# Effect of moringa leaf powder and agave inulin on performance, intestinal morphology, and meat yield of broiler chickens

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**ABSTRACT** The addition prebiotics in broiler diets can benefit digestion and nutrient abortion. The objective of the present study was to evaluate the effects of moringa leaf powder and agave inulin on growth performance, intestinal morphology, and slaughter traits of broiler chickens over 40 d of grow-out. A total of 280 broilers (Ross 308) aged 1 d were randomly allocated to 4 treatments, with 7 replicates each and 10 chicks per replicate: T1 = control diet, T2 = control diet with 15 g/kg of moringa leaf powder, T3 = control diet with 15 g/kg of agave inulin, and T4 = control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin. The results showed that analysis of treatments at time were not different ($P > 0.05$) for broiler weights, feed and water intake, and weight gain. Treatment was significant ($P < 0.05$) for feed efficiency at 22 to 40 d; the T4 group presented higher ($P < 0.05$) values, and the T1 group presented lower ($P < 0.05$) values. However, the villus lengths of intestinal sections were different ($P < 0.05$) among treatments. In the duodenum, jejunum, and ileum, villus lengths were highest ($P < 0.05$) in the T2 group and lowest ($P < 0.05$) in the T3 and T4 groups. Villus widths in the duodenum and ileum were highest ($P < 0.05$) in the T2 group, but the T1 group showed highest ($P < 0.05$) values in the jejunum sections. The T3 and T4 groups showed lowest ($P < 0.05$) values in villus width in the duodenum, jejunum, and ileum. Thigh yield was highest ($P < 0.05$) in the T2 group and lowest ($P < 0.05$) in the T4 group. The T1 group exhibited the highest ($P < 0.05$) piece yields for leg, wing, and hip-back. The T4 group showed lowest ($P < 0.05$) leg and wing yields. Moringa leaf powder and agave inulin at a concentration of 15 g/kg in diets did not affect broiler performance, whereas moringa leaf powder improved intestinal morphology and thigh yield, and agave inulin improved leg yield. The results demonstrated benefits of these 2 feed additives to improve intestine health and meat yield in broilers over a 40-day grow-out.

**Key words:** productivity, slaughter variable, villus, carcass trait

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## INTRODUCTION

Poultry studies have used biochemical applications and physiological mechanisms to improve broiler productivity and carcass traits. Recently, broiler grow-out studies have evaluated effects of natural, antibiotic alternatives on performance and productivity of broiler chickens. Some of these natural, antibiotic alternatives as feed supplements have been in the form of aromatic plants, essential oils, probiotics, and phytobiotics such as *Moringa oleifera* (common names, moringa and drumstick tree) (Gopalakrishnan et al., 2016) and prebiotics such as agave inulin (Sánchez-Zamora et al., 2019).

Leaves of the moringa tree have been extensively studied for its effects on growth performance of broiler chicks (Olugbemi et al., 2010; Gadzirayi et al., 2012; Qwele et al., 2013; Tesfaye et al., 2013; Wapi et al., 2013; Gakuya et al., 2014; Paguia et al., 2014; Nkukwana et al., 2014a,b; Nkukwana et al., 2015; Sebola et al., 2015). Particularly, Tesfaye et al. (2013) indicated that broilers fed with 20% of moringa meal (5 mm in size) in the diet showed improvements in feed efficiency, while Nkukwana et al. (2014a,b) observed that 5, 10, and



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15% of dietary moringa improved BW at 7 d. Those authors concluded that moringa could be a phytobiotic alternative in diets of broilers to improve growth performance and feed efficiency.

In contrast, studies with inulin, such as fructans derived from chicory, when applied as a prebiotic, showed several enhanced effects on food animal productivity. Huang et al. (2015) showed that effects of inulin on poultry production could be influenced by product characteristics, supplementation levels in the diet, diet composition, animal traits and production hygiene. One source for inulin is a derivate of *Agave tequilana* (agave inulin), which is a cultivar of Mexican agriculture used for tequila production (Ruiz-Corral et al., 2002; Praznik et al., 2013). Agave inulin is a source of pure fructans and fructo-oligosaccharides (Bucław, 2016). Sánchez-Zamora et al. (2019) demonstrated with 5 g/kg of agave inulin that this prebiotic, as a broiler feed additive, enhanced performance, carcass traits, and meat quality.

The chemical structures and bioactive activities of moringa and inulin, as well as results obtained from their use in poultry studies, could indicate that these phytobiotics combined in broiler diets could show improvement in grow-out, small intestine traits, and meat production. The aim of the present study was to evaluate the effect of moringa leaf powder and agave inulin supplementation on growth performance, intestinal morphology, and carcass slaughter traits of broiler chickens.

## MATERIALS AND METHODS

The experiment was conducted on the Marin Experimental Farm, Facultad de Agronomía, Universidad Autónoma de Nuevo León, Marin, Nuevo León, México, located between 200 and 1,500 m, 25° 45′ and 26° 2′ N and 99° 48′ 100° 6′ W (INEGI, 2020). The broiler grow-out house consisted of 90 $m^2$ in which 1-day-old broiler chicks were allocated into floor pens (1.2 × 1.2 × 0.8 m) with fresh wood shaving litter.

### Experimental Design

A total of two hundred eighty 1-day-old unsexed Ross 308 broilers were randomly allocated to 28 pens and into 4 experimental groups (7 pens per treatment with 10 birds each). The treatments including moringa (*M. oleifera*) leaf powder and agave (*A. tequilana*) inulin: T1 = control diet, T2 = control diet with 15 g/kg of moringa leaf powder, T3 = control diet with 15 g/kg of agave inulin, and T4 = control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

The feeding program was starter (1–21 d) and finisher (22–40 d) feeds (Table 1). Feed and water were provided *ad libitum*. Moringa leaf powder and agave inulin were placed in a vertical mill (Maquinaria Para Moliendas y Mezclas, S.A. de C.V., Iztacalco, CDMX, México) and thoroughly mixed with the feed minor ingredients to be added to the mixer containing maize and soy. The management of birds were carried out as per the Mexican Standards of Animal Use (NOM-062-ZOO, 1999); husbandry practices and diet formulations were as per those of Cázares-Gallegos et al. (2019), Hernández-Coronado et al. (2019), and Sánchez-Zamora et al. (2019). The experiment was approved by the local Animal Care and Welfare Committee of the Universidad Autónoma de Nuevo León.

**Table 1.** Ingredients in broilers' starter and finisher diets.

| | Diets[1] | |
|---|---|---|
| Ingredients (g/kg) | Starter (0–21 d) | Finisher (22–40 d) |
| Corn | 467.2 | 556.4 |
| Soybean (48% CP) | 392.2 | 312.9 |
| Corn gluten | 53.3 | 44.4 |
| Vitamins and mineral premix[2] | 11.7 | 13.3 |
| Calcium carbonate | 14.4 | 21.4 |
| Dicalcium phosphate | 21.3 | 22.2 |
| Sodium chloride | 6.0 | 6.4 |
| DL-Methionine | 1.9 | 0.8 |
| Canola oil[3] | 32.0 | 22.2 |

[1]Diets were formulated based on the nutrient requirements for broilers as recommended by the NRC (1994).

[2]Vitamin and mineral premix provided from Agronutrientes del Norte S.A. de C.V.: chelated mineral concentrate (Ca, B, Zn, Mg, Mn), monocalcium orthophosphate, sodium chloride, calcium carbonate, manganese sulfate, magnesium sulfate, zinc sulfate, ferrous sulfate, copper sulfate, ethylenediamine dihydroiodide, biotin, folic acid, niacin, calcium D-pantothenate, DL-methionine, L-lysine hydrochloride, choline chloride, antioxidants, sodium bicarbonate, B-complex supplements (B1, B2, B6, B12), vitamin A supplement, vitamin D supplement, vitamin E supplement, vitamin K3, yellow pigment, red pigment, and natural flavorings.

[3]Canola oil was purchased from Industrial Patrona, S.A. de C.V. Córdoba, Veracruz, México.

The moringa leaves were obtained from moringa production trees cultivated in the Centro de Agricultura Protegida, Facultad de Agronomía, Universidad Autónoma de Nuevo León, General Escobedo, Nuevo Léon, México. The moringa leaf powder preparation was carried out according to Nkukwana et al. (2014a). Leaves were air-dried over 8 d and without exposure to direct sunlight. Dried leaves were ground to a fine powder using a horizontal mixer (Equipos Agropecuarios, S.A. de C.V., Monterrey, Nuevo Leon, México). The composition of moringa leaf powder (%, DM) was as follows: DM, 90.87 ± 1.29; moisture, 9.13 ± 1.30; ash, 8.57 ± 0.55; crude fiber, 18.43 ± 0.96; fat, 6.03 ± 0.15; CP, 25.97 ± 0.42; and carbohydrate, 41.03 ± 0.81. Agave inulin (Enature, VASERCO, S. de R.L. de C.V., Zapopan, Jalisco, México) was purchased from a commercial market, with a per 33-g composition of the following: moisture, 15 g; total carbohydrates, 2.82 g; sugars, 0.7 g; dietary fiber, 14.3 g; and sodium, 0.18 g.

### Performance Evaluation

Chick initial weights were measured at the beginning of the experiment. Broilers' body daily weight (**BDW**), ADFI, average daily water intake (**ADWI**), ADG, and feed conversion ratio (**FCR**) were determined as per equations of Cázares-Gallegos et al. (2019) and Hernández-Coronado et al. (2019). These variables were evaluated at 21 and 40 d. In addition, ADFI, ADWI, BDG, and FCR were evaluated for the overall period (1–40 d).

### Intestinal Morphology

At 40 d, the small intestines of 7 broiler chickens per treatment (n = 7; 1 chick per replicate per treatment) were randomly sampled during slaughter to evaluate intestinal morphology. The samples were prepared according to Bai et al. (2018) with slight modifications. Intestinal tissue (duodenum, jejunum, and ileum) sections at 1.0 cm in length were collected and fixed in 4% paraformaldehyde and then treated with a graded series of ethanol (70, 96, and 100%) to remove water. The tissues then were embedded in paraffin for mounting of 5-μm tissue sections onto slides. The mounted sections were deparaffinized using 100% xylene and rehydrated in graded dilutions of 100% xylene, 50% ethanol–50% xylene, 96% ethanol, 100% ethanol, and distilled water. The slides were stained with hematoxylin and eosin and observed using a microscope at magnification of 10× (Eclipse 50i Nikon Microscope; Melville, NY). A total of 10 slides were prepared and analyzed (n = 70 per treatment) per sample, and 3 observations were randomly taken per slide, using ImageJ software (ImageJ-1997 version 1.52a; NIH, Bethesda, Maryland). Villus measurements (μm) were determined using intact lamina and were based on length as measured from the villus apex to the villus crypt junction and width as measured across the base of the villus crypt (Nkukwana et al., 2015).

### Meat Yield

The slaughter protocol followed was as per the Official Mexican Standard (NOM-033-SAG/ZOO, 2014) and as reported by Cázares-Gallegos et al. (2019), Hernández-Coronado et al. (2019), and Sánchez-Zamora et al. (2019). A total of 5 chicks per pen (n = 35 per treatment) were randomly selected for slaughter by cervical dislocation. Slaughter weight (**SW**) and hot and cold carcass yields were calculated as reported by Hernández-Coronado et al. (2019) and Sánchez-Zamora et al. (2019). The carcasses were stored at 4°C for 12 h postmortem. Thirty-five carcasses per treatment were used to evaluate piece yields (Y) as described by Sánchez-Zamora et al. (2019) for breast meat yield (**BMY**), thigh yield (**TY**), leg yield (**LY**), wing yield (**WY**), and hip-back yield (**HBY**).

### Data Analysis

Broiler performance data ($y_{ijk}$) were analyzed using the General Linear Model procedure of Statistical Analysis System (PROC GLM; SAS Institute, 2006) considering in the statistical model the overall mean (μ), fixed effect of treatment ($T_i$; T1 to T4) for grow-out time (21 and 40 d), nested effect of treatment per pen for chicks over grow-out time ($\Phi_{k(ij)}$), initial weight as a covariate effect (λ), and random error ($_{ijk}$) with mean zero and variance [$_{ijk} \sim N(0, \sigma^2)$]. Total grow-out time (1–40 d), intestinal morphology variables, and slaughter and piece yields ($y_{ij}$) were analyzed with effects μ, $T_i$, λ, and $_{ij}$, respectively, using PROC GLM (SAS Institute, 2006). The null hypothesis ($H_0$) was tested to the significance level of 0.05. When probability values (*P*-values) in the variance analysis per response variable were lower than 0.05, $H_0$ was rejected and means were compared with the Tukey test to the 0.05 level, depending on the statistical model used per variables.

## RESULTS AND DISCUSSION

### Growth Performance

Broilers supplemented with moringa leaf powder and agave inulin did not show statistical effects ($P > 0.05$) at 40 d for BDW, ADFI, and ADWI (Table 2). Tako and Glahn (2012) demonstrated that chicory root inulin at 4% (40 g/kg) in diet did not affect weight in broilers. In contrast, Sánchez-Zamora et al. (2019) found effects on BW and feed intake using 5 and 10 g/kg of agave inulin, obtaining low values of 1.74 and 1.78 kg, respectively, for BW and high values of 5.63 and 5.44 kg, respectively, for feed intake with respect to the control group. Nkukwana et al. (2014b) indicated that low moringa leaf powder levels in the diet contributed low levels of antinutritive factors (tannins, saponins, and phytates) and had limited, if any, effects on broiler growth performance; those authors did not find effect on feed intake at 7 and 21 d with high (15 and 25 g/kg of diet) concentrations of moringa. In the present study, no effect was seen on growth performance, which could be due to low antinutritive factors in moringa, as well as supplementation levels and oligosaccharide compositions (Hai-qing et al., 2015), diet type, animal traits, and production site hygiene (Tako and Glahn, 2012; Hai-qing et al., 2015).

Numerically ($P > 0.05$), BDW was highest in the T4 (15 g/kg of moringa leaf powder and 15 g/kg of agave inulin) group in the period of 1 to 21 d, and the T1 (control diet) group showed highest values in the period of 22 to 40 d (Table 2). Treatments T1 and T4 resulted in the highest ($P < 0.05$) ADFI at 22 to 40 d. The T2 (15 g/kg of moringa leaf powder) and T4 groups showed similar ($P > 0.05$) values for BDW, and the T3 group showed lower ($P > 0.05$) values at both periods. Average daily water intake was high ($P > 0.05$) in the T4 group and low ($P > 0.05$) in the T1 group over the production period. These results indicated that 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin (T4) in broilers' diet did not improve growth performance. These results can be explained due to moringa leaves having high levels of phenolic and antioxidant compounds (Falowo et al., 2018). Importantly, high levels of dietary phenolic components may have negative effects on intestinal digestive enzymes and protein digestibility (Brenes et al., 2008); hence, these compounds may

**Table 2.** Growth performance over grow-out of broilers supplemented with moringa leaf powder and agave inulin.

| Variables | Days | Treatments[1] T1 | T2 | T3 | T4 | SEM | $P$-values |
|---|---|---|---|---|---|---|---|
| BDW (g) | 1 | 42.36 | 42.64 | 41.43 | 41.57 | 0.35 | - |
| | 1 to 21 | 26.87 | 27.37 | 25.37 | 29.65 | 1.59 | 0.284 |
| | 22 to 40 | 96.70 | 93.34 | 89.11 | 91.61 | 3.17 | 0.439 |
| | 1 to 40 | 45.89 | 44.33 | 42.30 | 43.52 | 1.51 | 0.445 |
| ADFI (g) | 1 to 21 | 44.34 | 43.04 | 41.69 | 39.91 | 1.60 | 0.296 |
| | 22 to 40 | 159.61 | 152.09 | 158.81 | 166.77 | 6.58 | 0.510 |
| | 1 to 40 | 99.01 | 94.90 | 97.31 | 100.08 | 3.69 | 0.771 |
| ADWI (mL) | 1 to 21 | 87.59 | 90.41 | 93.06 | 88.88 | 4.40 | 0.829 |
| | 22 to 40 | 281.10 | 294.10 | 293.10 | 322.20 | 12.98 | 0.173 |
| | 1 to 40 | 179.46 | 187.13 | 188.10 | 199.69 | 7.67 | 0.342 |

Values in rows are means (n = 7) per treatment per day.

Abbreviations: ADWI, average daily water intake; BDW, body daily weight.

[1]T1: control diet; T2: control diet with 15 g/kg of moringa leaf powder; T3: control diet with 15 g/kg of agave inulin; T4: control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

form complexes with dietary proteins when the hydroxyl groups interact with protein carbonyl groups, thus decreasing digestibility. This effect could inhibit the functionality of agave inulin as the prebiotic when digestive enzymes are affected owing to phenolic compounds of moringa.

A study with chicory root inulin at a concentration of 5, 10, 15, and 20 g/kg in the diet carried out by Alzueta et al. (2010) did not find effects on broilers growth performance. In contrast, Huang et al. (2015) saw low feed intake at 1 to 21 d with 15 g/kg of chicory root inulin. Peinado et al. (2013) obtained similar BW at 1–21 d with 20 g/kg of chicory root inulin with respect to the present study. In contrast, Nkukwana et al. (2014a,b) presented higher BW at a concentration of 25 g/kg, whereas in the present study, BDW was high for 15 g/kg of moringa leaf powder (T2). Moringa meal at 5% (50 g/kg) in the broiler diet, in a study by Tesfaye et al. (2013), did not improve feed intake; similarly, this result was obtained for the T2 group (15 g/kg of moringa), but moringa leaf powder combined with agave inulin increased ADFI. These contrasting results to those from the present study (moringa leaf powder and agave inulin) could be due to additive composition and sources.

## Production Efficiency

Table 3 shows broiler production efficiency after supplementation with moringa leaf powder and agave inulin for 40 d. ADG was not statistically different ($P > 0.05$) between treatments for all periods. Over 22 to 40 d, FCR had statistical difference ($P < 0.05$); the T4 group showed the worst ($P < 0.05$) FCR, and the T1 and T2 group showed the best ($P < 0.05$) FCR. For the overall period (1–40 d), FCR was similar ($P > 0.05$) between treatments. Moringa meal (2 mm in size) at a concentration of 25, 50, and 100 g/kg influenced feed efficiency owing to it being a source of protein, fiber, and minerals (Sebola et al., 2015). In another study, an effect on feed efficiency in broilers supplemented with 3% of moringa meal was found, and the authors suggested that plant bioactive compounds increased broiler digestive fluids and improved the immune system (Nkukwana et al., 2015). In contrast, Sánchez-Zamora et al. (2019) did not find effects on BW and efficiency when broilers were supplemented with 5 and 10 g/kg of agave inulin. The present study showed that 15 g/kg of agave inulin and moringa leaf powder (T4) did not improve FCR. Rebolé et al. (2010) did not obtain effects on BWG and efficiency with 10 and

**Table 3.** Productivity efficiency at 40 d for broilers supplemented with moringa leaf powder and agave inulin.

| Variables | Days | Treatments[1] T1 | T2 | T3 | T4 | SEM | $P$-values |
|---|---|---|---|---|---|---|---|
| ADG (g) | 1 to 21 | 24.87 | 25.37 | 23.37 | 27.65 | 1.59 | 0.284 |
| | 22 to 40 | 67.01 | 63.09 | 61.07 | 58.84 | 3.04 | 0.320 |
| | 1 to 40 | 44.84 | 43.28 | 41.25 | 42.47 | 1.51 | 0.445 |
| FCR | 1 to 21 | 1.79 | 1.70 | 1.83 | 1.51 | 0.12 | 0.228 |
| | 22 to 40 | 2.40[b] | 2.42[b] | 2.60[a,b] | 2.87[a] | 0.11 | 0.021 |
| | 1 to 40 | 2.10 | 2.06 | 2.21 | 2.22 | 0.10 | 0.649 |

[a,b]Means (n = 7 per treatment) in rows with different superscripts are different significantly ($P < 0.05$).

Abbreviation: FCR, feed conversion ratio.

[1]T1: control diet; T2: control diet with 15 g/kg of moringa leaf powder; T3: control diet with 15 g/kg of agave inulin; T4: control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

20 g/kg of chicory inulin, and that study showed that inulin had a stimulant effect on *Bifidobacteria* and *Lactobacillus* numbers in the gastrointestinal tract of broiler chickens. In the present study, the combination of moringa leaf powder and agave inulin did not improve broiler production during grow-out.

## Small Intestine Morphology

The effects of moringa leaf powder and agave inulin on small intestine morphology of broilers are shown in Table 4 and Figure 1. Villus traits of intestinal sections were different ($P < 0.05$) based on treatments. In the duodenum, jejunum, and ileum, villus lengths were highest ($P < 0.05$) in the T2 group (15 g/kg of moringa leaf powder), while the lowest values ($P < 0.05$) were observed in the T3 (15 g/kg of agave inulin) and T4 (15 g/kg of moringa leaf powder and 15 g/kg of agave inulin) groups. Villus widths of the duodenum and ileum sections were higher ($P < 0.05$) in the T2 group, but were higher ($P < 0.05$) in the T1 group in jejunum sections. The T3 and T4 groups showed lower ($P < 0.05$) values for villus widths in the duodenum, jejunum, and ileum. The small intestine contributes to nutrient absorption and digestion with breakdown of feed by the duodenum, absorption of nutrients by the jejunum, and fermentation and subsequent absorption of fermentation products by the ileum (Jiang et al., 2020). In the results from the present study, the agave inulin alone and in combination with moringa leaf powder in the diet presented a lower effect on villus traits; however, dietary moringa leaf powder alone improved villus traits in the duodenum, jejunum, and ileum. Similarly, Nkukwana et al. (2015) observed increased villus traits in these 3 sections when evaluating at 1, 3, and 5% (10, 30, and 50 g/kg) of moringa meal. Furthermore, Khan et al. (2017) found improvements in intestinal sections at 1.2% (12 g/kg) of moringa powder. As an increase in the weight and length of the small intestine is coupled with an increase in villus length in the duodenum, jejunum, and ileum (Khan et al., 2017), we suggest that moringa leaf powder at a concentration of 15 g/kg improves the absorption of nutrients because it presented the highest small intestine traits and, as a consequence, improved digestibility. In contrast, 1% (10 g/kg) of dietary chicory inulin resulted in longer jejunal villi at 5 wk (Rehman et al., 2007), as well as 20 g/kg of chicory inulin, with respect to the control group (Rebolé et al., 2010). Furthermore, Awad et al. (2011) found decreased villus length and width in the jejunum and ileum, which was similar to the results observed in the present study. Rebolé et al. (2010) did not find effects on jejunum villus length with 10 and 20 g/kg of chicory inulin, which contrasted with our results of decreases in intestinal section dimensions; these results can be related to a shortening of the villi and deeper crypts (Awad et al., 2011).

## Slaughter Variables and Meat Yields

Analyses of slaughter variables of broilers did not reveal statistical differences ($P > 0.05$) for SW, hot carcass yield, cold carcass yield, and BMY (Table 5). Qwele et al. (2013) studied effects of dietary blends of 5% (50 g/kg) of whole dried moringa leaves without finding differences in SW. In the present study, TY, LY, WY, and HBY exhibited significant effect ($P < 0.05$). Thigh yield was highest in the T2 group and lowest in the T4 group. Leg yield, WY, and HBY were higher in the T1 group. Leg yield and WY were lower in the T4 group, while the T3 group showed the relatively lowest value for HBY, although statistically similar to that of the T2 and T4 groups. These results are in agreement with those of Tesfaye et al. (2013) who observed improvements in SW, BMY, TY, and HBY at 5, 10, 15, and 20% (50, 100, 150, and 200 g/kg) of moringa meal added to the basal diet. Similarly, Sánchez-Zamora et al. (2019) using agave inulin at a concentration of 5 and 10 g/kg observed effects on WY. Moringa leaf powder at a concentration of 5, 15, and 25 g/kg of diet improved carcass weight and TY, which indicated that the natural extract improved muscular proportion (Nkukwana et al., 2014a). In agreement with our results, Swiatkiewicz et al. (2011) did not observe differences in carcass and breast yields at a concentration of 7 g/kg of chicory inulin and oligofructose.

**Table 4.** Effect of moringa leaf powder and agave inulin on small intestine villus morphology of broiler chickens at 40 d.

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Intestinal section villi (μm) | T1 | T2 | T3 | T4 | SEM | *P*-values |
| Duodenum | | | | | | |
| Length | 617.50$^{b}$ | 1,058.90$^{a}$ | 449.51$^{c}$ | 445.94$^{c}$ | 11.18 | 0.001 |
| Width | 54.58$^{b}$ | 74.61$^{a}$ | 37.60$^{c}$ | 34.82$^{c}$ | 1.07 | 0.001 |
| Jejunum | | | | | | |
| Length | 1,181.30$^{b}$ | 1,242.30$^{a}$ | 467.20$^{d}$ | 536.40$^{c}$ | 13.17 | 0.001 |
| Width | 78.02$^{a}$ | 71.09$^{b}$ | 36.82$^{c}$ | 37.45$^{c}$ | 1.26 | 0.001 |
| Ileum | | | | | | |
| Length | 663.90$^{b}$ | 1,186.90$^{a}$ | 365.50$^{d}$ | 480.86$^{c}$ | 12.60 | 0.001 |
| Width | 61.37$^{b}$ | 73.42$^{a}$ | 34.05$^{c}$ | 36.12$^{c}$ | 1.02 | 0.001 |

[a-c]Means (n = 70 per treatment) in rows with different superscripts are different significantly ($P < 0.05$).

[1]T1: control diet; T2: control diet with 15 g/kg of moringa leaf powder; T3: control diet with 15 g/kg of agave inulin; T4: control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

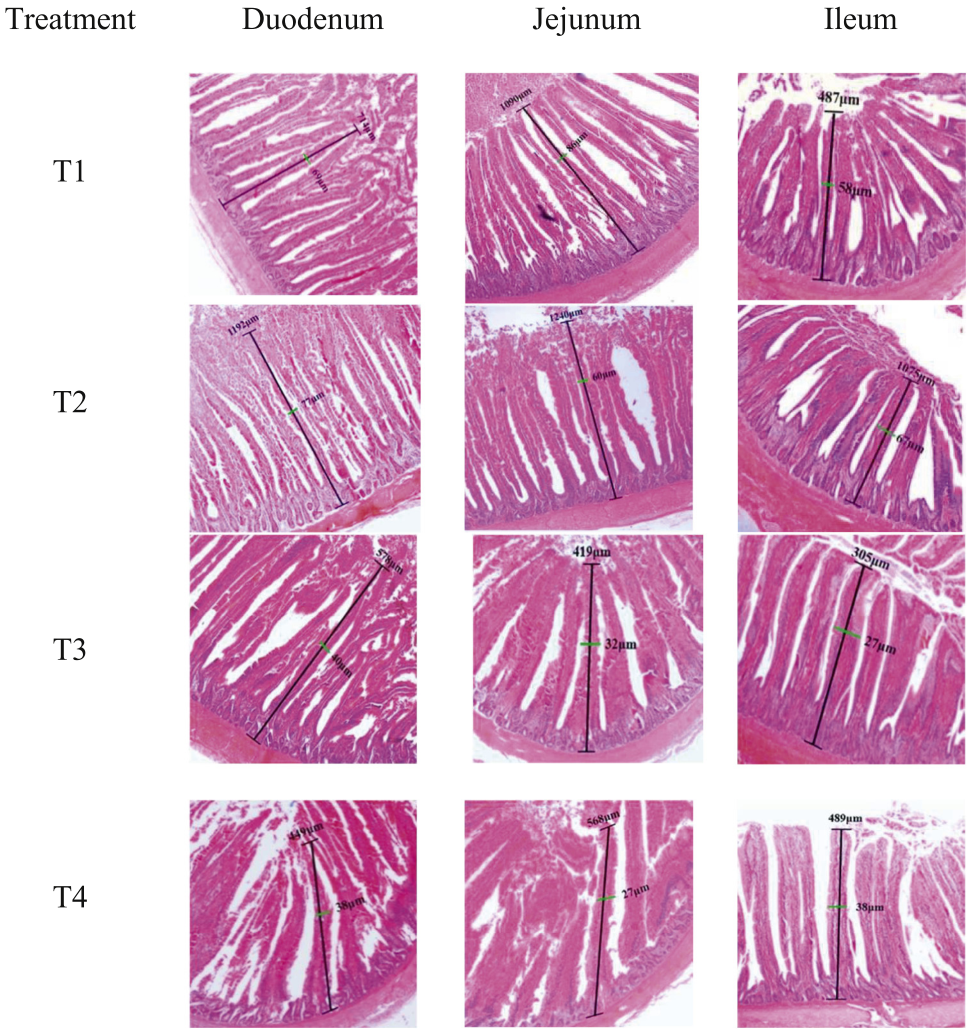


**Figure 1.** Small intestine villus morphology (magnification of 10×) of broilers at 40 d of age and supplemented with moringa leaf powder and agave inulin. T1 = control diet; T2 = control diet with 15 g/kg of moringa leaf powder; T3 = control diet with 15 g/kg of agave inulin; T4 = control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

## CONCLUSIONS

The addition of moringa (*M. oleifera*) leaf powder and agave (*A. tequilana*) inulin at a concentration of 15 g/kg in diets of broilers was not observed to have effects on broiler weights, feed intake, water intake, and weight gain, but moringa leaf powder improved feed efficiency at 40 d. Moringa leaf powder and agave inulin did not

**Table 5.** Slaughter variables at 40 d for broiler fed with diets containing moringa leaf powder and agave inulin.

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Variables (%) | T1 | T2 | T3 | T4 | SEM | *P*-values |
| SW | 1.89 | 1.91 | 1.94 | 1.91 | 0.05 | 0.891 |
| HCY | 71.59 | 72.50 | 71.51 | 72.04 | 0.58 | 0.601 |
| CCY | 70.65 | 70.47 | 70.54 | 70.68 | 0.46 | 0.986 |
| BMY | 35.11 | 35.58 | 35.45 | 35.03 | 0.34 | 0.616 |
| TY | $16.77^{a,b}$ | $17.11^{a}$ | $16.84^{a,b}$ | $16.45^{b}$ | 0.17 | 0.050 |
| LY | $15.48^{a}$ | $15.03^{a,b}$ | $15.18^{a}$ | $14.55^{b}$ | 0.16 | 0.001 |
| WY | $11.67^{a}$ | $11.25^{bc}$ | $10.95^{b,c}$ | $10.70^{c}$ | 0.12 | <0.001 |
| HBY | $20.12^{a}$ | $18.76^{b}$ | $18.64^{b}$ | $19.22^{b}$ | 0.18 | <0.001 |

[a-c]Means (n = 35 per treatment) in rows with different superscript are different significantly ($P < 0.05$).

Abbreviations: BMY, breast meat yield; CCY, cold carcass yield; HBY, hip-back yield; HCY, hot carcass yield; LY, leg yield; SW, slaughter weight; TY, thigh yield; WY, wing yield.

[1]T1: control diet; T2: control diet with 15 g/kg of moringa leaf powder; T3: control diet with 15 g/kg of agave inulin; T4: control diet with 15 g/kg of moringa leaf powder and 15 g/kg of agave inulin.

affect SW and carcass yields. Moringa leaf powder increased TY and agave inulin improved LY. The results of intestinal morphology improved at the concentration of 15 g/kg of moringa leaf powder in diets. The results observed in the present study demonstrated improvements in slaughter piece yields and suggest further study with higher levels of moringa leaf powder and agave inulin and potential effects on meat production and small intestine morphology.

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## DISCLOSURES

The authors declare they have no conflict of interest.

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