

RESEARCH ARTICLE

Effects of Crude Fiber Level on Growth Performance, Serum Biochemical Indicators, and Digestibility in Zhedong White Geese

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Article ID: KVFD-2022-28264 Received: 05.08.2022 Accepted: 05.12.2022 Published Online: 12.12.2022

Abstract: The purpose of this study was to investigate the feasibility and supplementation level of rice hull as a dietary fiber source for geese. The effect of rice hull addition level on growth performance, serum biochemical indices, and digestive performance of geese was explored. Three hundred 28-day-old Zhedong white geese (half male and half female) with similar body weights were selected and divided into three groups. The crude fiber (CF) level of the groups was 4.8%, 6.1% and 6.9%, respectively. The pre-feeding period was 7 days, and the formal test period was 21 days. The growth performance and serum biochemical indexes, amylase, lipase, and protease activities, and apparent digestibility were determined. CF level of 6.1% and 6.9% were higher than 4.8%, but the feed/gain at 6.9% CF level was higher than that at 4.8% ($P<0.05$). Serum total cholesterol and high-density lipoprotein cholesterol concentrations decreased at CF levels of 6.1% and 6.9%, and insulin or insulin-like growth factor-1 levels were increased. The intestinal amylase activity at 6.9% CF level was lower than that at 6.1%. In contrast, pancreatic amylase activity at 6.9% CF level was higher than that at 4.8%. The digestibility of crude ash and crude fat in CF level of 6.9% and 6.1% were lower than that at 4.8%, whereas the digestibility of crude protein increased. Rice hull as the main fiber source, with fiber level between 6.1% and 6.9%, maintains growth performance and improves some beneficial serum biochemical indicator levels and crude protein digestibility.

Keywords: Crude fiber, Digestive enzymes, Goose, Growth performance, Rice hull, Serum

Zhedong Beyaz Kazlarında Ham Lif Seviyesinin Büyüme Performansı, Serum Biyokimyasal İndikatörleri ve Sindirilebilirlik Üzerine Etkileri

Öz: Bu çalışmada, kazlarda pirinç kabuğunun bir diyet lifi kaynağı olarak uygulanabilirliği ve katkı düzeyinin araştırılması amaçlandı. Pirinç kabuğu ilavesinin kazların büyüme performansı, serum biyokimyasal indeksleri ve sindirim performansı üzerine etkileri araştırıldı. Benzer vücut ağırlıklarına sahip 300 adet 28 günlük Zhedong beyaz kaz seçildi (yarısı erkek ve yarısı dişi) ve üç gruba ayrıldı. Grupların ham selüloz (CF) düzeyleri sırasıyla %4.8, %6.1 ve %6.9 olarak belirlendi. Hayvanlar uygulama öncesi 7 gün ve uygulama süresince 21 gün süreyle beslendi. Büyüme performansı, serum biyokimyasal indeksleri, amilaz, lipaz ve proteaz aktiviteleri ve saptanabilir sindirilebilirlik test edildi. Ham selüloz oranı, %6.1 ve %6.9'luk gruplarda yüksekti, ancak %6.9'luk gruptaki yem kazanç oranı %4.8'lik gruba göre daha yüksekti ($P<0.05$). Serum total kolesterol ve yüksek yoğunluklu lipoprotein kolesterol konsantrasyonları, %6.1 ve %6.9'luk gruplarda azaldı ve insülin ve insülin benzeri büyüme faktörü-1 seviyeleri yüksekti. %6.9'luk gruptaki bağırsak amilaz aktivitesi, %6.1'lik gruptan daha düşüktü. Buna karşılık, %6.9'luk gruptaki pankreas amilaz aktivitesi, %4.8'lik gruptan daha yüksekti. Ham kül ve ham yağın sindirilebilirliği %6.9 ve %6.1'lik grupta %4.8'lik gruba göre daha düşük iken, ham proteinin sindirilebilirliği artmıştı. Temel lif kaynağı olarak pirinç kabuğunun %6.1 ile %6.9 arasındaki lif konsantrasyonları, büyüme performansını sürdürülebilir kılmakta ve bazı faydalı serum biyokimyasal indikatörlerinin düzeylerini ve ham proteinlerin sindirilebilirliğini artırmaktadır.

Anahtar sözcükler: Ham selüloz, Sindirim enzimleri, Kaz, Büyüme performansı, Pirinç kabuğu, Serum

How to cite this article?

Wang HY, Li GQ, Wang X, Yang YZ, Liu Y, Wang C, Gong SM, He DQ: Effects of crude fiber level on growth performance, serum biochemical indicators, and digestibility in zhedong white geese. *Kafkas Univ Vet Fak Derg*, 28 (6): 761-766, 2022.
DOI: 10.9775/kvfd.2022.28264

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INTRODUCTION

In recent years, due to the impact of war and COVID-19, the prices of raw materials such as corn and soybean meal have risen ^[1,2]. Many countries are facing food challenges ^[3,4]. Therefore, the use of corn-soybean meal-based feed in animal husbandry should be reduced. It is important to reduce food competition between humans and animals ^[5,6]. Rice is a staple food in many countries. Rice hull is the main byproduct of rice processing. It is rich in cellulose and lignin, but the content of fat and protein is low, and its nutritional value is not as high as that of rice bran ^[7]. Rice hulls are commonly used as fermentation beds ^[8] and fertilizers ^[9]. Zhedong White Goose is a native species of China ^[10] being widely bred in the southern provinces due to its good flavor. Geese are herbivorous poultry and have a great advantage over other poultry in digesting crude fiber (CF). Under natural conditions, green grasses are the preferred feed of geese under natural conditions ^[11]. The upper and lower beaks of the goose have serrations, the tongue has barbs, and the stomach and cecum contain cellulolytic bacteria ^[12,13]. Currently, there are different reports for geese nutritional requirements. The American NRC (1994) poultry feed nutrition standard recommends a CF level of 4% to 10% for geese over 4 weeks of age ^[14]. If the CF level is too low, the goose intestinal microbial flora will be disordered, which will affect the absorption and utilization of nutrients, thereby affecting its growth rate and increasing mortality. A high CF level will affect the digestion and absorption of other nutrients, such as proteins ^[5]. The source and level of fiber in the diet will affect the intestinal digestive enzyme activity, along with glucose and lipid absorption. Thatcher et al. ^[15] pointed out that different fiber sources can affect the digestive enzyme activity of livestock and poultry intestinal chyme. Zhan et al. ^[16] used ryegrass as the dietary fiber source of Yangzhou geese and found that ryegrass can reduce the content of serum triglyceride and total cholesterol in Yangzhou geese. Although the use of forages with different fiber sources in geese has received much attention ^[17,18], there are few reports on rice hulls as a fiber source. We explored the possibility and level of rice hull as a dietary fiber source for geese by measuring the growth performance, serum biochemical indices, metabolic enzyme activity, and apparent digestibility at different fiber levels in geese.

MATERIAL AND METHODS

Animal Ethics

The experiment was approved by the Laboratory Animal Ethics Committee of the Shanghai Academy of Agricultural Sciences (number: SYXK (HU), 2015-0007). Methods and ethics complied with the relevant regulations.

Experimental Design, Diets, and Birds

A total of 300 4-week-old Zhedong white geese with similar body weight were purchased from the Zhedong White Goose Research Institute of Xiangshan County and randomly divided into three treatments. CF levels, with rice hull as the main fiber source, were 4.8% (soybean 20.3%, soybean germ 0%, bran 9%, rice hull 5%), 6.1% (soybean 15.4%, soybean germ 4.5%, bran 2.1%, rice hull 10.6%), and 6.9% (soybean 0%, soybean germ 15.4%, bran 0%, rice hull 16.3%) in *Table 1*. Each treatment consisted of 10 repetitions (five male and five female). All the geese had free access to water or feed and were vaccinated in a timely manner. The pre-feeding period was 7 d, and the formal test period was 21 d.

Table 1. Feed ingredients and analyzed chemical composition of geese diets. (air-dry basis %)

Ingredients	CF Levels		
	4.8%	6.1%	6.9%
Corn	63.00	64.80	65.70
Soybean	20.30	15.40	0.00
Soybean germ	0.00	4.50	15.40
Bran	9.00	2.10	0.00
Rice hull	5.00	10.60	16.30
Premix ^{a)}	1.00	1.00	1.00
Stone powder	0.50	0.40	0.40
Calcium Hydrogen Phosphate	0.90	0.90	0.90
Salt	0.30	0.30	0.30
Total	100.00	100.00	100.00
Nutrient levels			
ME(Mcal/kg) ^{b)}	12.16	12.11	12.04
CP	15.38	15.50	15.26
EE	2.45	2.58	3.51
CF	4.80	6.10	6.90
Ca	0.50	0.45	0.44
TP	0.50	0.48	0.46

^a Per kilogram of diets including: multiple vitamin- 50 g, trace elements- 50 g, garlicin- 30 g, lysine- 100 g, methionine- 50 g, salt- 100 g, stone powder- 100 g, Myco-Ad- 100 g, Zeolite powder-420 g; ^b Nutrient levels were all calculated values

Sample Collection

At the end of the experiment, two geese (one male and one female), close to the average weight, were randomly selected from each replicate. Blood samples were collected from the wing veins, and the geese were slaughtered by jugular vein exsanguination. Serum was separated after 30 min and stored at -20°C. For each treatment 10 geese (five male and five female) close to the average weight were randomly selected, and the gizzard (containing chyme), duodenum (containing chyme), and pancreas were separated after execution. Samples were frozen in liquid nitrogen and stored in a refrigerator at -80°C. The

excrement from each replicate was collected for three consecutive days, which was then treated to remove impurities, dried at 65°C with 10% hydrochloric acid, crushed after 24 h, and stored at 4°C for later use.

Parameters Measured

Serum glucose, total cholesterol, high-density lipoprotein, low-density lipoprotein, and blood urea nitrogen were measured using the kits of Shanghai Bogu Biotechnology. The activities of protease, amylase, and lipase in the pancreas, gizzard, and duodenum were determined according to the instruction manual of the kit produced by Nanjing Jiancheng Bioengineering Institute. Serum Insulin (INS), Insulin-like Growth Factor-1 (IGF-1), Growth Hormone, thyroxine, and Thyroid Stimulating Hormone were determined by Nanjing Jiancheng Bioengineering Institute.

Acid-insoluble ash was used as an indicator of apparent nutrient availability. The crude ash content was determined using the burning method (GB/T 6438-2007); the crude protein content was determined using the Kjeldahl method (GB/T 6432-1994); and the crude fat content was determined using the ether extraction method (GB/T 6433-2006).

Statistical Analysis

Statistical analyses were performed using one-way ANOVA variance using SPSS statistical software (version 20.0, SPSS, Inc., Chicago, IL, USA). The Duncan method was used for multiple comparisons between groups, and $P > 0.05$ (insignificant difference), $P < 0.05$ (significant difference) and $P < 0.01$ (extremely significant difference) were used as the criteria for judging the difference.

RESULTS

Growth Performance

The results in *Table 2* show that when the CF level in the rice hull diet increased from 4.8% to 6.9%, the final body weight, average daily gain, and feed/gain (F/G) of geese increased; the CF level was 6.9% in final body weight (FBW), average daily gain (ADG), and (F/G), which were significantly higher than 4.8%, but there was no significant difference between the CF levels of 6.1% and 4.8%.

Serum Biochemical Indicators

As shown in *Table 3*, as the level of CF in the diet increased, the concentrations of INS and IGF-1 in the goose serum increased significantly, and the concentration was the

Table 2. Effects of CF levels on growth performance in geese

Items	CF Levels		
	4.8%	6.1%	6.9%
Initial body weight, g	2036.60±143.67	2021.08±211.14	2031.40±185.30
Final body weight, g	3447.00±276.81 ^b	3559.50±444.27 ^{ab}	3866.60±327.26 ^a
Average daily gain, g/d	67.16±6.65 ^b	73.26±7.76 ^{ab}	87.36±8.01 ^a
F/G	4.17±0.16 ^b	4.82±0.35 ^{ab}	5.65±0.86 ^a

Different lowercase letters with the same column date meant significant difference ($P \leq 0.05$). Each value represents the mean of 10 replicates

Table 3. Effects of CF levels on serum biochemical indicators in geese

Items	CF Levels		
	4.8%	6.1%	6.9%
INS, ng/mL	0.47±0.04 ^b	0.46±0.07 ^b	0.57±0.08 ^a
IGF-1, ng/mL	11.27±3.23 ^b	11.99±3.26 ^b	15.48±3.44 ^a
GH, ng/mL	6.87±1.47	6.29±2.94	6.39±2.09
T4, ng/mL	0.45±0.13	0.45±0.09	0.49±0.18
TSH, ng/mL	1.92±0.92	2.15±0.97	2.05±0.52
GLU, mmol/L	29.03±3.16	28.51±2.42	25.34±2.21
T-CHO, mmol/L	3.36±0.53 ^a	2.35±0.31 ^b	0.23±0.06 ^c
HDL-C, mmol/L	7.79±0.83 ^a	5.93±0.76 ^b	4.23±0.57 ^c
LDL-C, mmol/L	2.44±0.31	1.86±0.28	1.80±0.21
BUN, mmol/L	31.92±3.57	26.78±2.27	28.64±2.50

Different lowercase letters with the same column date meant significant difference ($P \leq 0.05$). Each value represents the mean of 10 replicates

Table 4. Effects of CF levels on the Digestive enzyme activity in geese

Items	CF Levels		
	4.8%	6.1%	6.9%
Tryptic amylase activity, U/mgprot	1092.69±102.11	939.53±78.26	845.25±74.24
Gastric amylase activity, U/mgprot	7.24±0.71	5.87±0.62	5.68±0.63
Intestinal amylase activity, U/mgprot	32.27±2.40 ^a	24.26±2.62 ^{ab}	13.61±1.16 ^b
Trypsin activity, U/mgprot	93.68±8.63 ^b	103.76±10.08 ^a	105.54±10.27 ^a
Pepsin activity, U/mgprot	26.33±2.17	21.1624±1.67	22.09±2.39
Intestinal protease activity, U/mgprot	0.74±0.07	0.63±0.06	0.54±0.06
Pancreatic lipase activity, U/mgprot	186.67±10.47	171.65±16.94	167.55±11.39
Gastric lipase activity, U/mgprot	142.08±12.64	109.69±10.92	97.03±9.27
Intestinal lipase activity, U/mgprot	9.55±0.84	7.84±0.70	12.08±0.96

Different lowercase letters with the same column date meant significant difference (PE 0.05). Each value represents the mean of 10 replicates

Table 5. Effects of CF level on the serum apparent digestibility in geese

Items	CF Level		
	4.8%	6.1%	6.9%
Crude ash, %	30.54±2.66 ^a	27.99±0.26 ^b	26.61±1.20 ^b
Crude protein, %	16.93±1.17 ^b	18.99±2.32 ^{ab}	19.59±1.85 ^a
Crude fat, %	47.46±3.51 ^a	39.66±2.85 ^b	38.91±3.69 ^b

Different lowercase letters with the same column date meant significant difference (PE 0.05). Each value represents the mean of 10 replicates

highest when the CF level was 6.9%, which was significantly higher than that of the other two groups ($P < 0.05$). There was no significant change in the serum concentrations of growth hormone, thyroxine, and thyrotropin ($P > 0.05$). Similarly, as the level of CF increased, the concentrations of total cholesterol and high-density lipoprotein cholesterol decreased, and the differences among the groups were extremely significant ($P < 0.01$)

Digestive Enzyme Activity

The results in *Table 4* show that the decreasing order of amylase activities was pancreatic, intestinal, and gastric. The intestinal amylase activity at a CF level of 6.9% was lower than that at 4.1% ($P < 0.05$); the decreasing order protease activities was pancreatic, gastric, and intestinal. Protease activities at CF levels of 6.9% and 6.1% were higher than that at 4.1% ($P < 0.05$). The decreasing order of lipase activities were pancreatic, gastric, and intestinal.

Nutrient Digestibility

The results in *Table 5* show that the apparent digestibility of crude ash and crude fat decreased significantly at CF levels of 6.9% and 6.1% ($P < 0.05$), whereas the digestibility of crude protein increased ($P < 0.05$).

DISCUSSION

The digestion and utilization of fiber in geese is a process involving gastrointestinal participation, cellulolytic enzymes,

and intestinal microorganisms, which mainly include mechanical grinding, chemical digestion, and microbial degradation, amongst other methods [19]. An appropriate source and level of fiber can promote intestinal peristalsis, increase the secretion of digestive enzymes, and improve growth performance [5,20,21]; however, poor fiber quality or high feeding levels can lead to an increase in the composition of anti-nutritional factors and interfere with the absorption of nutrients [22]. The results showed that a CF level of 6.9% significantly increased FBW and ADG, and the decomposition of cellulose in goose intestines mainly depends on cellulase and hemicellulase secreted by intestinal microorganisms. Cellulose was found to increase the abundance of cellulolytic bacteria in the gut [23] and increase the microbiome of hydrolyzed hemicellulose [24].

Nutrient digestibility is closely related to dietary composition and nutrient levels, especially lignin and acid detergent fiber content [25]. In this study, the apparent digestibility of crude ash and crude fat decreased gradually with the increase in rice hull addition to the diet, which may be due to the high acid washing lignin content of rice hull [26,27]. It may also be that the CF content in the diet is high, which causes the goose to eat more feed to maintain nutrition, and the speed of chyme passing through the intestine is accelerated, so that the residence time of the feed in the cecum is too short, which affects the digestion of CF in the large intestine. This may also be the reason for the significant increase in F/G.

IGF-1 can promote cell proliferation, differentiation, and secretion; participate in glucose metabolism and glucose transport in adipose tissue; promote fat and glucose synthesis; and improve glucose utilization [28]. INS is a multifunctional protein hormone secreted by pancreatic β -cells. Many in vitro experiments have shown that INS can stimulate glucose absorption and fat synthesis, and inhibit lipolysis [29]. The results of this study showed that the addition of rice hulls to the diet significantly increased

the concentration of INS and IGF1 in the serum, indicating that the addition of rice hulls was beneficial to the growth of geese and deposition of fat in them.

The mucus barrier, which is composed of gelatinous mucus secreted by intestinal epithelial cells and digestive glands, is an important part of the intestinal mucosal barrier. Along with their role in preventing potential opportunistic pathogens from adhering to the surface of the intestinal lumen, digestive enzymes are important indicators of animal feed intake. Its level of activity directly affects the digestion and absorption of food [30]. Dietary fiber affects the physicochemical properties of chyme, improves intestinal morphology, and stimulates the secretion of digestive enzymes [31]. The results of this study show that the activity of pancreatic amylase is the highest, which is tens to hundreds of times higher than that of intestinal and gastric amylase, and that intestinal alpha-amylase activity decreases with increasing dietary CF levels [32]. Trypsin secreted by the pancreas is an important digestive enzyme that breaks down proteins in the gut and hydrolyzes the proteins between cells to disperse the cells. Under this action, the protein ingested by the goose from the diet is hydrolyzed into small molecular peptides and amino acids [33]. Supplementation with trypsin inhibitors in the diet significantly reduces the digestibility of various amino acids [34]; in contrast, adding exogenous trypsin to the diet increases amino acid digestibility [35]. Therefore, trypsin affects the rate of digestion in poultry [36]. In this study, we found that CF was positively correlated with trypsin.

Rice hull is a fiber source for geese, and CF levels between 6.1% and 6.9% can significantly improve the growth performance of geese, increase IGF-1 and INS serum concentrations, reduce total cholesterol content, and increase trypsin levels.

Availability of Data and Materials

The original data and materials presented in the study are included in the article, further inquiries can be directed to the corresponding author (D-W He).

Acknowledgements

The authors would like to thank Zhuang Hang Experimental Station of Shanghai Academy of Agricultural Sciences, China.

Funding Support

This research was supported by China Agriculture Research System of MOF and MARA(CARS-42-35), Climbing plan of Shanghai Academy of Agricultural Sciences (PG21171) and SAAS Program for Excellent Research Team (2022-021).

Ethical Approval

The experiment was approved by the Laboratory Animal Ethics Committee of the Shanghai Academy of Agricultural Sciences (number: SYXK (HU), 2015-0007). Methods and ethics complied with the relevant regulations.

Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

Writing-original draft, H-Y Wang; Formal Analysis, G-Q Li and H-Y Wang; Investigation, X. Wang, Y-Z Yang; Conceptualization, S-M Gong, Y. Liu and C. Wang; Project administration, D-Q He; Writing-review, H-Y Wang and D-Q He; Editing, H-Y Wang and D-Q He; Validation, H-Y Wang and D-Q He; Supervision: H-Y Wang and D-Q He; Funding acquisition, H-Y Wang. All authors have read and agreed to the published version of the manuscript.

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