EFFECTS OF DIETARY CELLULOSE AND PROTEIN LEVELS ON NUTRIENT UTILIZATION IN CHICKENS

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Summary

Effects of dietary cellulose and protein levels on nutrient utilization in chickens were investigated. Four experimental diets containing 5% (low cellulose) or 20% (high cellulose) cellulose in combination with 10% (low protein) or 20% (high protein) protein of 70 g/day were alternatively forced-fed to eight colostomized White Leghorn cockerels once a day to make 4 × 4 Latin-square design. The digestibilities of DM and energy decreased with the increase in cellulose level, but not affected by dietary protein level. Ether extract digestibility was higher in the high cellulose diets than in the low cellulose diets The digestibility of nitrogen free extract had the same trend with the digestibility of DM and energy. The digestibility of acid detergent fiber was not so much different among the diets, but the NDF digestibility was lower in the high cellulose diets than in the low cellulose diets, due to the low hemicellulose digestibility. The true digestibility of protein was influenced by both of the dietary protein and cellulose levels, and their interaction was found. The dietary protein level affected the biological value of protein but the dietary cellulose level did not, and consequently the biological value of protein in the low protein diets was lower than in the high protein diets.
(**Key Words**: Dietary Cellulose, Protein, Interaction, Nutrient Utilization, Chicken)

Introduction

According to Shah et al. (1982), protein utilization decreased with the increase of dietary fiber level in rats. Cherry et al. (1983) reported that the pullets fed a 20% cellulose-supplemented diet consumed significantly more feed but less calories, exhibited decreased egg production and gained less weight than the birds fed a basal diet. Siri et al. (1992) reported that the increase in the dietary cellulose level reduced the digestibilities of dry matter and energy, but did not affect true digestibility and biological value of protein in chickens. According to Hove and King (1979), dietary cellulose stimulated growth of rats when the diet contained 8.5% casein, but did not when casein content was 22%. Nyman and Asp (1985) reported in rats that dietary protein seemed to be a limiting factor for dietary fiber fermentation when the dietary protein level was lower than 50 g/kg, but when the level was higher than 100 g/kg, no further increase in the fiber fermentation was observed. The present study was undertaken to investigate interactive effects of dietary cellulose and protein levels on the digestibility of nutrients and biological value of protein in chickens.

Materials and Methods

Four experimental diets were formulated as shown in table 1 so as to contain cellulose at 5% (low cellulose; LC) and 20% (high cellulose; HC) with a combination of protein at 10% (low protein; LP) and 20% (high protein; HP), and the abbreviations of the treatments were indicated as LC-LP, LC-HP, HC-LP and HC-HP. Vitamin and mineral contents were the same in all diets, but the contents of corn starch and corn oil were different so that the calculated metabolizable energy (ME) was uniform. The chemical compositions are also indicated in table 1. Five-month-old White Leghorn cockerels were colostomized by the method of Isshiki and Nakahiro (1988), and eight of which having a good health

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condition were used as experimental animals. They were divided into four groups of two birds each and were alternatively forced-fed 70 g/day of the experimental diets for 7 days to make a 4 × 4 Latin-square design. Feces and urine were separately collected every day from artificial and original, respectively, during last 3 days of each period. During the experimental period the birds were kept in individual metabolism cages which were placed in a room maintained at 21 ± 2℃ with continuous lighting for 24 hours. Pooled feces thus collected were dried up using a forced air oven at 55℃ for 72 hours, and ground for chemical analysis. Pooled urine was stored in a deep freezer until analysis.

Dry matter (DM), ash and ether extract (EE) of the diets and feces, and nitrogen of the diets, feces and urine were determined by AOAC (1984) method. Gross energy of the diets, feces and urine (adsorbed to a filter paper and dried) was determined using an automatic bomb calorimeter (Shimadzu, model CA-3). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) in the diets and feces were determined by the methods of Van Soest (1963) and Van Soest and Wine (1967), respectively. Nitrogen-free extract (NFE) was calculated by subtracting the sum of ash, CP, EE and NDF from DM, and hemicellulose content was estimated as a difference between NDF and ADF.

TABLE 1. INGREDIENT AND CHEMICAL COMPOSITIONS OF EXPERIMENTAL DIETS

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP
Ingredient composition (g/kg)				
Soybean protein	110.0	220.0	110.0	220.0
Corn starch	670.0	560.0	414.0	301.0
Corn oil	30.0	30.0	136.0	139.0
Cellulose powder	50.0	50.0	200.0	200.0
Aluminium silicate	80.0	80.0	80.0	80.0
DL-methionine	1.5	1.5	1.5	1.5
Choline chloride	1.5	1.5	1.5	1.5
Vitamin mixture[1]	0.7	0.7	0.7	0.7
Mineral mixture[1]	56.3	56.3	56.3	56.3
Chemical compositon (%)				
Dry matter (DM)	89.5	90.3	91.8	92.5
Ash	7.5	7.9	7.7	8.3
Crude protein (CP)	9.8	19.2	9.7	18.5
Ether extract (EE)	2.1	2.4	12.0	12.4
Nitrogen free extract (NFE)[2]	62.6	53.3	39.1	32.1
Neutral detergent fiber (NDF)	7.6	7.6	23.4	21.3
Acid detergent fiber (ADF)	5.0	4.7	19.8	19.1
Hemicellulose[3]	2.6	2.9	3.6	2.2
Gross energy (kJ/g)	15.3	16.0	18.0	18.4

LC-LP = low cellulose-low protein, LC-HP = low cellulose-high protein, HC-LP = high cellulose-low protein, HC-HP = high cellulose-high protein.

[1] Siri et al. (1992).

[2] NFE = DM − (Ash + CP + CF + NDF).

[3] Hemicellulose = NDF − ADF.

True digestibility and biological value of protein were calculated using the value of metabolic fecal nitrogen and endogenous urinary nitrogen which were obtained by Terapuntuwat and Tasaki (1984). A 2 × 2 factorial design was used to perform this experiment. The obtained data were statistically analyzed and the treatment means were compared by Duncan's new multiple range test (Steel and Torrie, 1980).

Results and Discussion

Fecal excretion and digestibility of dry matter, ether extract, nitrogen free extract, NDF, ADF, hemicellulose and energy are presented in table 2. Dietary cellulose increased fecal excretion, but dietary protein had no effects. No interactions were found between cellulose and protein levels. The amounts of dry matter and energy excreted into feces were significantly higher in the high cellulose diets than in the low cellulose diets. This is in agreement with the results of Siri et al. (1992) and of Okumura et al. (1982). Reflecting the amounts of dry matter and energy excreted into feces, the digestibility of dry matter and energy were lower in the high cellulose diets than in the low cellulose diets. In general, energy digestibility was not so much different from dry matter digestibility. In this experiment, however, the energy digestibility was rather high compared with the dry matter digestibility, because the diets used here contained 8% of aluminium silicate which might not be absorbed from the digestive tract. Siri et al. (1992) reported previously that dry matter and energy digestibilities of the 5% cellulose diet were 87.8% and 90.5%, and those of the 20% cellulose diet were 72.6% and 78.0 %, respectively. These values were higher than those in the present experiment. The discrepancy between the two experiments, might again be due to the inclusion of aluminium silicate in the present experiment to adjust the metabolizable energy content of the diets. Delorme and Wojcik (1982) also reported that the energy digestibility decreased in proportion with the increased cellulose level in diets, which resulted in lowering the digestible energy. Miles (1982) and Miles et al. (1988) suggested that the increase in the fiber content negatively affected that availability of the dietary energy when the dietary gross energy was the same. In the present experiment, however, the digestibile energy and metabolizable energy values of the diets were not different among the treatments. The discrepancy in the digestible energy values between the present experiment and Delorme and Wojcik (1982) might be due to the difference in gross energy values of the diets; in fact, the gross energy value was almost the same in all the diets of Delorme and Wojcik. but was higher in the 20% cellulose diets than in the 5 % cellulose diets in the present experiment as shown in table 1.

Fecal excretion of ether extract was lower in the low cellulose diets than in the high cellulose diets. This might be resulted from the difference levels of the dietary corn oil. The HC-LP group excreted significantly more fecal ether extract than the HC-HP group, but the effect of dietary protein level was not significant. The digestibility of ether extract in the low cellulose diets was lower than that in the high cellulose diets. The dietary protein level affected the ether extract digestibility being higher in the HC-HP group than in the HC-LP group, but this effect was not so large compared with the effect of cellulose level. On the contrary, Miles (1992) reported in humans that fat intake and fat digestibility were significantly higher in the subjects offered the low fiber-high fat diet than in those offered the high fiber-low fat diet. Kelsay et al. (1978) indicated that the high fiber diet altered colonic functions by decreasing transit time and subsequently increased fat excretion. In the present experiment, there were no interactions between dietary cellulose and protein levels on the fecal excretion and digestibility of dry matter, ether extract and energy.

Fecal excretion of NFE was not so much different among the treatments. But the digestibility of NFE had the same trend with the DM and energy digestibility, which was lower in the high cellulose diets than in the low cellulose diets. In the previous report (Siri et al., 1992), it was found that the increase in the cellulose level did not affect the fecal excretion of NFE, and not so much difference was found in NFE digestibility.

The amounts of NDF, ADF and hemicellulose excreted into the feces were higher in the high cellulose diets than in the low cellulose diets. According to Siri et al. (1992), the NDF, ADF and hemicellulose excretion increased with the increase in the dietary cellulose level, and the amounts of NDF and ADF excreted into the feces were 37.1 and 34.5 g/3 days for the 20% cellulose diet and 9.2 and 8.3 g/3 days for the 5% cellulose diet, respectively, which were similar to the value obtained in the present experiment. But the hemicellulose excretion in the previous report (Siri et al., 1992) was 2.6 and 0.9 g/3 days for the 20% and 5% cellulose diets, respectively, which were lower than in the present experiment.

However, the digestibility of NDF was lower in the HC-HP group, and there was not significant difference in the values between the LC-LP, LC-HP and HC-LP groups. The digestibility of ADF was low in the low cellulose diets, but there was significant difference only between the LC-HP and HC-LP groups. The effect of dietary protein level and interaction effect between dietary cellulose and protein levels on the NDF and ADF digestibility was not found. Consequently, the hemicellulose digestibility in the high cellulose diets was lower than that in the low cellulose diets. In the high cellulose diets, however, the digestibility of hemicellulose decreased with the increase in the dietary protein level, suggesting the interaction of dietary cellulose and protein levels. According to Siri et al. (1992), dietary cellulose level did not affect the ADF digestibility, but the NDF and hemicellulose digestibility was significantly lower in the 20% cellulose diet than in the 5, 10 and 15% cellulose diet, which was in agreement with the result of Stanogias and Pearce (1985), who reported with pigs that the digestibility of NDF and hemicellulose was significantly depressed by the higher levels of NDF intake.

TABLE 2. FECAL EXCRETION AND DIGESTIBILITY OF DRY MATTER, ETHER EXTRACT, NFE, NDF, ADF, HEMICELLULOSE AND ENERGY

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP	SEM	Statistical significance[1]		
						C	P	Interaction
Fecal excretion (g/3 days)								
DM	37.9[a]	37.9[a]	68.1[b]	66.7[b]	3.2	**	NS	NS
EE	0.3[a]	0.3[a]	1.1[c]	0.7[b]	0.1	**	NS	NS
NFE	3.7[a]	4.0[ab]	5.1[b]	4.6[ab]	0.3	*	NS	NS
NDF	11.6[a]	11.3[a]	39.8[b]	39.4[b]	1.7	**	NS	NS
ADF	10.0[a]	9.6[a]	35.6[b]	35.0[b]	1.5	**	NS	NS
Hemicellulose	1.6[a]	1.7[a]	4.2[b]	4.2[b]	0.4	**	NS	NS
Energy (kJ/3 days)	334.3[a]	363.7[a]	964.4[b]	919.9[b]	53.4	**	NS	NS
Digestibility (%)								
DM	79.9[b]	80.0[b]	64.7[a]	65.7[a]	1.6	*	NS	NS
EE	93.5[a]	94.0[a]	95.6[b]	97.2[c]	0.4	**	*	NS
NFE	97.2[b]	96.4[b]	93.8[a]	93.2[a]	0.4	**	NS	NS
NDF	26.8[b]	29.2[b]	19.0[ab]	12.1[a]	3.6	**	NS	NS
ADF	5.1[ab]	2.9[a]	14.2[b]	13.0[ab]	3.3	*	NS	NS
Hemicellulose	72.4[c]	70.1[c]	45.1[b]	13.1[a]	6.4	**	*	*
Energy	88.4[b]	88.0[b]	72.3[a]	74.3[a]	1.5	**	NS	NS
Digestible energy (kJ/g)	13.5	14.0	13.0	13.7	0.3	NS	NS	NS
Metabolizable energy (kJ/g)	12.9	12.7	12.5	12.8	0.3	NS	NS	NS

LC-LP, LC-HP, HC-LP and HC-HP see footnote of table 1.

[1] C and P mean the main effect of cellulose and protein.

Means not sharing a common superscript are significantly different ($p < 0.05$).

NS: Not significant, $p > 0.05$, * and **: Significant at $p < 0.05$ and $p < 0.01$, respectively.

Digestibility and biological value of protein are shown in table 3. Fecal and urinary nitrogen excretion were affected by the dietary protein level, being higher in the high protein diets than in the low protein diets, but were not affected by the dietary cellulose level. There was an interaction in the fecal nitrogen excretion; fecal nitrogen excretion was higher in the high cellulose group than in the low cellulose group when the dietary protein level was low, however, the increase in the protein level did not increase the fecal nitrogen excretion when the high cellulose diets were given. Although the nitrogen intake was almost double in the HC-HP group compared with the HC-LP group, no difference in fecal nitrogen excretion was found between them. Consequently, the true digestibility of protein was reduced by increasing the cellulose level in the low protein diets, but not in the high protein diets. Siri et al. (1992) reported that true digestibility of protein was not different among the diets containing 5% to 20% dietary cellulose, being 95-97%, when the diet contained 18% of protein. Hence, 20% dietary cellulose level reduced the protein digestibility only when the diet contained a low level of protein such as 10%.

TABLE 3. DIGESTIBILITY AND BIOLOGICAL VALUE OF PROTEIN

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP	SEM	Statistical significance[1]		
						C	P	Interaction
N intake (g/3 days)	3.30	6.45	3.26	6.20	–	–	–	–
N excretion, fecal (g/3 days)	0.33^{a}	0.50^{b}	0.44^{b}	0.49^{b}	0.02	NS	**	**
N excretion, urinary (g/3 days)	1.38^{a}	2.17^{b}	1.32^{a}	2.18^{b}	0.05	NS	**	NS
True digestibility (%)	91.8^{b}	93.2^{b}	88.5^{a}	93.2^{b}	0.6	*	**	*
Biological value (%)	60.6^{ab}	66.6^{c}	59.7^{a}	65.0^{bc}	1.3	NS	**	NS

LC-LP, LC-HP, HC-LP and HC-HP see footnote of table 1.

[1] See footnote of table 2.

Means not sharing a common superscript are significantly different ($p < 0.05$).

*NS: Not significant, $p > 0.05$, * and **: Significant at $p < 0.05$ and $p < 0.01$, respectively.*

Biological value of protein was influenced by the dietary protein level but not by the dietary cellulose level. According to Siri et al. (1992), the biological value of protein was not influenced by the dietary cellulose level from 5% to 20%, being 52-57%, and this value was lower than that obtained in the present experiment. Kelsay et al. (1978) reported in humans that nitrogen balance was not different between the low and high fiber diets with the same crude protein content.

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