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# Impact of Germinated off Season Sorghum Dietary on Apparent Digestibility and Small Intestinal Histology of Broilers in Maroua Far North Cameroon

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

In order to find a solution to maize in the composition of poultry feed, a study was conducted to evaluate the effect of the substitution of maize by germinated off-season sorghum as an alternative energy source on nutrients digestibility and histological of small intestinal of broilers. To achieve this, 180 of the 1-day-old chicks of the "Cobb 500" strain with a live weight of 34g ± 3.26, were randomly divided into 9 batches corresponding to 3 treatments with 3 replicates of 20 subjects. The batches were subjected to one of 3 diets: 100% maize (R0), 50% maize and 50% germinated off-season sorghum (R1) and 100% germinated off-season sorghum (R2). To achieve these objectives at 18 and then at 35 days of age, a total of 36 broilers were used, i.e. 18 in the start-up phase at a rate of 6 subjects per treatment and 18 in the growth/finishing phase at a rate of 6 subjects per treatment and the droppings and feed from digestibility trials; measured apparent digestibility (Ad) for energy, protein, fiber, mineral matter and organic matter; histological studies of the small intestine were performed. Energy, organic matter, mineral matter, proteins and fibres were not significantly influenced by the experimental diets used at the 0.05% threshold for digestibility and the histological sections did not show any structural and morphological alterations. We can therefore conclude that maize can be substituted at 50% and 100% by germinated off-season sorghum without negatively impacting digestibility in broilers at the start, as well as in growth/finishing.

*Keywords: Broilers; off-season sorghum; broiler; digestibility.*

## 1. INTRODUCTION

In developing countries, poultry production is one of the main sources of animal protein supply for the population. The lack of animal proteins in the world is a real problem that several countries have to face in the fight against food deficit. In Africa, about one to four people remains undernourished. The poultry sector, particularly modern poultry farming, has emerged in recent years as an attractive solution to compensate for the ever-increasing demand for animal-based protein (FAO, 2020. This sector occupies a prominent place in the livestock sector in Cameroon because of the short breeding cycle of the species that make it up, its low price, the ease of its production, and its nutritional qualities. Poultry farming is a source of income for women and households [1]. The development of the poultry sector has an important role to play in the fight against food insecurity in Africa in general, and in Cameroon in particular [2]. Poultry farming in Cameroon has evolved over the years, from 37800 tons in 2020 to 52.6% tons in 2021 of the 270000 tons of meat produced during the same year. In 2022, the proportion of poultry in meat production in Cameroon increased by 7% compared to 2021 when poultry meat production was 42369 tons, reflecting a slow increase in poultry production (INS, 2023), for the year 2023 poultry meat production was about 107680 tons. However, the development of poultry farming is limited by the availability and quality of feed. In addition, the high cost of feed remains a major obstacle to the profitability of poultry production and represents 60 to 70% of the total cost of feed production [3,4]. Indeed, feed is the first element involved in the cost price of poultry and is the most effective way to control production costs and meat quality. However, many feed ingredients commonly used in poultry feed are often out of stock due to food competition between humans and animals [5-7]. Maize imports in Cameroon were around 64.4% in 2022, these imports have risen again during the year 2023, reaching 39991.3 tons (INS 2023) and therefore the inflation of the cost on the market, is increasingly slowing down the development of the poultry sector [8,9]. In addition, the importation of inputs at very high prices leads to broiler production at prices beyond the reach of the population [10,11]. To reduce the cost of production due to the increases in the cost of conventional raw materials, research is directed towards alternative feed resources that can reduce dependence on corn and main ingredients such as soybean meal, fish meal...etc in poultry feed [12,13]. The Sahelian zone has large quantities of alternative food resources to maize, including off-season sorghum, which is widely used in the feed of poultry in traditional farming. Studies on the use of this variety in broiler feed remain scarce [1] [30]. The objective of this work is therefore to evaluate effect of germinated off-season sorghum as alternative energy source on nutrient digestibility and histology of small intestinal of broilers.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The experiment was carried out from June to August 2022 in the city of Maroua, located at 10°35'N latitude, 14°19'N longitude and 384m altitude in the Far North region of Cameroon. The climate is tropical of the Sahelian type and includes two main seasons: a dry season (October- January) and a rainy season (June – September). The rainy season was an average rainfall of 700 millimeters per year. The temperature was peak at 45°C in hot periods and, 30°C in the rainy season [14].

### 2.2 Animal Material

A total sample of 180 day-old chicks of Cobb 500 strain, obtained from the AGROCAM hatchery in Ngaoundere with an average weight of 35g± 3.26, was used. On arrival, the chicks were subjected to a routine check, including the condition of the legs, beak and liveliness. They were each given glucose water enriched with lemon and then they received an anti-stress to prevent possible effects related to transport stress. The chicks were raised in the same building on wood chip bedding on the floor; in compartments with a density of 8/m2 under the same environmental conditions. The chicks were given water and feed ad libitum in accordance with the recommendations of the ethics committee. The experiment was conducted from June to August 2022 and the digestibility test was carried out at the end of each rearing phase, using 6 birds per treatment.

### 2.3 Experimental Design

The chicks were randomly assigned without sexing into three batches of 60 chickens each. Each batch was randomized into 3 repeats of 20 subjects each. Batch 1 or R0 treatment consisted of birds fed only on diet where the maize substitution rate was 0%; batch 2 or R1 treatment consisted of birds fed on a diet where the rate of substitution of 50% of maize in R0 by sprouted sorghum and batch 3 or R2 treatment consisted of birds fed on a diet where the rate of substitution of 100% of maize in R0 by sprouted sorghum was. For digestibility, the chickens in the start-up phase as well as those in the finishing phase were installed in an experimental random block device consisting of 5 metabolic cages at the rate of one chicken per experimental unit. A total of 36 Cobb 500 broilers were used, 18 in the start-up phase at a rate of 6 subjects per treatment and 18 in the grower/finisher phase at a rate of 6 subjects per treatment. Each experimental subject was individually housed in a metal cage measuring 45 cm x 30 cm x 45 cm which allows a good collection of total droppings without contamination. This experimental device is also equipped with a feeder and a drinking trough. The subjects of the different batches received one of three experimental diets, the water was served ad libitum. The quantities of feed fed according to needs, age and leftovers were weighed per chicken. Droppings were collected by chicken during the stay in the metabolic case. The use of sterile aluminum foil sheets made it possible to take samples under conditions that limited the risk of contamination of the samples. The samples of manure collected were kept in the refrigerator to carry out chemical analyses.

### 2.4 Analysis of Experimental Diets and Droppings

The samples of lyophilized droppings and the 3 experimental diets were all scanned on the same spectrometer in reflectance mode, on the powdered samples (grinding = 1 mm) presented in cups. Each sample was passed twice and spectra were averaged. The wavelengths used in the analysis range from 800 to 2500 nm with a step of 2 nm. The visible wavelengths (400-800 nm) did not contribute anything to the models and were therefore discarded. The spectra were then subjected to mathematical pre-processing (second derivative, normalization, smoothing and baseline correction). The same pretreatment was applied to all spectra. For each manure spectrum, the spectrum of the corresponding food was associated, resulting in a concatenated spectrum with the two signals one after the other. Bourdillon et al., [15], Métayer et al., [16]. Apparent digestibility (Da) corresponds to the share of nutrients that disappear in the intestine, it is calculated using the following formula:

Ad (%) = quantity of nutrient ingested-quantity of nutrient excreted / quantity of nutrient ingested * 100

### 2.5 Experimental Diets

The diets were formulated from different ingredients purchased from the city's feed mills. Some ingredients such as concentrate, lysine and methionine have been used based on the nutritional characteristics indicated on the labels. Other ingredients such as off-season sorghum, maize, groundnut meal and maize bran were analyzed. A 100 g packet of each of these ingredients was sent for bromatological analysis to the Animal Nutrition and Feed Laboratory of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang (FASA).

Three iso-energetic and iso-protein starter rations were formulated (Table 2). The centesimal values of the diet's ingredients are reported in Table 2.

## 2.6 Statistical Analysis of the Data

Concerning the digestibility test, the ANOVA was carried out on apparent digestibility (Ad) proteins, organic matter (OM), mineral matter (MM), fibre and energy. The sources of variation considered were diets containing germinated off- season sorghum and maize; these were presented as a mean ± standard deviation. Analysis of variance using Graphpad Sprint 5 software was used to test the effect of different diets on digestibility. The comparison of the means was made using the Tukey test at the 5% threshold.

**Table 1. Chemical composition of sprouted off-season sorghum, maize, groundnut meal and maize bran**

| Samples | Dry matter (%) | Organic matter (% DM) | Crude protein (%DM) | Raw cellulose (%DM) | Fat (%DM) | Gross energy (Kcal/kg DM) | Metabolizable energy (Kcal/kg DM) |
|---|---|---|---|---|---|---|---|
| Maize bran | 90.90 | 92.38 | 1.20 | 7.80 | 4.30 | 4220 | 2460 |
| Groundnut cake | 95.62 | 93.52 | 37.68 | 11.15 | 13.32 | 5201.18 | 3422.45 |
| Maize | 95.05 | 98.49 | 7.98 | 3.41 | 3.68 | 4400.15 | 3787.72 |
| Sprouted sorghum | 95.67 | 98.49 | 6.99 | 3.22 | 3.06 | 4359.94 | 3770.41 |

*DM: Dry Matter*

**Table 2. Percentage of ingredients and nutritional composition of experimental diets of broilers at the start-up phase**

| Ingredients | Maize-based feed diet $R_0$ (%) | Maizeand sprouted sorghum feed diet $R_1$ (%) | Sprouted sorghum feed diet $R_2$ (%) |
|---|---|---|---|
| Maize | 40 | 20 | 00 |
| Bran | 15 | 15 | 14.50 |
| Sprouted sorghum | 00 | 20 | 40.50 |
| Groundnut cake | 37.50 | 37.50 | 37.50 |
| 5 % concentrate* | 5 | 5 | 5 |
| Bone powder | 1 | 1 | 1 |
| Shell | 1 | 1 | 1 |
| Salt | 0.20 | 0.20 | 0.20 |
| Lysine | 0.15 | 0.15 | 0.15 |
| DL-Methionine | 0.15 | 0.15 | 0.15 |
| **Total** | 100 | 100 | 100 |
| **Calculated chemical analysis** | | | |
| **Crude protein (%)** | 20.77 | 20.87 | 20.87 |
| **Metabolizable energy (Kcal/kg DM)** | 3253.74 | 3250.38 | 3254.54 |
| **Energy / Protein** | 156.28 | 155.76 | 155.92 |

*%: Percentage*

**Table 3. Percentage of ingredients and nutritional composition of experimental diets of broilers at the growth/finishing phase**

| Ingredients | Maize-based feed diet $R_0$(%) | Maize and sprouted sorghum feed diet $R_1$ (%) | Sprouted sorghum feed diet $R_2$ (%) |
|---|---|---|---|
| Maize | 42.5 | 21.25 | 00 |
| Bran | 15 | 14.75 | 14.50 |
| Sprouted sorghum | 00 | 21.25 | 43 |
| Groundnut cake | 35 | 35 | 35 |
| 5 % concentrate* | 5 | 5 | 5 |
| Bone powder | 1 | 1 | 1 |
| Shell | 1 | 1 | 1 |
| Salt | 0.20 | 0.2 | 0.20 |
| Lysine | 0.15 | 0.15 | 0.15 |
| DL-Methionine | 0.15 | 0.15 | 0.15 |
| **Total** | 100 | 100 | 100 |
| **Calculated chemical analysis** | | | |
| **Crude protein (%)** | 18.85 | 19.05 | 18.95 |
| **Metabolizable energy (Kcal/kg DM)** | 3150.4565 | 3180.3301 | 3158.65 |
| **Energy / Protein** | 167.13 | 166.94 | 166.68 |

*%: Percentage*

## 3. RESULTS

### 3.1 Effects of Rations at Different Levels of Incorporation of Germinated Off-Season Sorghum on Apparent Digestibility at Start-Up

Table 4 presents the values of apparent digestibility (Ad) in broilers subjected to the three rations in the start-up phase. It appears that energy, organic matter, mineral matter, proteins and fibers were not significantly influenced by the experimental rations used at the 0.05% threshold.

### 3.2 Effects of Rations at Different Levels of Incorporation of Germinated Off-Season Sorghum on the Intestines of Broilers

Fig. 1 shows the effects of the different rations on the architecture of the small intestine of broiler chickens in the start-up phase. Indeed, compared to the R0 control, the histological sections did not show any structural and morphological alterationsR1.

### 3.3 Effects of Rations at Different Levels of Incorporation of Sprouted Off-Season Sorghum on Apparent Digestibility during Growth/Finishing

Table 5 shows the apparent digestibility (Ad) values for broilers fed the three rations during the growth/finishing phase. It can be seen that energy, organic matter, mineral matter, protein and cellulose were not significantly influenced by the experimental rations used at the 0.05% threshold.

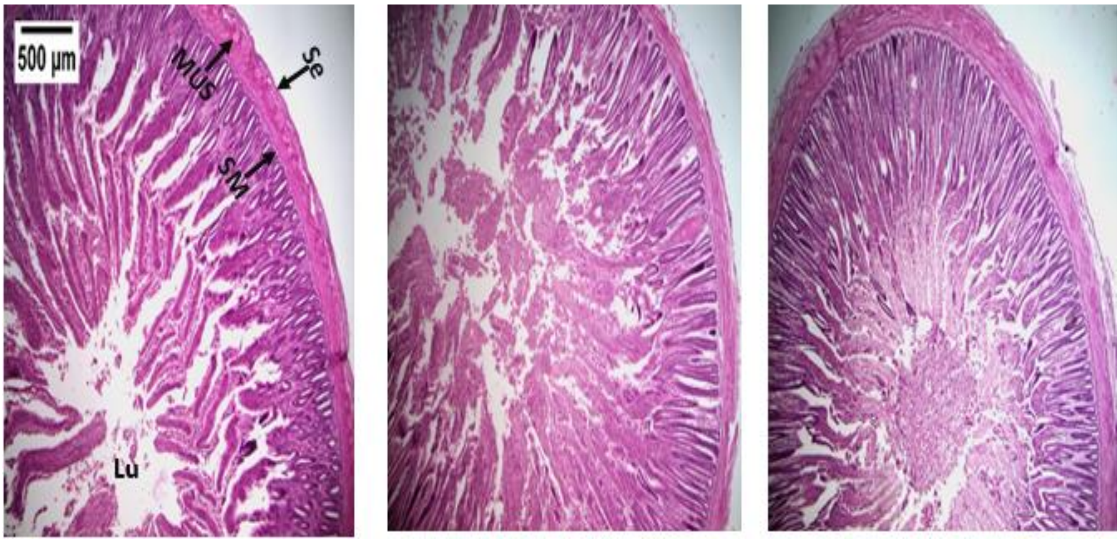
### 3.4 Effects of Rations at Different Levels of Incorporation of Sprouted Off-Season Sorghum on the Gut of Broilers

Fig. 2 shows the effects of the different rations on the structure and morphology of the small intestine of broilers in the growth/finishing phase. Compared with the R0 control, the histological sections showed no structural or morphological alterations.

## 4. DISCUSSION

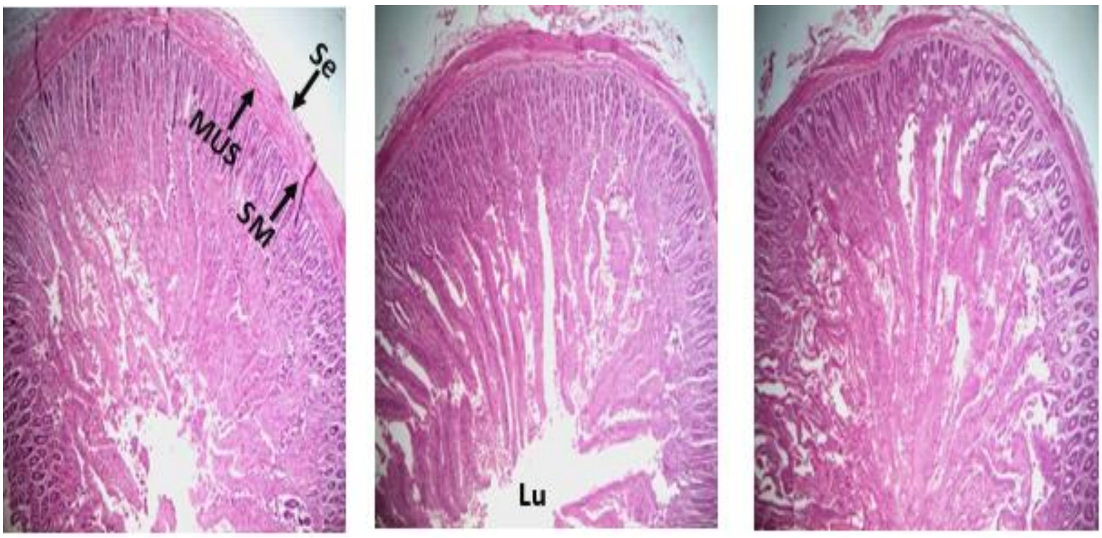
### 4.1 Digestibility

Energy, organic matter, mineral matter, proteins and fibre were not significantly influenced by the experimental rations used at the 0.05% threshold for digestibility. These results would be due to malting which would have hydrolyzed the starch and antinutrients of the sorghum. These results do not corroborate those of Selle et al. [17] who demonstrated that the digestibility of sorghum is lower than that of maize; because of the intrinsic factors of sorghum including kafirin, phenolic compounds and phytate which can compromise the use of starch by broilers subjected to a sorghum-based diet. These results are confirmed by the in vitro and in vivo experiments of Vilariño et al. [18]. In addition, the results of Métayer et al. [16]. on starch digestibility confirm the hypothesis of starch degradation, more or less important depending on the cereal, with the age of the subjects. The lack of significance with regard to the experimental rations would be justified by the good fibre content; because the presence of high amounts of fiber can impact the intestinal wall and reduce nutrient absorption [19]. These results can also be explained by the use of dry droppings because the quality of the predicted measurements is lower than that obtained on dried droppings, which leads to better results [20]. Decreases in digestibility in birds fed diets containing high tannin sorghum have been observed [21]. As well as a significant reduction in nitrogen retention was found in broilers fed red sorghum as the only source of cereals in the diet [22].




R0 R1 R2

**Fig. 1. Histological sections of the small intestine of chickens in the starter phase**
*Lu = Intestinal Lumen; SM = Submucosa; Mus = Muscularis; Se = Serosa*




R0 R1 R2

**Fig. 2. Histological sections of small intestine of chicken in growth/finishing phase**
*Lu = Intestinal Lumen; SM = Submucosa; Mus = Muscularis; Se = Serosa*

**Table 4. Apparent digestibility of nutrients for broilers fed diets containing different levels of germinated off-season sorghum at starter phase**

| | R0 100% Maize | | | R1 50% sprouted sorghum feed | | | R2 100% sprouted sorghum feed | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Feed** | **Droppings** | **Ad** | **Feed** | **Droppings** | **Ad** | **Feed** | **Droppings** | **Ad** |
| **Proteins (%)** | 26.55± 0.33 | 7.17± 0.43[b] | 72.99± 0.12[b] | 26.87± 0.59 | 8.1± 0.09[b] | 0.698± 0.22[b] | 26.61± 0.13 | 7.14± 0.13[b] | 0.731± 0.21[b] |
| **OM (%)** | 54.36± 0.53 | 33.16± 0.63[b] | 0.63± 0.36[b] | 56.18± 0.32 | 36.08± 0.12[b] | 0.55± 0.41[b] | 52.62± 0.29 | 32.32± 0.52[b] | 0.62± 0.37[b] |
| **MM (%)** | 33.79± 0.54 | 30.94± 0.15[a] | 0.08± 0.19[a] | 32.51± 0.67 | 30.65± 0.49[a] | 0.06± 0.23[a] | 36.89± 0.26 | 34.38± 0.72[a] | 0.073± 0.1[a] |
| **Fibers (%)** | 33.21± 0.82 | 31.32± 0.64[a] | 0.06± 0.67[a] | 32.79± 0.86 | 31.17± 0.54[a] | 0.05± 0.72[a] | 3.68± 0.73 | 30.27± 0.44[a] | 0.046± 0.51[a] |
| **Met.En (kcal/kg)** | 3287.37± 0.65 | 3015.43± 0.51[a] | 0.095± 0.48[a] | 3300.01± 0.72 | 3002.01± 0.27[a] | 0.090±0.32[a] | 3291.92± 0.82 | 3024.41± 0.65[a] | 0.088± 0.36[a] |

*Values with the same letter on the same line are not significantly different at the 5% threshold. OM (organic matter); MM (Mineral Matter); Met.En (Metabolizable Energy)*

**Table 5. Apparent digestibility of nutrients for broilers fed diets containing different levels of sprouted off-season sorghum at grower and finisher phases**

| | R0 100% Maize | | | R1 50% sprouted sorghum feed | | | R2 100% sprouted sorghum feed | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Feed** | **Droppings** | **Ad** | **Feed** | **Droppings** | **Ad** | **Feed** | **Droppings** | **Ad** |
| **Protein (%)** | 22.38± 0.23 | 6.21± 0.39 | 0.722±0.21 | 22.97± 0.69 | 6.49± 0.58 | 0.717±0.225 | 22.12± 0.09 | 5.89± 0.29 | 0.733±0.29 |
| **OM (%)** | 31.84± 0,10 | 27.45± 0.27 | 0.159± 0.22 | 29.31± 0.45 | 24.94± 0.38 | 0,175±0.19 | 35.19± 0.17 | 30.06± 0.44 | 0.170±0.32 |
| **MM (%)** | 23.75± 0.14 | 21.91± 0,21 | 0.083±0.34 | 22.49± 0.85 | 20.74± 0.36 | 0.084±0.44 | 24.38± 0.24 | 22.42± 0.33 | 0.087±0.29 |
| **Fiber (%)** | 21.86± 0.78 | 19.35± 0.27 | 0.129±0.14 | 22.63± 0.23 | 19.92± 0.18 | 0.136±0.21 | 21.67± 0.39 | 19.01± 0.25 | 0,139±0.27 |
| **Meta. En (kcal/kg)** | 3198.48± 0.31 | 2857.35± 0.45 | 0.11±54 | 3189.86±0.52 | 2874.54± 0.41 | 0.1096±0.41 | 3195.84± 0.33 | 2862.84± 0.44 | 0.116±0.39 |

*Values with the same letter on the same line are not significantly different at the 5% threshold. OM (organic matter); MM (Mineral Matter); Meta.En.(Metabolizable Energy)*

### 4.2 Histological Sections of the Intestines

The histological sections showed no structural or morphological alterations. This testifies to the non-toxicity of the various experimental rations, as well as the absence of pathogenic elements. The height of the villi and the depth of the crypts can be used as indicators of the health of the intestine and are therefore associated with the condition of the animals and the quality of the feed [23]. A thicker mucosa would consist of larger intestinal villi (length, width) to optimise absorption of digested nutrients Carré et al [28]. large (length, width) to optimise absorption of digested nutrients Carré et al. [24]. A thicker muscularis could indicate the need for greater muscular work to promote the transit of a greater volume of digesta towards the distal parts of the small intestine. These results are consistent with those of Mathlouthi et al. [25] who demonstrated that the association of bacteria with the intestinal mucosa and the production of different metabolites lead to anatomical and physiological changes in intestinal wall cells and smooth muscle. The poor quality of the food can be responsible for the alteration and inflammation of the mucosa Gabriel et al., 2009; Irène et al., [26]. The type of cereal often has a direct influence on intestinal transit [27]. Weurding et al. [28]. compared small intestine retention times for several types of cereals, including maize, wheat, sorghum, and other types of cereals [29].

## 5. CONCLUSION

The aim of this study was to assess the digestibility of feed rations containing sprouted off-season sorghum used as an energy source in broilers in the start-up phase and then in the growth/finishing phase. The results showed that broilers fed the three experimental rations showed no significant difference in the apparent digestibility of protein, fibre, organic matter, mineral matter and energy. Histological sections of the small intestine showed no structural or morphological alterations. Sprouted off-season sorghum can be used as a total replacement for maize in broiler diets without affecting morphology, small intestine function or digestibility.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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