±0.45 [a]	10.33±0.45 [a]	10.27±0.45 [a]	NS
Gizzard weight (g)	34.00±2.04 [a]	37.67±2.04 [a]	33.67±2.04 [a]	32.67±2.04 [a]	NS
Abdominal fat (g)	23.33±2.38[a]	18.33±2.38 [a]	20.00±2.38 [a]	9.33±2.38 [b]	*
Spleen (g)	2.67±0.25 [a]	3.40±0.25 [a]	2.67±0.25 [a]	2.67±0.25 [a]	NS

[a, b, c, d] Means with different superscripts in the same row are significantly different); SL: Significance level Significant* (P<0.05), Non-significant (NS-P>0.05)

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