

Effect of Hops (*Humulus lupulus*)  
Supplementation on Growth Performance  
of Broiler Chickens

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## Abstract

The hop plant contains flavonoids, bitter acids and essential oils that confer antibacterial properties. An experiment was conducted to evaluate the possibility of supplementing broiler chicken diets with hop pellets. Accordingly, growth performance response of broiler chickens given hops-supplemented diets was evaluated in a 49-day floor-pen trial. Day-old (320) male broiler chicks were commercially obtained and randomly assigned to 4 treatments. Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level. On d 21, 42, and 49, body weight, body weight gain, and Feed Conversion Ratio (FCR) were evaluated. Transient benefits of hops supplementation in form of higher feed intake and body weight gain ( $P < 0.05$ ) compared to other treatments were observed but were not sustained. The FCR of birds in the hops-supplemented treatments (HL and HH) were similar ( $P > 0.05$ ) to those of birds in the BMD antibiotic-supplemented treatment (MX) throughout the study. It was concluded that supplementation of hops pellets into broiler diets at 1% or 2% level of the diet had no detrimental effect on broiler growth performance. Therefore, future studies should be conducted to evaluate the efficacy of dietary hops in mitigating the colonization of poultry intestine by economically important zoonotic and/or disease pathogens.

## Introduction

The movement towards prohibiting the use of antibiotics in animal feed has become stronger in recent years due to the emergence of antibiotic resistant bacterial strains. Resistant strains of zoonotic pathogens such as *Salmonella spp.*, *Campylobacter spp.*, *Escherichia coli*, and *Clostridium perfringens* have been isolated from the intestines of commercial broiler chickens [1-4]. Ongoing efforts to replace antibiotics with alternative biogenics such as direct-fed microbials, yeast-based products, organic acids, essential oils, antimicrobial peptides, acidifiers, and plant extracts in poultry diets have met limited success because, none of these alternatives is able to solely replace antibiotics [5-7]. This warrants continuing research efforts to identify novel effective alternatives, and also perhaps formulate superior combination(s) of these products.

Hops (*Humulus lupulus L.*) are a plant that contains various compounds that have been determined as beneficial for therapeutic use in human medicine. In particular, it contains various flavonoids, bitter acids (comprising of humulones ( $\alpha$ -acids), lupulones ( $\beta$ -acids), isohumulones (iso- $\alpha$ -acids)), and essential oils that are responsible for its antibacterial, antioxidant, and digestion accelerating properties [8]. In addition, the hop plant is recognized as generally safe for use in brewing and in other human foods. It has been reported that hop extracts containing  $\beta$ -acids and xanthohumol inhibited the growth of Gram-positive bacteria in vitro with minimum inhibitory values of 6.3 and 12.5 ppm, respectively [9]. Information is scanty regarding the possibility of using hops (and products) as alternatives to antibiotics in live poultry. Siragusa et al., [10] reported that untreated chickens challenged with *C. perfringens* had higher ( $P < 0.05$ ) *C. perfringens* counts in the jejunum and ceca ( $\log_{10}$  6.20 cfu/g), compared to their counterparts treated with administration of 62.5, 125, or 250 ppm lupulone extract in tap water ( $\log_{10}$  2.00 cfu/g). Similarly, Tillman et al., [11] observed that administration of lupulone at 125 mg L<sup>-1</sup> significantly decreased the *C. perfringens* subgroup 16S rRNA gene Cluster I (which contains several pathogenic species) in the midgut and cecum of broiler chickens challenged with *C. perfringens*.

There has been no attempt to include hops (or its products) in the diet of poultry. Dietary inclusion of hops in broiler diets may allow greater realization of its potential antibacterial, antioxidant, and digestion accelerating properties. To promote the inclusion of hops in poultry diets, it will be necessary to first determine the optimum level of inclusion with respect to feed intake, palatability, and growth performance. The objective of this study was to evaluate the growth performance response of broiler chickens given hops-supplemented diets. Growth performance indices such as body weight, body weight gain, feed intake, and feed conversion ratio were evaluated on days 21, 42, and 49 of experiment.

## Materials and Methods

All the procedures used in this study were approved by the Auburn University Institutional Animal Care and Use Committee.

### Experimental animals and treatments

Day-old male broiler chicks (320; Cobb x Cobb) were obtained from a commercial hatchery and utilized in a 49-day floor-pen trial that simulated industry settings. Chicks were weighed, wing-banded, and randomly assigned to four dietary treatments. Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

**Table 1:** Composition of experimental starter diets (% “as is”).

| Ingredient                                 | CX diet <sup>1</sup> | MX Diet <sup>1</sup> | HL Diet <sup>1</sup> | HH Diet <sup>1</sup> |
|--|----------------------|----------------------|----------------------|----------------------|
| Corn                                       | 55.04                | 55.04                | 54.04                | 53.04                |
| Soybean meal                               | 36.75                | 36.75                | 36.75                | 36.75                |
| Poultry oil                                | 3.7                  | 3.7                  | 3.7                  | 3.7                  |
| DL-Methionine                              | 0.19                 | 0.19                 | 0.19                 | 0.19                 |
| Limestone                                  | 1.68                 | 1.68                 | 1.68                 | 1.68                 |
| Dicalcium Phosphate                        | 1.74                 | 1.74                 | 1.74                 | 1.74                 |
| Vitamin Premix <sup>2</sup>                | 0.25                 | 0.25                 | 0.25                 | 0.25                 |
| Mineral Premix <sup>3</sup>                | 0.25                 | 0.25                 | 0.25                 | 0.25                 |
| Salt                                       | 0.4                  | 0.4                  | 0.4                  | 0.4                  |
| Bacitracin (Antibiotic, g/kg)              | ----                 | 0.055                | ----                 | ----                 |
| Hops Pellet (%)                            | ----                 | ----                 | 1                    | 2                    |
| Analyzed nutrient composition <sup>4</sup> |                      |                      |                      |                      |
| Metabolizable energy (Kcal/kg)             | 3256                 | 3144                 | 3106                 | 3115                 |
| Crude protein, %                           | 22.7                 | 22.81                | 22.41                | 22.01                |
| Crude fat, %                               | 6.29                 | 5.73                 | 5.78                 | 5.61                 |
| Crude fiber, %                             | 2.2                  | 2.6                  | 3                    | 3.3                  |
| Calculated nutrient composition            |                      |                      |                      |                      |
| Total Sulfur Amino Acids, %                | 0.89                 | 0.89                 | 0.89                 | 0.89                 |
| Lysine, %                                  | 1.24                 | 1.24                 | 1.24                 | 1.24                 |
| Calcium, %                                 | 1.11                 | 1.11                 | 1.11                 | 1.11                 |
| Available phosphorus, %                    | 0.46                 | 0.46                 | 0.46                 | 0.46                 |

<sup>1</sup>Diets used in this study included i) the Control (CX) diet comprising of corn-Soybean Meal (SBM) basal without Bacitracin Methylene Disalicylate (BMD) or hops pellet added, ii) the medicated diet (MX) comprising of corn-SBM basal into which BMD was added at 0.055g/kg, iii) the low hops (HL) diet comprising of corn-SBM basal into which hops pellet was added at 1.0% level, and iv) the high hops (HH) diet comprising of corn-SBM basal into which hops pellet was added at 2.0% level.

<sup>2</sup>Vitamin Premix, supplied per kilogram of diet: vitamin A (retinyl acetate), 7356 IU; vitamin D<sub>3</sub> (cholecalciferol), 2,205 ICU; vitamin E, (8 IU); vitamin B<sub>12</sub> (cyanocobalamin), 0.2 mg; riboflavin, 5.5 mg; niacin, 36 mg; D-pantothenic acid, 13 mg; choline, 501 mg; vitamin K (menadione sodium bisulfate), 2 mg; folic acid, 0.5 mg; vitamin B<sub>6</sub> (pyridoxine), 2.2; vitamin B<sub>1</sub> (thiamin), 1.0 mg; D-biotin, 0.5 mg; and ethoxyquin, 0.13 mg.

<sup>3</sup>Mineral Premix, supplied per kilogram of diet: manganese, 65 mg; zinc, 55 mg; iron, 55 mg; copper, 6 mg; iodine, 1 mg; and selenium, 0.3 mg.

<sup>4</sup>Diets were analyzed by Eurofins Scientific Inc., Nutrition Analysis Center, 2200 Rittenhouse St., Suite 150, Des Moines, IA 50321.

was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

The Cascade hops pellets used in this study were obtained from S.S. Steiner, Inc. (New York, NY) and were certified to contain 4.5 to 7% alpha-acid (humulones) and 4.5 to 7% beta-acid (lupulone). The hops pellets were crumbled prior to being included into HL and HH diets. Experimental diets were formulated to meet the recommendations of the National Research Council [12], and their nutrient compositions are presented in Tables 1, 2, and 3. Starter diets were fed to chicks from day-old to 3 weeks as a crumble after steam-

**Table 2:** Composition of experimental grower diets (% “as is”).

| Ingredient                      | CX diet <sup>1</sup> | MX Diet <sup>1</sup> | HL Diet <sup>1</sup> | HH Die <sup>1</sup> |
|---------------------------------|----------------------|----------------------|----------------------|---------------------|
| Corn                            | 65.36                | 65.36                | 64.36                | 63.36               |
| Soybean meal                    | 29.48                | 29.48                | 29.48                | 29.48               |
| Poultry oil                     | 1.54                 | 1.54                 | 1.54                 | 1.54                |
| DL-Methionine                   | 0.65                 | 0.65                 | 0.65                 | 0.65                |
| Limestone                       | 1.43                 | 1.43                 | 1.43                 | 1.43                |
| Dicalcium Phosphate             | 1.32                 | 1.32                 | 1.32                 | 1.32                |
| Vitamin Premix <sup>2</sup>     | 0.25                 | 0.25                 | 0.25                 | 0.25                |
| Mineral Premix <sup>3</sup>     | 0.25                 | 0.25                 | 0.25                 | 0.25                |
| Salt                            | 0.3                  | 0.3                  | 0.3                  | 0.3                 |
| Bacitracin (Antibiotic, g/kg)   | ----                 | 0.055                | ----                 | ----                |
| Hops Pellet (%)                 | ----                 | ----                 | 1                    | 2                   |
| Calculated nutrient composition |                      |                      |                      |                     |
| Metabolizable energy (Kcal/kg)  | 3058                 | 3058                 | 3024                 | 2990                |
| Crude protein, %                | 20.12                | 20.12                | 20.05                | 20                  |
| Crude fat, %                    | 4.33                 | 4.33                 | 4.29                 | 4.26                |
| Crude fiber, %                  | 2.76                 | 2.76                 | 2.73                 | 2.71                |
| Total Sulfur Amino Acids, %     | 0.72                 | 0.72                 |                      |                     |
|                                 |                      |                      | 0.72                 | 0.72                |
| Lysine, %                       | 1.03                 | 1.03                 | 1.03                 | 1.03                |
| Calcium, %                      | 0.89                 | 0.89                 | 0.89                 | 0.89                |
| Available phosphorus, %         | 0.36                 | 0.36                 | 0.36                 | 0.36                |

<sup>1</sup>Diets used in this study included i) the Control (CX) diet comprising of corn-soybean meal (SBM) basal without Bacitracin Methylene Disalicylate (BMD) or hops pellet added, ii) the medicated diet (MX) comprising of corn-SBM basal into which BMD was added at 0.055g/kg, iii) the low hops (HL) diet comprising of corn-SBM basal into which hops pellet was added at 1.0% level, and iv) the high hops (HH) diet comprising of corn-SBM basal into which hops pellet was added at 2.0% level.

<sup>2</sup>Vitamin Premix, supplied per kilogram of diet: vitamin A (retinyl acetate), 7356 IU; vitamin D<sub>3</sub> (cholecalciferol), 2,205 ICU; vitamin E, (8 IU); vitamin B<sub>12</sub> (cyanocobalamin), 0.2 mg; riboflavin, 5.5 mg; niacin, 36 mg; D-pantothenic acid, 13 mg; choline, 501 mg; vitamin K (menadione sodium bisulfate), 2 mg; folic acid, 0.5 mg; vitamin B<sub>6</sub> (pyridoxine), 2.2; vitamin B<sub>1</sub> (thiamin), 1.0 mg; D-biotin, 0.5 mg; and ethoxyquin, 0.13 mg.

<sup>3</sup>Mineral Premix, supplied per kilogram of diet: manganese, 65 mg; zinc, 55 mg; iron, 55 mg; copper, 6 mg; iodine, 1 mg; and selenium, 0.3 mg.

pelleting. Grower diets were fed as whole pellets from 3 to 6 weeks of age, and finisher diets were fed as whole pellets during week 7.

Experimental chicks were kept in pens inside a house with cross ventilation and temperature control. Each treatment had 4 replicate pens, with each pen containing 20 chicks placed on fresh pine shaving litter. Chicks were provided with continuous lighting commensurate with day (1,400 to 2,800 lx) and night (4 to 17 lx) intensities. Chicks were allowed ad-libitum access to feed and water throughout the experiment. Duration of experiment was 49 days (i.e. 7 weeks).

### Assessment of growth performance and statistical analysis

On days 21, 42, and 49 of experiment, body weight, Body Weight Gain (BWG), feed intake, and Feed Conversion Ratio (FCR) were calculated for the evaluation of broiler growth performance. Mortality

**Table 3:** Composition of experimental finisher diets (% “as is”).

| Ingredient                      | CX diet <sup>1</sup> | MX Diet <sup>1</sup> | HL Diet <sup>1</sup> | HH Diet <sup>1</sup> |
|---------------------------------|----------------------|----------------------|----------------------|----------------------|
| Corn                            | 66.45                | 66.45                | 65.45                | 64.45                |
| Soybean meal                    | 26.8                 | 26.8                 | 26.8                 | 26.8                 |
| Poultry oil                     | 3.49                 | 3.49                 | 3.49                 | 3.49                 |
| DL-Methionine                   | 0.19                 | 0.19                 | 0.19                 | 0.19                 |
| Limestone                       | 1.02                 | 1.02                 | 1.02                 | 1.02                 |
| Dicalcium Phosphate             | 1.1                  | 1.1                  | 1.1                  | 1.1                  |
| Vitamin Premix <sup>2</sup>     | 0.25                 | 0.25                 | 0.25                 | 0.25                 |
| Mineral Premix <sup>3</sup>     | 0.25                 | 0.25                 | 0.25                 | 0.25                 |
| Salt                            | 0.47                 | 0.47                 | 0.47                 | 0.47                 |
| Bacitracin (Antibiotic, g/kg)   | ----                 | 0.055                | ----                 | ----                 |
| Hops Pellet (%)                 | ----                 | ----                 | 1                    | 2                    |
| Calculated nutrient composition |                      |                      |                      |                      |
| Metabolizable energy (Kcal/kg)  | 3203                 | 3203                 | 3169                 | 3135                 |
| Crude protein, %                | 17.97                | 17.97                | 17.89                | 17.82                |
| Crude fat, %                    | 6.31                 | 6.31                 | 6.27                 | 6.23                 |
| Crude fiber, %                  | 2.68                 | 2.68                 | 2.66                 | 2.63                 |
| Total Sulfur Amino Acids, %     | 0.8                  | 0.8                  | 0.8                  | 0.8                  |
| Lysine, %                       | 0.96                 | 0.96                 | 0.96                 | 0.96                 |
| Calcium, %                      | 0.69                 | 0.69                 | 0.69                 | 0.69                 |
| Available phosphorus, %         | 0.32                 | 0.32                 | 0.32                 | 0.32                 |

<sup>1</sup>Diets used in this study included i) the Control (CX) diet comprising of corn-Soybean Meal (SBM) basal without Bacitracin Methylene Disalicylate (BMD) or hops pellet added, ii) the medicated diet (MX) comprising of corn-SBM basal into which BMD was added at 0.055g/kg, iii) the low hops (HL) diet comprising of corn-SBM basal into which hops pellet was added at 1.0% level, and iv) the high hops (HH) diet comprising of corn-SBM basal into which hops pellet was added at 2.0% level.

<sup>2</sup>Vitamin Premix, supplied per kilogram of diet: vitamin A (retinyl acetate), 7356 IU; vitamin D<sub>3</sub> (cholecalciferol), 2,205 ICU; vitamin E, (8 IU); vitamin B<sub>12</sub> (cyanocobalamin), 0.2 mg; riboflavin, 5.5 mg; niacin, 36 mg; D-pantothenic acid, 13 mg; choline, 501 mg; vitamin K (menadione sodium bisulfate), 2 mg; folic acid, 0.5 mg; vitamin B6 (pyridoxine), 2.2; vitamin B<sub>1</sub> (thiamin), 1.0 mg; D-biotin, 0.5 mg; and ethoxyquin, 0.13 mg.

<sup>3</sup>Mineral Premix, supplied per kilogram of diet: manganese, 65 mg; zinc, 55 mg; iron, 55 mg; copper, 6 mg; iodine, 1 mg; and selenium, 0.3 mg.

was also recorded on daily basis. Data collected were subjected to one-way ANOVA using the General Linear Models (GLM) procedure of SAS [13]. Significant differences among means were determined using the Duncan option of the GLM procedure as a post hoc test, and statements of statistical significance were based upon  $P < 0.05$ . Data are presented as means  $\pm$  SEM.

### Results and Discussion

An experiment was conducted to determine if dietary supplementation of hops at 1 or 2% level of the diet will adversely affect body weight, body weight gain, and FCR of broiler chickens. Results obtained from this study are presented in Tables 4 to 7. On day 21, there were no differences ( $P > 0.05$ ) in body weight, body weight gain, and Feed Conversion Efficiency (FCR) of chicks in all

**Table 4:** Effect of Hops supplementation on growth performance during starter phase (Day 1 to 21).

| Treatments <sup>1</sup> | Body weight (kg/bird) <sup>2</sup> | Body weight gain (kg/bird) <sup>2</sup> | Feed intake (kg/bird) | Feed conversion ratio (kg:kg) <sup>3</sup> |
|-------------------------|------------------------------------|---|-----------------------|--|
| CX                      | 0.837                              | 0.792                                   | 1.29b                 | 1.41                                       |
| MX                      | 0.82                               | 0.777                                   | 1.29b                 | 1.41                                       |
| HL                      | 0.82                               | 0.775                                   | 1.23b                 | 1.43                                       |
| HH                      | 0.852                              | 0.81                                    | 2.03a                 | 1.38                                       |
| SEM                     | 0.025                              | 0.024                                   | 0.101                 | 0.043                                      |
| P-value                 | 0.7649                             | 0.7162                                  | 0.0003                | 0.8408                                     |

<sup>a,b</sup>Mean values bearing different superscript letters within a column are significantly different ( $P < 0.05$ ).

<sup>1</sup>Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

<sup>2</sup>Values are based only on weight of live birds.

<sup>3</sup>Feed conversion ratio calculated as feed-to-gain ratio and adjusted for mortality by including the gains of dead birds in the calculations.

**Table 5:** Effect of Hops supplementation on growth performance during grower phase (Day 22 to 42).

| Treatments <sup>1</sup> | Body weight (kg/bird) <sup>2</sup> | Body weight gain (kg/bird) <sup>2</sup> | Feed intake (kg/bird) | Feed conversion ratio (kg:kg) <sup>3</sup> |
|-------------------------|------------------------------------|---|-----------------------|--|
| CX                      | 2.69                               | 1.85                                    | 3.73                  | 1.78                                       |
| MX                      | 2.72                               | 1.9                                     | 3.71                  | 1.72                                       |
| HL                      | 2.69                               | 1.87                                    | 3.49                  | 1.67                                       |
| HH                      | 2.73                               | 1.87                                    | 3.63                  | 1.74                                       |
| SEM                     | 0.082                              | 0.07                                    | 0.097                 | 0.06                                       |
| P-value                 | 0.9795                             | 0.9613                                  | 0.3394                | 0.641                                      |

<sup>1</sup>Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

<sup>2</sup>Values are based only on weight of live birds.

<sup>3</sup>Feed conversion ratio calculated as feed-to-gain ratio and adjusted for mortality by including the gains of dead birds in the calculations.

**Table 6:** Effect of Hops supplementation on growth performance during finisher phase (Day 42 to 49).

| Treatments <sup>1</sup> | Body weight (kg/bird) <sup>2</sup> | Body weight gain (kg/bird) <sup>2</sup> | Feed intake (kg/bird) | Feed conversion ratio (kg:kg) <sup>3</sup> |
|-------------------------|------------------------------------|---|-----------------------|--|
| CX                      | 3.32                               | 0.62 <sup>ab</sup>                      | 1.46                  | 2.14                                       |
| MX                      | 3.25                               | 0.53 <sup>b</sup>                       | 1.32                  | 2.33                                       |
| HL                      | 3.29                               | 0.60 <sup>ab</sup>                      | 1.39                  | 2.09                                       |
| HH                      | 3.44                               | 0.72 <sup>a</sup>                       | 1.52                  | 2.07                                       |
| SEM                     | 0.099                              | 0.046                                   | 0.091                 | 0.131                                      |
| P-value                 | 0.554                              | 0.059                                   | 0.4353                | 0.5043                                     |

<sup>a,b</sup>Mean values bearing different superscript letters within a column are significantly different ( $P < 0.05$ ).

<sup>1</sup>Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

<sup>2</sup>Values are based only on weight of live birds.

<sup>3</sup>Feed conversion ratio calculated as feed-to-gain ratio and adjusted for mortality by including the gains of dead birds in the calculations.

treatments (Table 4). On the other hand, there were differences in feed intake. Specifically, chicks in the HH treatment consumed a significantly higher ( $P < 0.05$ ) quantity of feed (2.03 kg / chick) compared to chicks in CX (1.23 kg / chick), MX (1.29 kg / chick), and HL (1.29 kg / chick). The higher feed intake in HH translated to numerically higher body weight and body weight gain in the chicks, but these did not culminate in a significantly superior FCR compared to other treatments. It was also important to include the BMD antibiotic-supplemented MX treatment in this study for comparison with hops as its candidate replacement. Chicks given the hops-supplemented diets (HL and HH) had comparable ( $P > 0.05$ ) body weight, Body weight gain, and FCR to chicks in the MX treatment.

**Table 7:** Effect of Hops supplementation on cumulative growth performance (Day 1 to 49).

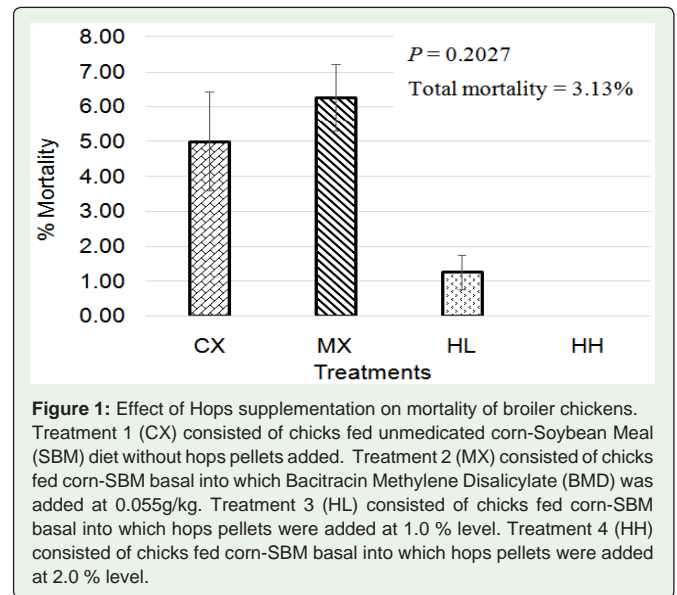
| Treatments <sup>1</sup> | Body weight (kg/bird) <sup>2</sup> | Feed intake (kg/bird) | Feed conversion ratio (kg:kg) <sup>3</sup> |
|-------------------------|------------------------------------|-----------------------|--|
| CX                      | 3.32                               | 6.48 <sup>b</sup>     | 3.32                                       |
| MX                      | 3.25                               | 6.32 <sup>b</sup>     | 3.25                                       |
| HL                      | 3.29                               | 6.12 <sup>b</sup>     | 3.29                                       |
| HH                      | 3.44                               | 7.19 <sup>a</sup>     | 3.44                                       |
| SEM                     | 0.099                              | 0.187                 | 0.038                                      |
| P-value                 | 0.554                              | 0.0085                | 0.4187                                     |

<sup>a,b</sup>Mean values bearing different superscript letters within a column are significantly different ( $P < 0.05$ ).

<sup>1</sup>Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

<sup>2</sup>Values are based only on weight of live birds.

<sup>3</sup>Feed conversion ratio calculated as feed-to-gain ratio and adjusted for mortality by including the gains of dead birds in the calculations.



**Figure 1:** Effect of Hops supplementation on mortality of broiler chickens. Treatment 1 (CX) consisted of chicks fed unmedicated corn-Soybean Meal (SBM) diet without hops pellets added. Treatment 2 (MX) consisted of chicks fed corn-SBM basal into which Bacitracin Methylene Disalicylate (BMD) was added at 0.055g/kg. Treatment 3 (HL) consisted of chicks fed corn-SBM basal into which hops pellets were added at 1.0 % level. Treatment 4 (HH) consisted of chicks fed corn-SBM basal into which hops pellets were added at 2.0 % level.

Between d 22 and 42, no differences were observed ( $P > 0.05$ ) among treatments for any of the parameters evaluated (Table 5). However, on d 49, there were differences among treatments ( $P < 0.05$ ) in weight gain from d 42 to 49 (Table 6). Birds in HH treatment had a significantly higher weight gain (0.72 kg / bird) compared to those in MX (0.53 kg / bird). Weight gain values were similar for CX, MX, and HL. Looking at the overall bird performance from d 1 to 49, there were no differences in body weight and FCR among treatments ( $P > 0.05$ ). However, feed intake was higher for HH treatment ( $P < 0.05$ ) compared to other treatments. Total mortality in this study was 3.13%, and this is below 4.4% reported by National Chicken Council in 2017 as typical for U.S. broiler flocks [14]. In addition, mortality levels were similar ( $P > 0.05$ ) among treatments (Figure 1).

Although hops are known to contain bitter acids, this did not seem to affect palatability of the diets in this study because, birds in HL and HH treatments had similar FCR ( $P > 0.05$ ) to hop-free treatments (CX and MX). In conclusion, supplementation of hops pellets into broiler diets at 1% or 2% level of the diet had no detrimental effect on broiler growth performance under the conditions of this experiment. Therefore, future studies should be conducted to evaluate the efficacy of dietary hops in mitigating the colonization of poultry intestine by economically important zoonotic and/or disease pathogens such as *Salmonella* spp., *Campylobacter* spp., *Escherichia coli*, and *Clostridium perfringens*.

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