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Growth, Carcass, and Physiological Traits of Growing Male China Micro-Ducks Fed Various Levels of Dietary Crude Fibre

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ABSTRACT

Wang S.P., Wang W.J., Yang D.S., Zhao X.L., Luo D.M., Guo Y.B. (2017): **Growth, carcass, and physiological traits of growing male China Micro-ducks fed various levels of dietary crude fibre**. Czech J. Anim. Sci., 62, 347–356.

The objective of this study was to evaluate the responses of growth performance, organ development, carcass characteristics, and serum biochemical parameters to the diets with different levels of crude fibre (CF) in growing male China Micro-ducks (CMD). A total of 240 nineteen-day-old CMD were blocked on the basis of body weight, and then randomly allocated to four treatments, each with 6 replicate pens of 10 ducklings. The formal feeding experiment lasted for 35 days. The CF levels for four diets were 16.7, 42.6, 77.9, and 101.6 g/kg of dry matter (DM), respectively. The diet with the CF level of 101.6 g/kg of DM resulted in the first-rank growth performance, followed by the diets with the CF level of 42.6 and 77.9 g/kg of DM, and then the diet with the CF level of 16.7 g/kg of DM. The diet with the CF level of 42.6 g/kg of DM led to the optimum slaughter performance, followed by the diets with the CF levels of 16.7 and 77.9 g/kg of DM, and then the diet with the CF level of 101.6 g/kg of DM. With the increase of the CF level in the diets, the serum glucose concentration and the relative weights of proventriculus and gizzard significantly rose ($P < 0.05$), but the serum concentrations of low-density lipoprotein cholesterol and creatinine, the percentages of head, feet, and abdominal fat, and the relative weights of liver, jejunum, and ileum significantly decreased ($P < 0.05$). For the percentages of pectoral muscle and lean meat and the relative weight of thymus, dietary treatment with the CF level of 16.7 g/kg of DM was significantly lower than the other dietary treatments ($P < 0.05$). The recommended range of dietary CF level for growing male CMD should therefore be between 42.6 and 77.9 g/kg of DM.

Keywords: dietary fibre; production; carcass characteristics; physiological responses

Crude fibre (CF) is a fraction of carbohydrate of the food. The CF fraction contains cellulose, lignin, and hemicelluloses, but not necessarily the whole amounts of these that are present in the plant material as a consequence of an imperfect analytical method. In poultry, dietary fibre (DF) is known for its negative effects as well as its beneficial physiological functions (Mateos et al. 2012). Traditionally, DF has been considered to be a diluent and an antinutritional factor in poultry diets because of its passive impacts upon palatability, voluntary energy intake, and nutrient digestibility (Sklan et al. 2003). However, recent studies have suggested that the inclusion of moderate amounts of fibre in poultry diets might benefit the development of digestive organs (Gonzalez-Alvarado et al. 2007;

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Svihus 2011), the production of HCl, bile acids, and endogenous enzymes (Gonzalez-Alvarado et al. 2008), the digestibility of non-fibre nutrients, and the gastrointestinal refluxes (Jimenez-Moreno et al. 2011). These beneficial effects ultimately might result in improved growth performance as well as gastrointestinal tract (GIT) health (Yokhana et al. 2016). Mateos et al. (2012) concluded that the potential responses to fibre inclusion might rely on the source and level of DF and the properties of the diet as well as on the physiological status and health of the bird. The levels of DF might bring about the differences in GIT transit rates, pH values, and volatile fatty acid productions in poultry (Raninen et al. 2011). Consequently, DF level might affect voluntary feed intake, organ size, GIT motility, enzyme production, nutrient digestibility, microbial growth, and growth performance. Therefore, it is very necessary to evaluate the optimum CF level in the diet of poultry so as to make full use of fibre. Most researches have focused on the effects of DF on chicken, goose, and turkey. However, there is little information about the impacts of DF on duck.

China has the largest amount of ducks in the world. Protein from eggs and meat of duck has a great potential in helping meet the increased demand for high quality protein to satisfy the nutritional requirements of the growing Chinese population. Thus, duck production is becoming specialized and more widespread. China Micro-duck (CMD) is a complete set line which was acquired from selective hybridization among several specialized native and domestic sheldrakes/shelducks (Wang et al. 2013a, b). CMD has white feather and skin, small body size, tender meat with positive quality and high yield, and good adaptabilities to inferior food and diverse production situations. The production practice revealed that CMD has a strong digestive capability to fibrous feedstuffs due to its excellent roughage utilization and adaptability. However, the ideal CF concentration in the diet of CMD is unknown.

The present study was conducted to evaluate the effect of dietary CF on the growth performance, organ development, carcass characteristics, and serum biochemical parameters of growing male CMD.

MATERIAL AND METHODS

The experimental design and procedures were approved by the Animal Care and Use Committee of Southwest University following the requirements of the Regulations for the Administration of Affairs Concerning Experimental Animals of China (The State Science and Technology Commission 1988).

Animals, housing, and management. One-day-old male CMD were purchased from a local hatchery and fed *ad libitum* a starter diet containing 230.9 g/kg crude protein (CP) and 12.43 MJ/kg apparent metabolizable energy (AME) according to the recommendation of Wang et al. (2013a) until 18 days of age. The birds were vaccinated against viral hepatitis (at 1 day of age via intramuscular injection), viral enteritis (at 4 days of age via intramuscular injection), and infectious serositis plus colibacillosis (at 10 days of age via subcutaneous injection) according to the normal immunization procedures (Yang 2002).

At 19 days of age, a total of 240 male CMD with similar body weight were selected and randomly allocated to 4 dietary treatments with 6 replicate pens per diet and 10 ducklings per pen. In days 19–21, the diet of the experimental male CMD was gradually changed over to the corresponding experimental grower diet. The formal period of the feeding experiment began at 22 days of age and ended at 57 days of age. The experiment lasted for 35 days. All birds were fed on the net bed with plastic slatted floorings. A floor space of 0.1 m^2 was provided for each bird. One flat bottom round feeder was supplied for each experimental pen. The temperature (T), relative humidity (RH), and temperature-humidity index (THI) of the duck house were determined daily at 2:00, 8:00, 11:00, and 20:00 h during the entire experimental period using the Multi-Channel In-Out Cable Free Thermo-Hygrometer EMR812HGN (Oregon Scientific, USA). The means of the determined T, RH, and THI of the experimental room during the experiment were 24.96°C, 63.96%, and 73.13, respectively. THI values serve as the basis for calculating the livestock environmental safety index (LCI 1970) (normal, ≤ 74; alert, 75–78; danger, 79–83; emergency, ≥ 84). The THI value (73.13) of the experimental room showed that the experimental ducks were kept under a nice breeding environment. As a result, all birds were healthy during the experiment. The experimental room was lit continuously throughout the whole experimental period. Each experimental diet was pelleted with 2.5 mm of particle size by dry granulation process. The birds had free access to feed and water throughout the experiment.

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Dietary treatment and analyses. The diets with four levels of CF were formulated to meet or exceed the NRC (1994) requirements for ducks. The four levels of dietary CF were 16.7, 42.6, 77.9, and 101.6 g/kg of dry matter (DM), respectively. The modification of dietary CF levels was attained by altering the amount of alfalfa meal in the diet. All diets were isonitrogenous and isoenergetic. The concentrations of dietary CP and AME were set up on the basis of the recommendation of Wang et al. (2013b). The ingredient composition and the analyzed nutrient content of each diet are shown in Table 1.

Samples from the experimental diets (1000 g) were randomly collected and then finely ground to pass through a 1-mm sieve for the further analysis. Gross energy was quantified by an isoperibol bomb calorimeter XRY-1C (Henghe Instrument Company, China) with benzoic acid as a standard. DM (Loss on Drying Method 930.15), organic matter (Ashing Method 942.05), CF (Fritted Glass Crucible Method 962.09), CP (Kjeldahl Method 984.13), ether extract (Ether Extraction Method 920.39), calcium (Atomic Absorption Spectrophotometric Method 968.08), and total phosphorus (Photometric Method 964.06) were determined using the AOAC official methods (AOAC 2005). All diets were analyzed for amino acids by high-pressure liquid chromatography (UPLC®; Waters Corp., USA) following the procedure of Llames and Fontaine (1994). All assays were conducted in triplicate.

Live performance. At the end of the feeding experiment, birds were weighed and feed consumption was recorded by replicate to calculate average daily gain (ADG), average daily feed intake (ADFI) on the basis of DM, and feed conversion ratio (FCR, feed DM intake/weight gain). Birds were deprived from feed for 12 h (water was provided) before weighing to ensure the emptying of the digestive tract of the bird. Mortality was recorded on a daily basis as it occurred. Any bird that died or was removed was weighed and used to correct FCR.

Blood sampling and serum analyses. After weighing, 2 birds near to the mean weight of the pen were randomly selected from each replicate and leg banded for identification. About 4 ml blood per bird was taken out from the wing vein with a sterile syringe. The collected blood samples were kept in sterile 5 ml centrifugal tubes. Blood samples were

Table 1. Ingredient and energy and nutrient composition of the experimental diets[1]

Item	Dietary crude fibre levels (g/kg of dry matter)			
	16.7	42.6	77.9	101.6
Ingredients composition (g/kg)				
Purified corn starch	652.0	442.0	272.0	177.0
Corn	–	160.0	265.0	280.0
Fish meal	290.0	210.0	115.0	70.0
Corn gluten meal	–	45.0	120.0	150.0
Alfalfa meal	–	65.0	130.0	205.0
Soybean oil	–	20.0	40.0	60.0
Calcium hydrogen phosphate	15.0	15.0	15.0	15.0
Calcium carbonate	10.0	10.0	10.0	10.0
Sodium chloride	3.0	3.0	3.0	3.0
Premix[2]	30.0	30.0	30.0	30.0
Chemical composition (g/kg)				
Dry matter	873.3	874.1	883.1	885.6
Gross energy (MJ/kg)	18.46	18.50	18.83	19.01
Organic matter	918.6	919.6	923.1	927.9
Crude fibre	16.7	42.6	77.9	101.6
Crude protein	216.1	220.1	218.3	219.9
Total amino acids	185.5	190.8	186.6	187.4
Lysine	16.6	16.1	17.1	16.9
Methionine	3.0	3.4	3.1	3.3
Cystine	5.4	5.0	4.7	4.7
Threonine	8.3	7.8	7.6	7.4
Valine	10.7	10.4	9.5	9.8
Leucine	19.9	21.2	20.6	22.0
Isoleucine	7.3	6.9	6.8	6.7
Phenylalanine	9.5	10.3	9.3	9.6
Histidine	2.7	3.2	2.8	3.2
Arginine	11.5	11.2	10.3	10.9
Ether extract	39.5	41.3	49.9	55.0
Calcium	16.0	15.0	14.7	14.9
Total phosphorus	7.4	7.1	6.7	6.7

[1]all values were expressed on a dry matter basis except for the dry matter on an air-dried matter basis

[2]feed sample contains (per 1 kg): vitamin A 13 000 IU, vitamin D_3 5 300 IU, vitamin E 50 IU, vitamin K_3 4 mg, vitamin B_1 3 mg, vitamin B_2 10 mg, vitamin B_6 7 mg, vitamin B_{12} 12 mg, folic acid 2 mg, biotin 170 mg, calcium pantothenate 33 mg, nicotinic acid 86 mg, Fe ($FeSO_4 \cdot 7H_2O$) 100 mg, Cu ($CuSO_4 \cdot 5H_2O$) 10 mg, Zn ($ZnSO_4 \cdot 7H_2O$) 53 mg, Mn ($MnSO_4 \cdot H_2O$) 80 mg, Se ($Na_2SeO_3 \cdot 5H_2O$) 0.2 mg, I (as KI) 0.44 mg

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maintained for 1–2 h at room temperature before being centrifuged for 10 min at approximately 3000 *g*. The harvested serum was removed and frozen at –80°C immediately for further analysis. Before serum metabolite analyses were carried out, repeated freeze-thaw cycles were avoided. The serum concentrations of metabolites, including total protein (TP), albumin, triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), urea nitrogen (UN), creatinine, uric acid (UA), and glucose were detected using an automatic biochemistry analyzer Synchron CX5 PRO (Beckman Coulter, USA) by the appointed commercial kits from Beckman Coulter.

Organ and carcass characteristics. After blood collection, the same birds were weighed individually to measure the slaughter weight. All birds were further processed by trained personnel of the plant in a commercial abattoir. Each bird was stunned effectively via electro anaesthetic, bled immediately through cutting carotid arteries and partial slicing of the neck by a manual neck cutter, and then removed the feather and the horny layer of claw and beak following the scalding. After being stored in a cold chamber at 4°C overnight, the sacrificed birds were weighed separately to estimate the dressing weight. The dressed percentage was calculated by dividing the dressing weight by the slaughter weight. Subsequently, all carcasses were eviscerated. The half-eviscerated weight was evaluated as the weight of carcass without trachea, esophagus, pseudo-crop, guts, spleen, pancreas, gallbladder, reproduction organs, and the chyme and cutin membrane of gizzard. The eviscerated weight was quantified when the weights of heart, liver, proventriculus, gizzard, lungs, and abdominal fat were subtracted from the half-eviscerated weight. The percentages of half-eviscerated and eviscerated yield were calculated by dividing half-eviscerated and eviscerated weight by slaughter weight, respectively. The eviscerated body of each bird was manually dissected with surgical blades into head, neck, wings, feet, pectoral muscle, leg muscle, and abdominal fat, and their weights were determined separately, and then their percentages were calculated by dividing their respective weights by eviscerated weight. The head, the neck, the wings, and the feet were cut up from the occipito-atlantoid articulations, the scapula, the articulatio humeri, and the ankle joint, respectively. The stripped muscles of pectoral and leg excluded the skins, the subcutaneous fats, the bones, and the tendons. Abdominal fat included the fat that could be manually excised from the abdominal cavity, including that adhering to the gizzard, surrounding the bursa of Fabricius, but neither the mesenteric nor the cloaca and the perirenal fat. The percentage of lean meat was a sum of the percentages of pectoral and leg muscle. The weights of the isolated body organs, including heart, liver, kidney, pancreas, spleen, thymus, and bursa of Fabricius were evaluated accurately, and then their relative weights, expressed in g/100 g of slaughter weight, were calculated. The relative weight of major viscera was a sum of the relative weights of the above-mentioned internal organs. After the opening of the body cavity, GIT of each bird was removed and ligated into 7 segments: proventriculus, gizzard, duodenum, jejunum (from duodenum to the Meckel's diverticulum), ileum (from the Meckel's diverticulum to 1 cm above the ileo-ceco-colonic junction), caecum, and colon. The fresh weights of the empty digestive tract sections were assessed precisely, and then their relative weights, expressed in g/100 g of slaughter weight, were calculated. The relative weights of whole stomachs and total intestines were a sum of the relative weights of 2 gastro sections and 5 intestinal fractions, respectively. The relative weight of major GIT was a sum of the relative weights of the whole stomachs and total intestines.

Statistical analysis. All data were subjected to a one-way analysis of variance using the PROC GLM procedure of the SAS software (Statistical Analysis System, Version 9.1.3., 2005) with dietary treatments as the classification factors. The pen was considered as the experimental unit. Results were expressed as the means ± standard deviations (M ± SD). Multiple comparisons of the means among the treatments were conducted by the Duncan's Multiple Range Test. The degree of significance was defined as follows: not significant ($P > 0.05$), significant ($P \leq 0.05$).

RESULTS

Growth and slaughter performance. No differences ($P > 0.05$) were observed in the initial weight, the ADFI, and the dressed percentage between different dietary treatments (Table 2).

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Table 2. Effect of dietary crude fibre levels on growth and slaughter performances of growing male China Micro-ducks

Item	Dietary crude fibre levels (g/kg of dry matter)				SEM	*P*-value
	16.7	42.6	77.9	101.6		
Growth performance						
Initial weight (g)	730.8 ± 26.5	728.3 ± 15.3	722.5 ± 14.0	732.5 ± 14.4	3.50	0.796
Final weight (g)	1636.7 ± 40.7^{c}	1920.8 ± 53.4^{b}	1877.7 ± 69.5^{b}	2075.6 ± 157.1^{a}	37.20	0.000
Average daily gain (g/day)	25.88 ± 0.93^{c}	34.07 ± 1.14^{b}	33.00 ± 1.67^{b}	38.37 ± 4.34^{a}	1.04	0.000
Average daily feed intake (g/day)	133.3 ± 4.3	132.7 ± 6.6	130.8 ± 5.8	132.3 ± 7.3	1.10	0.906
Feed conversion ratio	5.15 ± 0.29^{a}	3.89 ± 0.16^{b}	3.96 ± 0.23^{b}	3.46 ± 0.23^{c}	0.13	0.000
Slaughter performance (g/100 g of slaughter weight)						
Dressed percentage	82.78 ± 2.39	83.08 ± 0.87	82.65 ± 1.73	82.46 ± 1.79	0.30	0.914
Half-eviscerated percentage	76.32 ± 1.92^{ab}	78.12 ± 0.84^{a}	74.74 ± 2.18^{bc}	73.68 ± 2.39^{c}	0.44	0.001
Eviscerated percentage	68.31 ± 1.89^{b}	70.37 ± 0.77^{a}	66.78 ± 2.28^{bc}	65.68 ± 2.54^{c}	0.46	0.000

SEM = standard error of the mean

$^{a–c}$means with different superscripts within the same row differ at $P \leq 0.05$

On the basis of the final weight, the ADG, and the FCR, the ranking of dietary CF levels in descending order of the growth performance was 101.6, 42.6, 77.9, and 16.7 g/kg of DM. In light of the half-eviscerated and eviscerated percentages, the ranking of dietary CF levels in descending order of the slaughter performance was 42.6, 16.7, 77.9, and 101.6 g/kg of DM. In addition, no bird died during the whole experimental period, and therefore the data about the mortality of birds are not presented.

Serum biochemical parameters. The change in dietary CF levels did not affect ($P > 0.05$) the serum concentrations of TP, albumin, globulin, TG, TC, HDL-C, UN, and UA (Table 3). With increasing levels of dietary CF, the serum glucose concentration increased ($P = 0.000$), but the serum concentrations of LDL-C ($P = 0.001$) and creatinine ($P = 0.000$) decreased.

Carcass quality. There were no significant differences ($P > 0.05$) for the neck and leg muscle percentages within several dietary treatments

Table 3. Effect of dietary crude fibre levels on serum biochemical parameters of growing male China Micro-ducks

Item	Dietary crude fibre levels (g/kg of dry matter)				SEM	*P*-value
	16.7	42.6	77.9	101.6		
Total protein (g/l)	33.5 ± 2.6	33.7 ± 1.8	33.4 ± 2.1	33.4 ± 2.1	0.30	0.993
Albumin (g/l)	13.6 ± 1.0	13.8 ± 0.8	13.5 ± 0.7	13.7 ± 0.7	0.10	0.950
Globulin (g/l)	19.9 ± 1.8	19.9 ± 1.7	19.8 ± 1.5	19.6 ± 1.5	0.20	0.983
Albumin/globulin	0.68 ± 0.04	0.69 ± 0.07	0.68 ± 0.04	0.70 ± 0.03	0.00	0.893
Triglyceride (mmol/l)	1.19 ± 0.37	1.04 ± 0.22	1.01 ± 0.13	0.96 ± 0.10	0.04	0.256
Total cholesterol (mmol/l)	5.04 ± 1.17	4.58 ± 0.51	4.52 ± 0.66	4.50 ± 0.43	0.13	0.443
High-density lipoprotein cholesterol (mmol/l)	2.20 ± 0.32	2.26 ± 0.26	2.43 ± 0.38	2.62 ± 0.31	0.06	0.071
Low-density lipoprotein cholesterol (mmol/l)	0.83 ± 0.07^{a}	0.81 ± 0.12^{ab}	0.70 ± 0.14^{bc}	0.59 ± 0.11^{c}	0.02	0.001
Urea nitrogen (mmol/l)	0.61 ± 0.15	0.50 ± 0.07	0.52 ± 0.08	0.53 ± 0.11	0.02	0.250
Creatinine (μmol/l)	15.0 ± 1.8^{a}	12.1 ± 1.7^{b}	11.1 ± 1.7^{b}	10.8 ± 1.0^{b}	0.40	0.000
Uric acid (μmol/l)	322 ± 52	314 ± 25	310 ± 36	309 ± 18	6.00	0.884
Glucose (mmol/l)	10.1 ± 1.1^{b}	10.6 ± 1.4^{b}	12.0 ± 0.9^{a}	13.3 ± 1.4^{a}	0.30	0.000

SEM = standard error of the means

$^{a–c}$means with different superscripts within the same row differ at $P \leq 0.05$

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Table 4. Effect of dietary crude fibre levels on carcass quality (g/100 g of eviscerated weight) of growing male China Micro-ducks

Item	Dietary crude fibre levels (g/kg of dry matter)				SEM	*P*-value
	16.7	42.6	77.9	101.6		
Head percentage	7.88 ± 0.75^{a}	7.48 ± 0.24^{ab}	7.43 ± 0.49^{ab}	7.02 ± 0.20^{b}	0.09	0.012
Neck percentage	12.29 ± 1.80	11.95 ± 1.29	11.83 ± 1.33	11.79 ± 0.59	0.22	0.875
Wings percentage	13.31 ± 0.69^{a}	12.70 ± 0.35^{b}	12.85 ± 0.34^{ab}	12.46 ± 0.65^{b}	0.10	0.027
Feet percentage	3.50 ± 0.19^{a}	3.20 ± 0.15^{b}	3.17 ± 0.21^{b}	3.13 ± 0.23^{b}	0.04	0.004
Breast muscle percentage	8.39 ± 1.00^{b}	11.50 ± 1.01^{a}	11.13 ± 0.76^{a}	11.06 ± 1.10^{a}	0.27	0.000
Leg muscle percentage	12.78 ± 1.11	12.61 ± 0.58	12.80 ± 0.97	12.62 ± 0.58	0.14	0.946
Lean meat percentage[1]	21.17 ± 1.34^{b}	24.11 ± 1.33^{a}	23.94 ± 1.11^{a}	23.68 ± 1.07^{a}	0.29	0.000
Abdominal fat percentage	1.01 ± 0.12^{a}	0.74 ± 0.25^{b}	0.67 ± 0.06^{bc}	0.54 ± 0.06^{c}	0.03	0.000

SEM = standard error of the means

$^{a–c}$means with different superscripts within the same row differ at $P \leq 0.05$

[1]the percentage of lean meat was a sum of the percentages of breast and leg muscle

(Table 4). The increase in dietary CF levels caused a significant decrease in the percentages of head ($P = 0.012$), feet ($P = 0.004$), and abdominal fat ($P = 0.000$). The wings percentage of dietary treatments with CF level of 42.6 and 101.6 g/kg of DM was significantly lower ($P = 0.027$) than that of dietary treatment with CF level of 16.7 g/kg of DM. The pectoral muscle ($P = 0.000$) and lean

Table 5. Effect of dietary crude fibre levels on relative weights of major body organs and gastrointestinal tract (g/100 g of slaughter weight) of growing male China Micro-ducks

Item	Dietary crude fibre levels (g/kg of dry matter)				SEM	*P*-value
	16.7	42.6	77.9	101.6		
Major body organs						
Heart	0.66 ± 0.02	0.68 ± 0.03	0.67 ± 0.03	0.65 ± 0.02	0.00	0.389
Liver	3.78 ± 0.27^{a}	3.41 ± 0.17^{b}	3.29 ± 0.20^{b}	3.23 ± 0.29^{b}	0.05	0.000
Kidney	0.80 ± 0.03	0.79 ± 0.04	0.78 ± 0.02	0.78 ± 0.04	0.00	0.470
Pancreas	0.35 ± 0.03	0.34 ± 0.01	0.35 ± 0.03	0.34 ± 0.01	0.00	0.692
Spleen	0.06 ± 0.00	0.07 ± 0.01	0.07 ± 0.00	0.07 ± 0.01	0.00	0.156
Thymus	0.21 ± 0.02^{b}	0.33 ± 0.02^{a}	0.31 ± 0.04^{a}	0.30 ± 0.03^{a}	0.00	0.000
Bursa of Fabricius	0.13 ± 0.01	0.14 ± 0.02	0.14 ± 0.01	0.14 ± 0.01	0.00	0.382
Total	6.02 ± 0.30^{a}	5.78 ± 0.21^{ab}	5.64 ± 0.18^{b}	5.54 ± 0.29^{b}	0.05	0.005
Major GIT organs – stomachs						
Proventriculus	0.29 ± 0.01^{b}	0.30 ± 0.01^{b}	0.32 ± 0.03^{ab}	0.34 ± 0.02^{a}	0.00	0.009
Gizzard	2.57 ± 0.23^{c}	2.81 ± 0.25^{b}	3.22 ± 0.20^{a}	3.40 ± 0.15^{a}	0.06	0.000
Total	2.87 ± 0.23^{c}	3.12 ± 0.26^{b}	3.54 ± 0.19^{a}	3.74 ± 0.15^{a}	0.07	0.000
Major GIT organs – intestines						
Duodenum	0.34 ± 0.05	0.31 ± 0.03	0.30 ± 0.04	0.30 ± 0.03	0.00	0.137
Jejunum	0.71 ± 0.06^{a}	0.65 ± 0.05^{ab}	0.60 ± 0.06^{bc}	0.56 ± 0.06^{c}	0.01	0.000
Ileum	0.64 ± 0.08^{a}	0.53 ± 0.07^{b}	0.52 ± 0.06^{b}	0.45 ± 0.04^{c}	0.01	0.000
Caecum	0.17 ± 0.01	0.15 ± 0.00	0.16 ± 0.02	0.15 ± 0.02	0.00	0.158
Colon	0.19 ± 0.03	0.18 ± 0.03	0.19 ± 0.03	0.19 ± 0.01	0.00	0.832
Total	2.07 ± 0.22^{a}	1.84 ± 0.11^{b}	1.79 ± 0.19^{b}	1.67 ± 0.07^{b}	0.03	0.000
Stomachs + intestines	4.94 ± 0.27^{b}	4.96 ± 0.35^{b}	5.34 ± 0.24^{a}	5.42 ± 0.18^{a}	0.05	0.002

SEM = standard error of the means, GIT = gastrointestinal tract

$^{a–c}$means with different superscripts within the same row differ at $P \leq 0.05$

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meat (P = 0.000) percentages of dietary treatment with CF level of 16.7 g/kg of DM were significantly inferior to those of other dietary treatments.

Organ yield. The relative weights of heart, kidney, pancreas, spleen, bursa of Fabricius, duodenum, caecum, and colon were not influenced (P > 0.05) by increasing levels of dietary CF (Table 5). A significantly lighter thymus relative weight (P = 0.000) was observed in dietary treatment with CF level of 16.7 g/kg of DM compared to other dietary treatments. Greater relative weights of proventriculus (P = 0.009), gizzard (P = 0.000), whole stomachs (P = 0.000), and major GIT (P = 0.002), while lower relative weights of liver (P = 0.000), major viscera (P = 0.005), jejunum (P = 0.000), ileum (P = 0.000), and total intestines (P = 0.000) were noticed with increasing levels of dietary CF.

DISCUSSION

It has usually been agreed that an increase in DF decreases feed intake in poultry. However, several studies have proved that the addition of moderate quantities of insoluble DF does not influence voluntary feed intake in broilers (Gonzalez-Alvarado et al. 2007; Jimenez-Moreno et al. 2011), growing turkeys (Sklan et al. 2003), or laying hens (Perez-Bonilla et al. 2011). Moreover, Leeson et al. (1996) indicated that broilers possessed the ability to adjust feed intake when the energy concentration of the diet was diluted with up to 7.5% oat hulls. In the present study, all experimental diets were classified as semipurified diets and had the similar ingredients and nutrients. In particular, four diets were isonitrogenous and isoenergetic. The current results showed that the ADFI of the experimental ducks was not different between the four dietary treatments. Although the graded difference existed for the CF level between the experimental diets, the vast majority of dietary CF was plant-derived and originated from alfalfa meal. Alfalfa, which contains a plenty of insoluble fibre, can be considered as high-quality forage, and can be fed to waterfowl because the CF from alfalfa has a large proportion of digestible part (Yang 2002). In the actual production process, it was found that CMD is highly adaptable to a wide range of fibrous feedstuffs. In the present study, the higher level of CF in the diet might help improve the ADG and the FCR of the experimental ducks, suggesting that the variations of the dietary CF level within a certain range would not negatively impact the growth performance of CMD. Similar results have been reported by Sklan et al. (2003) in growing-finishing turkeys, Boguslawska-Tryk (2005) in broilers from 0 to 42 days of age, Gonzalez-Alvarado et al. (2007) and Jimenez-Moreno et al. (2016) in broilers from 1 to 21 days of age, and Jimenez-Moreno et al. (2013) in broilers from 1 to 18 days of age, which showed that an increase of the CF content of the diet in the appropriate range did not affect ADFI but improved ADG and FCR. Mateos et al. (2012) considered that the benefits of fibre supplementation on the growth performance of birds were probably linked with improved nutrient digestibility arising from a better development and function of the gizzard rather than from changes in the metabolic pathways.

Little information is available about the influence of DF on the slaughter performances and the carcass quality in poultry. Increasing the content of DF might reduce fat deposition and thus heighten the carcass lean percentage in the latter finishing period in pigs. Siregar et al. (1982) also reported that feeding White Pekin ducklings the increased amounts of DF resulted in the reduced carcass fat content. Gonzalez-Alvarado et al. (2010) reported that the inclusion of oat hulls did not affect the yield of valuable parts (pectoral and leg quarters) in broiler chickens. Jorgensen et al. (1996) pointed out that the increase of the insoluble fibre content in the diet often results in a decrease in carcass yield in broiler chickens. In the current research, the rise of dietary CF levels did not affect the dressed percentage, but decreased the half-eviscerated and eviscerated percentage, which revealed that dietary CF levels might have some major impacts on the slaughter performance of CMD. Mateos et al. (2012) hinted that augmenting the insoluble fibre content of the diet often leads to a reduction in carcass yield as a consequence of an improved development of the GIT in poultry. Moreover, the present findings indicated that feeding CMD the diet with CF level of 42.6 g/kg of DM instead of other diets would gain the optimal slaughter performance. Although Chinese consumers prefer to purchase live birds at local markets and slaughter at home, poultry carcass segmentation is becoming increasingly acceptable and popular. In China, most parts of duck carcass can be processed into delicious foods. The current data demonstrated

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that the ducks fed the diets with CF level of 42.6 and 77.9 g/kg of DM had the same carcass traits. And it might be observed that the carcass quality of the ducks fed the diets with CF level of 42.6 and 77.9 g/kg of DM was superior to that of the ducks fed other diets. In addition, the abdominal fat percentage of the experimental ducks was reduced with the rise of dietary CF levels, implying that DF positively affected the fat deposition in ducks.

Release of nutrients from diets represents the central function of the gastrointestinal system. It is generally accepted that DF can promote the growth as well as the function of the alimentary canal. Birds adapt quickly to alterations in the DF content by the modifications of the length and weight of the digestive organs as well as the rate of passage through the diverse sections of the GIT (Mateos et al. 2012). Elevating the insoluble fibre content of the diet resulted in a decreased length of the small intestine (Sklan et al. 2003), along with an increased relative weights of proventriculus and gizzard (Gonzalez-Alvarado et al. 2007, 2008; Jimenez-Moreno et al. 2011; Svihus 2011; Yokhana et al. 2016). The current research exhibited that DF might advance the relative weights of proventriculus and gizzard instead of those of jejunum and ileum. In order to fully utilize the nutrients from alfalfa meal, both the glandular and the muscular stomachs of duck, especially the gizzard, would become larger in the volumes, more active in the secretion of gastric juices, and more powerful in the contraction of muscles. In this instance, it was predicable that a higher level of dietary CF would result in the better development of duck stomachs. Jimenez-Moreno et al. (2011) found that the relative weight of caeca in broilers from 1 to 18 days of age increased linearly with the increasing level of pea hulls in the diet. Freitas et al. (2014) suggested that 7-week-old Hy-Line Brown pullets given increased dietary neutral detergent fibre for 5 weeks had significantly increased intestinal weights. Yokhana et al. (2016) reported that the relative weights of the small intestines were raised in 19-week-old hens but were not changed in 8-week-old pullets with the dietary supplementation of insoluble fibre. These results are not consistent with the current findings. Taylor and Jones (2004) implied that increased gizzard size could be a reason for the reduction in weight of the small intestine they found and might reflect an adaptation of the gut to increased availability of nutrients as a result of feeding a diet containing increased fibre content. Consequently, further investigations would be needed to explain why feeding CMD the rising quantities of dietary CF resulted in the falling relative weights of jejunum and ileum.

The information about the effects of DF on the evolution of animal viscera was very scarce. Limited studies have been focused on the relationship between DF and the development of pancreas and liver in poultry. Hetland et al. (2003), Boguslawska-Tryk (2005), and Yokhana et al. (2016) reported no effect of the insoluble fibre inclusion in the diet on the relative pancreas weight in poultry, which is almost consistent with the present results. Freitas et al. (2014) and Yokhana et al. (2016) illustrated that feeding pullets the diets with addition of insoluble fibre for more than 5 weeks resulted in significantly greater relative liver weight, which was opposite to the present results. In addition, the present study displayed that the dietary CF level positively influenced the relative thymus weight. The reasons behind this phenomenon would need to be elucidated by additional experiments.

Nutritional factors, such as diet quantity and composition, may influence intermediary metabolism, resulting in the changes of blood metabolite levels in poultry. DF can protect human health from a series of metabolic problems and diseases, including constipation, obesity, type II diabetes, colon cancer, serum glucose levels and cardiovascular diseases (Mateos et al. 2012). Furthermore, DF may favour the protection of the GIT mucosa, lowering the incidence of ulcers, colitis, and chronic inflammation of the digestive mucosa. The concentrations of serum metabolites determined in the present study are usually used to evaluate the metabolism status of glucose, lipid, and nitrogen (Wang and Wang 2016). Raised serum glucose concentration often means better energy nutrition when it varies within the normal range. Low-density lipoprotein particles can transport their content of lipid molecules into artery walls, attract macrophages, and thus drive atherosclerosis. So LDL-C is sometimes called bad cholesterol. In contrast, HDL-C is often referred to as good or healthy cholesterol because high-density lipoprotein particles can remove lipid molecules from macrophages in the wall of arteries. It has been reported that DF reduces the cholesterol and TG concentrations in blood because fibre intervenes

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with the reabsorption of lipids and cholesterol by absorbing bile acid and cholesterol, consequently disarranging the lipid metabolism. The serum nitrogen metabolites comprise of true protein nitrogen and non-protein nitrogen. The higher concentration of true protein nitrogen or the lower concentration of non-protein nitrogen in blood always represents better nitrogen metabolism (Wang et al. 2016). According to the corresponding results of the serum biochemical parameters in the experimental ducks, DF might ameliorate the metabolism of glucose and lipids. The relationship between the DF and the nitrogen metabolism of duck was not clear because the enhancement of the dietary CF level only reduced the serum creatinine concentration of the experimental ducks.

CONCLUSION

It is concluded from the present findings that the recommended levels of dietary CF for growing male CMD is within the range of 42.6 and 77.9 g/kg of DM. Feeding CMD the diet with the CF level of 16.7 g/kg of DM resulted in the worst growth performance as well as the poorest carcass quality. CMD eating the diet with the CF level of 101.6 g/kg of DM possessed the highest-ranking growth performance but the lowest-ranking slaughter performance. The enhancement of CF level in the diet of CMD prompted the development of stomachs, and amended the metabolism of glucose and lipids. Further studies are recommended to investigate the influences of DF on the development of intestines and viscera along with the nitrogen metabolism in CMD.

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