Influence of dietary phytase and protease, individually or in combination, on growth performance, intestinal morphology, microbiota composition and nutrient utilisation in broiler chickens fed sesame meal-based diets

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ABSTRACT
Efficacy of phytase and protease supplements, individually or in combination, on growth performance, carcass, intestinal morphology, microbiota composition and nutrient digestibility was investigated in broilers fed diets containing sesame meal. A total of 375 day-old male broiler chickens of ROSS 308 strain were randomly allocated into five dietary treatments with five replicates per treatment and 15 broilers per each. Dietary treatments were T1: a basal diet (control), T2: sesame meal diet (150 g/kg sesame meal to replace soybean meal), T3: T2 + 500 FTU/kg phytase, T4: T2 + 0.2 g/kg protease and T5: T2 + combination of phytase and protease supplements. At the end of the study, body weight gain of the T5 broilers was greater than those of the T1 birds (\( p < .05 \)). Feed conversion ratio improved in broiler chickens fed the T3, T4 and T5 diets compared with T1 diet (\( p < .05 \)). An increase in villus length (VL) was found in broilers which received T3, T4 and T5 diets compared with control (\( p < .05 \)). The greatest value of crypt depth (CD), and villus surface area observed in the birds fed with T4 diet compared with control (\( p < .05 \)). Inclusion of phytase in broiler diet increased VL/CD ratio compared with control group (\( p < .05 \)). Combination of protease and phytase (T5) increased the caecal Lactobacillus and decreased E. coli counts compared with T1, T2 and T4, while T3 group was intermediate (\( p < .05 \)). Ileal nutrients digestibility was greatest in broilers which received T5 diet (\( p < .05 \)). In conclusion, addition of protease and phytase to sesame meal diets may be a suitable strategy for improving growth performance, intestinal morphology, microbiota composition and nutrient utilisation in broiler chickens.

HIGHLIGHTS
- Combination of phytase and protease enzymes in sesame meal diets improved growth performance, nutrient utilisation and microbiota activity of broiler chickens.
- Supplemental phytase or protease improved jejunal morphology of broiler chickens fed sesame meal diets.

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Introduction
One of the most problems of poultry industry in developing countries is the supply of dietary protein. In Iran, soybean meal is the main source of plant protein in the poultry diets. However, the increase of soybean meal cost may decline its utilisation in poultry nutrition. Therefore, there is a clear need for suitable alternatives to soybean meal in poultry industry. Sesame (Sesamum indicum) seed is cultivated extensively at the north and northeast parts of Iran as an oilseed plant (Rezaeipour et al. 2016). The world sesame production is about 5,532,000 metric tons (MT) behind soybean, groundnut, cottonseed, sunflower, linseed and rapeseed, in the quantity of world oilseed production (Daisy et al. 2020). Sesame seed is composed of 45–50% fats, 15–20% protein and 10–15% carbohydrate (Yamauchi et al. 2006). Sesame meal is a by-product of oil extraction process from sesame seeds in which its protein content is up to 40–60% (Liu et al. 2015). Sesame meal is a rich source of amino acids such as leucine, arginine and methionine but relatively poor in lysine (Rezaeipour et al. 2016; Hajimohammadi et al. 2020a). Moreover, the antioxidant and anti-hyperlipidaemic activities of sesame...
meal protein have been elucidated in rats and broiler chickens (Biswas et al. 2010). Several studies have been demonstrated the contradictory influence of sesame meal on the growth performance of broilers and quails (Mamputu and Buhr 1995; Rama Rao et al. 2008; Rezaeipour et al. 2016; Hajimohammadi et al. 2020b). However, sufficient information on the intestinal morphology and microbiota composition of broiler chickens with dietary sesame meal is not available. Furthermore, it has been reported that the high amount of calcium and phosphorous in sesame meal are less available for broilers attributed to its high phytic acid content (Rahimian et al. 2013). Besides, diets containing high levels of phytic acid can reduce the digestibility coefficients of nutrients such as protein (Selle et al. 2000).

The beneficial effects of exogenous enzymes on the nutrient utilisation and subsequently growth performance of broiler chickens have been extensively studied (Cowieson et al. 2009, 2017; Borda-Molina et al. 2019; Roofchaei et al. 2019). Regarding to the phytic acid content in sesame meal diets, phytase supplementation may be a suitable scenario to increase the efficiency of phosphorus and calcium bioavailability in broiler chickens (Rezaeipour et al. 2016). In a study, supplementing phytase increased apparent ileal digestibility (AID) of all nutrients and growth performance of broiler chickens fed with diets containing high levels of phytic acid (Walk and Olukosi 2019). In addition, it has been observed that inclusion of phytase enzyme into the broiler diets improved gut health and intestinal morphometric indices (Selle et al. 2009). Despite the secretion of endogenous proteases in the intestinal region, a valuable amounts of protein pass from the gastrointestinal tract without being completely utilised (Angel et al. 2011). Therefore, exogenous proteases have been included in the diets of broiler chickens for several years. The use of exogenous proteases enables nutritionists to meet broiler needs at a lower protein concentration that in turn has a positive effect on litter conditions, the hind-gut ecosystem and the sustainability of poultry production in general (Cowieson et al. 2017). It is well established that high phytic acid diets can reduce the total tract digestibility of crude protein in broiler chickens (Ravindran et al. 2000; Cowieson et al. 2009). Therefore, it can be hypothesised that the use of protease or phytase enzymes, individually or in combination, in sesame meal diets improved gut health and intestinal morphology, microbiota activity and nutrient digestibility of broiler chickens.

Materials and methods

The birds and diets

This study was conducted in a commercial farm at the north part of Iran (Qaemshahr, Iran) and was approved by the animal welfare commissioner of the Department of Animal Science, Islamic Azad University, Qaemshahr Branch (Qaemshahr, Iran). A total of 375 one-day-old male broiler chickens of ROSS 308 strain were randomly allocated into five dietary treatments. Five replications per treatment and 15 broilers per replicate were used. Dietary treatments were T1: a basal diet, T2: sesame meal diet (150 g/kg sesame meal to replace soybean meal), T3: T2 + 100 g/ton Phyzyme® XP 5000 with 500 FTU/g, T4: T2 + 0.2 g/kg protease and T5: T2 + combination of phytase and protease supplements. Phyzyme® XP 5000 was a feed enzyme that contains 6-phytase produced by a genetically modified strain of S. pombe (ATCC 5233) and protease supplement was Ronozyme® (Basel, Switzerland). All used ingredients and chemical composition of the basal and experimental diets are shown in Table 1. The basal and experimental diets were formulated to meet the nutrient requirements of broiler chickens (Aviagen 2014) during starter (1–10 d), grower (11–24) and finisher (25–42 d) periods. Chemical composition and amino acids content of sesame meal and soybean meal are presented in Table 2. A total of 375 one-day-old male broiler chicks (Ross 308 strain) were purchased from a commercial hatchery and then randomly allocated into five treatments with five replicates (pens) per each. Water and feed were ad libitum for broiler chickens throughout the experiment. The farm temperature was set at 33 °C when broilers received and was lowered stepwise to 21 °C.

Growth parameters and carcass characteristics

At the end of each experimental phase (starter, grower, finisher and total experimental periods), body weight gain and feed consumption were measured on a pen basis. Feed consumption per weight gain (feed conversion ratio) was calculated for individual replicates of each dietary treatment and was adjusted for mortality. At 42 days of age, five broiler chickens from each treatment (with a weight close to the pen average) were selected and weighed, and then euthanised by cervical dislocation. Carcass yield and the weight of carcass parts and internal organs were recorded. Briefly, the gut region of each broiler was removed.
Then, carcass traits including breast, thigh, pancreas, liver, heart and abdominal fat were weighed. Data for carcass characteristics were reported as percentage of live weight of each bird (g/100 g body weight).

Ileal digesta viscosity

At 42 days of age, five broiler chickens were randomly selected from each treatment, and then were sacrificed by cervical dislocation. The digestive tract was carefully excised to examine ileal viscosity, caecal microbial enumeration and jejunal morphological parameters. To determine the ileal viscosity, ileum segment was removed from Meckel’s diverticulum to ileo-caecal junction. The ileal contents were collected and centrifuged at 10,000 g to separate the supernatant. The viscosity of supernatant was measured by a viscometer (Brookfield, MA).

Microbial enumeration

To determine the caecal microbial population, the fresh digesta content of caecum for each broiler chicken was sampled and gently transferred into sterile laboratory tubes. Laboratory tubes containing fresh digesta were kept in ice pack box to inhibit microbial growth during transferring to laboratory. One gram of caecal sample was serially diluted from 10⁻⁰ to 10⁻⁷ in phosphate buffer saline (PBS). To determine the population of *Escherichia coli*, *Lactobacillus* and total count bacteria, aliquots of 0.1 mL of each dilution were then spread on petri dishes containing the appropriate media culture. Plate count agar (PCA, Merck, Darmstadt, Germany), eosin methylene blue agar (Merck, Darmstadt, Germany) and de Man, Rogosa, sharpe agar (MRS, Merck, Darmstadt, Germany) were used for total, *E. coli* and *Lactobacillus* counts, respectively. Bacteria were enumerated using a colony counter and the results expressed as the

### Table 1. Ingredients and chemical composition of basal (corn–soybean meal) and experimental diets (corn–soybean and sesame meal).

| Feed ingredients (%) | SBM-based diets | SM-based diets |
|----------------------|-----------------|---------------|
|                      | (1–11 d)        | (11–24 d)     | (24–42 d)    | (1–11 d)        | (11–24 d)     | (24–42 d)    |
| Corn grain           | 55.19           | 59.71         | 63.17        | 55.60           | 60.08         | 63.63        |
| Soybean meal (45.83%)| 38.27           | 33.92         | 29.44        | 23.1            | 18.76         | 14.27        |
| Sesame meal (46.03%) | –               | –             | –            | 15.00           | 15.00         | 15.00        |
| Dicalcium phosphate  | 1.73            | 1.49          | 1.44         | 1.71            | 1.47          | 1.35         |
| Oyster shell         | 1.20            | 1.13          | 1.00         | 0.54            | 0.47          | 0.36         |
| Vitamin supplement   | 0.25            | 0.25          | 0.25         | 0.25            | 0.25          | 0.25         |
| Mineral supplement   | 0.25            | 0.25          | 0.25         | 0.25            | 0.25          | 0.25         |
| DL-Methionine        | 0.26            | 0.23          | 0.21         | 0.16            | 0.13          | 0.11         |
| L-Lysine HCl         | 0.39            | 0.31          | 0.29         | 0.65            | 0.57          | 0.56         |
| L-Threonine          | 0.04            | 0.02          | 0       | 0.09            | 0.05          | 0.04         |
| Common salt          | 0.38            | 0.33          | 0.31         | 0.30            | 0.20          | 0.20         |
| Soybean oil          | 1.57            | 1.91          | 3.34         | 1.76            | 2.12          | 3.52         |
| Choline              | 0.27            | 0.26          | 0.10         | 0.27            | 0.26          | 0.10         |
| Sodium bicarbonate   | 0.20            | 0.20          | 0.20         | 0.32            | 0.39          | 0.36         |
| Chemical composition (calculated) |       |               |              |                 |               |              |
| Metabolizable energy (kcal/kg) | 2950 | 3020 | 3150 | 2950 | 3020 | 3150 |
| Crude protein (%)    | 22.6            | 21            | 19.2         | 22.6            | 21            | 19.2         |
| Calcium (%)          | 0.94            | 0.85          | 0.78         | 0.94            | 0.85          | 0.78         |
| Available phosphorus (%) | 0.47 | 0.42 | 0.40 | 0.47 | 0.42 | 0.39 |
| Methionine (%)       | 0.55            | 0.50          | 0.46         | 0.55            | 0.50          | 0.46         |
| Lysine (%)           | 1.42            | 1.26          | 1.14         | 1.42            | 1.26          | 1.14         |
| Threonine            | 0.94            | 0.84          | 0.74         | 0.94            | 0.84          | 0.74         |
| Methionine + Cysteine| 0.96            | 0.83          | 0.79         | 0.96            | 0.83          | 0.79         |

### Table 2. Chemical composition of sesame meal compared with soybean meal (% DM).

| Item | Sesame meal | Soybean meal |
|------|-------------|--------------|
| Dry matter, % | 93.62 | 92.26 |
| Crude protein | 46.03 | 45.83 |
| Ash | 9.31 | 5.97 |
| Ether extract | 1.69 | 1.96 |
| Total phosphorus | 1.72 | 0.71 |
| Available phosphorus | 0.38 | 0.28 |
| Phytic acid | 1.34 | 0.43 |
| AMEn, kcal/kg | 2210 | 2440 |

### Chemical composition (calculated)

| Item | SBM-based diets | SM-based diets |
|------|-----------------|---------------|
| Methionine | 1.01 | 0.66 |
| Lysine | 0.81 | 2.98 |
| Threonine | 1.29 | 1.93 |
| Cysteine | 0.45 | 0.62 |
| Valine | 2.02 | 2.36 |
| Arginine | 4.63 | 3.31 |
| Isoleucine | 1.79 | 2.41 |
| Histidine | 1.00 | 1.19 |
| Tryptophan | 0.78 | 0.68 |

aEach value is the mean of two replicates. Amino acid profiles and chemical composition were estimated by near-infrared spectroscopy (NIRs; Evonik-Degussa, Hanau, Germany). AMEn values were obtained from NRC (1994).
logarithm of the number of bacteria per gram of the sample.

**Jejunal morphology**

Villus length (VL), villus width (VW), crypt depth (CD), the ratio of VL to CD, and villus surface area (VSA) were measured as jejunal morphological characteristics. Briefly, after removing the small intestine segment, approximately 2 cm of the jejunum was sampled. The jejunum was defined as being midway between the end of the duodenum and Meckel’s diverticulum. Sample was carefully flushed clean with distilled water and a physiological saline solution. Jejunal samples were subjected in a sterilised tube containing formalin solution (20%) for tissue fixation and a 5-mm section was processed, embedded in paraffin. Tissue sections (2 μm) were cut by microtome, floated onto slides, and stained with haematoxylin and eosin. Histological parameters including VL, VW, CD and VL/CD ratio were measured by a light microscope system (Model U-TV0.5 XC-2, Olympus Corporation, BX41, Tokyo, Japan). The VSA was also calculated using the following formula (Sakamoto et al. 2000):

\[
VSR = (2\pi) \times (\frac{VW}{2}) \times (VL).
\]

**Nutrient digestibility**

From days 37–42, chromium oxide (3 g of Cr₂O₃/kg of diet) as an indigestible marker was added to the diets. In order to determine AID coefficients of the nutrients, five broiler chickens per treatment group were randomly chosen, and then euthanised by cervical dislocation on 42 days of age. The ileum segment was defined (from Meckel’s diverticulum to the ileo-caecal junction) and then separated from the rest of the intestinal tract. Samples of fresh digesta from the end half of this section were collected and dried at 55 °C for 72 h, and then ground to pass through a one-mm screen. The diets and ileal samples were analysed for crude protein, calcium and phosphorus. Chromium oxide content of dried diets and ileal digesta samples were determined according to the method of Fenton and Fenton (1979). AID coefficients were then calculated relative to the chromium oxide concentration using the following equation:

\[
D (\%) = 100 - \left( \frac{100 \times (A/B) \times (C/E)}{D} \right)
\]

where \(D\) is the digestibility, \(A\) is the chromium oxide in feed (%), \(B\) is the chromium oxide in ileal digesta (%), \(C\) is the nutrient concentration in ileal digesta (%), \(E\) is the nutrient concentration in feed (%).

**Statistical analysis**

Data obtained from this study were analysed as a completely randomised design using GLM procedure of SAS software (Cary, NC) (SAS 1999). Statistically significant of differences among experimental treatments were detected using Tukey’s test. Differences were considered to be statistically significant at \(p < .05\).

**Results**

The effects of dietary treatments on growth performance of broilers are presented in Table 3. During days 1–10, feed intake significantly increased in all experimental treatments compared with control group

| Table 3. The feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR) in broiler chickens fed sesame meal-based diets with phytase and/or protease supplement. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | BD              | ED              | EDH             | EDR             | EDHR            | SEM             | p Value         |
| FI, g           |                 |                 |                 |                 |                 |                 |                 |
| 1–10 d          | 267.5 b         | 284.3 a         | 282.7 a         | 279.5 a         | 280.2 a         | 1.80 p          | .005            |
| 11–24 d         | 819.3           | 844.0           | 829.3           | 817.0           | 828.7           | 9.66 p          | .328            |
| 24–42 d         | 3237.7 b        | 3363.0 ab       | 3360.0 ab       | 3270.7 b        | 3417.8 a        | 33.4 p          | .004            |
| 1–42 d          | 4324.5          | 4491.3          | 4482.8          | 4367.2          | 4526.7          | 114.1 p         | .674            |
| BWG, g          |                 |                 |                 |                 |                 |                 |                 |
| 1–10 d          | 193.0 b         | 227.7 a         | 227.5 a         | 220.8 a         | 226.8 a         | 2.38 p          | .006            |
| 11–24 d         | 525.5 b         | 579.3 a         | 577.7 a         | 566.2 a         | 590.0 a         | 6.65 p          | .004            |
| 24–42 d         | 1603.3 b        | 1668.8 a        | 1760.8 a        | 1664.2 b        | 1823.0 a        | 20.9 p          | .001            |
| 1–42 d          | 2366.3 b        | 2520.3 ab       | 2562.0 ab       | 2495.7 ab       | 2684.3 a        | 56.4 p          | .010            |
| FCR, g/g        |                 |                 |                 |                 |                 |                 |                 |
| 1–10 d          | 1.39 a          | 1.25 b          | 1.24 b          | 1.27 b          | 1.23 b          | 0.012 p         | .002            |
| 11–24 d         | 1.55 a          | 1.45 b          | 1.43 bc         | 1.47 b          | 1.39 c          | 0.008 p         | .001            |
| 24–42 d         | 2.02 a          | 2.02 a          | 1.91 ab         | 1.96a b         | 1.87 b          | 0.028 p         | .003            |
| 1–42 d          | 1.83 a          | 1.78 ab         | 1.75 bc         | 1.75 bc         | 1.69 c          | 0.017 p         | .008            |

BD: fed on basal diets based on a corn-soybean meal; ED: fed on experimental diets (based on a corn-soybean meal-sesame meal); EDH: fed on the ED diets supplemented with phytase; EDR: fed on the ED diets supplemented with protease; EDHR: fed on the ED diets supplemented with protease and phytase; SEM: standard error of the means. Means followed by different letters in the same row are different (\(p < .05\)).
During 24–42 days, supplementation of protease in combination with phytase enhanced feed intake compared with T1 and T4 groups \( (p<0.05) \) while T3 and T2 were intermediate. Body weight gain increased in broilers fed with all experimental diets compared with control group (T1) during starter and grower periods \( (p<0.05) \). At the end of the study (42 d), body weight gain of the T5 broilers was greater than those of the T1 birds \( (p<0.05) \) and the other groups were intermediate. Feed conversion ratio improved in broiler chickens which received all experimental diets compared with basal diet (T1) during starter and grower periods \( (p<0.05) \). At 25–42 d, feed conversion ratio was better in T5 treatment than T1 and T2 groups \( (p<0.05) \) while T3 and T4 groups were intermediate. During the whole of the study (1–42 d), feed conversion ratio improved in broilers fed with T3, T4 and T5 groups compared with T1 group \( (p<0.05) \).

In carcass traits (Table 4), a higher relative weight of liver and thigh was found in T2and T5 groups compared with T1 group \( (p<0.05) \). The relative weight of breast increased in broiler chickens which received T5 diet compared with other groups \( (p<0.05) \). The percentage of abdominal fat was lower in birds fed with T3 and T5 diets compared with control group \( (p<0.05) \).

The results of jejunal morphometric indices are summarised in Table 5. A decrease in VL was found in broilers which received control (T1) diet compared to other groups \( (p<0.05) \). Meanwhile, the greatest value CD, and VSA observed in the birds fed with T4 diet compared with control group \( (p<0.05) \). Phytase supplemented group (T3) had a greater value for the ratio of VL to CD compared with control \( (p<0.05) \).

In microbial population (Table 6), an increased total count of bacteria was observed in broilers fed with all experimental diets compared with T1 diet \( (p<0.05) \).
These results agree with those reported by Mamputu and Buhr (1995) who observed that incorporating sesame meal in the diets at level greater than 30% of the diet significantly decreased growth performance of broilers. Similarly, a decrease in growth parameters has been found in ducks fed with diets containing sesame meal up to 15% of the diet (Ravindran and Blair 1992). Therefore, in the present experiment a level of 15% sesame meal replaced to soybean meal has been used to overcome these undesired impacts. The beneficial effects of phytase supplementation on growth performance of broiler chickens have been well elucidated (Selle et al. 2009; Roofchaei et al. 2019; Walters et al. 2019). According to Selle et al. (2009), phytase enzyme improves intestinal health, nutrient digestibility and bioavailability of amino acids and minerals such as calcium or phosphorus in the poultry. In a study, inclusion of phytase enzyme to sesame meal-based diets improved growth performance of Japanese quails (Rezaeipour et al. 2016). Overall, the specific benefits of phytase supplementation in broilers diets may vary between studies, according to the levels of phytate complex (Selle et al. 2009). The range of endogenous proteases produced and secreted in the duodenum is commonly considered to be sufficient to optimise feed protein digestion and absorption (Angel et al. 2011). However, valuable amounts of undigested protein such as phytate-protein pass from the intestinal tract without being completely digested (Lemme et al. 2004). Besides, several studies on the beneficial effects of supplemental proteases in broiler diets have been recently published (Cowieson et al. 2017, 2018). On the other hand, Walk et al. (2019) observed no influence on growth performance of broiler chickens with the addition of a protease supplementation. These inconsistent effects may be due to the type of proteases tested, as well as in experimental design.

The addition of phytase enzyme supplementation in sesame meal diets increased VL to CD ratio of the jejumum in broiler chickens. VL to CD ratio is a desirable indicator for efficiency of nutrients digestibility and absorption capacity in the gastrointestinal tract (Kolbadinejad and Rezaeipour 2020). It has been reported that the jejumum segment is the main site of nutrient absorption in the gut region, and increasing in the ratio of VL to CD may represent an attempt to improve intestinal capacity to maximise function (Hazzrati et al. 2019). The positive influence of dietary phytase on the intestinal morphology of broiler chickens has been extensively (Wu et al. 2004; Smulikowska et al. 2010; Zaeefarian et al. 2013; Hezaveh et al. 2020). The mode of action of dietary phytase on the intestinal morphological variables has not been well understood. However, this functional mechanism of phytase may be due to the alteration of the gut microbial population. According to Borda-Molina et al. (2019), inclusion of dietary phytase can decrease the colonisation of pathogenic bacteria such as E. coli by possible decreasing the quantity of available substrates for their proliferation. This positive impact of phytase on the gut microbiota activity decreases the damage to the gut mucosa and subsequently improves the intestinal morphological parameters in broiler chickens. In the present study, protease supplement have also been observed to increase VSA in broiler chickens. In parallel with our results, it has been reported that dietary exogenous proteases improved gut morphological variables in broiler chickens (Ding et al. 2016; Xu et al. 2017). However, no data are available on the mechanism of action of protease supplementation in diets on the gut morphology in broiler chickens. Therefore, more studies are needed to explain the exact mechanism that mediates these protease influences.

In the present study, the use of dietary protease in combination with phytase supplement in sesame meal-based diets resulted in a decrease of E. coli enumeration and an increase in Lactobacillus population, respectively. Several studies reported the effects of phytase enzyme on the intestinal microbial enumeration in broiler chickens (Aydin et al. 2010; Borda-Molina et al. 2016). According to the previous studies, these effects may be attributed to the increased phosphorus and calcium releasing from phytic acid complex in the diets (Ptak et al. 2015), resulting in reduced intestinal pH and consequent alteration in the microbial colonisation (Walk et al. 2012). In addition, it has been found that inclusion of exogenous protease affected the intestinal microbial composition of broiler chickens (Borda-Molina et al. 2018). In accordance with these results, Cowieson et al. (2018)
reported that dietary exogenous protease may have an antibacterial effect in the gastrointestinal tract. The mechanism of action of dietary protease on the intestinal bacteria of poultry can be due to the increased protein digestibility and subsequent amino acids bioavailability in the digestive tract which may affect the bacterial population (Borda-Molina et al. 2019). However, more studies are needed to better understand the influence of dietary protease supplements on the change of gut microbiota activity in broiler chickens.

In nutrient digestibility, feeding dietary protease in combination with phytase increased ileal digestibility coefficient of crude protein, calcium and phosphorus in broilers. These results are consistent with the findings of Olukosi et al. (2007) who indicated that dietary protease, individually or in combination with phytase supplementation, increased nutrient digestibility of broiler chickens which received nutritionally marginal corn-soybean meal-based diets. Enhanced protein digestibility coefficients were observed in broilers fed diets containing exogenous protease or phytase enzymes (Murugesan et al. 2014; Borda-Molina et al. 2019). In addition, the positive influence of phytase on the bioavailability of protein, calcium and phosphorus in broilers has been well accepted (Ravindran et al. 2000). It has been reported that chemical composition of sesame meal composed of 1.32% phytic acid which reduce minerals and protein availability in broilers (Hajimohammadi et al. 2020a). Therefore, the effectiveness of phytase supplementation on increasing nutrient digestibility in the broiler diets containing sesame meal was expected. Besides, it has been explained that protease enzyme may neutralise anti-nutritive factors such as protease inhibitors and thus could account for its positive effect on protein digestibility (Borda-Molina et al. 2019). In the present study, increased growth performance may be partially attributed to increased crude protein digestibility.

Conclusion

Based on the results of this study, it can be concluded that the addition of protease and phytase, individually or in combination, increased growth performance and some carcass traits in broilers fed with sesame meal diets. Besides, inclusion of phytase alone or in combination with protease supplement in sesame meal diets had beneficial effects on the jejunal morphometric indices and intestinal microbiota activity of broiler chickens.

Disclosure statement

The authors declare that they have no conflicts of interest.

Animal welfare statement

All animal protocols for this study were approved by the Animal Care and Use Committee at the Qaemshahr Branch, Islamic Azad University (Qaemshahr, Iran).

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Data availability statement

All data generated and analysed during this study are included in this published article.

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