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

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Summary

In order to investigate the effects of dietary cellulose and protein levels on chick performance, four semi-purified diets were formulated so as to contain cellulose at levels of 5% (LC) and 20% (HC) in combination with 10% (LP) and 20% (HP) protein, and fed *ad libitum* to 1-week-old White Leghorn male chicks for 3 weeks. There were no significant differences in feed intake, body weight gain and feed efficiency between the LC-HP and HC-HP groups. All parameters were lower in the LP groups; the HC-LP group consumed very small amount of feed and lost body weight during the experiment. The retention rates of DM, ash, nitrogen and energy were higher in the HP than the LP groups. The triglyceride concentration of carcass was lower in the HC-LP group and that of liver was higher in the LC-LP group. The carcass total cholesterol level was higher in the HC-HP group. The relative weight of most digestive organs was higher in the HP group irrespective of the cellulose level. In conclusion, the chick performance was primarily influenced by dietary protein level, and when the chicks were fed inadequate levels of protein, the low cellulose level gave a better performance than the high cellulose level.

(**Key Words**: Dietary Cellulose, Dietary Protein, Chick Growth, Internal Organ, Nutrient Utilization)

Introduction

Delorme et al. (1981) and Savory and Gentle (1976) demonstrated that dietary cellulose increased feed intake and body weight gain in rats and Japanese quail, respectively. Siri et al. (1992b) demonstrated that the dietary cellulose level should be more than 5% to give an adequate growth performance of chicks when the diet contained a required level of protein. On the contrary, Akiba and Matsumoto (1978b) suggested that the cellulose feeding did not affect feed intake and feed efficiency in chicks. Moran and Evans (1977) reported that hens fed a diet containing high fiber but low crude protein and low energy retained more dry matter and energy but not protein and fat than the hens given a diet containing low fiber but high protein and energy. Akiba and Matsumoto (1977) reported that the dietary cellulose depressed liver lipid accumulation in growing chicks. According to Siri et al. (1992b), carcass cholesterol level increased but phospholipid level decreased in chicks when the dietary cellulose level was increased. Stewart et al. (1987) indicated that dietary carbohydrate, lipid or protein would be a better criterion than dietary fiber for predicting serum and liver lipid responses. However, it is still not clear whether the effect of dietary cellulose on the chick performance is related with the levels of other nutrients. Hence, the present study was undertaken to investigate the effects of dietary cellulose level on the chick performance when adequate or inadequate levels of protein were given.

Materials and Methods

Four experimental diets were formulated so as to contain cellulose at 5% (LC) and 20% (HC) with a combination of 10% (LP) and 20 % protein (HP), and they were abbreviated as LC-LP, LC-HP, HC-LP and HC-HP as shown in table 1. Vitamin and mineral contents were same in all diets but the contents of starch and oil were changed so that the all diets contained

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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 composition (%)				
Dry matter (DM)	94.0	95.4	94.6	95.4
Ash	8.3	9.0	8.1	8.3
Crude protein (CP)	10.3	20.2	10.1	19.4
Crude fat (EE)	2.7	2.6	14.1	14.1
Nitrogen free extract (NFE)[2]	63.5	54.9	37.1	28.1
Neutral detergent fiber (NDF)	9.1	8.7	25.2	25.5
Acid detergent fiber (ADF)	5.6	5.8	22.3	22.4
Gross energy (kJ/g)	15.6	16.2	17.9	18.8
ME, calculated (kJ/g)	13.0	13.0	13.0	13.0

[1] Siri et al. (1992a).
[2] NFE = DM − (Ash + CP + EE + NDF).

same ME value. The chemical compositions are also indicated in table 1.

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 2-hour fasting, 30 chicks of which were selected on body weight basis to make 5 groups of 6 birds each, so that the initial body weights of groups were uniform. Chicks of one group were immediately killed to obtain initial data, and the remaining chicks were randomly placed in individual metabolism cages which were in a room maintained at 35℃ for first 7 days, then the temperature was decreased 2℃ every week. The birds were given the diets and water *ad libitum* during the experimental period of 3 weeks from 8 to 29 days of age, and body weight and feed intake were recorded. Two hours after the last feed final body weight was measured and blood was taken from the heart with a heparinized syringe. The blood was centrifuged for 15 minutes at 1,500 × g and the plasma obtained was kept in a deep freezer till analysis. Soon after the blood was taken, most of 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 the digestive organs, heart, spleen and pancreas were measured. Whole carcasses together with internal organs excluding liver were repeatedly minced so as to be well homogenized. A part of the minced carcass was stored in a deep freezer for determination of lipid, and the rest portions were dried at 55℃ for 72 hours using a forced air oven, then ground for chemical analysis.

Proximate chemical composition of the diets and carcasses, and liver nitrogen were determined by the method of AOAC (1984). Gross energy of the diets and carcasses were determined using an automatic bomb calorimeter (Shimadzu, model CA-3). Dry matter, ash, nitrogen and energy retained in the body during the 3-week period were estimated by subtracting the initial values

from the final values. Lipids of fresh carcass, liver and 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.

A 2 × 2 factorial design was used to perform this experiment. The data were statistically analyzed, and the treatment means were compared by using the Duncan's new multiple range test (Steel and Torrie, 1980).

Results and Discussion

(1) Feed intake, body weight gain and feed efficiency

Feed intake, body weight gain and feed efficiency of each group and statistically analyzed results are shown in table 2. The LC-HP and HC-HP chicks consumed almost the same amount of feed and gained almost the same weight, which resulted in the same feed efficiency. These values were a little lower than those given by the previous report (Siri et al., 1992b), but the differences would not be significant. The LC-LP chicks gained significantly lower weight than the LC-HP and HC-HP chicks. This discrepancy might be due to the lower feed intake in the LC-LP chicks, however, the LC-LP diet had another deteriorative effect, since the feed efficiency was also very low compared with that for the LC-HP and HC-HP diets. When the chicks were given the HC-LP diet, feed intake was very low compared with that of the LC LP diet, and the chicks lost their body weight. It might be said from the results that the low level of dietary cellulose did not affect the chick growth if the dietary protein level met the requirement, but affected badly if the protein level was half of the requirement. This might be a reason why the interaction between the levels of cellulose and protein existed. When the protein level was very low, the 20% cellulose diet remarkably reduced feed intake, and consequently the chicks lost their body weight. Moran and Evans (1977) demonstrated that hens fed a high fiber (5.75%) but low protein (13.8%) diet containing 2,390 kcal (9.91 MJ) ME/kg consumed more feed but gained lower weight than the hens fed a low fiber (2.44%) but high protein (17.8%) diet containing 3,060 kcal (12.8 MJ) ME/kg. Cherry et al. (1983) also reported that pullets fed the basal diet supplemented with 20% cellulose consumed more feed but less calories and gained less weight than the birds fed the basal diet alone. This discrepancy would be due to the fact that the high fiber fed birds failed to consume sufficient amounts of feed to meet their protein and energy requirements. Since the diets of their experiment were not iso-caloric, their result could not be compared with that of the present experiment. According to Hove and King (1979), cellulose did not influence the weight gain of rats when the diets contained adequate amounts of protein (20%), and they also demonstrated that at all cellulose levels a diet containing 22% casein gave greater feed intake and weight gain than a diet containing 8% casein. The present experiment might support their result.

TABLE 2. FEED INTAKE, BODY WEIGHT GAIN AND FEED EFFICIENCY (GAIN / FEED) OF CHICKS FOR 3 WEEKS FROM 8 TO 29 DAYS OF AGE

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP	SEM	Statistical significance		
						C[1]	P[2]	Interaction
Initial body weight (g)	83.1	83.6	84.1	83.3	0.6	–	–	–
Body weight gain (g)	26.4[b]	165.6[c]	−21.6[a]	172.0[c]	6.9	**	**	**
Feed intake (g)	176.9[b]	355.2[c]	75.3[a]	360.9[c]	16.5	**	**	**
Gain/feed (g/g)	0.14[a]	0.47[b]	–	0.48[b]	0.02	–		–

[a,b,c] Means not sharing a common superscript are significantly different ($p < 0.05$).

** Significant at $p < 0.01$.

[1] Effect of cellulose level.

[2] Effect of protein level.

(2) **Retention of dry matter, ash, nitrogen and energy**

Intake, retention and retention rate of dry matter, ash, energy and nitrogen during the experimental period of 3 weeks are shown in table 3. In calculating the retention rate, amounts of dry matter, ash and energy in the liver were neglected, because the liver samples were too small to be analyzed. The intake and retention of dry matter showed the almost same trend as the feed intake and body weight gain, respectively. However, the retained dry matter was 53%, 35% and 35% of the body weight gain in the LC-LP, LC HP and HC-HP groups, respectively, and the dry matter lost as the body weight loss was 17 %. This means that the body mass of the LC-LP chicks was denser than that of the LC-HP and HC-HP chicks. The presence of interaction between cellulose and protein may be explained as discussed in the previous section. The retention rate was not different between the LC-HP and HC-HP chicks, and these were higher than that of the LC-LP chicks.

Although the ash intake was proportional to the dry matter intake, the retention was a little different between them. The HC-LP chicks lost their body weight and showed negative dry matter retention, however, those chicks retained ash in the body although the amount was very small, being 3.2% of the intake. This means that the loss of dry matter of the HC-LP chicks was not mainly due to the loss of inorganic matters but due to the loss of organic matters; in fact, half of the dry matter loss was body protein (0.28 g nitrogen) as shown in the lower row of the table. The ash retention was significantly higher

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

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP	SEM	Statistical significance		
						C[1]	P[2]	Interaction
Dry matter								
Intake (g)	166.2[b]	338.8[c]	71.2[a]	344.4[c]	15.6	**	**	**
Retention (g)	14.0[b]	55.2[c]	−3.6[a]	60.8[c]	2.7	*	**	**
Retention rate (%)	8.1[a]	16.3[b]	–	17.6[b]	0.7		–	–
Ash								
Intake (g)	14.8[b]	31.8[c]	7.5[a]	29.9[c]	1.4	**	**	*
Retention (g)	1.7[b]	5.3[c]	0.3[a]	6.0[d]	0.2	NS	**	**
Retention rate (%)	11.5[b]	16.6[c]	4.1[a]	20.1[d]	0.3	NS	**	**
Nitrogen								
Intake (g)	2.92[b]	11.48[c]	1.22[a]	11.23[c]	0.39	*	**	NS
Retention (g)	1.04[b]	5.21[c]	−0.28[a]	5.21[c]	0.18	**	**	**
in carcass (g)	1.03[b]	5.09[c]	−0.24[a]	5.06[c]	0.17	**	**	**
in liver (g)	0.01[b]	0.12[c]	−0.04[a]	0.15[c]	0.02	NS	**	*
Retention rate (%)	35.2[a]	45.5[b]	–	46.4[b]	1.9	–		
Energy								
Intake (kJ)	2,764[b]	5,773[c]	1,350[a]	6,777[d]	274	NS	**	**
Retention (kJ)	351[b]	1,436[c]	−133[a]	1,646[c]	84	NS	**	**
Retention rate (%)	12.0[a]	24.9[b]	–	24.2[b]	1.5	–	–	–

Initial body composition (8 days of age) was as follows: carcass DM 18.7 g, carcass ash 1.9 g, carcass N 1.89 g, liver N 0.08 g, carcass energy 456 kJ.

[a,b,c,d] *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.

[1,2] See the footnote of table 2.

in the HC-HP chicks than in the LC-HP chicks. Reflecting the amounts of retention, the retention rate was significantly different among the dietary treatments.

The intake, retention and retention rate of nitrogen showed almost the same trend to those of dry matter. These values were not so much different from those reported in the previous paper (Siri et al., 1992b). According to Akiba and Matsumoto (1978b, 1980), the addition of cellulose to the diet did not increase nitrogen retention in chicks. Stanogias and Pearce (1985) demonstrated that the nitrogen retention was related with the nitrogen intake in pigs, and they suggested that when the fiber intake was high, the animal needed more nitrogen and available energy to synthesize new tissues. It can be concluded that nitrogen retention may be influenced by nitrogen intake but not by cellulose intake if the diet contains an adequate amount of available energy. The nitrogen retained in the liver was 2.9%, 2.3% and 1.0% of the whole retention in the HC HP, LC-HP and LC-LP chicks, respectively, and the nitrogen lost from the liver was 4.3% of the whole loss in the LC LP chicks. Liver protein seemed to be firstly catabolized when protein depletion occured.

The gross energy intake was significantly highest in the HC-HP group followed by the LC-HP and LC-LP groups, and that in the HC-LP group was lowest. The reason why the HC-HP chicks consumed higher gross energy than the LC-HP chicks though the feed intake was not different, was that the former diet contained higher gross energy than the latter diet. The energy retention was shown to be the same order, and the retention rate of energy was not different between the LC-HP and HC-HP groups and they were higher than that of the LC-LP group. Again, the chicks consumed the low protein diet lost body energy during the 3-week period when the diet contained high cellulose level.

(3) Lipid contents of the body

The lipid contents in carcass, liver and blood plasma are presented in table 4. The levels of carcass triglyceride were not different among the LC-LP, LC-HP and HC-HP groups, and these values were basically the same as those reported in the previous paper (Siri et al., 1992b). The value of the HC-LP group was significantly ($p < 0.05$) lower than those of the other groups. The levels of liver triglyceride were not different between the HC-LP and HC-HP groups and these values were almost the same as that reported previously (Siri et al., 1992b). The value of the LC-HP group was lower and that of the LC-LP groups was significantly ($p < 0.05$) higher than

TABLE 4. LIPID CONTENTS IN CARCASS, LIVER AND BLOOD PLASMA OF CHICKS

Dietary treatment	LC-LP	LC-HP	HC-LP	HC-HP	SEM	Statistical significance		
						C[1]	P[2]	Interaction
Triglycerides in								
Carcass (mg/g)	106.6^{b}	91.8^{b}	29.2^{a}	102.3^{b}	11.9	*	*	**
Liver (mg/g)	25.0^{c}	9.4^{a}	12.5^{b}	11.5^{b}	1.1	*	**	**
Plasma (mg/dl)	204	215	249	224	15	NS	NS	NS
Phospholipids in								
Carcass (mg/g)	10.1	9.5	10.3	9.4	0.5	NS	NS	NS
Liver (mg/g)	24.3^{a}	26.8^{ab}	33.3^{c}	30.2^{bc}	1.9	**	NS	NS
Plasma (mg/dl)	203	189	186	201	6	NS	NS	NS
Total cholesterol in								
Carcass (mg/g)	5.7^{a}	6.0^{a}	5.7^{a}	10.7^{b}	0.4	**	**	**
Liver (mg/g)	7.1	7.0	8.0	7.4	0.4	NS	NS	NS
Plasma (mg/dl)	179	184	168	171	9	NS	NS	NS

[a,b,c] 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.
[1,2] See the footnote of table 2.

the others. The high content of liver triglycerides in the LC LP group might be due to the low protein intake which caused hepatic lipogenesis as reported by Rosebrough and Steele (1990). They demonstrated with an *in vitro* study that hepatic lipogenesis of young chicks was enhanced by reducing the dietary protein level from 20% to 12%. Akiba and Matsumoto (1977, 1978a, 1982) reported that synthesis of tryglycerides was depressed by an increase in dietary cellulose level. Since the values of the LC-LP and LC-HP groups were different and the values of the HC-LP and HC-HP groups were not different, the higher value of the LC-LP group could not be explained as a single effect of dietary levels of either cellulose or protein, in fact there was an interaction of dietary levels of cellulose and protein for hepatic lipogenesis in chickens. The levels of plasma triglycerides were not different among the treatments and these values were similar to those of the previous report (Siri et al., 1992b). The contents of carcass phospholipids were not different among the treatments, and these values were a little higher than the values previously reported (Siri et al., 1992b). The liver phospholipid contents were not different either between the HC-LP and HC-HP groups or between the LC-LP and LC-HP groups, and the former values were higher than the latters. The former values were almost the same as those of the previous report (Siri et al., 1992b). The statistical analysis indicates that the liver phospholipid contents were influenced only by the dietary cellose level and not by the dietary protein level. The plasma phospholipid contents were not influenced by the treatments. The total cholesterol levels of liver and plasma were not influenced by the treatmens, and these values were higher than those of the previous report (Siri et al., 1992b). The HC-HP chicks accumulated cholesterol more than the other groups, and the levels of the latter groups were not different from each other. In the previous experiment, Siri et al. (1992b) observed that the carcass total cholesterol level increased with an increase in dietary cellulose level from 5% to 20%. The values of the LC (5% cellulose) groups in the present experiment were comparable to that of the 5% cellulose level in the previous report, and the values of the HC (20% cellulose) groups were lower than that of the corresponding group in the previous experiment. According to Mueller et al. (1983), the concentration of carcass total cholesterol was not influenced by the dietary cellulose level in rats, however, cellulose seemed to affect the carcass cholesterol level when the dietary portien level was high. Plasma cholesterol level was not influenced by the dietarty treatments of either cellulose or protein. Stewart et al. (1987) suggested that the dietary soluble carbohydrates, lipids and proteins were a better criterion for predicting the serum and liver lipid responses than the dietary fibers, however, more experiments should be necessary to determine which nutrients would be most effective on lipid metabolism in the chicken body.

(4) Length and/or weight of internal organs

Effects of dietary cellulose and protein levels on the development of internal organs of chicks are presented in table 5. As parameters, the length and/or weight of each organ were measured and indicated as per 100 g of body weight. The values of the initial stage at 1 week of age were also measured and presented in the table, and it was found that the values of all organs of the 1-week-old chicks were quite similar to the values reported in the previous paper (Siri et al., 1992b).

The effects of the treatments on the relative length of all parts of the digestive tract and pancrease were the same, being longest in the HC-LP group, followed by the LC-LP group and shortest in the LC-HP and HC-HP groups both of which were not statistically different. There were interactions between the cellulose and protein treatments in all parts, and this might be interpreted as that when the protein level was low the high cellulose level lengthened the organs, and when the protein level was high the cellulose level did not affect the organ length. The organ lengths of the LC-LP chicks were almost the same as those of the initial stage at 8 days of age.

In all parts of the digestive tract except for ceca, the relative weight was higher in the LP chicks than in the HP chicks, however, the effect of the cellulose level was different from each other. Esophagus, small intestine and rectum showed lighter weight in the LC chicks than in the HC chicks, and on the contrary, the low cellulose level increased the weight of proventriculus and duodenum. The cellulose level did not affect the relative organ weight in crop and

TABLE 5. LENGTH AND / OR WEIGHT OF INTERNAL ORGANS (PER 100 G BODY WEIGHT) OF CHICKS AT 8 AND 29 DAYS OF AGE

Dietary treatment	LC-LP	LC-HP	HC-LP	HC HP	SEM	Statistical significance			At 8 days of age
						C[1]	P[2]	Interaction	
Esophagus (cm)	7.6[b]	4.1[a]	12.9[c]	4.1[a]	0.6	**	**	**	9.1(0.3)
Esophagus (g)	0.7[ab]	0.6[a]	0.9[b]	0.7[ab]	0.1	*	**	NS	0.9(0.1)
Crop (g)	0.9[b]	0.5[a]	0.9[b]	0.6[a]	0.1	NS	**	NS	0.9(0.1)
Proventriculus (g)	0.9[b]	0.7[ab]	0.7[ab]	0.6[a]	0.1	*	*	NS	1.0(0.0+)
Gizzard (g)	3.2[b]	2.2[a]	3.1[b]	2.1[a]	0.1	NS	**	NS	4.6(0.2)
Duodenum (cm)	17.5[b]	9.9[a]	26.7[c]	8.5[a]	0.6	**	**	**	20.4(0.6)
Duodenum (g)	1.2[b]	0.9[ab]	0.8[ab]	0.7[a]	0.1	*	*	NS	0.9(0.0+)
Small intestine (cm)	41.4[b]	24.7[a]	94.5[c]	26.3[a]	4.3	**	**	**	63.4(2.5)
Small intestine (g)	1.4[a]	1.4[a]	2.2[b]	1.6[a]	0.2	*	*	*	2.2(0.2)
Ceca(sum of 2) (cm)	10.8[b]	6.3[a]	21.4[c]	6.5[a]	0.5	**	**	**	14.8(0.2)
Ceca(sum of 2) (g)	0.3	0.3	0.4	0.3	0.0+	NS	NS	NS	0.3(0.1)
Rectum (cm)	4.8[b]	2.6[a]	9.7[c]	2.7[a]	0.4	**	**	**	6.1(0.3)
Rectum (g)	0.5[a]	0.4[a]	0.8[b]	0.5[a]	0.1	**	**	*	0.5(0.0+)
Pancreas (cm)	4.9[b]	2.6[a]	8.2[c]	2.7[a]	0.3	**	**	**	6.4(0.2)
Pancreas (g)	0.4	0.4	0.3	0.3	0.0+	NS	NS	NS	0.5(0.0+)
Heart (g)	1.0[b]	0.8[ab]	0.7[a]	0.8[ab]	0.1	*	NS	*	1.0(0.1)
Liver (g)	3.0[b]	2.4[a]	2.2[a]	2.3[a]	0.1	**	NS	*	3.5(0.2)
Spleen (g)	0.1	0.1	0.1	0.1	0.0+	NS	NS	NS	0.1(0.0+)

Figures in parentheses show standard errors.
[a,b,c] 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.
[1,2] See the footnote of table 2.

gizzard. The weight of ceca was not affected by either protein or cellulose levels. No interaction between cellulose and protein levels was found in most parts of the digestive tract except for small intestine and rectum. In these two organs the effect of protein level was more pronounced when the high cellulose diet was given. Younoszai et al. (1978) reported that in rats the dietary fiber enhanced the growth of small intestine and more remarkably the growth of colon, but did not affect the growth of stomach and cecum. They further suggested that the type of dietary protein did not influence the growth of stomach, small intestine, cecum and colon.

The ratio of weight to length in the digestive tract seemed to show the relative thickness of the tract. The weight/length ratio was always higher in the HP chicks than in the LP chicks irrespective of the cellulose levels, whereas no difference was observed between the low and high celluloses levels. The values of the LP chicks were shown to be almost the same as those of the 1-week-old chicks. This means that the high protein diet makes the digestive tract thicker, but the cellulose level does not show such an effect. This result was disagreeable with the result of Hegde et al. (1978), who reported that the muscular layers of small intestine was thicker when the chicks were fed a diet supplemented with fiber.

In pancreas, no effect of either the cellulose level or the protein level on the relative weight was found, although the relative length was increased by the low protein level and decreased by the low cellulose level. The relative weight of heart and liver was higher in the LC-LP chicks than the other groups, and it means that the effect of the cellulose level was shown only when the low protein diet was given. Spleen did not respond by the cellulose or the protein level.

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