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Original Research Article

Effect of storage time on the characteristics of corn and efficiency of its utilization in broiler chickens

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ABSTRACT

Corn is one of the staple food and feed ingredients in China, therefore its storage is of particular importance. Corn is typically stored for 2 or more years in national barns before it is sold as a food or feed ingredient. However, the effects of stored corn in national barns on the animal performance and nutrient utilization have not been investigated thus far. This study attempted to determine the effects of storage time on the chemical and physical characteristics of corn and its nutritional value, broiler growth performance, and meat quality. Corn grains used in the present study were stored for 4 different periods, from 2 to 5 yr, under the same conditions in a building at the Beijing National Grain Storage Facility. A total of 240 birds in Exp. 1 and 90 birds in Exp. 2 were used to compare the effects of storage time on the utilization of nutrients of corn, the performance, and meat quality of broilers. The content of starch, crude protein, amino acids, fatty acids, and test weight generally decreased with increasing storage time. Corn stored for over 4 yr showed decreased catalase (CAT) and peroxidase (POD) activities and increased fat acidity. Body weight gain (BWG) and European production index (EPI) of broilers from 0 to 3 wk tended to decrease linearly with storage time ($0.05 < P < 0.10$), and the BWG and EPI of broilers from 4 to 6 wk decreased quadratically ($P < 0.05$), whereas feed conversion ratio (FCR) increased with storage time ($P < 0.05$). The FCR, performance, and EPI of broilers positively correlated with CAT activity ($P < 0.05$), and negatively correlated with fat acidity ($P < 0.05$). Drip loss of breast muscle increased linearly with corn storage time ($P < 0.001$); however, pH decreased linearly with corn storage time. Drip loss had a strong negative correlation with POD ($P < 0.05$). There were no significant differences of the storage length on metabolizable energy (ME), digestibility of crude protein, and starch ($P > 0.05$). The digestibility of histidine and arginine, and C18:2 and C18:3 changed quadratically with storage time ($P < 0.05$). Collectively, the results suggest that the use of corn stored for 4 yr in animal feed decreased the performance and meat quality of broilers. Fat acidity, CAT, and POD activities can be used as indexes for evaluating the storage quality of corn.

1. Introduction

Globally, over 2.58 billion tons of cereal grains such as corn, wheat, and rice (FAO, 2017) are produced annually, and these cereal grains are stored for the purpose of food security and sustainability. Unfortunately, a considerable amount of such stored grains can be lost due to interactions among various physical, chemical, and biological factors (Choct and Hughes, 2000).

Activities of alpha-amylase and beta-amylase are decreased during storage, whereas those of proteases, lipases, and lipoxygenase of rice are increased (Chrastil, 1990a; Dhaliwal et al., 1991); thus the solubility and digestibility of protein in rice are

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reduced during the storage process (Chrastil, 1990a,b). In addition, during storage, lipid oxidation and free fatty acid content in whole meal flour are increased (Galliard, 1986), and fat acidity in wheat flour is increased whereas iodine-binding values are decreased (Salman and Copeland, 2007). Free fatty acids can be easily oxidized to produce H_2O_2, and thus affect catalase (CAT) and peroxidase (POD) activities in corn (Bailly et al., 2002). The activities of CAT and POD are also affected by cell-membrane lipid peroxidation and are used as indicators to assess the quality of stored corn (Zhou et al., 2007).

Usually, corn is stored for 2 or more years in many countries and then used as a food or feed ingredient. Cabell and Ellis (1955) found a decrease in protein efficiency in corn from 2.72 to 1.81 g after 5 yr of storage; however, no effect was observed in the growth rate of rats fed corn that was stored for as long as 6 yr (Cabell and Ellis, 1955). Bartov (1996) indicated that the chemical composition of corn stored inside a storehouse was relatively stable for at least 110 mo, and the content of metabolizable energy corrected for N (AME_n) was not affected by the storage duration. However, storage conditions likely affect the nutritional value of corn (Bartov, 1996), as indicated by changes in the lysine content. Previous studies have focused on the nutrient utilization of corn stored in good condition or the effect of stored corn on the growth of rats. Little attention has been paid to the effects of corn stored in a natural environment (room temperature in barns) on the animal performance and the utilization of nutrients in broilers.

Thus, the present study determined the effects of storing corn up to 5 yr in national barns on the performance, meat quality, and utilization of energy and nutrients in broiler chickens.

2. Materials and methods

All corn samples used in the present study were stored in brick structures, each of which could hold up to 5,000 t of corn (Yanqing, Beijing, China). The study protocol was approved by the China Agricultural University (Beijing, China) and consistent with the Chinese National Guidelines for Experimental Animals.

2.1. Corn samples

Corn samples stored at room temperature for 2, 3, 4, or 5 yr after harvest were used for the analyses (Table 1). All corn samples were yellow corn, which were sun-dried to attain a moisture content of 15% or less to prevent microbial growth. No information on the varieties of corn was available. At the storage facility, corn was treated with phosphine every year to control insects and weevils, and an axial flow ventilator was used to aerate the facility to reduce the temperature and moisture to prevent mycotoxin contamination.

2.2. Characterization of the corn

The content of dry matter, crude protein (CP), amino acids, fatty acids, and the CAT and POD activities were determined (Table 1). Dry matter was determined by drying samples at 105 °C using a forced-air drying oven (AOAC, 1995). Nitrogen content was determined by the Kjeldahl method (AOAC, 1995), and CP content was calculated as N × 6.25. The amino acid content was determined by HPLC (Agilent 1200, Santa Clara, CA, USA) as described by Ravindran et al. (2009). The fatty acids content was determined using gas chromatography GC-17A (Shimadzu, Kyoto, Japan) according to Sukhija and Almquist (1988). Catalase and POD activities were determined according the method described by Cakmak et al. (1993).

Table 1
Selected nutrient components of corn stored for different years (air dry).[1]

Item	Corn storage time, yr			
	2	3	4	5
Moisture, %	11.42	11.50	11.10	12.40
Test weight, g/L	719.0	718.5	718.5	687.5
CP, %	6.97	7.58	7.12	7.15
Amino acid, %				
Asp	0.46	0.48	0.47	0.43
Thr	0.26	0.27	0.27	0.25
Ser	0.33	0.36	0.36	0.33
Glu	1.47	1.54	1.51	1.44
Pro	0.58	0.63	0.62	0.60
Gly	0.27	0.28	0.28	0.26
Ala	0.52	0.54	0.52	0.51
Cys	0.19	0.19	0.20	0.18
Val	0.43	0.42	0.42	0.40
Met	0.18	0.11	0.14	0.15
Ile	0.23	0.24	0.24	0.23
Leu	0.84	0.88	0.85	0.84
Tyr	0.16	0.18	0.15	0.15
Phe	0.28	0.35	0.27	0.33
Lys	0.22	0.37	0.23	0.34
His	0.23	0.31	0.24	0.27
Arg	0.27	0.28	0.27	0.25
Fatty acid, mg/g				
C16:0	3.09	3.28	3.01	2.81
C16:1	0.03	0.03	0.03	0.03
C18:0	0.34	0.38	0.33	0.30
C18:1	6.11	6.74	5.86	5.19
C18:2	11.38	12.27	10.55	9.69
C18:3	0.28	0.31	0.26	0.22
C20:1	0.07	0.04	0.07	0.07
Catalase activity, mg H_2O_2/g	151.1	151.6	183.8	6.8
Peroxidase activity, U/g per min	381.9	595.2	416.3	159.3
Acidity of fatty acids, KOH mg/100 g dry matter	56.2	48.8	54.5	108.1

[1] Analysis based on a duplicate.

2.3. Broiler chickens, management, and sample collection

In Exp. 1, a total of 192 one-day-old Cobb 500 female broiler chickens from a local hatchery were used. The broiler chickens were randomly allotted to 4 dietary treatments with 8 replicates of 6 broiler chickens per pen. The 4 dietary treatments for the starter (0 to 3 wk) and grower (4 to 6 wk) phases were established using corn stored for 2, 3, 4, or 5 yr. Thus, the only difference among the experimental diets was the corn used. The basal starter and grower diets met or exceeded the nutritional recommendations by the Chinese Ministry of Agriculture (2004) except linoleic acid (Table 2).

Boiler chickens were weighed at hatching and at 3 and 6 wk after a 6-h fasting, and feed intake (FI) was recorded from 0 to 3 wk and from 4 to 6 wk to determine body weight gain (BWG) and feed conversion ratio (FCR). Mortality and culling were recorded daily for each pen and were used to determine the European production index (EPI) = 100 × [BWG (kg) × livability (%)]/[FCR × age (d)].

At d 42, 1 bird from each of the 6 pens, were selected randomly, weighed, and sacrificed by intravenous injection of sodium pentobarbital after fasting for >10 h. The breast muscle was removed, and its pH and drip loss were measured. The pH was measured by direct insertion of an electrode (Testo 205; Testo Pty Ltd., Testo AG, Lenzkirch, Germany) into 1 cm below the left major pectoralis muscle. Drip loss of raw muscle of breast was determined by placing the sample in a plastic bag and hanging it in a refrigerator at 4 °C for 24 h; it was calculated as the weight lost from the initial weight and expressed as a percentage.

In Exp. 2, one-day-old Cobb 500 female chickens were allotted to 4 dietary treatments with 6 replicates of 18 birds per pen. The

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