EFFECTS OF DIETARY CELLULOSE LEVEL ON GROWTH PERFORMANCE DEVELOPMENT OF INTERNAL ORGANS, ENERGY AND NITROGEN UTILIZATION AND LIPID CONTENTS OF GROWING CHICKS

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Summary

In order to determine the effect of dietary cellulose levels on chick performance, 1-week-old White Leghorn male chicks were fed semi-purified diets containing either 5%, 10%, 15% or 20% cellulose for 3 weeks. All diets were iso-nitrogenous and iso-caloric. Feed intake and body weight were increased as the cellulose level was increased. Feed conversion was lower in the 5% cellulose diet than in the other diets. Compared to the case of 10% to 20% cellulose diets, relative length (per 100 g body weight) of esophagus, duodenum, small intestine and cecum was longer, and relative weight of esophagus, duodenum and crop was also heavier in the chicks fed the 5% cellulose diet. The other internal organs were not affected by the cellulose level. The retention rates of dry matter and nitrogen were lower in the 5% cellulose group than in the other groups. Concentration of carcass phospholipids was higher in the 5% cellulose group, and that of carcass cholesterol was increased as the cellulose level increased. In conclusion, the dietary cellulose level should be more than 5% to give an adequate chick performance, and no ill effect was found even at 20% level.

(Key Words: Dietary Cellulose, Chick Growth, Internal Organ, Nitrogen Utilization)

Introduction

Although dietary fiber has no nutritional value, it is an important component of the diet (Gordon, 1990) because of its effect on gastrointestinal functions and fecal output (Araujo, 1978; Kies et al., 1984). Cellulose is one of the dietary fibers commonly present in the feeds, and its effects on nutritional and physiological functions have been studied. According to Akiba and Matsumoto (1978), Fleming and Lee (1983) and Wagner et al. (1988), dietary cellulose had no influence on feed intake, weight gain and feed efficiency but decreased apparent protein digestibility in some animals including poultry. Nomani et al. (1979) and Hove and King (1979) reported that dietary cellulose improved utilization of absorbed nitrogen and body weight gain in rats when protein and energy intakes were at marginal levels. Saito et al. (1959) reported that chicks fed a diet containing as high as 26.5% cellulose grew better than the chicks fed low cellulose diets, and Kibe et al. (1964) showed that cellulose feeding influenced the development of some internal organs. The present experiment was carried out to obtain adequate dietary cellulose level for giving the best chick performance.

Materials and Methods

Day old White Leghorn male chicks were reared in electrically heated brooders with a commercial chick starter diet for 7 days. The chicks were individually weighed after fasting for 2 hours, then 30 chicks were selected on body weight basis to make 5 groups of 6 birds each, so that the initial body weight of the groups was as uniform as possible. Chicks of one group were immediately killed to obtain initial data, and the remaining chicks were randomly placed individually in metabolism cages which were in a room maintained at 35℃ for first 7 days, thereafter the temperature was decreased 2℃ every week. Four experimental diets were formulated as shown in table 1 to contain 5%, 10%, 15% and 20% of cellulose powder. These diets were iso-caloric and iso-nitrogenous. Feed and water were given *ad libitum* during the entire experimental period of 3 weeks from 8 to 29 days of age. Body

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TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS

Ingredient (%)	Cellulose (%)			
	5	10	15	20
Soybean protein	21.40	21.40	21.40	21.40
Corn starch	66.60	58.05	49.55	41.00
Corn oil	1.00	4.55	8.05	11.60
Cellulose	5.00	10.00	15.00	20.00
DL-Methionine	0.15	0.15	0.15	0.15
Choline chloride	0.15	0.15	0.15	0.15
Vitamin mixture[1]	0.07	0.07	0.07	0.07
Mineral mixture[2]	5.63	5.63	5.63	5.63
Analysed				
Dry matter (%)	93.94	94.38	94.05	94.38
Crude protein (DM %)	21.69	20.63	20.88	19.88
Gross energy (Mcal/kg DM)	4.42	4.70	4.92	5.11

[1] Contained, in mg/0.7 g, Thiamin · HCl 100, Niacin 100, Riboflavin 16, Ca-pantothenate 20, Vitamin B_{12} 0.02, Pyridoxine · HCl 6, Biotin 0.6, Folic acid 4, Inositol 100, p-Amino-benzoic acid 2, Menadione 5, Ascorbic acid 250, Vitamin A acetate (10^6 IU/g) 10, Vitamin D_3 cryst. 0.015 (600 ICU), DL-alpha-tocopherol 5, Buthylated hydroxy-toluene cryst. 0.0156, the rest was corn starch.

[2] Contained, in g/56.3 g, $CaHPO_4$ 20.7, $CaCO_3$ 14.8, KH_2PO_4 10.0, NaCl 6.0, KCl 1.0, KI 0.0026, $MgSO_4$ 3.0, $MnSO_4 \cdot H_2O$ 0.333, $CoCl \cdot 6H_2O$ 0.0017, $FeSO_4 \cdot H_2O$ 0.333, $CuSO_4 \cdot 5H_2O$ 0.0167, $Na_2MoO_4 \cdot 2H_2O$ 0.0083, ZnO 0.062, Na_2SeO_3 0.0001, the rest was corn starch.

weight and feed intake were recorded weekly. Two hours after the last feed was given, final body weight was measured and blood was taken with a heparinized syringe by heart puncture. The blood was centrifuged for 15 minutes at 1500 × g and the plasma thus obtained was kept in a deep freezer for analysis. Soon after the blood was taken, most of the internal organs were removed from the body. Liver was immediately weighed and stored in a deep freezer. Digestive organs were divided into parts, then lumen contents were removed by scraping with fingers. Natural length and/or weight of each part of the digestive organs, heart, pancreas and spleen were measured. Whole carcasses including internal organs but not liver were repeatedly minced until the carcasses were well homogenized. A part of the minced carcass was stored in a deep freezer for lipid determination, and the rest was dried at 55℃ for 72 hours using a forced air drier, and then finely ground for chemical analysis.

Dry matter in the diets and carcasses, and nitrogen in the diets, carcasses and liver were both determined by AOAC (1984) method. Gross energy of the diets and carcasses were determined using an automatic bomb calorimeter (Shimazu, model CA-3). Dry matter, energy and nitrogen retained in the body during the experimental period of 3 weeks were estimated by subtracting the initial values from the final ones. Lipids of fresh carcasses, liver and blood plasma were extracted by the method of Folch et al. (1957), and triglycerides, phospholipids and total cholesterol were determined by the methods of Fletcher (1968), Bartlett (1959) and Zlatkis and Zak (1969), respectively.

The data were expressed as mean values together with standard errors of the mean. The analysis of variance was performed and the treatment means were compared using Duncan's new multiple range test (Steel and Torrie, 1980).

Results and Discussion

Feed intake, body weight gain and feed conversion ratio are shown in table 2. Feed intake tended to increase with an increase in the dietary cellulose level. The 20% cellulose level significantly increased feed intake. Weight gain increased with the increase in the cellulose level; it was lowest

TABLE 2. FEED INTAKE, BODY WEIGHT GAIN AND FEED CONVERSION RATIO FOR 3 WEEKS FROM 8 TO 29 DAYS OF AGE

	Cellulose (%)				SEM
	5	10	15	20	
Initial body weight (g)	78.3	78.2	76.7	76.6	0.6
Feed intake (g)	293.3^{a}	301.2^{a}	319.0^{a}	371.3^{b}	15.9
Body weight gain (g)	124.9^{a}	147.2^{ab}	161.7^{bc}	190.8^{c}	10.7
Feed conversion ratio	0.42^{a}	0.49^{b}	0.51^{b}	0.51^{b}	0.02

^{abc}Means not sharing a common superscript letter are significantly different ($p < 0.05$).

in the 5% cellulose diet and highest in the 20% cellulose diet. This tendency was similar to the result of Saito et al. (1959), indicating that the chicks fed the 26.5% cellulose diet did not lose their appetite and showed better body weight gain than those fed the diet without cellulose. Delorme et al. (1981) also reported that weight gain and feed intake were significantly higher in rats fed a high level cellulose diet than in those fed the low level cellulose diet. On the contrary, Shah et al. (1982) reported that feed intake increased but body weight gain decreased when the dietary cellulose level was increased in rats. This discrepancy might result from the difference in protein content in the diets. Since Shah et al. (1982) did not adjust the protein content when the cellulose level was increased, nitrogen intake decreased in the high cellulose diet feeding even though the feed intake increased. This might be a reason why the rats receiving the diet high in cellulose had reduced body weight gain. As shown in table 2, feed conversion ratio was significantly higher in the 10 to 20% cellulose diets than in the 5% cellulose diet. This result indicated that the level of dietary cellulose at 5% was not enough to give better feed efficiency.

The effects of dietary cellulose level on the developement of some internal organs are shown in table 3 together with the initial values at 1 week of age. In this experiment, esophagus was divided into 2 parts, from oral cavity to crop and from crop to proventriculus, and right and left ceca were measured separately, however, no different trends were found between the two parts, and the values were shown as the sum of the two parts. Values of all organs in the 10% cellulose group and those of the 1-week-old chicks were quite similar to the values reported in the previous paper (Siri et al., 1992).

The length of esophagus was straightly shortened by an increase in cellulose level, and the 5% cellulose level gave significantly heavier esophagus than the higher levels. Consequently, the weight : length ratio was not different between the 5% and 10% levels, being 0.185-0.187, but thereafter the ratio became higher, being 0.195 and 0.219 in the 15% and 20% levels, respectively. Since the weight : length ratio at the initial stage was 0.100, the esophagus seemed to be thicker with the increase in age and in cellulose level. The crop weight was significantly heavier in the 5% cellulose group followed by the 10% group, but the 15% and 20% cellulose diets gave any difference in the crop weight. Proventriculus and gizzard weights were not different among the cellulose levels. Kibe et al. (1964) reported that addition of cellulose to a diet increased gizzard weight, but such an effect was not observed in this experiment.

Duodenum was longer and heavier in the 5 % cellulose group, however, the weight : length ratio was not different among the treatments, being 0.10 0.11, but 1-week-old chicks had relatively longer duodenum and the weight : length ratio was very small, being 0.05. The length of small intestine and ceca showed the same tendency as that of duodenum, but the weight was not different among the treatments. The length and weight of rectum, the weight of heart, liver, pancreas and spleen were not different among the cellulose levels.

The relative length of the digestive organs was longer at 1 week of age than at 4 weeks of age, but the relative weight of these organs and that of heart, pancreas and spleen were not different between the growing stages. Only gizzard and liver were relatively heavier in 1-week-old chicks than in 4-week-old chicks. In general, the thick-

TABLE 3. LENGTH AND / OR WEIGHT OF INTERNAL ORGANS ON 100 g BODY WEIGHT BASIS AT 4 WEEKS OF AGE

		Cellulose (%)					Initial (1-week old) value
		5	10	15	20	SEM	(mean ± SE)
Esophagus	(cm)	3.25[b]	2.84[ab]	2.56[a]	2.24[a]	0.22	6.99 ± 0.58
	(g)	0.60[b]	0.53[a]	0.50[a]	0.49[a]	0.02	0.70 ± 0.05
Crop	(g)	0.56[b]	0.51[ab]	0.41[a]	0.45[a]	0.04	0.70 ± 0.05
Proventriculus	(g)	0.66	0.64	0.66	0.60	0.03	0.98 ± 0.02
Gizzard	(g)	2.40	2.04	1.92	2.24	0.20	4.01 + 0.16
Duodenum	(cm)	7.69[b]	6.92[ab]	6.69[a]	6.20[a]	0.32	15.78 ± 0.46
	(g)	0.82[b]	0.69[a]	0.74[ab]	0.69[a]	0.04	0.92 ± 0.09
Small intestine	(cm)	31.40[b]	28.09[ab]	26.96[ab]	24.39[a]	1.83	67.19 ± 2.04
	(g)	2.13	1.83	2.10	1.99	0.10	2.55 ± 0.13
Ceca (sum of 2)	(cm)	6.12[b]	5.63[ab]	5.70[ab]	5.14[a]	0.28	13.86 ± 0.83
	(g)	0.31	0.26	0.29	0.28	0.02	0.41 ± 0.05
Rectum	(cm)	2.29	1.89	2.19	2.01	0.19	4.59 ± 0.43
	(g)	0.25	0.19	0.25	0.30	0.03	0.33 ± 0.03
Heart	(g)	0.67	0.61	0.63	0.61	0.03	0.68 ± 0.04
Liver	(g)	2.13	2.11	2.16	1.94	0.07	3.36 + 0.21
Pancreas	(g)	0.38	0.42	0.39	0.34	0.02	0.41 ± 0.02
Spleen	(g)	0.16	0.18	0.15	0.15	0.02	0.13 ± 0.00

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

ness of the digestive tract increased with aging, but was not influenced by the dietary cellulose level.

Intake, gain and retention rate of dry matter, energy and nitrogen during the experimental period of 3 weeks are shown in table 4. For calculating the retention rate in this experiment, the gains of dry matter and energy in the liver were not used bacause of small amount of liver samples. However, no apparent effect could exist even if those values were neglected for calculation, since the gains of dry matter and energy in the liver were very low.

The intake of dry matter and energy increased with an increase in cellulose level, and significantly higher in the 20% cellulose group than in the other groups because of higher feed intake. The trend of dry matter gain in carcass was quite similar to the body weight gain, being lowest in the 5% cellulose group and highest in the 20% cellulose group. However, the retention rate was very low in the 5% cellulose group (14.9) compared with those in the 10% to 20% cellulose groups (18.0-19.0). The rates were not significantly different among the 10% to 20% cellulose groups. This fact indicates that in the range of 10% to 20% cellulose levels the dry matter gain in the carcass was completely controlled by the dry matter intake, but when the 5% cellulose diet was fed, fecal dry matter loss was probably increased. For confirming this assumption, it would be necessary to determine the dry matter digestibility.

The intake and gain of energy also tended to be similar to the feed intake and body weight gain, respectively, but the retention rate was not significantly different among the groups. This trend is a little different from that of the dry matter. The following interpretation can be given from this fact; the energy loss may be lower in the chicks fed the 5% cellulose diet than in the chicks fed the higher cellulose diets. This could support the result of Akiba and Matsumoto (1980), who reported that the energy retention was not influenced by the addition of dietary fibers.

Nitrogen intake and nitrogen retentions in both carcass and liver increased with the increase

TABLE 4. DRY MATTER, ENERGY AND NITROGEN RETENTIONS IN THE BODY DURING 3 WEEKS FROM 8 TO 29 DAYS OF AGE

	Cellulose (%)				SEM
	5	10	15	20	
Dry matter					
Intake (g)	275.5^{a}	284.3^{a}	300.0^{a}	350.4^{b}	15.0
Gain in carcass (g)	41.3^{a}	51.3^{ab}	55.2^{bc}	67.3^{c}	4.4
Retention rate (%)	14.9^{a}	18.0^{b}	18.5^{b}	19.0^{b}	0.8
Energy					
Intake (Mcal)	1.22^{a}	1.34^{ab}	1.48^{b}	1.79^{c}	0.06
Gain in carcass (Mcal)	0.24^{a}	0.30^{a}	0.32^{ab}	0.41^{b}	0.03
Retention rate (%)	20.0	22.0	21.9	22.9	1.4
Nitrogen					
Intake (g)	9.56^{a}	9.38^{a}	10.02^{ab}	11.14^{b}	0.49
Gain in carcass (g)	3.98^{a}	4.52^{a}	4.67^{a}	5.53^{b}	0.28
Gain in liver (g)	0.07	0.08	0.10	0.11	0.01
Total gain (g)	4.06^{a}	4.60^{a}	4.77^{a}	5.64^{b}	0.29
Retention rate (%)	42.3^{a}	49.0^{b}	47.6^{b}	50.5^{b}	1.2

Initial values per bird at 8 days of age were as follows: carcass dry matter 16.6 g, carcass energy 0.10 Mcal, carcass nitrogen 1.65 g, and liver nitrogen 0.08 g.

^{abc} Means not sharing a common superscript letter are significantly different ($p < 0.05$).

in feed intake. Particularly the intake and the gain in carcass were significantly higher in the 20% cellulose group. Akiba and Matsumoto (1978) also reported that cellulose feeding slightly increased nitrogen retention in chicks. Alike in the case of dry matter, the retention rate of nitrogen in the 5% cellulose group was inferior to that in the other groups. According to Hove and King (1979) and Delorme et al. (1981), true nitrogen digestibility in rats decreased with an increase in cellulose level due to the increase in endogenous nitrogen excretion as reported by Shah et al. (1982). However, the result of this experiment indicated that the chicks fed the 5%

TABLE 5. LIPID CONTENTS IN CARCASS, LIVER AND BLOOD PLASMA

	Cellulose (%)				SEM
	5	10	15	20	
Triglycerides in					
Carcass (mg/g)	80.40	81.69	77.24	90.92	7.24
Liver (mg/g)	10.86	13.73	9.07	10.23	1.53
Plasma (mg/ml)	2.65	2.92	2.63	2.67	0.48
Phospholipids in					
Carcass (mg/g)	6.77^{b}	5.94^{a}	5.93^{a}	5.74^{a}	0.23
Liver (mg/g)	32.24	33.82	32.27	33.75	1.82
Plasma (mg/ml)	1.90	1.94	1.99	1.97	0.25
Total cholesterol in					
Carcass (mg/g)	5.68^{a}	10.41^{b}	13.46^{b}	18.25^{c}	1.02
Liver (mg/g)	5.60	5.75	5.67	6.05	0.24
Plasma (mg/ml)	0.92	0.89	1.08	0.80	0.07

^{abc} Means not sharing a common superscript letter are significantly different ($p < 0.05$)

cellulose diet excreted more nitrogen into either feces or urine, or even into both. In conclusion, the cellulose level at 5% gave inferior feed efficiency for chick growth, and any ill effects were not shown even when the chicks were fed diets containing as high as 20% of cellulose.

The lipid contents in carcass, liver and blood plasma are presented in table 5. Triglycerides in carcass, liver and plasma, phospholipids and total cholesterol in both liver and plasma were not different among the dietary cellulose levels. In agreement with this results, Tsai et al. (1976) also reported that purified cellulose did not show any significant effect on serum and liver cholesterol levels in rats. Sutton et al. (1981) also reported that no significant change in levels of serum and liver cholesterol in quails fed dietary cellulose was observed. Contrary to the present experiment, Akiba and Matsumoto (1980) reported that liver and plasma triglyceride concentrations were significantly reduced by feeding the cellulose, and liver cholesterol and plasma phospholipids were also influenced by the 4% dietary cellulose. In the present experiment, carcass phospholipid concentration was significantly higher in the 5% cellulose group, and total cholesterol concentration of carcass increased with the increase in cellulose level. At present, the significance of the changes in carcass phospholipids and cholesterol was not clarified, and further experiment is necessary.

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