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# Effects of bee pollen inclusion on performance and carcass characteristics of broiler chickens

Munyadziwa Felicia Dorcus Nemauluma, Tlou Grace Manyelo,[1] Jones Wilfred Ng'ambi, Sekobane Daniel Kolobe, and Emmanuel Malematja

*Department of Agricultural Economics and Animal Production, University of Limpopo, Sovenga 0727, South Africa*

**ABSTRACT** This study was conducted to determine the effect of bee pollen (**BP**) inclusion on performance and carcass characteristics in broiler chickens. A total of 240 Ross 308 broiler chicks were allocated to 4 treatments (BP inclusion levels of 0, 4, 8, or 12 g/kg DM feed) in a randomized complete block design with sex as a block having 3 replicates with 10 chickens per replicate. After 21 d, the chickens remained in their treatment groups and fed standard grower diet. The results of the current study revealed that BP inclusion had positively improved ($P < 0.05$) average weekly feed intake (**FI**), body weight (**BW**), body weight gain (**BWG**), and feed conversion ratio (**FCR**) in both sexes. However, the apparent nutrient digestibility, metabolizable energy (**ME**), and nutrient digestibility were not affected by the dietary BP. Furthermore, carcass yield in both sexes was improved ($P < 0.05$) by BP inclusion levels. In contrast, meat pH, shear force, and sensory evaluation in both sexes were not affected ($P > 0.05$). The results suggest that the broiler chicks can utilize bioactive compounds in BP when supplemented in the starter diets and subsequently improve their growth parameters throughout the growing period as well as carcass yield at slaughter age. These positive improvements could be due to high quality amino acids, essential oils, vitamins, and minerals of BP. Therefore, it is concluded that BP inclusion level of 12 g/kg or more in the starter diets could have positive effects on growth performance and carcass yield at slaughter age without causing adverse effects on meat physico-chemical properties and sensory evaluation in both male and female broiler chickens.

**Key words:** antibiotic, bee pollen, broiler, carcass characteristic, live weight

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## INTRODUCTION

Chicken production has a major impact on employment and source of income and it takes part in food security within the people of Africa (Ngongolo et al., 2021). As the human population continues to increase worldwide, there is a need for farmers to produce enough protein from poultry (Huis, 2013). The use of antibiotics against enteric microorganisms has been done for decades to improve the health and growth of chickens (Babaei et al., 2016). The use of antibiotics in livestock diets have been reported to enhance the utilization of feed and growth performance (Nemauluma et al., 2022). However, the usage and mismanage of antibiotics has caused bacteria to become resistant and residues in livestock and human community as well, hence in many countries, it has been ruled out (O'Neill, 2016). As a consequence of the aforementioned concerns, there is need to search for alternative and safe growth enhancers for replacement of antibiotic growth promoters in poultry diets (Malematja et al., 2022). Recently, there are upsurge interests in the use of natural growth enhancers and among the possible alternatives are bee pollen, prebiotics, and other medical herbs (Attia et al., 2014; Nemauluma et al., 2022). Bee pollen possesses bioactive compounds mainly phenolics, antioxidants, therapeutic properties such as antimicrobial and immunomodulatory (Attia, 2022). It also rich in protein, essential amino acids, oils, vitamins, minerals, enzymes, and carbohydrates (Xu et al., 2009; Attia et al., 2019). Several studies have shown the possibility of using bee pollen in the chickens' diets as growth promoter (Attia et al., 2013, 2014; Zafarnejad et al., 2016). Wang et al. (2005) and Hosseini et al. (2016) revealed that bee pollen can be used as a growth promoter and stimulator of the immune system in broiler chickens. Amino acids, vitamins and trace elements of bee pollen stimulate early development, proliferation and differentiation of intestinal cells to modulate intestinal microbial ecosystem



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[1]Corresponding author: manyelo.t.g@gmail.com

(Dias et al., 2013). Hosseini et al. (2016) investigated the effects of bee pollen on growth performance of broiler chickens and observed increased feed intake and daily weight gain during the starter period. Similarly, Babaei et al. (2016) reported increased feed intake and weight gain in quails fed diets containing bee pollen. Attia et al. (2014) reported increased feed intake, body weight and body weight gain in Arbor Acres broiler chickens fed diets containing bee pollen. In addition, it was suggested that phenolic constituents and antioxidants are the active keys in bee pollen to enhance growth performance in chickens and rabbits (Saric et al., 2009). Furthermore, it was suggested that incorporating bee pollen into chicken diets could offer a strategy way of reducing heat stress in chickens (Hosseini et al., 2016). Lika et al. (2021) also indicated that this type of natural substance can promote gut health, digestibility, and decrease pathogens in poultry. Contrary to these findings, Farag and El-Rayes (2016) observed reduced feed intake in broiler chickens fed dietary bee pollen diets. Similarly, Demir and Kaya (2020) reported reduced feed intake and poor feed conversion ratio (**FCR**) in egg layer hens fed diets containing bee pollen meal. Although effects of bee pollen in poultry diets have been widely investigated, still there is a death information on the effect of bee pollen on the carcass characteristics of broiler chickens fed started diets containing bee pollen. Hence, this study is aimed to investigate the effects of bee pollen as an alternative natural growth promoter in chickens' diets. Therefore, it was hypothesized that incorporating bee pollen into broiler starter diet will improve growth performance and carcass characteristics in broiler chickens.

## MATERIALS AND METHODS

### Study Site

The study was conducted at the University of Limpopo Animal Unit, Limpopo Province, South Africa. The University of Limpopo lies at latitude 27.55°S and longitude 24.77°E. The study was conducted between March and April 2021 when the mean ambient temperature around the study area ranged 28 to 36°C (Shiringani, 2007). The experimental procedures were approved by the University of Limpopo (**UL**) Ethics Committee (AREC/06/2020:PG).

### Acquisition, Preparation of Bee Pollen, and Experimental Diet Formulation

Fresh bee pollen was purchased from Magoebaskloof Honey in Tzaneen, Limpopo Province, South Africa. Bee pollen was air-dried in a well-ventilated laboratory to obtain a constant weight, with no direct sun exposure. The bee pollen was then pulverized into powder using a hammer mill with a sieve size of 1 mm. The dried bee pollens were stored polythene bags prior to proximate analysis (Table 1) and diet formulation. Four isoenergetic and isonitrogenous starter diets were formulated in accordance with the nutrient requirements of broiler chickens as recommended by the National Research Council (NRC, 1994) as follows: 1) $BP_0$ = basal diet with no bee pollen; 2) $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; 3) $BP_8$ = basal diets in which 8 g/kg bee pollen was included; or 4) $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients. Similarly, 4 isoenergetic and isonitrogenous standard grower diets were formulated (Table 2).

**Table 1.** Nutrient contents of bee pollen.

| Component | Bee pollen |
|---|---|
| Dry matter (g/kg) | 88.5 |
| Ash (g/kg DM) | 2.9 |
| Crude protein (g/kg DM) | 21.8 |
| Crude fat (g/kg DM) | 5.2 |
| Gross energy (MJ/kg) | 404.3 kJ/100 g |
| Amino acid (mg/g DM) | |
| Methionine | 0.47 |
| Lysine | 7.64 |
| Threonine | 4.63 |
| Histidine | 4.60 |
| Leucine | 11.45 |
| Isoleucine | 6.04 |
| Valine | 9.11 |
| Phenylalanine | 2.55 |
| Tryptophan | 1.02 |
| Arginine | 3.60 |
| Minerals (%) | |
| K | 42.5 |
| Mg | 7.0 |
| N | 2.1 |
| Ca | 15.7 |
| P | 31.2 |

### Experimental Design and Animal Management

A total of 240 Ross 308 broiler chicks (120 males and 120 females) were used in this study. The design of the experiment was a 2 (sex) as a block in a randomized complete block design (**RCBD**). Thus, there were 8 treatments, 3 replicates per treatment, and 10 chickens per replicate with an average weight of 40 ± 42 g per bird. The birds were reared on floor pens (120 cm W × 100 cm L × 80 cm H) bedded with wood shavings in an environmentally controlled house for 42 d. The house temperature was kept at 32°C during the first few days and adjusted according to their ideal temperature as the chicks grow. After 21 d, chickens were introduced to broiler standard diets until they are 42 d of age. The chickens were offered access to food and water ad libitum and photoperiod was 23L:1D. All pens were monitored regularly for sickness and mortalities.

### Data Collection

Initial live weight (**ILW**) of each chick was determined at the start of the experiment, thereafter, live weights (**LW**) were taken on weekly basis using an electronic weighing balance (Model AFP 110L) to calculate body weight gain (**BWG**) per bird (g) as follows:

**Table 2.** Ingredients and nutrient composition of experimental diets.

| Ingredients | Experimental diets | | | | |
|---|---|---|---|---|---|
| | Starter (1−21 d) | | | | Grower (22−42 d) |
| | $BP_0$ | $BP_4$ | $BP_8$ | $BP_{12}$ | $BP_0$ |
| Maize meal (%) | 63.63 | 63.59 | 62.72 | 64.01 | 63.63 |
| Wheat bran (%) | 8.42 | 8.90 | 9.12 | 10.00 | 8.42 |
| Maize gluten meal | 3.40 | 3.48 | 3.16 | 3.20 | 3.40 |
| Soya bean meal (44% CP) | 13.38 | 12.43 | 13.05 | 10.40 | 13.38 |
| Fish meal (2−8% fat) (%) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Sunflower oil (%) | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Limestone (%) | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Dicalcium phosphate (%) | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 |
| DL-Methionine (%) | 0.18 | 0.19 | 0.19 | 0.19 | 0.18 |
| L-Lysine (%) | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| Vitamin/trace element premix[1] (%) | 0.23 | 0.25 | 0.20 | 0.24 | 0.23 |
| Salt (%) | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Bee pollen (%) | 0 | 0.40 | 0.80 | 1.2 | 0 |
| Total (%) | 100 | 100 | 100 | 100 | 100 |
| Nutrient analysis | | | | | |
| Metabolizable energy (MJ/kg) | 11.60 | 11.60 | 11.60 | 11.60 | 11.50 |
| Crude protein (%) | 22.00 | 22.00 | 22.00 | 22.00 | 20.00 |
| Lysine (%) | 1.11 | 1.11 | 1.11 | 1.11 | 1.10 |
| Methionine (%) | 0.57 | 0.56 | 0.56 | 0.56 | 0.56 |
| Methionine + Cysteine (%) | 0.82 | 0.82 | 0.82 | 0.82 | 0.84 |
| Threonine (%) | 0.83 | 0.77 | 0.77 | 0.77 | 0.81 |
| Calcium (%) | 0.91 | 0.91 | 0.91 | 0.91 | 0.90 |
| Potassium (%) | 0.69 | 0.66 | 0.66 | 0.66 | 0.67 |
| Sodium (%) | 0.26 | 0.26 | 0.26 | 0.26 | 0.25 |
| Available phosphorus (%) | 0.67 | 0.48 | 0.48 | 0.48 | 0.65 |

[1]The active ingredients contained in the vitamin−mineral premix were as follows (per kg of diet): vitamin A 12,000 IU, vitamin D3 3,500 IU, vitamin E 30.0 mg, vitamin K3 2.0 mg, thiamine 2 mg, riboflavin 6 mg, pyridoxine 5 mg, vitamin B12 0.02 mg, niacin 50 mg, pantothenate 12 mg, biotin 0Æ01 mg, folic acid 2 mg, Fe 60 mg, Zn 60 mg, Mn 80 mg, Cu 8 mg, Se 0Æ1 mg, Mo 1 mg, Co 0Æ3 mg, I 1 mg.

$$BWG = LW - ILW$$

where LW is the live weight and ILW is the initial weight.

Weekly average feed intake (**AWFI**) per chicken was determined by calculating the difference between the weight of feed offered and weight of feed leftover, the difference was divided by the total number of chickens in the pen. AWFI and BWG were used to calculate FCR of each bird every 7 d as follows:

$$\text{FCR (g : g)} = \frac{\text{Feed intake (g)}}{\text{Body weight (g)}}$$

## Apparent Digestibility

At 14 d of age, 2 birds were randomly selected from each replicate and used for apparent digestibility (**AD**) determination. The birds were assigned to the same experimental diets and given a 3-day acclimatization period prior to a 4-day collection period. Feces voided by the chickens were collected daily at 08h00. Care was taken to ensure that the droppings were not contaminated with feathers, scales, feeds, and debris. Apparent digestibility (%) for dry matter (**DM**), crude protein (**CP**), and minerals were calculated using the formula:

$$\text{Apparent nutrient digestibility} = \frac{\text{Nutrient intake} - \text{Excreta nutrient}}{\text{Nutrient intake}} \times 100$$

## Carcass Weight, Meat Organ Weight, and Meat pH

At the age of 42 d, 3 chickens per replicate were randomly selected weighed and humanely slaughtered for carcass evaluation. They were allowed to completely bleed out, then de-feathered, eviscerated, and weighed and recorded as hot carcass. The weight and pH of carcass and meat organs were determined immediately after slaughtering using an electronic weighing balance (Model AFP 110L) as hot carcass weight and using a pH meter (Model 4 Corning Glass Works, Medfield, MA) calibrated at pH of 7.0) as initial meat pH and stored in cold freezer (−4°C). The following day, meat pH from breast meat, thigh, drumstick, and wing at 3 different place was taken as ultimate pH (**pHu**) using a pH meter.

## Sensory Evaluation and Meat Shear Force

A total of 40 samples were used for sensory evaluation and meat shear force. Meat samples which were previously frozen at −40°C for 4 d were thawed for 7 h at room temperature prior to cooking (Pavelková et al., 2013). The breast meat was prepared and the skin was left on the meat samples. The individual breast meat was selected for sensory evaluation because of ease of handling. An oven set at 105°C was allowed to preheat prior to cooking. The meat samples were put in trays and they were covered with aluminum foil to prevent water loss. Nothing was added to the meat samples so as not to affect taste. The trays with meat were put in an oven for approximately 60 min and the meat samples were turned every 10 min. Samples were cut into small 5 cm cubic pieces and served immediately after cooking. The method adopted by Pavelková et al. (2013) was used for sensory evaluation of the meat. The following sensory attributes were evaluated by the sensory panel: tenderness, juiciness, and flavor of meat samples. The sensory panel consisted of 20 trained panelists. Each panelist was offered to drink lemon juice after tasting meat from each treatment before proceeding to the next treatment as to wash out the previous treatment to avoid confusion of tastes.

### Chemical Analysis

Bee pollen, formulated diets, feed, and excreta samples were analyzed with accordance to Association of Official Agricultural Chemists (**AOAC**) methods (2012), DM (method no 930.15), ash (method no 924.05), nitrogen (**N**) (method no 984.13). Crude protein was calculated as N × 6.25. Gross energy was determined using a bomb calorimeter (AOAC, 2012). Neutral detergent fiber (**NDF**) and acid detergent fiber (ADF) were determined using the ANKOM2000 Fibre Analyzer (ANKOM Technology, New York, NY). Metabolizable energy was determined by models from NIRs SpectraStar XL (Unity Scientific, Emu Plains, Australia) at Pietermaritzburg Laboratory, Kwa-Zulu Natal, South Africa.

### Statistical Analyses

Data were analyzed using general linear model (**GLM**) procedures of the statistical analysis of variance SAS (2012) to detect dietary treatment effects on the broiler chickens. The statistical model Yijk = $\mu$ + Ti + Bj + (TB)ij + eijk was applied, where Yijk is the observation on feed intake, digestibility, live weight, carcass characteristics, FCR, and mortality due to dietary treatment effects; $\mu$ is the overall mean; Ti is the ith effect of bee pollen inclusion in starter diets; Bj is the jth effect of sex of the chickens, (TB)ij is the interaction between bee pollen inclusion and sex, and eijk is the residual effect (error). Where significant differences were observed, mean separation was done using Tukey test at the 5% level of significance (SAS, 2012). The responses in optimal feed intake, live weight, growth rate, digestibility, FCR, metabolizable energy and carcass characteristics to bee pollen inclusion levels were modeled using the quadratic equation (SAS, 2012). The responses in optimal feed intake, live weight, growth rate, digestibility, FCR, metabolizable energy, and carcass characteristics to bee pollen inclusion levels were modeled using the quadratic equation SAS (2012).

## RESULTS AND DISCUSSION

### Nutrient Digestibility, Metabolizable Energy, and Nitrogen Retention

Nutrient digestibility is an extent to which nutrient from the feedstuff are absorbed in the digestive tract of an animal and utilized by the body (Hascik et al., 2017). Dietary supplementation with BP has a positive effect on chickens' intestinal morphology, hence improves nutrient digestibility (Attia et al., 2014; Prakatur et al., 2019). The apparent digestibility values in broiler chicks fed dietary BP supplementation are presented in Table 3. The current study reveals that the incremental levels of BP in broiler starter diet had no effects ($P > 0.05$) on apparent DM, CP, ADF, NDF, ash digestibility, ME and N-retention in Ross 308 broiler chicks. The results suggest that BP can be efficiently absorbed and utilized by broiler chicks same as the control diet. Despite few literatures available on the effect of BP supplementation on nutrient digestibility in chickens, Prakatur et al. (2019) demonstrated that the key active compounds in BP are flavonoids and phenolic acids which are responsible modulating gut microbiota and increases beneficial bacteria while reducing the population of pathogenic microbes, providing improved nutrient digestibility. This implies that BP can be safely included in broiler starter diets without causing adverse effects on broiler chicks.

**Table 3.** Effect of bee pollen incremental levels on apparent nutrient digestibility (%), metabolizable energy (MJ/kg), and nitrogen retention (g) of Ross 308 broiler chicks aged 21 d.

| | Parameter# | | | | | | |
|---|---|---|---|---|---|---|---|
| Diets* | DM (%) | CP (%) | ADF | NDF | Ash | ME | N-retention |
| Male | | | | | | | |
| BP0 | 82.45 ± 2.61 | 79.97 ± 2.56 | 18.51 ± 3.01 | 21.90 ± 1.45 | 12.83 ± 3.15 | 11.79 ± 0.18 | 1.89 ± 0.60 |
| BP4 | 81.80 ± 1.90 | 80.21 ± 2.78 | 18.73 ± 3.40 | 20.76 ± 2.38 | 12.56 ± 2.90 | 12.0 ± 0.19 | 1.89 ± 0.40 |
| BP8 | 82.29 ± 2.32 | 80.49 ± 2.68 | 19.16 ± 2.39 | 20.94 ± 2.58 | 12.27 ± 3.01 | 11.97 ± 1.9 | 1.87 ± 0.28 |
| BP12 | 82.10 ± 1.80 | 80.92 ± 2.13 | 18.41 ± 2.90 | 20.86 ± 0.01 | 12.50 ± 2.33 | 12.02 ± 0.11 | 1.90 ± 0.16 |
| Female | | | | | | | |
| BP0 | 81.0 ± 2.36 | 79.73 ± 1.96 | 18.30 ± 2.71 | 21.13 ± 2.17 | 12.11 ± 2.59 | 11.96 ± 0.98 | 1.71 ± 0.59 |
| BP4 | 81.20 ± 2.23 | 79.85 ± 2.11 | 20.09 ± 2.20 | 20.95 ± 3.07 | 12.47 ± 2.17 | 11.83 ± 1.0 | 1.69 ± 0.80 |
| BP8 | 80.33 ± 2.02 | 79.77 ± 1.72 | 20.07 ± 2.53 | 20.79 ± 2.14 | 12.42 ± 3.71 | 12.01 ± 1.18 | 1.70 ± 0.48 |
| BP12 | 80.98 ± 1.42 | 78.95 ± 2.68 | 22.15 ± 2.78 | 22.01 ± 3.12 | 12.30 ± 2.16 | 11.98 ± 1.02 | 1.72 ± 0.39 |

*Dietary diets: $BP_0$ = basal diet with no bee pollen; $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; $BP_8$ = basal diets in which 8 g/kg bee pollen was included; $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients.ME, metabolizable energy intake; N-retention, nitrogen retention.

#DM (Dry Matter), CP (Crude Protein), Neutral detergent fibre (NDF), ADF ( Acid Detergent Fibre), Ash, ME (Metabolizable Energy), NR (Nitrogen Retention): Values presented as mean ± standard error (SE).

## Growth Performance Parameters

There were no mortalities reported throughout the experimental period. Repeated measures of GLM procedure revealed no interaction ($P > 0.05$) between the bee pollen inclusion levels and sex performances. However, the current study showed that the incremental levels of BP had positively affected ($P < 0.05$) AWFI, FCR, LW, and BWD values of both male and female Ross 308 broiler chickens aged 1 to 42 d (Table 4). However, there were no significant in growth performance in response to $BP_0$, $BP_4$, and $BP_{12}$ inclusion levels. The results suggest that the broiler chicks can utilize bioactive compounds contained in BP during the starter phase and subsequently improve their growth parameters throughout the growing period. These positive improvements could be due to high quality amino acids, essential oils, vitamins, and minerals of BP (Attia et al., 2019; Nemauluma et al., 2022). The results of the current are in line with the observations made by Hascik et al. (2012) who reported increased BW in male broiler chickens fed diets supplemented with 400 or 800 mg/kg BP extracts. Similarly, Farag and El-Rayes (2016) observed increased BWG and low FCR in broilers supplemented with 0.6% BP. In addition, Ivana et al. (2018)also observed low FCR in broiler fed starter diet containing 20 g/kg BP. In contrast, bee propolis supplementation into broiler diets did not affect FI, however, FCR was negatively affected as compared to the control diet (Ibrahim and Al-Jebory, 2020). The difference between the results obtained from the current study and those from literatures could be caused by the differences in inclusion levels and the duration of supplementation. Nevertheless, the overall results indicate that BP levels used in this study could be safely included in broiler chickens' diets to improve growth performance without causing any adverse effects.

## Carcass Traits

The statistical analysis of 2-way ANOVA did not show ($P > 0.05$) interactions between BP inclusion levels and sex. The data on meat traits of broiler chickens fed dietary BP supplementation during the starter period is shown in Table 5. The carcass weight, breast meat, wing, and drumstick weights were positively affected ($P < 0.05$) in both sexes, which is in line with Neeraj (2016) and Hascik et al. (2017) who reported that adding BP into chicken diets increased slaughter and carcass weights of broiler chickens. Similarly, Attia et al. (2011) and Eyng et al. (2014) observed positive effects of bee pollen on the body and carcass weights of broiler chickens. The positive improvements could be associated with BWG. This implies that BP did not change the physico-chemical properties of the diets. Hence, the palatability and the functional property of the diet were not affected by the inclusion level of BP. It was tangibly demonstrated that the improvement in carcass yield could be due to nutrient composition of BP along with bioactive compounds such phenolics, antimicrobial, and immunomodulatory effect as well as health protection (HaÅ et al., 2019; Hascik et al., 2015). In addition, the effects of bee pollen compounds on the gastrointestinal tract of broiler chickens, which tend to stimulate digestion and increase nutrient absorption, thus improving growth performance and the carcass yield of the chickens (HaÅ et al., 2019).

## Meat pH, Sensory Evaluation, and Shear Force

Poultry meat consumers' acceptance is driven by factors such as meat color, texture, and flavor of the meat (Kostić et al., 2020; Malematja et al., 2022). Meat physico-chemical hinges on the environment and nutrition. Determining meat pH helps to determine the rate at which glycogen in the meat is converted into lactic acid soon after slaughtering (Hascik et al., 2013). The antioxidants contained in bee pollen have been demonstrated to improve meat quality in broiler chickens (Wang et al., 2005). Furthermore, the antioxidant compounds also help to improve meat pH by reducing meat oxidative stability and further inhibiting of the meat

**Table 4.** Effect of bee pollen inclusion level in starter diets on growth performance of chickens aged 1 to 42 d.

| | Parameter# | | | |
|---|---|---|---|---|
| Diets* | AWFI (g) | FCR (g:g) | BW (g) | BWG (g) |
| Male | | | | |
| $BP_0$ | $183.10^{c} \pm 8.02$ | $2.38^{a} \pm 0.08$ | $1990.90^{b} \pm 15.89$ | $1945.90^{b} \pm 10.26$ |
| $BP_4$ | $198.50^{abc} \pm 7.47$ | $2.33^{ab} \pm 0.06$ | $2007.10^{ab} \pm 18.22$ | $1962.10^{ab} \pm 8.92$ |
| $BP_8$ | $206.50^{b} \pm 15.10$ | $2.35^{ab} \pm 0.09$ | $2007.30^{ab} \pm 31.72$ | $1962.30^{ab} \pm 11.15$ |
| $BP_{12}$ | $201.90^{a} \pm 10.10$ | $2.25^{b} \pm 0.03$ | $2023.30^{a} \pm 15.12$ | $1978.30^{a} \pm 7.47$ |
| Female | | | | |
| BP0 | $161.90^{b} \pm 7.39$ | $2.45^{a} \pm 0.08$ | $1978.60^{b} \pm 8.71$ | $1933.60^{b} \pm 10.16$ |
| $BP_4$ | $171.40^{ab} \pm 4.64$ | $2.40^{ab} \pm 0.08$ | $1983.20^{ab} \pm 9.61$ | $1938.20^{ab} \pm 16.87$ |
| $BP_8$ | $170.57^{ab} \pm 3.05$ | $2.44^{ab} \pm 0.07$ | $1992.90^{ab} \pm 8.26$ | $1947.90^{ab} \pm 17.58$ |
| $BP_{12}$ | $179.60^{a} \pm 8.19$ | $2.32^{b} \pm 0.04$ | $2000.30^{ab} \pm 11.47$ | $1955.3000^{a} \pm 11.19$ |

[a–c]Means with different superscripts in the same column indicate significant differences.

*Dietary diets: $BP_0$ = basal diet with no bee pollen; $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; $BP_8$ = basal diets in which 8 g/kg bee pollen was included; $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients.

#Average weekly feed intake (AWFI); Body weight (BW); Body weight gain (BWG); Feed Conversion Ratio (FCR): Values presented as mean±standard error (SE).

**Table 5.** Effect of bee pollen inclusion level in starter diets on carcass and meat-parts weight (g) of broiler chickens at slaughter age.

| | Parameter[#] | | | | |
|---|---|---|---|---|---|
| Diets* | Carcass | Breast | Drumstick | Thigh | Wing |
| Male | | | | | |
| $BP_0$ | $1386.9^b \pm 54.96$ | $206.7^b \pm 8.65$ | $102.3^b \pm 3.55$ | $99.6^b \pm 5.17$ | $83.6^b \pm 2.66$ |
| $BP_4$ | $1489.8^a \pm 47.08$ | $220.9^a \pm 5.22$ | $109.8^a \pm 3.19$ | $119.5^a \pm 8.91$ | $88.7^a \pm 2.06$ |
| $BP_8$ | $1490.4^a \pm 47.87$ | $225.9^a \pm 18.11$ | $109.6^a \pm 3.04$ | $121.3^a \pm 11.24$ | $90.5^a \pm 3.01$ |
| $BP_{12}$ | $1503.7^a \pm 50.99$ | $233.1^a \pm 7.11$ | $110.6^a \pm 4.31$ | $129.5^a \pm 12.37$ | $91.9^a \pm 3.44$ |
| Female | | | | | |
| $BP_0$ | $1360.6^b \pm 50.42$ | $199.7^b \pm 8.89$ | $97.4^b \pm 4.43$ | $97.4^b \pm 4.14$ | $79.6^b \pm 4.95$ |
| $BP_4$ | $1470.8^a \pm 48.97$ | $218.3^a \pm 9.00$ | $112.0^a \pm 7.65$ | $117.4^a \pm 2.74$ | $90.2^a \pm 3.71$ |
| $BP_8$ | $1490.4^a \pm 45.47$ | $221.8^a \pm 13.05$ | $110.9^a \pm 5.78$ | $117.2^a \pm 8.2$ | $92.1^a \pm 3.15$ |
| $BP_{12}$ | $1497.2^a \pm 50.54$ | $224.0^a \pm 11.69$ | $110.9^a \pm 7.17$ | $120.2^a \pm 4.91$ | $95.9^a \pm 4.41$ |

[a–b]Means with different superscripts in the same column indicate significant differences.

*Dietary diets: $BP_0$ = basal diet with no bee pollen; $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; $BP_8$ = basal diets in which 8 g/kg bee pollen was included; $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients.Values presented as mean ± standard error (SE).

[#]Carcass, breast, drumstick, thigh, wing: Values presented as mean ± standard error (SE).

oxidation (Hascik et al., 2015). The results of the present study show that incremental levels of BP in diet in broiler starter diet did not affect ($P > 0.05$) meat pH values after 24 h (Table 6) and sensory evaluation with regard to juiciness, flavor, and shear force in both male and female Ross 308 broiler chickens at slaughter age (Table 7). Since BP inclusion in the diets has the same effect as the standard diet, therefore, this suggests that BP can be safe as feed additives to enhance growth performance and carcass yield in broilers' diets without altering the meat pH and sensory evaluation. This supported by the observations made by Hascik et al. (2013) who observed unaffected ultimate meat pH in broiler chickens fed diets containing BP inclusion levels of up to 4,500 mg/kg. In contrast, Farag and El-Rayes (2016) reported that dietary bee pollen can influence meat pH in chickens after slaughter. Similarly, Hascik et al. (2013) reported significant positive impacts of bee pollen

**Table 6.** Effect of incremental levels of bee pollen in starter diets on meat pH of Ross 308 broiler chickens aged 42 d.

| | Parameter[#] | | | |
|---|---|---|---|---|
| Treatment* | Breast | Drumstick | Thigh | Wing |
| Male | | | | |
| $BP_0$ | 6.2 ± 0.92 | 6.1 ± 0.69 | 6.0 ± 0.25 | 6.1 ± 0.48 |
| $BP_4$ | 5.9 ± 0.65 | 5.9 ± 0.18 | 6.1 ± 0.95 | 6.1 ± 0.36 |
| $BP_8$ | 5.9 ± 0.17 | 6.0 ± 0.53 | 6.2 ± 0.92 | 6.1 ± 0.69 |
| $BP_{12}$ | 5.8 ± 0.16 | 5.9 ± 0.19 | 6.2 ± 0.17 | 6.0 ± 2.06 |
| Female | | | | |
| $BP_0$ | 6.2 ± 0.85 | 6.0 ± 0.10 | 6.0 ± 0.32 | 6.1 ± 0.14 |
| $BP_4$ | 5.9 ± 0.12 | 6.0 ± 0.21 | 6.2 ± 0.26 | 6.1 ± 0.08 |
| $BP_8$ | 6.0 ± 0.22 | 5.9 ± 0.09 | 6.2 ± 0.32 | 6.0 ± 0.15 |
| $BP_{12}$ | 6.1 ± 0.29 | 5.9 ± 0.11 | 6.0 ± 0.62 | 5.9 ± 0.19 |

*Dietary diets: $BP_0$ = basal diet with no bee pollen; $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; $BP_8$ = basal diets in which 8 g/kg bee pollen was included; $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients.Values presented as mean ± standard error (SE).

[#]Breast, drumstick, thigh, wing: Values presented as mean ± standard error (SE).

**Table 7.** Effect of bee pollen inclusion level in starter diets on meat tenderness, juiciness, flavor, and shear force values of Ross 308 broiler chickens aged 42 d.

| | Parameter[#] | | | |
|---|---|---|---|---|
| Treatment* | Tenderness | Juiciness | Flavor | Shear force |
| Male | | | | |
| $BP_0$ | 3.7 ± 0.33 | 4.3 ± 0.33 | 3.7 ± 0.25 | 7.4 ± 3.29 |
| $BP_4$ | 3.6 ± 0.33 | 4.1 ± 0.13 | 3.3 ± 0.26 | 7.5 ± 2.30 |
| $BP_8$ | 3.7 ± 0.33 | 4.1 ± 0.23 | 3.0 ± 0.58 | 7.9 ± 2.40 |
| $BP_{12}$ | 3.7 ± 0.33 | 4.3 ± 0.33 | 3.7 ± 0.17 | 7.3 ± 2.31 |
| Female | | | | |
| $BP_0$ | 3.5 ± 0.33 | 4.3 ± 0.03 | 3.7 ± 0.28 | 7.6 ± 2.74 |
| $BP_4$ | 3.7 ± 0.13 | 4.3 ± 0.25 | 3.7 ± 0.58 | 7.1 ± 2.48 |
| $BP_8$ | 3.5 ± 0.27 | 4.6 ± 0.67 | 3.5 ± 0.24 | 7.9 ± 5.64 |
| $BP_{12}$ | 3.6 ± 0.33 | 4.2 ± 0.01 | 3.6 ± 0.45 | 7.2 ± 2.55 |

*Dietary diets: $BP_0$ = basal diet with no bee pollen; $BP_4$ = basal diet in which 4 g/kg of bee pollen was included; $BP_8$ = basal diets in which 8 g/kg bee pollen was included; $BP_{12}$ = basal diet in which 12 g/kg bee pollen was included in the diet with other ingredients.Values presented as mean ± standard error (SE).

[#]Tenderness, Juiciness, flavor, shear force: Values presented as mean ± standard error (SE).

on the taste, aroma, juiciness and tenderness of chicken thighs and breasts. The differences in results obtained from the current investigation and those of literatures maybe explained by the period of supplementation, for instance, in the current study the BP was only supplemented during the starter phase whereas in other studies it was supplemented throughout the experimental period. There is less information reported on the effect of BP inclusion in broiler chicken diets on meat sensory attributes; therefore, more studies are recommended to verify these findings.

## CONCLUSIONS

The addition of 4, 8, or 12 g/kg of BP to broiler starter diets for Ross 308 broiler chicks, resulted in significant improvements in growth performance throughout the experimental period as well as improved and carcass yield at slaughter age. However, the BP incremental levels did not affect the apparent nutrient digestibility, metabolizable energy, and nitrogen retention in broiler diets aged 21 d. Similarly, meat pH, shear force, and sensory evaluation in broiler chickens fed diets containing BP levels. Therefore, it is concluded that BP inclusion level of beyond 12 g/kg in the starter diets could have positive effects on growth performance and carcass yield at slaughter age without causing adverse effects on meat physico-chemical properties and sensory evaluation in both male and females broiler chickens. However, it would be appropriate to conduct further investigations to ascertain these findings. Furthermore, supplementation of BP in growing phase is suggested.

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Data Availability Statement: Data of the current study are available from authors on request.

Ethics Statement: The experimental procedures were conducted in accordance with the University of Limpopo (UL) Animal Research Ethics committee, reference number: AREC/06/2020:PG.

## DISCLOSURES

All the authors do not have any conflicts of interest to declare.

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