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Effects of dietary nanocrystalline cellulose supplementation on growth performance, carcass traits, intestinal development and lipid metabolism of meat ducks



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ABSTRACT

The influence of nanocrystalline cellulose (NCC) supplementation on growth performance, carcass traits, intestinal development, and lipid metabolism was assessed in 600 one-day-old male meat ducks (Cherry Valley ducks) from 1 to 35 d of age. Diets were supplemented with 0, 200, 500, 800 and 1,500 mg/kg NCC during both the starter (1–14 d) and grower (15–35 d) phases. Each dietary treatment consisted of 8 replicate cages of 15 birds. Supplementation of NCC was associated with dose dependent increases in BW gain and feed intake ($P < 0.01$) during 1–14 d of age and in BW at 35 d of age. As NCC content increased, the percentage of breast meat weight ($P < 0.05$) and leg (with bone) weight ($P < 0.05$) linearly increased, while the percentage of abdominal fat weight ($P < 0.01$) linearly decreased in ducks at 35 d of age. Supplementation of NCC resulted in a dose-dependent increase in the weight ($P < 0.05$) and density ($P < 0.01$) of the cecum. The percentage of total hepatic lipid content ($P < 0.01$) at 14 d of age and serum triglyceride (TG) concentration ($P = 0.052$) at 35 d of age linearly decreased with increasing of dietary NCC addition. In conclusion, inclusion of 1,500 mg/kg NCC in feed resulted in the greatest improvements in duck performance, intestinal development and lipid deposition.

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1. Introduction

Dietary fiber has been included in experimental diets for monogastric animals for many years, which has been shown to promote gut health and microflora in monogastric animals (Barry et al., 2001). There are 3 main groups of fiber: cellulose, non-cellulosic polymers, and pectic polysaccharides (Bailey and Macrae, 1973). In contrast to pectin, crystalline cellulose is a non-fermentable fiber commonly used as an inert ingredient or bulk-ing agent in monogastric diets (Montagne et al., 2003; Hetland

et al., 2004). Wils-Plotz and Dilger (2013) verified that cellulose contributed no nutritive value to birds. However, some studies observed that supplementation of 3% cellulose, sugar beet pulp, and oat hulls to poultry diets resulted in better litter quality and a lower moisture content of the excreta (Jiménez-Moreno et al., 2009a).

The physicochemical characteristics of fiber (i.e., chemical composition, solubility, and particle size) have been shown to influence intestinal physiology and function (Figuerola et al., 2005). Jiménez-Moreno et al. (2010) observed that particle size of the fiber source did not affect performance, but a reduction in particle size of the oat hull and sugar beet pulp improved total tract apparent retention of DM, nitrogen, and soluble ash as well as the AMEn of the diet. Supplementation with micronized insoluble fiber particles, which had an average length and width of 250 and 25 μm , respectively, led to an increase in growth performance, ileal villus height to crypt depth ratio, and the number of goblet cells in broilers throughout the experimental period (Rezaei et al., 2011). Nanocrystalline cellulose (NCC), a by-product of the paper industry that is smaller in size than micronized insoluble particles, was obtained from the Center for Nanoscience and Technology (Beijing,

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China). The geometric diameter and length of the NCC particle were 3 to 5 nm and 100 to 300 nm, respectively. This product is 99.0% cellulose on dry matter basis. To the best of our knowledge, there is no available information on the nutritional effects of NCC supplementation for monogastric animals.

There is a growing interest in evaluating the effects of fiber inclusion of the diets on lipid metabolism. Several studies reported that dietary cellulose depresses lipid accumulation in the liver of growing chicks fed *ad libitum* or reduces abdominal fat content and liver weight with effects being more pronounced with 3% cellulose than with 3% inulin (Jiménez-Moreno et al., 2010; Mohiti-Asli et al., 2012). Also, the weight and lipid content of the liver increased in force-fed chicks, but the values of all these parameters were reduced by the addition of 4% cellulose to the diet (Akiba and Matsumoto, 1978). Although the effects of dietary fiber on lipid metabolism of broilers have been investigated, little is known about the effects of dietary fiber on lipid metabolism of meat ducks. Therefore, this study determined the effects of dietary NCC supplementation on growth performance, carcass traits, intestinal development, and lipid metabolism in meat ducks from 1 to 35 d of age.

2. Materials and methods

This study was approved by the Institutional Animal Care and Use Committee of Sichuan Agricultural University.

2.1. Experimental design, birds and diets

Six hundred 1-d-old male Cherry Valley ducks were randomly assigned to 5 dietary treatment groups. There were 8 cages with 15 ducks per cage for each group. The 5 diets contained 0, 200, 500, 800, and 1,500 mg NCC per kg diet, respectively. The feeding program consisted of 2 diets: starter diets supplied from d 1 to 14, followed by a grower diet from d 15 to 35. The basal starter (d 1 to 14) and grower (d 15 to 35) experimental diets were formulated to meet or exceed the nutrient requirements for meat ducks in NRC (1994) (Table 1). The different levels of NCC in the experimental diets were produced by mixing a control diet (treatment 1) and 1,500 mg/kg of NCC to the diet (treatment 5) at a ratio of 13:2 (treatment 2), 2:1 (treatment 3), or 7:8 (treatment 4) to produce diets containing 200, 500, or 800 mg/kg of NCC, respectively. Feed was steam-pelleted and the diameters of the pellets in the starter and growers diet were 2 and 3 mm, respectively.

2.2. Bird housing and management

All ducks were reared in cages (2.2 m × 1.2 m × 0.9 m) in a temperature and humidity controlled room with a 24 h constant light schedule and free access to water and feed throughout the experimental period.

2.3. Sampling and measurement

At d 14 and 35, after feed withdrawal for 12 h, the ducks and feed in each cage were weighed. Body weight gain (BWG), cumulative feed intake (FI), and feed-to-gain ratio (FCR) were calculated. Then, one duck with a weight closest to the cage average was selected and bled through the jugular vein. The blood samples were immediately placed on ice, transported to the laboratory within 3 h of collection, and centrifuged at $2,000 \times g$ for 15 min in a refrigerated centrifuge at about 4°C. Serum was collected and stored at −20°C until certain biochemical parameters were assayed. Serum triglyceride (TG), total cholesterol (TC), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) concentrations, as well as alanine aminotransferase (ALT) and aspartate

Table 1

Ingredients and chemical composition of the basal diets (dry matter basis).

Item	Starter (1–14 d)	Grower (15–35 d)
Ingredient, %		
Corn	62.4	72.6
Soybean meal	33.5	23.29
L-Lysine-HCL	0	0.131
DL-Methionine	0.185	0.165
Limestone	1.072	1.071
Dicalcium phosphate	1.696	1.615
Bentonite	0.107	0.088
Sodium chloride	0.35	0.35
Choline chloride	0.15	0.15
Premix ¹	0.54	0.54
Total	100.00	100.00
Calculated value, %		
ME, kcal/kg	2,850	2,900
CP	19.5	16.0
Calcium	0.90	0.85
Available phosphorus	0.42	0.40
Digestible lysine	0.94	0.81
Digestible methionine	0.45	0.39
Digestible methionine + cysteine	0.78	0.64
Digestible threonine	0.67	0.54
Digestible tryptophan	0.09	0.15
Crude fiber ²	2.97	2.54

¹ Premix provided per kilogram of diet: vitamin A, 8,000 IU; cholecalciferol, 2,000 IU; vitamin E, 5 IU; vitamin K₃, 1 mg; thiamine, 0.4 mg; riboflavin, 3.2 mg; pyridoxine, 1.2 mg; vitamin B₁₂, 6 µg; folic acid, 100 µg; niacin, 7 mg; calcium pantothenate, 5 mg; Fe (FeSO₄·H₂O) 80 mg; Cu (CuSO₄·5H₂O) 8 mg; Mn (MnSO₄·H₂O) 70 mg; Zn (ZnSO₄·H₂O) 90 mg; I (KI) 0.4 mg, Se (Na₂SeO₃) 0.3 mg.

² The crude fiber (CF) in starter diet (1–14 d): 2.99% for treatment 2 (200 mg/kg nanocrystalline cellulose [NCC]), 3.02% for treatment 3 (500 mg/kg NCC), 3.05% for treatment 4 (800 mg/kg NCC), 3.12% for treatment 5 (1,500 mg/kg NCC); the CF in grower diet (15–35 d): 2.55% for treatment 2, 2.58% for treatment 3, 2.61% for treatment 4, 2.68% for treatment 5.

aminotransferase (AST) activities, which were important indices to evaluate lipid metabolism and liver function, were analyzed using a commercial biochemistry analyzer (Yellow Springs Instrument Co., Inc., Yellow Springs, OH, USA).

After blood collection, the birds were euthanized by cervical dislocation. Samples of liver tissues were removed and weighed, and the left lobes of the livers were stored in 10% neutral formalin solution. Then, the tissues were trimmed, fixed, and embedded in paraffin. Thin (5 µm) sections of the tissues were prepared and mounted on slides, stained with hematoxylin and eosin for lipid deposition, and examined by a histologist. Morphological images of the liver sections were captured to determine the degree of lipid accumulation. The right lobe of the livers were collected into sample bags and immediately frozen at −20°C, freeze-dried, and ground through a 0.5 mm screen for later analysis of total hepatic lipid concentrations, as determined by ether extraction of moisture-free samples (Cherry and Jones, 1982).

Moreover, at 35 d of age, another duck from each replicate was randomly selected for evaluation of carcass traits and intestinal development. Feed was withdrawn 4 h before processing, and then the birds were weighed, slaughtered, defeathered, and weighed to obtain carcass weights (with feet and head attached), breast meat (including the pectoralis major and pectoralis minor muscles), leg (with bone), and abdominal fat weight. Carcass yield was determined as the percentage of carcass weight in relation to total body weight, whereas the yield of the eviscerated carcass with giblet (including the heart, liver, proventriculus, gizzard, and abdominal fat), eviscerated carcass, breast meat, leg (with bone), and abdominal fat were expressed as percentages of the carcass weight. The weight and length of each segment of the intestinal tract, including the duodenum, jejunum (defined as the region from the pancreas tail to Meckel's diverticulum), ileum, cecum, and rectum

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