ISSN 1682-8356
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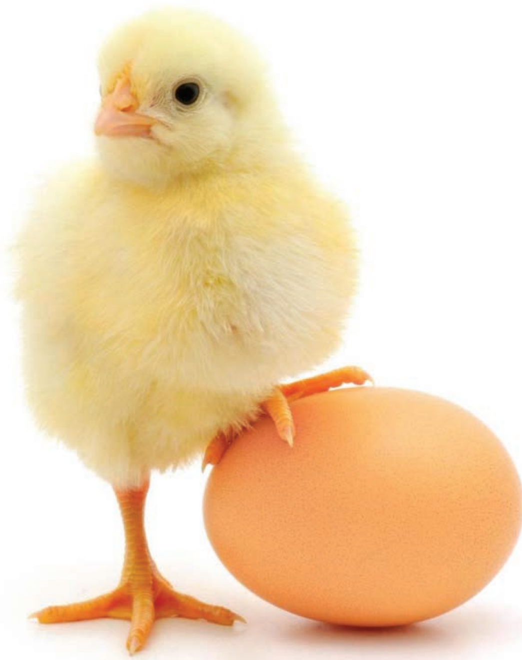

# INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2020.372.379

Research Article

# Effects of Inclusion Levels of Discarded Corn Grain on Growth Performance, Edible Portions and Economic Response in Broilers

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## Abstract

**Background and Objective:** The challenge for nutritionists is to formulate diets with available alternative sources to reduce production costs, without depressing animal performance. The objective of this study was to evaluate the effects of inclusion levels of discarded corn grain on growth performance, edible portions and economic response in broilers. **Materials and Methods:** A total of 1,200 one-day-old Ross 308® broilers were distributed in a completely randomized design with four treatments and six replications. Diets with inclusion levels of 0, 100, 200 and 300 g kg$^{-1}$ of discarded corn grain were formulated. **Results:** Throughout the experimental stage, the inclusion level of 300 g kg$^{-1}$ of discarded corn grain improved body weight and feed conversion ratio (starter and grower), without affecting feed intake (except 0-32 days). Likewise, this inclusion level (300 g kg$^{-1}$) improved the viability in the grower phase compared to the control. Dietary use of discarded corn grain did not change ($p<0.05$) the relative weight of the carcass, leg, liver and heart, however, the inclusion of 200 g kg$^{-1}$ of discarded corn grain improved the relative weight of the breast and 300 g kg$^{-1}$ increased the relative weight of abdominal fat and gizzard. Likewise, a higher inclusion of discarded corn grain in broiler diets decreased the feed cost, the cost to produce one kg of body weight, carcass and breast. **Conclusion:** The inclusion level of 300 g kg$^{-1}$ of discarded corn grain in broiler diets promoted a better productive and economic response; however, the inclusion of 200 g kg$^{-1}$ improved the breast yield, without affecting the other edible portions.

Key words: Broiler, discard cereal, productive behavior, carcass, economic response, edible portions

Citation: Elmer Modesto Elvir, Andrés Sebastian Vega, Yordan Martínez, Manuel Valdivié and Roman Rodríguez, 2020. Effects of inclusion levels of discarded corn grain on growth performance, edible portions and economic response in broilers. Int. J. Poult. Sci., 19: 372-379.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The production of chicken meat increases rapidly worldwide due to higher slaughter weight in a shorter time, high feed efficiency and the price of chicken meat compared to other meats[1]. However, the use of conventional raw materials, mainly corn, becomes challenging because it increases the demand to produce biofuels[2]. It is estimated that for the production of balanced feed, the poultry industry requires around 900 thousand tons of corn per year[2], thus the high prices of imported corn substantially increase the cost of production[3].

Also, feed cost represents up to 70% of the total cost of production and corn could make up to 65% of diets for broilers[3]. One of the premises of poultry researchers and producers is to find economical, innovative and viable feed alternatives that assure the partial or total substitution of corn without affecting the growth performance and carcass traits of broilers[4]. The discard corn grain is seed proposed for sowing but failed to meet the standard quality due to broken seeds, with unwanted or contaminated sizes with some non-toxic material.

Thus, discarded corn grain is rich in protein and essential amino acids could use as an alternative feed for animal[5,6]. In this sense, Castilloand Delgado[5] and Viana[6] have reported that the use of discarded corn grain as a partial substitute for conventional corn did not depress the egg production and quality in laying hens (38-52 weeks) and batch uniformity in pullets (1-16 weeks). However, no studies reported the use of discarded corn grain as a partial substitute for imported yellow corn in broiler diets. Therefore, the objective of this study was to evaluate the effect of inclusion levels of discarded corn grain on growth performance, edible portions and economic response in broilers.

## MATERIALS AND METHODS

All the procedures adopted in carrying out this experiment were approved by the Pan-American Agricultural School, Zamorano, San Antonio de Oriente, Honduras and conducted in accordance with the Guidelines for Experimental Animals.

**Experimental location:** The study was conducted in June-July/2019 at the Poultry Research and Training Center of the Pan-American Agricultural School (Zamorano), located in Valle del Yegüare at 32 km of the Tegucigalpa road to Danlí. The place is 800 meters above sea level with an average temperature of 26°C.

**Experimental animals, treatments and diets:** A total of 1200 mixed chickens (male and female) from the Ross 308® one-day-old genetic line were randomly distributed in a completely randomized design with four treatments, six repetitions per treatment and 50 chickens per repetition. The experimental treatments consisted of a basal diet and dietary inclusion of100, 200 and 300 g kg$^{-1}$ of discarded corn grain.

The diets to supply the nutritional requirements of the genetic line under study in the starter (0-10 days), grower (11-24 days) and finisher (25-32 days) phases were formulated. For the formulation of the diets, the chemical composition of imported yellow corn and discarded corn grain reported by the food analysis laboratory of the Pan-American Agricultural School (LAAZ) Zamorano was taken into account (Table 1). The experimental diets are shown in Table 2-4.

**Experimental conditions:** Each repetition consisted of a pen with a wood chip bed and 11 birds m$^{-2}$. Feed and water were offered *ad libitum* in hopper feeders and nipple waterers, respectively. The temperature and ventilation inside the house were controlled by gas brooders, curtain and fans. The ship was disinfected according to environmental quality standards. No medications or therapeutic veterinary care were used throughout the experimental stage. The birds against Marek and Smallpox (first day)were vaccinated.

**Growth performance:** In each experimental phase (starter, grower and finisher), the indicators of the growth performance

Table 1: Chemical composition of imported corn and discard corn

| | Content (g kg$^{-1}$) | |
|---|---|---|
| Chemical composition | Imported corn | Discard corn |
| Crude protein | 77.0 | 96.3 |
| Methionine | 1.6 | 2.0 |
| Cystine | 1.8 | 2.1 |
| Lysine | 2.5 | 2.5 |
| Threonine | 2.9 | 3.5 |
| Tryptophan | 0.6 | 0.7 |
| Arginine | 4.0 | 4.2 |
| Isoleucine | 2.6 | 3.3 |
| Leucine | 8.8 | 12.5 |
| Valine | 3.7 | 4.5 |
| Histidine | 2.3 | 2.8 |
| Phenylalanine | 3.6 | 4.9 |
| Glycine | 3.2 | 3.5 |
| Serine | 3.7 | 4.8 |
| Proline | 6.8 | 9.0 |
| Alanine | 5.5 | 7.5 |
| Aspartic acid | 5.1 | 6.2 |
| Glutamic acid | 13.4 | 18.5 |

Table 2: Ingredients and nutritional contributions of broilers (starter, 0-10 days)

| | Experimental diets (g kg$^{-1}$) | | | |
|---|---|---|---|---|
| Ingredients (g kg$^{-1}$) | Control | 100 | 200 | 300 |
| Cornmeal | 473.60 | 381.10 | 290.00 | 198.80 |
| Discarded corn grain | 0.00 | 100.00 | 200.00 | 300.00 |
| Soymeal | 396.70 | 394.00 | 389.20 | 384.40 |
| Mineral and vitamin premix[1] | 5.00 | 5.00 | 5.00 | 5.00 |
| Sodium chloride | 5.00 | 5.00 | 5.00 | 5.00 |
| African palm oil | 82.00 | 80.60 | 78.70 | 76.90 |
| Choline | 0.80 | 0.80 | 0.80 | 0.80 |
| DL-Methionine | 3.70 | 2.80 | 2.80 | 2.70 |
| L-Threonine | 1.00 | 0.90 | 0.80 | 0.70 |
| L-Lysine | 2.70 | 2.60 | 2.70 | 2.80 |
| Calcium carbonate | 11.00 | 9.00 | 7.20 | 5.50 |
| Biophos | 16.30 | 16.00 | 15.60 | 15.20 |
| Mycotoxin sequestrant | 1.20 | 1.20 | 1.20 | 1.20 |
| Enzymes | 0.50 | 0.50 | 0.50 | 0.50 |
| Coccidiostat | 0.50 | 0.50 | 0.50 | 0.50 |
| Diet cost, $/t | 457.20 | 430.61 | 407.49 | 379.26 |
| **Nutritional contributions** | | | | |
| Metabolizable energy (kcal kg$^{-1}$ DM) | 3000.00 | 3000.00 | 3000.00 | 3000.00 |
| Crude protein | 234.00 | 234.00 | 234.0 | 234.00 |
| Crude fiber | 25.40 | 26.50 | 27.5 | 28.50 |
| Crude fat | 110.30 | 109.70 | 108.5 | 107.40 |
| Ca | 9.60 | 9.60 | 9.60 | 9.60 |
| P available | 4.90 | 4.90 | 4.90 | 4.90 |
| Methionine+cystine | 9.50 | 9.50 | 9.50 | 9.50 |
| Threonine | 7.00 | 7.00 | 7.00 | 7.00 |
| Valine | 9.10 | 9.10 | 9.00 | 9.00 |
| Isoleucine | 8.00 | 8.00 | 8.00 | 8.00 |
| Lysine | 12.80 | 12.80 | 12.80 | 12.80 |
| Arginine | 13.00 | 12.90 | 12.80 | 12.70 |
| Tryptophan | 3.70 | 3.90 | 4.00 | 4.20 |

[1]Each 2.5 kg contains; Vitamin A: 12,000,000 IU, Vitamin D3: 2,500,000 IU, Vitamin E: 4000 mg, Vitamin K: 1000 mg, B1: 500 mg, B2: 4000 mg, B6: 1000 mg, Vitamin B12: 10 mg, Niacin: 20,000 mg, Pantothenic acid: 1000 mg, Folic acid: 1000 mg, Mn: 70,000 mg, Fe: 30,000 mg, Cu: 3,500 mg, I: 1000 mg, Zn: 30,000 mg, Se: 300 mg, Co: 200 mg

Table 3: Ingredients and nutritional contributions of broilers (grower, 11-24 days)

| | Experimental diets (g kg$^{-1}$) | | | |
|---|---|---|---|---|
| Ingredients (g kg$^{-1}$) | Control | 100 | 200 | 300 |
| Cornmeal | 527.00 | 438.10 | 349.00 | 257.20 |
| Discarded corn grain | 0.00 | 100.00 | 200.00 | 300.00 |
| Soymeal | 352.50 | 347.50 | 342.20 | 338.50 |
| Mineral and vitamin premix[1] | 5.00 | 5.00 | 5.00 | 5.00 |
| Sodium chloride | 5.00 | 5.00 | 5.00 | 5.00 |
| African palm oil | 77.50 | 73.80 | 70.00 | 68.50 |
| Choline | 0.50 | 0.50 | 0.50 | 0.50 |
| DL-Methionine | 3.30 | 3.00 | 2.70 | 2.40 |
| L-Threonine | 0.60 | 0.50 | 0.40 | 0.30 |
| L-Lysine | 2.10 | 2.10 | 2.00 | 1.90 |
| Calcium carbonate | 10.80 | 8.80 | 7.50 | 5.00 |
| Biophos | 13.50 | 13.50 | 13.50 | 13.50 |
| Mycotoxin sequestrant | 1.20 | 1.20 | 1.20 | 1.20 |
| Enzymes | 0.50 | 0.50 | 0.50 | 0.50 |
| Coccidiostat | 0.50 | 0.50 | 0.50 | 0.50 |
| Diet cost, $/t | 438.07 | 412.82 | 387.12 | 363.04 |
| **Nutritional contributions** | | | | |
| Metabolizable energy (kcal kg$^{-1}$ DM) | 3100.00 | 3100.00 | 3100.00 | 3100.00 |
| Crude protein | 215.00 | 215.00 | 215.00 | 215.00 |
| Crude fiber | 24.80 | 25.90 | 26.90 | 27.90 |

Table 3: Continue

| | Experimental diets (g kg$^{-1}$) | | | |
|---|---|---|---|---|
| Ingredients (g kg$^{-1}$) | Control | 100 | 200 | 300 |
| Crude fat | 107.00 | 104.10 | 101.10 | 100.30 |
| Ca | 8.70 | 8.70 | 8.70 | 8.70 |
| P available | 4.30 | 4.30 | 4.30 | 4.30 |
| Methionine+cystine | 8.70 | 8.70 | 8.70 | 8.70 |
| Threonine | 7.70 | 7.70 | 7.70 | 7.70 |
| Valine | 8.40 | 8.40 | 8.40 | 8.40 |
| Isoleucine | 7.30 | 7.30 | 7.30 | 7.30 |
| Lysine | 11.50 | 11.50 | 11.50 | 11.50 |
| Arginine | 11.90 | 11.80 | 11.70 | 11.70 |
| Tryptophan | 2.20 | 2.20 | 2.20 | 2.30 |

[1]Each 2.5 kg contains; Vitamin A: 12,000,000 IU, Vitamin D3: 2,500,000 IU, Vitamin E: 4000 mg, Vitamin K: 1000 mg, B1: 500 mg, B2: 4000 mg, B6: 1000 mg, Vitamin B12: 10 mg, Niacin: 20,000 mg, Pantothenic acid: 1000 mg, Folic acid: 1000 mg, Mn: 70,000 mg, Fe: 30,000 mg, Cu: 3,500 mg, I: 1000 mg, Zn: 30,000 mg, Se: 300 mg, Co: 200 mg

Table 4: Ingredients and nutritional contributions of broilers (finisher, 24-32 days)

| | Experimental diets (g kg$^{-1}$) | | | |
|---|---|---|---|---|
| Ingredients (g kg$^{-1}$) | Control | 100 | 200 | 300 |
| Cornmeal | 565.40 | 475.60 | 383.00 | 292.60 |
| Discarded corn grain | 0.00 | 100.00 | 200.00 | 300.00 |
| Soymeal | 305.50 | 300.40 | 295.80 | 290.70 |
| Mineral and vitamin premix[1] | 5.00 | 5.00 | 5.00 | 5.00 |
| Sodium chloride | 5.00 | 5.00 | 5.00 | 5.00 |
| African palm oil | 89.00 | 86.00 | 84.20 | 81.50 |
| Choline | 0.50 | 0.50 | 0.50 | 0.50 |
| DL-Methionine | 2.80 | 2.50 | 2.20 | 2.00 |
| L-Threonine | 0.50 | 0.60 | 0.60 | 0.60 |
| L-Lysine | 1.90 | 2.00 | 2.10 | 2.20 |
| Calcium carbonate | 10.00 | 8.00 | 7.20 | 5.50 |
| Biophos | 12.20 | 12.20 | 12.20 | 12.20 |
| Mycotoxin sequestrant | 1.20 | 1.20 | 1.20 | 1.20 |
| Enzymes | 0.50 | 0.50 | 0.50 | 0.50 |
| Coccidiostat | 0.50 | 0.50 | 0.50 | 0.50 |
| Diet cost, $/t | 428.92 | 404.86 | 381.00 | 357.15 |
| **Nutritional contributions** | | | | |
| Metabolizable energy (kcal kg$^{-1}$ DM) | 3200.00 | 3200.00 | 3200.00 | 3200.00 |
| Crude protein | 195.00 | 195.00 | 195.00 | 195.00 |
| Crude fiber | 23.80 | 24.60 | 25.80 | 26.80 |
| Crude fat | 119.10 | 116.70 | 115.70 | 113.70 |
| Ca | 7.90 | 7.90 | 7.90 | 7.90 |
| P available | 4.00 | 4.00 | 4.00 | 4.00 |
| Methionine+cystine | 8.00 | 8.00 | 8.00 | 8.00 |
| Threonine | 7.00 | 7.00 | 7.00 | 7.00 |
| Valine | 7.70 | 7.60 | 7.60 | 7.60 |
| Isoleucine | 6.60 | 6.60 | 6.60 | 6.60 |
| Lysine | 10.30 | 10.30 | 10.30 | 10.30 |
| Arginine | 10.70 | 10.60 | 10.50 | 10.40 |
| Tryptophan | 2.00 | 2.00 | 2.00 | 2.10 |

[1]Each 2.5 kg contains; Vitamin A: 12,000,000 IU, Vitamin D3: 2,500,000 IU, Vitamin E: 4000 mg, Vitamin K: 1000 mg, B1: 500 mg, B2: 4000 mg, B6: 1000 mg, Vitamin B12: 10 mg, Niacin: 20,000 mg, Pantothenic acid: 1000 mg, Folic acid: 1000 mg, Mn: 70,000 mg, Fe: 30,000 mg, Cu: 3,500 mg, I: 1000 mg, Zn: 30,000 mg, Se: 300 mg, Co: 200 mg

were determined. Viability was determined as the difference between the initial number of birds and recorded mortality. The feed intake was calculated using the offer and reject method. The feed conversion ratio was calculated as the amount of feed ingested, for a gain of 1 kg of body weight. The initial and final weight of each stage was performed on a Mettler Toledo® IND226 industrial balance with precision $\pm$1.00 g, respectively.

**Carcass traits:** At 32 days of age, 10 birds from each treatment were euthanized by bleeding the jugular vein by a registered veterinarian after 6h of fasting. The broiler chickens were weighed before slaughter using a Truweigh Blaze digital scale (BL-100-01-BK with an accuracy of ±0.1 g). The carcass, edible viscera (liver, heart and gizzard), breast and abdominal fat were weighed after slaughter.

**Economic feasibility:** To determine the cost of the experimental diets, the cost of conventional cornmeal ($ 260.16/t), discard corn grain ($ 50/t), soybean meal ($ 492.68/t), vitamins and minerals premix ($ 2601.62/t), common salt ($ 107.72/t), African palm oil ($ 731.70/t), choline chloride ($ 2,154.47/t), DL-methionine ($ 4479.60/t), L-threonine ($ 3,422.76/t), L-lysine ($ 2,688.21/t), calcium carbonate ($ 130.08/t), dicalcium phosphate ($ 894.31/t), mycotoxin sequestrant ($ 8,871.95/t), multi-enzyme complex ($ 1,1100/t) and coccidiostat ($ 8871.95/t) were taken into account. In addition, the cost of the feed consumed was considered, as well as the cost to produce one kg of body weight, carcass and breast per treatment. The average cost of the diet was taken into account in the different production phases (starter, grower and finisher).

**Statistical analysis:** The data were processed using one-way analysis of variance (ANOVA), for the normality of the data the Kolmogorov Smirnov test was used and for the uniformity of the variance Bartlett's test was used, before carrying out the ANOVA. The Duncan's test[7] was used to determine the differences between means, according to the statistical software SPSS version 17.1[8]. P<0.05 were considered statistically significant.

## RESULTS

Table 5 shows that the inclusion of 300 g kg$^{-1}$ of discarded corn grain in broiler diets improved (p<0.05) the body weight in all production stages (0-32 days), however, the other treatments with this feedstuff did not show significant differences (p>0.05) compared to the control treatment. Furthermore, this treatment (300 g kg$^{-1}$) improved (p<0.05) feed conversion ratio and feed intake in the start-growth stage and throughout the experimental stage, respectively. Likewise, viability was not affected during the experiment (p>0.05).

The dietary use of discarded corn grain did not change the (p>0.05) performance of the carcass, leg, liver and heart. However, the use of200 g kg$^{-1}$ of discarded corn grain improved (p<0.05) the breast yield (Table 6). In addition, the higher inclusion of discarded corn grain (300 g kg$^{-1}$) showed (p<0.05) a higher yield of abdominal fat and gizzard (Table 6). Table 7 shows that the inclusion of 300 g kg$^{-1}$ of discarded corn grain in broiler diets reduced the feed cost by 0.13 USD compared to the control treatment. In addition, this treatment (30% of discarded corn grain) obtained benefits of 0.08 USD in

Table 5: Effect of the inclusion levels of discarded corn grain on growth performance of broilers (0-32 days)

| | Inclusion levels of discarded corn grain (g kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| Items | Control | 100 | 200 | 300 | SEM± | p-value |
| **0-10 days** | | | | | | |
| IBW (g) | 45.57 | 45.73 | 45.57 | 45.73 | 0.230 | 0.912 |
| BW (g) | 166.30$^{b}$ | 161.8$^{b}$ | 166.60$^{b}$ | 186.80$^{a}$ | 4.650 | 0.029 |
| FI (g) | 144.30 | 143.31 | 151.50 | 157.08 | 4.445 | 0.260 |
| FCR | 1.20$^{a}$ | 1.30$^{a}$ | 1.30$^{a}$ | 1.10$^{b}$ | 0.079 | 0.042 |
| Viability (%) | 99.00 | 99.33 | 99.33 | 99.33 | 0.550 | 0.953 |
| **10-24 days** | | | | | | |
| BW (g) | 877.00$^{b}$ | 871.30$^{b}$ | 850.80$^{b}$ | 924.10$^{a}$ | 12.667 | 0.005 |
| FI (g) | 938.70 | 937.60 | 942.20 | 954.50 | 14.345 | 0.984 |
| FCR | 1.30$^{ab}$ | 1.30$^{ab}$ | 1.40$^{a}$ | 1.30$^{b}$ | 0.022 | 0.001 |
| Viability (%) | 99.00 | 98.99 | 98.33 | 98.67 | 0.553 | 0.804 |
| **25-32 days** | | | | | | |
| BW (g) | 1583.20$^{b}$ | 1605.90$^{ab}$ | 1594.10$^{ab}$ | 1640.50$^{a}$ | 17.247 | 0.007 |
| FI (g) | 1190.40$^{b}$ | 1288.70$^{a}$ | 1270.4$^{ab}$ | 1267.80$^{ab}$ | 8.028 | 0.009 |
| FCR | 1.70 | 1.70 | 1.70 | 1.70 | 0.059 | 0.825 |
| Viability (%) | 98.64 | 98.31 | 98.98 | 98.98 | 0.423 | 0.634 |
| **0-32 days** | | | | | | |
| FI, g | 2273.40$^{b}$ | 2369.70$^{ab}$ | 2364.10$^{ab}$ | 2379.40$^{a}$ | 10.151 | 0.047 |
| FCR | 1.50 | 1.50 | 1.50 | 1.50 | 0.021 | 0.306 |
| Viability (%) | 96.67 | 96.67 | 96.67 | 97.00 | 0.619 | 0.974 |

$^{a,b}$Means with different letters in the same row differ to p<0.05. BW: Body weight, FI: Feed intake, FCR: Feed conversion ratio

Table 6: Effect of the inclusion levels of discarded corn grain on carcass traits of broilers (32 days)

| Inclusion levels of discarded corn grain (g kg$^{-1}$) | Items | | | | | |
|---|---|---|---|---|---|---|
| | Control | 100 | 200 | 300 | SEM± | p-value |
| Carcass (g kg$^{-1}$ de PV) | 66.62 | 66.88 | 67.84 | 67.44 | 0.645 | 0.556 |
| Breast (g kg$^{-1}$ de PV) | 32.04$^{ab}$ | 32.03$^{ab}$ | 32.68$^{a}$ | 30.52$^{b}$ | 0.632 | 0.017 |
| Leg (g kg$^{-1}$ de PV) | 10.95 | 10.66 | 10.85 | 11.20 | 0.240 | 0.641 |
| Abdominal fat (g kg$^{-1}$ de PV) | 0.67$^{b}$ | 0.73$^{ab}$ | 0.79$^{ab}$ | 0.94$^{a}$ | 0.085 | 0.013 |
| Liver (g kg$^{-1}$ de PV) | 2.10 | 1.93 | 2.04 | 1.98 | 0.079 | 0.493 |
| Heart (g kg$^{-1}$ de PV) | 0.67 | 0.56 | 0.63 | 0.56 | 0.036 | 0.093 |
| Gizzard (g kg$^{-1}$ de PV) | 1.74$^{b}$ | 1.66$^{b}$ | 1.71$^{b}$ | 1.96$^{a}$ | 0.096 | 0.024 |

$^{a,b}$Means with different letters in the same row differ to p<0.05

Table 7: Effect of inclusion levels of discarded corn grain on cost-benefit ratio of broilers (32 days)

| Items | Inclusion levels of discarded corn grain (g kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Control | 100 | 200 | 300 | SEM± | p-value |
| Cost of feed consumed (USD bird$^{-1}$) | 1.00$^{a}$ | 0.99$^{a}$ | 0.93$^{b}$ | 0.87$^{c}$ | 0.033 | 0.004 |
| Utility control$^{-1}$ (USD) | | 0.01 | 0.07 | 0.13 | | |
| Feed cost kg$^{-1}$ BW$^{-1}$ (USD) | 0.63$^{a}$ | 0.61$^{ab}$ | 0.60$^{ab}$ | 0.55$^{b}$ | 0.016 | 0.009 |
| Utility control$^{-1}$ (USD) | | 0.02 | 0.03 | 0.08 | | |
| Cost kg$^{-1}$ carcass$^{-1}$ (USD) | 0.95$^{a}$ | 0.92$^{ab}$ | 0.88$^{b}$ | 0.81$^{c}$ | 0.034 | 0.042 |
| Utility control$^{-1}$ (USD) | | 0.03 | 0.07 | 0.14 | | |
| Cost kg$^{-1}$ breast$^{-1}$ (USD) | 1.98$^{a}$ | 1.92$^{ab}$ | 1.83$^{bc}$ | 1.79$^{c}$ | 0.055 | 0.038 |
| Utility control$^{-1}$ (USD) | | 0.06 | 0.15 | 0.19 | | |

$^{a,b,c}$Means with different letters in the same row differ to p<0.05

cost kg$^{-1}$ BW$^{-1}$ and the inclusion of 20 and 30% of discarded corn grain showed benefits of 0.07 and 0.14 and 0.15 and 0.19 USD for cost kg carcass$^{-1}$ and cost kg$^{-1}$ breast$^{-1}$ in relation to the control treatment, respectively.

## DISCUSSION

The data obtained on viability confirm that the use of this energy source (discarded corn grain) does not harm the health of the birds, since the viability was not affected with the inclusion of 300 g kg$^{-1}$ of discarded corn grain (Table 5). In this sense, Castillo and Delgado[5] and Viana[6]have found similar results, due to the safety of the feed product used.

Protein and amino acids are essential parts of the nutritional base of broilers[9]. In this sense, the discarded corn grain has more protein (1.93%) and essential and non-essential amino acids than imported corn (Table 1). Also, the diets were formulated to meet the requirements of crude protein and amino acids in broilers such as methionine, lysine and threonine. The inclusion of up to 300 g kg$^{-1}$ of discarded corn grain increased the contribution of the essential amino acid tryptophan, which could favor the productive performance of broiler (Table 5).

In this sense, Bello *et al.*[10] reported that a higher contribution of the amino acid (tryptophan) in broiler diets improved the productive performance, due to a decrease in acute phase proteins like C reactive protein and HSP70, which benefited the intestinal health of the young bird. Recent research reported that increased tryptophan in broiler diets has a favorable impact on digestive physiology due to increased 5-hydroxytryptamine receptors and decreased cortisol levels[11]. Likewise, tryptophan is part of a series of metabolic pathways that regulate behavior, appetite and intestinal activity, as well as increases the expression and excretion of ghrelin. Furthermore, it is a precursor to niacin, a water-soluble vitamin that is involved in many oxidation reactions in the Krebs cycle[12]. Interestingly, increasing levels of discarded corn grain decreased the contributions of arginine (essential amino acid) in the formulations (Table 2-4), without affecting the body weight of broilers (Table 5); apparently, a higher feed intake (0-32 days) with the inclusion of 300 g kg$^{-1}$ of discarded corn grain maintained a balanced consumption of this amino acid[13].

Goodarzi *et al.*[14]and Ebling *et al.*[15] have obtained more efficient results in the variables of weight gain, feed intake and feed conversion ratio by including white rice (*Oryza sativa*), pre-cooked rice and foxtail millet (*Setaria italica*), respectively, as substitutes for imported corn in broiler diets. In addition, Leyva *et al.*[16] reported that the substitution of 300 g kg$^{-1}$ with cornmeal by breadfruit (*Artocarpus altilis*) meal rich in starch maintained similar results to the control diet in broilers. However, Van Krimpen *et al*[17]. showed that the inclusion

(50 and 100 g $kg^{-1}$) of rye (*Secale cereale*) rich in non-starch carbohydrates in broiler diets limits productivity and immune competence. Likewise, Reddy *et al.*[18] did not observe improvements in body weight and feed conversion ratio when they used up to 50% of finger millet (*Eleusine coracana*) and sorghum (*Sorghum bicolor*) in broiler diets.

It is important to note that starch is the primary energy source in the nutrition of birds; this carbohydrate is found in high concentrations in corn and tubers[19]. In this sense, Valdivié *et al.*[20] and Ayuk and Essien[21] found that the total substitution of imported cornmeal by cassava meal (*Manihot esculenta*) and sweet potato (*Ipomoea batata*) in diets did not depress the productive response and haematological profile in broilers, respectively. Thus, according to the productive results (Table 5), discarded corn grain could be a viable and feasible alternative in broiler diets, especially in locations with high availability of this cereal.

Chicken meat is known to compete with other meats due to its nutrient-rich content, low cost and easy market access[22]. Therefore, the management and nutrition of broilers have a direct influence on edible portions[23]. Despite the better productive response with the inclusion of 300 g $kg^{-1}$ of discarded corn grain (Table 5), this was not enough to improve the breast yield; perhaps a higher feed intake (Table 5; 0-32 days) and energy concentration decreased the leanest edible portion (breast) and increased the abdominal fat yield (0.67 vs 0.94) (Table 6). On the other hand, both products (imported corn and discarded corn grain) have similar lysine contents. In this sense, Lucas *et al.*[24] and Berri *et al.*[25] have found a better breast yield when using LY038 corn fortified with lysine and diets with more contributions of lysine (3 g $kg^{-1}$). The inclusion of 200 g $kg^{-1}$ of discarded corn grain indicated the highest breast yield. These diets had a better balance between essential amino acids and energy intake in broiler, especially because abdominal fat did not increase significantly (p>0.05) with this treatment (200 g kg especially because abdominal ; Table 6).

Also, the liver remained unchanged in all the experimental groups. Generally, this organ grows due to hypertrophy by the functional excess of the organ, causing hepatosis and hepatomegaly[26]. Despite a higher abdominal fat yield (mainly 300 g $kg^{-1}$ of discarded corn grain), this did not cause significant changes in relative liver weight (p>0.05), considering that lipid metabolism in birds is hepatic. On the other hand, the gizzard is a highly active organ that responds immediately to nutritional changes, mainly related to the grain size of the feed and/or the content of insoluble fiber[27]. In this sense, the diets formulated (Table 2-4) had a higher contribution of crude fiber, which can increase the relative weight of the gizzard, although without causing harmful effects in the birds (Table 6).

Feeding represents the highest cost of chicken production. In this sense, Martins *et al.*[28] recommended the inclusion of alternative feeds and by-products as substitutes for conventional ingredients such as corn to reduce the feed cost and in turn production cost. As observed in the diets (Table 2-4), the progressive increase of the discarded corn grain reduced the cost of finished feed (USD/t) and its inclusion up to 30% increased productive performance (Table 5) and in turn the economic response (Table 7). These results demonstrate that the dietary use of discarded corn grain promotes economic gains in poultry production, perhaps more focused on small and medium-scale. It is important to note that the use of this product will depend on availability in the market. Other studies with alternative feeds have found a favorable economic response in broiler production. In this sense, Leyva *et al.*[16] and Valdivié *et al.*[20] found economic benefits to produce one kg of body weight, carcass and breast using energy-rich feeds such as bread fruitmeal and cassava meal replacing imported corn.

## CONCLUSION

The dietary inclusion of 300 g $kg^{-1}$ of discarded corn grain partially replacing the imported corn in broiler diets promoted a better productive and economic response compared to the control treatment. However, the inclusion of 200 g $kg^{-1}$ improved the breast yield, without affecting the other edible portions.

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