Effects of feed systems on growth performance, carcass characteristics, organ index, and serum biochemical parameters of pigeon

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ABSTRACT This study aimed to investigate the effects of feed systems in parent pigeons on the growth performance, carcass characteristics, organ index, and serum biochemical parameters of squabs. A total of 60 pairs of parent pigeons were selected and divided into 2 groups randomly. The parent pigeons were fed with two feed systems that were whole grains plus granulated feed (**WGG**) and complete-formula granulated feed (**CFG**) for 21 d. The results showed that CFG diet could increase carcass yield, heart index, content of trypsin, and growth hormone of squabs ($P < 0.05$), but decrease feed intake, gizzard index, b^* value, malondialdehyde concentration, and uric acid concentration significantly ($P < 0.05$) comparing with WGG diet. There were no significant differences among the 2 groups in feed intake from d 1 to d 21, abdominal fat yield and body weight changes of squabs and parent pigeons ($P > 0.05$). It can be concluded from these observations that CFG was beneficial to squab which could improve digestive enzyme and antioxidant ability in the serum, so the CFG should be suggested in practice.

Key words: pigeon, feed systems, whole grains plus granulated, complete-formula granulated

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INTRODUCTION

Currently, the world's 80% of pigeon meat and 680 million squabs was produced in China (Jiang et al., 2019). As a type of altricial bird, pigeons didn't have independent foraging ability after hatching, and required feeding by the parent pigeons (males and females) with pigeon milk for the first 3 days after hatching, and this characteristic differentiates pigeons from other poultry species. Thereafter, pigeon milk mixed with soaked grains was fed to squabs until they could eat by themselves (Shetty et al., 1992; Gillespie et al., 2013). Thus, the constitution of feed of parent pigeons plays an important role in young squab performance.

Generally, pigeons were separately fed with raw feed grains added with health sand (Xiao et al., 2020), which causatively induced the imbalance of nutrition provision, and serious feed waste (Chen et al., 2015; Xiao et al., 2020). Feeding with complete-formula granulated feed might solve the large-scale and modern development needs of pigeon, but application of complete-formula granulated feed in pigeon was slow due to its own digestion, physiological characteristics and unique breeding mod. Granular feed, as a balancing diet, which could be accurately supplemented with a certain essential amino acids or trace elements, showed the important use in pigeon breeding.

Due to the whole grains and seeds were most selected by pigeons (Biedermann et al., 2012), feed of pigeon primarily consisted of whole grains and seeds because of the ingesting tendency while minerals, vitamins, and some other nutrients were provided as supplements at present (Khashaba et al., 2009). Waldie et al. (1990) indicated that it was feasible to substitute complete-formula granulated feed for whole grains and seeds.

However, the effects of complete-formula granulated feed on squabs growth need to be further studied. The object of this study was to evaluate the effects of feed systems on growth performance, carcass characteristics, organs, meat quality, oxidative status, serum parameters, and hormones in squabs in order to provide a basis for production application.

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MATERIALS AND METHODS

Experimental Diets

The parent pigeons were randomly assigned to 2 groups. The pigeons in the first group were fed with whole grains (35% pea, 25% corn, 5% wheat) plus 35% granulated feed (**WGG**). Another group was fed with complete-formula granulated feed (**CFG**). The composition of 2 groups was shown in Table 1. The raw materials were ground and mixed properly, and then the diets were pelleted and cooled to decrease temperature and moisture, and the diameter and length of the pellets were about 4.0 mm and 5.0 mm, respectively. Health care sand, feed, and water were provided for ad libitum consumption throughout the experiment. Moreover, the levels of nutrition remained the same in the 2 groups.

Birds and Housing

A total of 60 pairs of parent White King pigeons at breeding stage (60 pairs, 60 females, and 60 males) were obtained from the commercial pigeon farm (Shanxi Province, China), and randomly assigned to 2 groups. Each group contained 30 pairs of parent pigeons, which consisted of 6 replicates of 5 pairs of parent pigeons. Each pair of parent pigeons raised 3-day-old squabs and was housed in a man-made aviary, the cages were equipped with a perch and a nest. The replicates were equally distributed into upper, middle, and lower cage levels to minimize cage-location effects. Parent pigeons and squabs were weighted at 1, 14, and 21 d. Pigeons were weighted after 12 h fasting. The animal feeding and pigeon slaughter involved in the experiment were in accordance with the principles and specific guidelines in "Guide for the Care and Use of Agricultural Animals in Research and Teaching" (Vaughn, 2010). They were approved for animal experiments by Welfare Ethics Committee Approval (Approval Reference Number: IAS2021-99) of Institute of Animal Sciences of Chinese Academy of Agricultural Sciences.

Table 1. Composition, formulation and nutrient values of the two groups[1].

Items	WGG	CFG
Ingredient(%)		
Granulated		
Corn	13.65	38.30
Wheat	0.70	5.70
Soybean meal	14.35	14.35
Soyabean oil	1.66	1.66
Pea	1.75	36.75
Sorghum	1.05	1.05
Rock flour	0.67	0.67
Dicalcium phosphate	0.67	0.67
Premix[2]	0.88	0.88
Whole grain		
Corn	25.00	0.00
Wheat	5.00	0.00
Pea	35.00	0.00
Nutrient levels		
GE (MJ/Kg)	16.76	16.82
ME (MJ/Kg)[3]	12.04	12.04
CP(%)	18.09	17.53
Ca(%)	0.18	0.17
P(%)	0.39	0.39
Lysine (%)	1.09	1.09
Methionine (%)	0.23	0.23
EE(%)	3.56	3.66
CF(%)	4.89	4.83
DM(%)	88.46	88.48

[1]WGG, whole grains plus granulated feed; CFG, complete-formula granulated feed.

[2]Premix provided the following (per kilogram of diet): VA, 400 KIU; VD_3,100 KIU; VE, 400 IU; VK_3, 125 mg; VB_1, 38 mg; VB_2, 125 mg; VB_6, 80 mg; VB_{12}, 0.4 mg; folic acid, 0.75 mg; calcium pantothenate, 80 mg; biotin, 0.75 mg.

[3]ME level was calculated from practical measured values. Other nutrient levels were measured from the feed.

Sample Collection

At the end of experiment, 2 squabs were selected randomly from each replicate, and a total of 12 squabs in each group for slaughter and post-slaughter analysis. Before weight and slaughter, pigeons were withdrawn from feed for 12 h, then blood sampled by jugular vein. The whole blood was put aside for approximately 20 min. Pure serum was collected by pipette and stored in 1.5 mL tubes at −20°C until analysis. After blood and feathers were removed, carcasses were weighted to calculate carcass yield. Then, samples were immediately collected from the left breast muscles and thigh muscles and stored at 4°C to determine meat quality, including meat color, and drip loss. At the same time, the other organs, including heart, liver, spleen, pancreas, proventriculus, gizzard, breast, thigh, abdominal fat, and kidney of squabs, were extracted and weighed. Carcass yield, eviscerated yield and semi-eviscerated yield were calculated as percentage of body weight. Breast muscle yield and thigh muscle yield were calculated as percentage of eviscerated weight.

Meat Quality Measurement

At 24 h after slaughter, the color of breast muscle was evaluated. We measured 3 times at 3 different locations around the meat sample and averaged using a handheld colorimeter based on the CIELAB system (L^* = lightness; a^* = redness; b^* = yellowness). Next, meat samples were weighed, hung in a sealed plastic bag and stored at 4°C for 24 h. Then, samples were weighed again to calculate drip loss.

Measurement of Antioxidant Activities in Liver

Liver samples of approximately 200 mg were homogenized by an Automatic Sample Rapid Grinding Machine. Then, the homogenization buffer was centrifuged at 3,500 rpm for 10 min. The supernatant was used for assaying the antioxidant indices, including the total antioxidant capacity (**T-AOC**), the concentration of MDA, the activities of glutathione peroxidase (**GSH-Px**) and total superoxide dismutase (**T-SOD**). These parameters were determined by a commercial colorimetric kit. Briefly, the absorbance of each sample was spectrophotometrically measured using a spectrometer against a blank.

Serum Biochemical Indices

At the end of the feeding study, blood samples were collected from squabs. Serum of squabs were aspirated from blood by pipette and stored in 1.5 mL Eppendorf tubes at 80°C. They were thawed at 4°C before analysis. Serum concentrations of total cholesterol (**TC**), total protein (**TP**), albumin (**ALB**), triglyceride (**TG**), alanine aminotransferase (**ALT**), aspartate transaminase (**AST**), and uric acid (**UA**) were measured spectrophotometrically, using an automated system (CLS880 analyzer, Jiangsu Zecheng Bioengineering Institute, Jiangsu, China). Immunoglobulin G (**IgG**) and trypsin (**TPS**) in the serum were measured using commercial ELISA kits. Absorbance at 450 nm was measured by microplate reader (THERMO Multiskan Ascent, Waltham, MA, USA).

Serum Hormone Measurement

Growth hormone (**GH**), Follicle-stimulating hormone (**FSH**), luteinizing hormone (**LH**), and prolactin (**PRL**) were assayed using the multitube radio immune counter (BFM-96, Zhongcheng Electromechanical technology Company, Anhui, China). Each assay was run in duplicates.

Statistical Analysis

All data were presented as means ± SEM and evaluated by using Student t test of SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL), the differences between groups were considered statistically significant if $P < 0.05$.

RESULTS

Growth Performance

Effects of feed system on growth performance were presented in Table 2. Pigeons fed with CFG showed significant lower feed intake than those fed with WGG at 14 d for the parent pigeon ($P < 0.05$), but there was no difference at 21 d. The body weight between 2 groups didn't show significant difference both for parent pigeons and their squabs.

Slaughter Performance of Squabs

The effects of feed systems on the carcass yield, semi-eviscerated yield, eviscerated yield, breast muscle yield, thigh muscle yield, and abdominal fat yield of the squabs were showed in Table 3. The carcass yield of the squabs was increased by 2.48%, when the parent pigeons were fed with CFG compared with those fed with the WGG ($P < 0.05$). There was little difference in other characteristics of the squabs among all of the groups ($P > 0.05$).

Table 2. Effect of feed systems on growth performance of parent pigeons and squabs[1,2].

Items	WGG	CFG	P value
Feed intake (g)			
1−14 d	847.67 ± 18.17[a]	750.34 ± 41.86[b]	<0.05
1−21 d	1,229.81 ± 34.48	1,177.43 ± 49.86	0.40
Body weight changes (g)			
Squab			
1−14 d	383.06 ± 7.34	363.98 ± 5.93	0.05
1−21 d	410.21 ± 5.21	396.83 ± 11.11	0.29
Parent pigeon			
1−14 d	34.02 ± 4.98	26.97 ± 4.08	0.28
1−21 d	43.99 ± 7.54	43.56 ± 6.26	0.97

[1]Data are shown as means ± SEM.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Table 3. Effects of parent pigeon feed systems on the slaughter performance of squabs[1,2]

Items	WGG	CFG	P value
Carcass yield (%)	79.5 ± 0.69[a]	81.47 ± 0.65[b]	<0.05
Semi-eviscerated yield (%)	69.87 ± 0.29	70.12 ± 0.54	0.69
Eviscerated yield (%)	56.13 ± 1.25	55.48 ± 0.51	0.64
Breast muscle yield (%)	20.60 ± 0.70	20.76 ± 0.28	0.83
Thigh muscle yield (%)	7.79 ± 0.21	7.64 ± 0.17	0.61
Abdominal fat yield (%)	1.12 ± 0.13	1.71 ± 0.25	0.06

[1]Values are presented as means ± SEM; n = 12.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Organ Index

Significance analysis of organ index was showed in Table 4. In comparison to the values of WGG, the heart index of CFG increased significantly ($P < 0.05$), while the gizzard index decreased significantly ($P < 0.05$). No other significant alterations were observed ($P > 0.05$).

Meat Quality

The results of meat quality traits, including pH, muscle color and drip loss rate were presented in Table 5. In comparison to the CFG, WGG increased the b^* value in the breast muscle of squabs (P < 0.05).

Table 4. Effects of feed systems on organ index[1,2].

Items	WGG	CFG	P value
Heart index (%)	0.88± 0.02[a]	0.99 ± 0.04[b]	0.02
Liver index (%)	2.91 ± 0.11	2.70 ± 0.07	0.13
Gizzard index (%)	2.23 ± 0.06[a]	1.66 ± 0.08	<0.01
Gland stomach index (%)	0.38 ± 0.02	0.37 ± 0.01	0.56
Thymus index (%)	0.40 ± 0.04	0.36 ± 0.04	0.49
Spleen index (%)	0.12 ± 0.01	0.14 ± 0.02	0.31
Bursa of fabricius index (%)	0.23 ± 0.02	0.21 ± 0.02	0.32

[1]Values are presented as means ± SEM; n = 12.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Table 5. Effects of parent pigeon feed systems on the meat quality of squabs[1,2,3].

Items	WGG	CFG	*P* value
pH	6.11 ± 0.04	6.15 ± 0.03	0.43
*L**	38.37 ± 0.51	38.73 ± 0.50	0.62
*a**	18.81 ± 0.32	18.65 ± 0.30	0.72
*b**	9.32 ± 0.29[a]	7.56 ± 0.21[b]	<0.01
Drop loss rate (%)	0.02 ± 0.01	0.02 ± 0.01	0.85

[1]Values are presented as means ± SEM; n = 12.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[3]*L** = lightness; *a** = redness; *b** = yellowness.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Antioxidant Activity

As shown in Table 6, T-AOC, GSH-Px, and SOD not differ significantly between groups. MDA content of squabs in WGG was significantly higher than CFG ($P < 0.05$).

Serum Biochemical Parameters

The concentrations of TC, TP, and ALB in parent pigeons were not affected by the feed systems. As shown in Table 7, it was found that feed systems had no effect on the concentrations of TC, TG, ALT, AST, and IgG in squabs ($P > 0.05$). However, the serum concentrations of UA of squabs in WGG were significantly higher than CFG ($P < 0.05$). TPS of squabs fed with CFG was higher than squabs fed with WGG ($P < 0.05$).

Table 6. Effects of feed systems on immune index[1,2,3].

Items	WGG	CFG	*P*-value
T-AOC (U/mg)	6.84 ± 0.54	6.66 ± 0.49	0.81
MDA (nmol/mg)	1.09 ± 0.08[a]	0.86 ± 0.05[b]	0.03
GSH-Px (umol/g)	7.30 ± 0.63	6.13 ± 0.43	0.15
SOD (U/mg)	1,291.69 ± 82.96	1,220.70 ± 78.81	0.55

[1]Values are presented as means ± SEM, n = 8.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[3]T-AOC, total antioxidant capacity; MDA, malondialdehyde; GSH-Px, glutathione peroxidase; SOD, superoxide dismutase.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Table 7. Effects of feed systems on serum concentrations of TC, TG, ALT, AST, UA, TPS in squabs and TC, TP, ALB in parent pigeons[1,2,3].

Items	WGG	CFG	*P* value
Parent pigeons			
TC (mmol/L)	7.40 ± 0.55	7.42 ± 0.49	0.97
TP (g/l)	25.98 ± 1.54	26.57 ± 1.40	0.78
ALB (g/l)	8.84 ± 0.02	9.30 ± 0.19	0.08
Squabs			
IgG (mg/mL)	10.09 ± 0.29	9.66 ± 0.49	0.46
TC (mmol/L)	6.93 ± 0.41	7.47 ± 0.55	0.44
TG (mmol/L)	2.03 ± 0.09	2.28 ± 0.24	0.35
ALT (U/L)	14.78 ± 1.69	19.03 ± 3.69	0.31
AST (U/L)	85.54 ± 4.46	87.09 ± 1.11	0.74
UA (umol/L)	327.36 ± 8.61[a]	276.55 ± 11.62[b]	<0.01
TPS (ng/mL)	43.10 ± 1.03[a]	47.05 ± 0.77[b]	0.022

[1]Values are presented as means ± SEM, n = 8.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[3]ALB, albumin; ALT, alanine aminotransferase; AST, aspartate transaminase; IgG, immunoglobulin G; TC, total cholesterol; TP, total protein; TG, triglyceride; TPS, trypsin; UA, uric acid.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Table 8. Effects of feed systems on concentrations of serum hormones[1,2,3].

Items	WGG	CFG	*P* value
Parent pigeons			
GH (ng/mL)	2.18 ± 0.27	1.90 ± 0.21	0.45
FSH (mIU/mL)	3.58 ± 0.62	4.21 ± 0.27	0.38
LH (mIU/mL)	6.00 ± 0.81	8.68 ± 1.57	0.17
PRL (μIU/mL)	83.67 ± 8.99	59.93 ± 6.75	0.07
Squabs			
GH (ng/mL)	1.24 ± 0.07[a]	1.74 ± 0.20[b]	0.04

[1]Values are presented as means ± SEM, n = 8.
[2]WGG, whole grains plus granulated; CFG, complete-formula granulated.
[3]FSH, follicle-stimulating hormone; GH, growth hormone; LH, luteinizing hormone; PRL, prolactin.
[a-b]Mean values within the same row not sharing a common superscript letter are significantly different ($P < 0.05$).

Hormones

Different feed systems significantly affected hormonal concentration in squabs serum. As shown in Table 8, the concentration of GH in CFG was significantly higher than WGG ($P < 0.05$). While concentration of serum hormones didn't show significant changes in parent pigeons ($P > 0.05$).

DISCUSSION

Pigeons are mainly fed with WGG in present, but this feed system is not accord with the nutritional strategies. This study was designed to confirm the effects of CFG on the growth performance of parent pigeons and squabs. Feeding pigeons with CFG improved the carcass yield and the content of growth hormone in squabs. Our results were consistent with the findings of Fan (1986), who found that CFG avoided nutrient imbalance caused by pigeon picky food and squabs grew well. Bu et al. (2013) found that feeding pigeons with CFG decreased the daily feed intake and improved the body weight.

Feed intake and body weight are important economic traits in pigeons. In our results, we found that the feed systems did not affect feed intake from d 1 to d 21 and body weight. Meng et al. (2017) found that whole grains, whole grains plus premix, and whole grains plus granulated have no significant differences in feed intake and body weight. Yang et al. (2013) found that the feed intake of squabs during the group had significant difference, compared with WGG, the feed intake in CFG were significantly decreased. In our research, the feed intake from d 1 to d 14 in CFG was decreased. This finding may be attributable to the maladjustment with new feed.

Carcass characteristics are indicators of nutrient deposition, and the abdominal adipose percentage is an important indicator used to measure lipid deposition in poultry (Wan et al., 2021). It was reported that body fat content changed rapidly in birds, for instance, as an adaptation to predation risk (Gosler, 1996). Li et al. (2010) found that feeding goose with pulverized brown rice-pulverize rice husks improved abdominal adipose percentage. The increased abdominal adipose percentage might indicate that CFG was easy to digest and absorb, which resulted in fat deposition. In the present study, we found the increasing in abdominal fat yield in GFG but not significant. Previous studies (Bu et al., 2013) have shown that the increasing in slaughter rate is directly related to the CFG. In our results, gizzard index significantly decreased in the CFG. Xie et al. (2016) also found that compound feed group had a lower relative weight of gizzard than other groups. In previous reports, compared with birds given a single compound feed, those offered whole grains have heavier gizzard (Olver and Jonker, 1997; Banfield and Forbes, 2001; Rutkowski and Wiqz, 2001; Plavnik et al., 2002). We speculated that WGG compared to CFG generally resulting in an increasing digestion time due to a long retention time in the gizzard.

Prolactin induced serum albumin translation and promoted lactation (Baruch et al., 1998). FSH and LH could monitor ovulation (Xie et al., 2018). ALT and AST activities were used as the most sensitive indicators for liver function. ALB was a carrier protein for many hormones and metalions (Refetoff et al., 1970), which played a very important role in maintaining blood colloid osmotic pressure, metabolism transport, and nutrition. Blood metabolites, such as ALB and TG, were indicator of nutritional status in general (Xie et al., 2018). Serum levels of TG and TC could reflect the absorption and metabolism of lipids (Chou et al., 2012). Our data showed that GH of squabs significantly increased in CFG, it could promote anabolism, protein synthesis, and amino acid transport and uptake. TPS promoted protein digestion. UA came mainly from digestion, the break down products of the digestive tract, and the metabolites released from tissue cells (Wang et al., 2009). Its changes could reflect the efficiency of amino acid use throughout the body (Donsbough et al., 2010). We speculated that increased protein digestibility may incur the UA decrease in the CFG.

The quality of meat affecting consumer's purchasing decision was mainly affected by muscle color, drip loss, shear force, and cooking loss (Jiang et al., 2019). Deviations from the bright cherry-red color of fresh meat led to consumer's rejection of product and concomitant loss in revenue (Ramanathan et al., 2020). However, the feed system on the meat quality of squabs has not been characterized. The present study indicated that parent pigeons fed with CFG significantly decreased the b^* value, compared with the WGG. The odor and appearance of meat may improve by reducing lipid peroxidation in the body. There is a close relationship between the body's antioxidant activity and muscle quality. MDA was the main end product of lipid peroxidation by ROS and increased MDA concentration was an important indication of lipid peroxidation (Sumida et al., 1989). In present study, the lower liver MDA content of squabs in the CFG compared to that of squabs in the WGG indicated that CFG-enhanced antioxidant status of broilers.

CONCLUSIONS

In summary, compared with the WGG, the CFG could significantly improve the carcass yield, but significantly decrease MDA of squabs. TPS and GH in the serum of squabs were significantly higher in the CFG. The present results indicated that CFG was beneficial to squab growth by increasing some of the growth factors and digestive enzyme in the serum and improving the antioxidant ability. Thus the carcass yield was higher in the CFG, although the body weights at 21 d were not different significantly. It can be concluded from these observations that CFG should be suggested in practice.

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DISCLOSURES

The authors declare no conflict of interest.

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