Effects of newly harvested corn on growth performance, intestine development and metabolism of nutrients in broilers

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ABSTRACT

This experiment was to study the effects of newly harvested corn on growth performance, intestine development and metabolism of nutrients in broilers. A total of 380 one-day-old Arbor Acres male broilers were assigned to ageing corn group (AC group), 1/3 newly harvested corn group (1/3 NC group), 2/3 newly harvested corn group (2/3 NC group), and newly harvested corn group (NC group), which according to the proportion of newly harvested corn in the total amount of corn of basal diets. Each group included six replicates with 16 birds. Digestion and metabolism trials were conducted at 39 to 42 days of age. Results showed that feed: gain ratio (F/G) of NC group was higher than that of 1/3 NC group and 2/3 NC group at 22 to 42 and 1 to 42 days of age (p < .05). The metabolic rates of calcium and phosphorus in NC group were lower than those in AC group, 1/3 NC group and 2/3 NC group (p < .05). In NC group, the relative weight of caecum was significantly higher than that in 2/3 NC group and AC group at 21 days of age (p < .05), while the relative weight of jejunum was lower than that in 2/3 NC group and AC group at 42 days of age (p < .05). In summary, newly harvested corn can reduce the growth performance and metabolism of some nutrients in broilers. Newly harvested corn should be controlled during actual production.

HIGHLIGHTS

• Newly harvested corn can reduce the growth performance in broilers.
• Newly harvested corn can reduce apparent metabolic rate of calcium and phosphorus in broilers.
• Newly harvested corn can affect the intestine development in broilers.

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Newly harvested corn; Arbor Acres broilers; growth performance; intestine development

Introduction

The production of corn is insufficient to meet the requirements with the rapid development of the large-scale breeding of livestock and poultry, and it has become a serious problem, especially in China (Yin et al. 2018). Moreover, global warming, deterioration of natural environment and the development of urbanisation have reduced the area of crop planting, which exacerbated the shortage of feed resources (Sobhan 1994). According to an incomplete survey from the last five years in China, the amount of imported corn is increasing year by year, but it is mainly allocated to high-yield feed processing enterprises. Therefore, massive amounts of newly harvested corn must be directly processed as animal feed each year to meet the needs of livestock and poultry farming, especially in autumn, the season of corn harvested. However, using newly harvested corn as a diet directly ignored the different nutrimental value between ageing corn and newly harvested corn, as well as the harm of newly harvested corn to animals.

Studies have found that using too much newly harvested corn in diets might affect growth performance, the digestion and absorption of nutrients, and the development of the immune system of broilers, even lead to immunodeficiency (Cui et al. 2013), which ultimately destroyed the tissue structure of the liver and immune organs and even caused an inflammatory reaction (Liu et al. 2015). Another study found that feeding much newly harvested corn has increased diarrhoea...
and mortality of chicks (Mao 2014), while decreased egg production and egg quality, even resulting in the poor colour of feathers (Song 2011). Recently, some studies found the reason that newly harvested corn affected growth of chicks was that, newly harvested corn contained much more anti-nutritional factors, such as resistant starch, which could resist the decomposition by enzymes, stimulate intestinal peristalsis, decrease the retention time of feed in the intestine and cause diarrhoea (Yuan et al. 2016). It also affected the absorption of other nutrients by physical embedding and the barrier effect, changed the pH of the intestinal tract and promoted protein decomposition to produce excessive urate (Yang and Zhao 2012). These reasons finally inhibited the development of immune organs and the metabolic rate of some nutrients. Previous studies also showed that the nutrients in corn would be changed during storage (Setiawan et al. 2010), and compared with newly harvested corn (harvested less than one month), the contents of ether extract (EE), crude fibre (CF), crude acid (CA), nitrogen-free extracts (NFE) and histidine (His) in ageing corn (stored more than one year) were significantly higher (Liu 2011; Xu et al. 2012).

Unfortunately, there were few studies abroad about the effects of newly harvested corn and how to rationally apply it as feed material in the diets of poultry, and there were also quite few systematic studies in China, especially when some scholars suggested that mixed use of new harvested corn and ageing corn may be practicable, but no systematic research and appropriate proportions had been found. In this experiment, the effects of newly harvested corn on growth performance, intestine development and metabolism of nutrients in broilers were studied by changing the proportion of newly harvested corn in the total amount of corn of basal diets.

Materials and methods

Experimental design, animals and diets

A total of 380 one-day-old Arbor Acres male broilers were obtained from Jinghai Poultry Industry Group Co., Ltd., Yangzhou, Jiangsu Province, China. All birds were weighed and randomly assigned to ageing corn group (AC group), 1/3 newly harvested corn group (1/3 NC group), 2/3 newly harvested corn group (2/3 NC group), and newly harvested corn group (NC group), which according to the proportion of newly harvested corn in the total amount of corn of basal diets. Each group included six replicates with 16 birds. Experimental diets were in pelleted form. The digestion and metabolism trials were carried out from 07:00 on d 39 to 07:00 on d 42. Feed intake and body weight were recorded at 21 days and 42 days of age. All corn was purchased from Oriental Hope Animal Nutrients Food Co., Ltd, Yangzhou, Jiangsu Province, China. Corns (Suyu No.9) were produced from Yancheng, Jiangsu Province, China, where there is similar climate every year. The ageing corn was stored for a whole year (October, 2014 to October, 2015), while the newly harvested corn was harvested less than two weeks. Nutrient levels of newly harvested corn and ageing corn are shown in Table 1.

| Groups                      | Newly harvested corn | Ageing corn |
|-----------------------------|----------------------|-------------|
| Volume weight (g/L)         | 745                  | 760         |
| Water (%)                   | 16.05                | 13.60       |
| Dry matter (%)              | 83.95                | 86.40       |
| GE (MJ/kg)                  | 16.08                | 16.63       |
| Crude protein (%)           | 7.70                 | 7.80        |
| Calcium (%)                 | 0.02                 | 0.02        |
| TP (%)                      | 0.28                 | 0.27        |
| NPP (%)                     | 0.05                 | 0.05        |

GE: gross energy; TP: total phosphorous; NPP: non-phytate phosphorous. The determination of the content of crude protein, calcium, total phosphorous and non-phytate phosphorous were based on air dry basis.

Digestion and metabolism trials

The digestion and metabolism trials began to feed at 07:00 on d 39 after fasting for 12 h to discharge the residual faeces in vivo, whereas stopping feeding at 07:00 on d 42, and excreta were collected until 19:00 on d 42, 12 hours after stopping feeding, which ensured that all the excreta converted by feed was harvested during the digestion and metabolism trials. During 39 to 42 days of age, all excreta were collected every 12 h and stored at -20 °C until analysis. The feed intake was also recorded.

Management

This experiment was approved by the Institute of Poultry Sciences, Chinese Academy of Agricultural Sciences, which was carried out through the mode of net rearing for 42 days. The size of the cage was 120 cm×90 cm (length×width). All broilers were provided with free drinking water, normal feed, indoor ventilation, lighting and immunisations. The ambient temperature starts at 33 °C, then decreases by 2 °C to 3 °C per week and finally reaches room temperature. The relative humidity was 60 to 65%. Basal diets were formulated to meet or exceed requirements suggested by the NRC (1994) in Table 2.

Table 1. Nutrients level of newly harvested corn and ageing corn.
Table 2. Composition and nutrient levels of the basal diet (air dry basis).

| Items             | 1–21 days | 22–42 days |
|-------------------|-----------|------------|
| Ingredients (g/kg) |           |            |
| Corn              | 593.8     | 629.0      |
| Soya bean         | 313.4     | 262.7      |
| Corn gluten meal  | 40.0      | 40.0       |
| Soya bean oil     | 12.2      | 28.5       |
| Limestone         | 13.0      | 12.6       |
| CaHPO₄             | 15.0      | 15.0       |
| DL-Met            | 1.9       | 1.2        |
| Lys               | 1.1       | 1.4        |
| NaCl              | 3.0       | 3.0        |
| Choline chloride  | 3.0       | 3.0        |
| Aureomycin        | 1.0       | 1.0        |
| Microelements     | 0.3       | 0.3        |
| Vitamins          | 2.0       | 2.0        |
| Thr               | 0.3       | 0.3        |
| Nutrient levels   |           |            |
| ME (MJ/kg)        | 12.12     | 12.75      |
| CP %              | 21.8       | 19.25      |
| Ca %              | 1.03      | 1.00       |
| Total phosphorus % | 0.70     | 0.70       |
| NPP %             | 0.47      | 0.47       |
| SID Lys %         | 1.05      | 0.93       |
| SID Met + Cys %   | 0.79      | 0.68       |
| SID Trp %         | 0.18      | 0.17       |
| SID Thr %         | 0.56      | 0.56       |

Premixes provide the following per kg of diet: Vitamin A, 7715 IU; Vitamin D, 2755 IU; Vitamin E, 8.8 IU; Vitamin K, 2.2 mg; Vitamin B₁₂, 4.41 mg; Vitamin B₆, 5.51 mg; Vitamin B₉, 0.55 mg; nicotinic acid, 19.8 mg; folinic acid, 0.28 mg; Mn, 50 mg; Iron, 25 mg; Cu, 2.5 mg; Zn, 50 mg; I, 1.0 mg; and Se, 0.15 mg. Metabolisable energy and SID AA are calculated, whereas all other values are analysed. Nutritive level of the material is referenced by Analysis of Nutritional Value of Feed Ingredients in China (Evonik Industries AG 2014). SID: standardized ileal digestible.

Sample collection

At 21 and 42 days of age, 12 birds per treatment group were equally selected from six replicates and slaughtered by severing the jugular veins after weighing. To ensure the representativeness of the two birds, the chosen birds from every replicate had the same body weight (BW) as the average BW. After excising the viscera of the birds, the whole segments of the duodenum, jejunum, ileum and caecum were rapidly separated, cleaned and harvested. The contents of the duodenum and jejunum were immediately collected in microtubes, frozen in liquid nitrogen, and stored at −80 °C until analysis of the activities of digestive enzymes, including protease and amylase in the duodenum and maltase, sucrose, lactase in the jejunum.

Growth performance

The feed intake and body weight were recorded at the start of this experiment and at 21 and 42 days of age. The average daily gain (ADG), average daily feed intake (ADFI) and feed: gain ratio (F/G) were calculated at 1 to 21 days of age, 22 to 42 days of age and 1 to 42 days of age.

Intestine development

Each intestinal segment was cut off and the mucosal side was exposed, nipped by forceps and gently rinsed in normal saline until the whole content was cleaned. The water was dried with a filter paper and then weighed and recorded with the balance of accuracy of 0.01 g. The relative weight of each intestinal segment was calculated by dividing by BW at 21 days and 42 days of age.

Activities of digestive enzymes

Approximately 0.1 g of intestinal sample was transferred into a 1.5 mL precooled centrifuge tube with 0.9 mL physiologic saline and homogenised into 10% homogenates (50 Hz for 3 min through tissue grinder, SCIENCE-48, Scientz Biotechnology Co., Ltd., Ningbo, Zhejiang Province, China). It was then centrifuged through low speed centrifuge (2500–3000 rpm/min for 10 min, DL-5M, Xiangyi Power Testing Instrument Co. Ltd, Hunan, China) and further homogenised into 1% homogenates and even lower. Test kits were purchased from the Jiancheng Bioengineering Institute, Nanjing, Jiangsu Province, China.

Metabolism of nutrients

At 39 to 42 days of age, all excreta were collected every 12 h and stored at −20 °C until analysis. The feed intake was also recorded. The excreta for each cage were weighed, mixed, subsampled, dried at 65 °C, ground, weighted, and assayed for gross energy (GE), measured with an adiabatic bomb calorimeter (PARR 6400, Parr Instrument Company, Delaware, USA), crude protein (CP) was measured by an automatic kjeldahl apparatus (Kjeltec™ 2300, Foss Company, Hillerød, Denmark). Assayed of Calcium (Ca) and phosphorus (P) were referred to the method in the textbook of Zhang (2007). The composition of diets were also analysed by the same method. Apparent metabolisable energy (AME), apparent metabolic rates of crude protein, calcium and phosphorus were also calculated.

Statistical analysis

All parametric data were analysed using one-way ANOVA in SPSS 17.0 (SPSS Inc., Chicago, IL) with time and treatment as factors. Data were expressed as Mean ± SEM. The differences among the four groups were determined with Duncan’s multiple range test.
Probability values less than .05 were considered statistically significant differences ($p < .05$).

**Results**

**Growth performance**

All broilers appeared to be healthy throughout the entire experimental period (data not shown). The effects of newly harvested corn on growth performance of broilers are shown in Table 3. F/G in NC group was higher than those in 1/3 NC group and 2/3 NC group ($p < .05$) at 22–42 days of age and 1–42 days of age.

**Intestine development**

The effects of newly harvested corn on intestine development are shown in Table 4 (Absolute weight of organs were not analysed). The relative weights of caecum in NC group and 1/3 NC group were higher than those in 2/3 NC group and AC group ($p < .05$) at 21 days of age, while the relative weight of jejunum in NC group was significantly lower than that in AC group and 1/3 NC group ($p < .05$) at 42 days of age.

**Activities of digestive enzymes**

The effects of newly harvested corn on activities of digestive enzymes in duodenum and jejunum are shown in Tables 5 and 6, respectively. The activities of protease and amylase of duodenum in NC group and 1/3 NC group were significantly lower ($p < .05$) than those in AC group and 2/3 NC group.

**Metabolism of nutrients**

The effects of newly harvested corn on the metabolism of nutrients of broilers are shown in Table 7. The metabolic rate of Ca in NC group was significantly lower than that of any other group ($p < .05$), 1/3 NC group was significantly higher than that of 2/3 NC group ($p < .05$). The

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**Table 3.** Effects of newly harvested corn on growth performance in broilers.

| Days       | Items    | AC group | 1/3 NC group | 2/3 NC group | NC group | $p$-value |
|------------|----------|----------|--------------|--------------|----------|-----------|
| 1–21 days  | ADG(g)   | 47.61 ± 2.03 | 45.82 ± 2.69 | 46.31 ± 2.02 | 45.62 ± 1.40 | .826      |
|            | ADFI(g)  | 69.32 ± 2.48 | 68.10 ± 2.44 | 68.36 ± 2.09 | 67.33 ± 2.22 | .738      |
|            | F/G      | 1.46 ± 0.02 | 1.49 ± 0.04 | 1.48 ± 0.04 | 1.48 ± 0.03 | .453      |
| 22–42 days | ADG(g)   | 89.27 ± 10.88 | 89.80 ± 6.98 | 90.12 ± 7.17 | 82.83 ± 4.80 | .674      |
|            | ADFI(g)  | 174.03 ± 14.30 | 169.20 ± 8.31 | 169.73 ± 10.28 | 167.77 ± 5.83 | .538      |
|            | F/G      | 1.96 ± 0.11 | 1.89 ± 0.07 | 1.89 ± 0.06 | 2.03 ± 0.06 | .012      |
| 1–42 days  | ADG(g)   | 68.44 ± 5.53 | 67.81 ± 4.25 | 68.22 ± 4.14 | 64.22 ± 2.68 | .579      |
|            | ADFI(g)  | 121.68 ± 7.33 | 118.65 ± 4.98 | 119.05 ± 5.66 | 117.55 ± 3.07 | .894      |
|            | F/G      | 1.78 ± 0.06 | 1.75 ± 0.04 | 1.75 ± 0.04 | 1.83 ± 0.04 | .028      |

In the same row, values with the same small letter or no letter superscripts mean no significant difference ($p > .05$), while values with adjacent small letter superscripts mean a significant difference ($p < .05$).

**Table 4.** Effects of newly harvested corn on intestine development in broilers.

| Days | Weight of intestine | AC group | 1/3 NC group | 2/3 NC group | NC group | $p$-value |
|------|---------------------|----------|--------------|--------------|----------|-----------|
| 21 d | Absolute weight of duodenum /g | 5.12 ± 0.18 | 5.36 ± 0.24 | 5.38 ± 0.22 | 5.01 ± 0.15 | .383      |
|      | Absolute weight of jejunum /g | 8.95 ± 0.22 | 8.26 ± 0.36 | 8.95 ± 0.37 | 7.38 ± 0.28 | .038      |
|      | Absolute weight of ileum /g | 7.04 ± 0.33 | 7.92 ± 0.34 | 6.92 ± 0.24 | 7.15 ± 0.31 | .158      |
|      | Absolute weight of caecum /g | 9.12 ± 0.08 | 9.76 ± 0.08 | 9.07 ± 0.08 | 8.53 ± 0.08 | .476      |
|      | Relative weight of duodenum % | 0.64 ± 0.11 | 0.43 ± 0.12 | 0.45 ± 0.12 | 0.38 ± 0.12 | .143      |
|      | Relative weight of jejunum % | 1.12 ± 0.08 | 0.43 ± 0.08 | 0.43 ± 0.08 | 0.38 ± 0.08 | .35       |
|      | Relative weight of ileum % | 0.88 ± 0.10 | 0.93 ± 0.22 | 0.81 ± 0.13 | 0.96 ± 0.09 | .894      |
|      | Relative weight of caecum % | 0.31 ± 0.05 | 0.37 ± 0.03 | 0.31 ± 0.04 | 0.36 ± 0.05 | .035      |
| 42 d | Absolute weight of duodenum /g | 12.25 ± 1.22 | 14.02 ± 0.85 | 11.24 ± 1.86 | 10.50 ± 1.32 | .109      |
|      | Absolute weight of jejunum /g | 18.25 ± 1.31 | 20.29 ± 1.20 | 15.03 ± 1.53 | 11.96 ± 1.12 | .044      |
|      | Absolute weight of ileum /g | 21.38 ± 1.32 | 25.03 ± 1.96 | 18.12 ± 1.56 | 19.98 ± 2.20 | .526      |
|      | Absolute weight of caecum /g | 7.68 ± 1.24 | 7.22 ± 1.38 | 7.46 ± 2.01 | 7.16 ± 1.86 | .324      |
|      | Relative weight of duodenum % | 0.61 ± 0.07 | 0.65 ± 0.10 | 0.48 ± 0.07 | 0.45 ± 0.05 | .029      |
|      | Relative weight of jejunum % | 0.76 ± 0.20 | 0.80 ± 0.19 | 0.58 ± 0.08 | 0.70 ± 0.19 | .143      |
|      | Relative weight of ileum % | 0.26 ± 0.06 | 0.23 ± 0.04 | 0.24 ± 0.03 | 0.25 ± 0.05 | .289      |

Absolute weight of intestine were only for reference.

AC: ageing corn; NC: newly harvested corn.
metabolic rate of P in NC group was significantly lower than that in any other group \( (p < .05) \).

**Discussion**

**Growth performance**

Corn occupies a large proportion in diets of livestock and poultry, which directly affects the quality of diets and then affects growth performance of animals (Liu 2011). However, because of the lacking of corn production every year in China, newly harvested corn has to be applied to the diets of livestock and poultry (Yin et al. 2018), whereas regardless of its adverse effects. Some studies have confirmed that feeding newly harvested corn directly to animal would affect growth performance, and the reasons were as follows, compared with ageing corn, newly harvested corn had much higher water content, which would dilute the nutrients of diets and decrease AME and the level of crude protein (Mao 2014). Newly harvested corn had more anti-nutritional factors, such as resistant starch and non-starch polysaccharides, which directly decreased growth rate, the utilisation of nutrients in animals (Yin et al. 2014). Studies also found the reasons were that, on the one hand, newly harvested corn contained more resistant starch, which was not easily digested and absorbed, whereas increased the feeling of satiety, thus reducing the energy intake, at the same time, it accelerated the decomposition of fat and reduce feed utilisation. On the other hand, the high water content in newly harvested corn reduced the content of vitamins, unbalanced nutrients and ultimately reduced the energy intake, while increased the feed intake but did not increase body weight, thereby reducing growth performance (Guo 2017). Studies also found that different storage times of corn showed different F/G (Cui et al. 2013). Our experiment showed that there was no significant differences on F/G between NC group and AC group, which was not similar to previous studies. Possible reason might be related to the varieties and storage conditions of newly harvested corn. Results also showed the lowest F/G appeared in 1/3 NC group and 2/3 NC group at 22 to 42 days of age and 1 to 42 days of age, which confirmed that combining newly harvested corn with ageing corn could play a more effective role in growth performance. Possible reason was that, ageing corn has lower energy than newly harvested corn due to the consumption of nutrients during the long storage.

**Table 5.** Effects of newly harvested corn on activities of digestive enzymes in duodenum in broilers.

| Days | Items       | Groups                                      | p-value |
|------|-------------|---------------------------------------------|---------|
|      |             | AC group 1/3 NC group 2/3 NC group NC group |         |
| 21d  | Protease (U/mgprot) | 47.63 ± 3.36\(^a\) 18.43 ± 4.25\(^b\) | .038    |
|      | Amylase (U/mgprot)  | 37.38 ± 3.14\(^a\) 17.25 ± 2.85\(^b\) | .021    |
| 42d  | Protease (U/mgprot) | 12.91 ± 1.21 13.16 ± 1.03 | .576    |
|      | Amylase (U/mgprot)  | 32.72 ± 1.18 32.99 ± 1.65 | .653    |

AC: ageing corn; NC: newly harvested corn.

In the same row, values with the same small letter or no letter superscripts mean no significant difference \((p > .05)\), while values with adjacent small letter superscripts mean a significant difference \((p < .05)\).

**Table 6.** Effects of newly harvested corn on activities of digestive enzymes in jejunum in broilers.

| Days | Items       | Groups                                      | p-value |
|------|-------------|---------------------------------------------|---------|
|      |             | AC group 1/3 NC group 2/3 NC group NC group |         |
| 21d  | Maltase (U/mgprot) | 51.85 ± 3.24 55.02 ± 2.51 | .874    |
|      | Sucrase (U/mgprot)  | 24.25 ± 1.12 25.13 ± 1.06 | .533    |
|      | Lactase (U/mgprot)  | 6.85 ± 0.82 14.22 ± 0.39 | .476    |
| 42d  | Maltase (U/mgprot) | 29.28 ± 3.80 30.78 ± 2.63 | .668    |
|      | Sucrase (U/mgprot)  | 1.83 ± 0.26 1.97 ± 0.32 | .528    |
|      | Lactase (U/mgprot)  | 5.37 ± 0.91 6.95 ± 0.86 | .875    |

AC: ageing corn; NC: newly harvested corn.

**Table 7.** Effects of newly harvested corn on metabolism of nutrients in broilers.

| Items               | Groups                                      | p-value |
|---------------------|---------------------------------------------|---------|
| AME (MJ/kg)         | AC group 1/3 NC group 2/3 NC group NC group | .925    |
| Crude protein (%)   | 12.86 ± 0.18 12.88 ± 0.29 12.89 ± 0.28 13.07 ± 0.25 | .893    |
| Calcium (%)         | 58.33 ± 2.38 57.96 ± 2.86 56.69 ± 1.30 57.72 ± 1.84 | .016    |
| Phosphorus (%)      | 44.21 ± 4.98\(^a\) 44.96 ± 4.57\(^a\) 51.50 ± 6.77\(^b\) 40.52 ± 3.23\(^b\) | .024    |

AC: ageing corn; NC: newly harvested corn; AME: apparent metabolisable energy.

In the same row, values with the same small letter or no letter superscripts mean no significant difference \((p > .05)\), while values with adjacent small letter superscripts mean a significant difference \((p < .05)\).
time, it also has lower content of water and anti-nutritional factors. This method mixed in proportion of 1:2 or 2:1 could both relieve the negative effects of anti-nutritional factors in newly harvested corn and the low energy in aging corn (Song 2011). This experiment only studied the different effects of newly harvested corn and ageing corn or mixture of both on broilers, and we found that the effect of mixed use was better. However, which proportion could play the best role still needs to further research.

**Intestine development**

Intestine is an important place for digestion, absorption, immunisation and physiological regulation of nutrients in vivo, and weight of organs usually reflect the physiological status and function of broilers. In general, the relative weight of organs was better reflected the development of organs (Du et al. 1999; He et al. 2005). Jejunum is the main place for digestion and absorption, and its length and height of epithelial cells are important indices to determine its digestion and absorption function of broilers (Song 2011). Cecum plays an important role in the metabolism of water and electrolytes, which decomposes many nutrients that are not digested through some digestive enzymes in the small intestine, such as carbohydrates and small peptides (Thomas 1982; Chaplin 1989). Studies found that corn was secondary ripening crop, and it needed to be fully matured for more than one month after being harvested (Ding 2011; Xu et al. 2012). Newly harvested corn had many anti-nutritional factors, such as resistant starch, non-starch polysaccharide and so on, which would affect the development and the structure and physiological integrity of mucosa in intestine (Song 2011). Only storing for more than four weeks, the newly harvested corn could reduce the contents of resistant starch and water-soluble pentosan, which reduced the adverse effects on the development of digestive organs and improved the morphological structure and physiological function of intestine (Rehman and Shah 1999; Yin et al. 2014). Our experiment showed that the relative weights of caecum of the NC group was significantly higher than that in the 2/3 NC group and AC group at 21 days of age, while the relative weight of jejunum in the NC group was significantly lower than that in the AC group and 2/3 NC group at 42 days of age. It was confirmed that newly harvested corn could promote the development of caecum during the early stage of growth, while inhibited the development of jejunum. A possible reason for this was that carbohydrates were not easily digested, such as resistant starch, which stimulated the development of caecum, while the anti-nutritional factors affected the development of jejunum (Wang et al. 2012). However, results also showed that the relative weights of caecum in 1/3 NC group were significantly higher than that of 2/3 NC group and AC group at 21 days of age, which was not similar with previous studies, it is hard to explain only relying on these data. Maybe it is a random phenomenon, and we need to do further research through a variety of proportions between newly harvested corn and ageing corn.

**Activities of digestive enzymes**

Nutrients must be decomposed into small molecules by digestive enzymes, and then can be absorbed and utilised, so digestion of enzymes is the most important and critical form in animals (Cui 2005), and the activities of digestive enzymes were also regarded as important indices in scientific research and clinical diagnosis (Gestetner et al. 1971). Studies showed that the activities of enzymes were affected by a variety of factors, such as the age of animal, secretion of digestive juice and composition of diets (Sun and Yan 2015). Different diets affected the activities of amylase, protease and lipase (Gestetner et al. 1971). Our results showed that the activities of protease and amylase in duodenum in NC group were significantly lower than that in AC group and 2/3 NC group on 21 days of age, which was similar to previous studies, and it confirmed that newly harvested corn could affect the activities of digestive enzymes in the duodenum. Compared with the AC group, the activity of maltase in the NC group increased by 8.93 and 30.98% at 21 days and 42 days, respectively. However, no significant differences appeared. Possible reason for this result was that newly harvested corn contained more maltose before full maturity.

However, the activities of protease and amylase in duodenum in 2/3 NC group was also lower than that in AC group and 2/3 NC group on 21 days of age, which was not similar to previous studies, but was corresponding to the results of intestine development. Perhaps, we should pay more attention to the differences between these four experimental diets, including the composition and nutrient levels and the levels of anti-nutritional factors, etc.

**Metabolism of nutrients**

Research has shown that the metabolism of feed nutrients was related to animal age, activities, action time of digestive enzymes and sources of feed fibre (Koch and Meyer 1957; Cabel and Ellis 1995). Some scholars found that there were no significant effects on AME
of corn after storage (Gestetner et al. 1971). Another study confirmed this point of view, and it also found that AME might be related to the method of storage. If newly harvested corn was properly stored in a closed iron container, AME will not be affected, even for a long time (Bartov 1996). Scholar also found that the apparent metabolic rate of crude protein in ageing corn was lower than that in newly harvested corn with the prolongation of storage time (Liu 2011). Our experiment showed that there were no significant differences in AME and the metabolic rate of crude protein among the four groups. The apparent metabolic rates of Ca and P of NC group was significantly lower than that of any other group, indicating that newly harvested corn could affect the digestion and absorption of calcium and phosphorus, which was not exactly similar to previous research and the result of AME in our experiment. The reason might be much anti-nutritional factors, such as resistant starch and non-starch polysaccharides in newly harvested corn inhibited the digestion and absorption of protein. We also found that the metabolism of Ca is reduced with increase in new corn, but not the case for energy and protein, possible reasons were that different nutrients had different ways of absorption. In addition, the ageing corn in this experiment was only stored for one year, and there were little differences between newly harvested corn and ageing corn with less nutrients consumption, which might be a reason causing these results.

Conclusions

This experiment showed that newly harvested corn could reduce the growth performance and apparent metabolic rate of some nutrients in broilers. It is suggested that the application of newly harvested corn should be controlled in actual production. First, newly harvested corn should not be used before completely maturing, for example, storing it for more than two months before using it to diets. Second, we should increase feed energy and rebalance feed to satisfy the nutrimental needs of the diets of livestock and poultry when we have to use newly harvested corn. Third, we should add some enzymes into diets to overcome the adverse effect of anti-nutrimental factors, such as amylase and glucoamylase. Finally, we suggest that feed enterprises should reserve enough corn in advance and use new corn as little as possible, because the complex mechanism of newly harvested corn has not yet been fully grasped.

Disclosure statement

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