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Effects of Dietary Cellulose on Liver Lipid Accumulation in Laying Japanese Quails

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Summary

Effects of feeding of cellulose on liver lipid content were investigated with 77-day old laying Japanese quails received fiber-free purified diet. They were fed *ad libitum* or force-fed the diet at the energy level of 130 per cent that of *ad libitum* feeding for 20 days. Abdominal fat deposition was markedly increased by the feeding of cellulose in the force-fed quails. Slight decrease of liver lipid content was induced by feeding of cellulose in the quails fed *ad libitum*. Feeding of cellulose induced a significant depression of liver lipid content in the quails force-fed excess food and it depressed the liver lipid accumulation to one-half that of the quails fed a fiber-free basal diet. It is suggested that the feeding of cellulose is effective in preventing the liver lipid accumulation in force-fed quails and dietary crude fiber has some influence on lipid metabolism in chicks.

The fatty liver was first described by Courch (1) in 1956 and was characterized by an excess of abdominal fat, fatty livers, capillary hemorrhages and hematomas in the liver. In 1972, a term, Fatty Liver Hemorrhagic Syndrome (FLHS) was suggested by Wolford and Polin (2) in their study on the relationship of fat accumulation and hemorrhages in the livers of laying hens. Among several factors affecting liver fat content in chicks (3), it has been reported that over-intake of food (energy) may be one cause of fatty livers in commercial laying flocks (1, 4). Wolford and Polin (4, 5) had produced FLHS in laying hens under laboratory condition through force-feeding of excess amount of food. In our previous report (6), it has been confirmed that liver lipid accumulation was greatly accelerated in laying Japanese quails when excess amount of food was force-fed.

It has been reported that dietary fiber may have protective effects against certain diseases of humans (7–9), and atherosclerosis in chicks (10–12) induced by increased serum cholesterol concentration. Recently, Akiba and Matsumoto (13) have investigated the nutritional effects of dietary fibers on lipid metabolism in growing chicks and they found that dietary fibers such as cellulose, pectin and mannan, depressed the liver lipid accumulation. The objective of the experiment reported herein is to confirm the effect of dietary cellulose on lipid metabolism, especially on liver lipid accumulation, in laying Japanese quails fed an excessive diet by force-feeding.

Materials and Methods

Seventy-seven-day old laying Japanese quails (average body weight 110 g) were housed individually in wire cages under controlled light and temperature (25°C) and fed fiber-free purified basal diet (Table 1). Calculated metabolizable energy content of the basal diet was 3.61 kcal/g. One group of the quails was fed *ad libitum* and the other was force-fed 130 per cent level of *ad libitum* feeding. Cellulose (filter paper, powdered 40 mesh) was added to the basal diet at the level of 5 per cent and the intake of basal diet was controlled to be identical between chicks fed fiber-free and cellulose-supplemented diet. Metabolizable energy of cellulose was calculated to be zero, since it has been confirmed that purified cellulose is not digestible in chicks (14). Force-feeding was performed in the same way as our previous report (6).

After the last feeding, a 6 ml of heparinized blood was taken *via* heart puncture from each chick and the chicks were sacrificed. Liver and abdominal fat were immediately withdrawn to be weighed and stored at –20°C until analysis. Determination of liver lipid content, liver moisture content and plasma concentration of glucose, non-esterified fatty acids and β-lipoprotein were described in our previous paper (6).

TABLE 1. *Composition of basal diet*

Ingredient	%
Corn starch	44.6
Sucrose	5.9
Glucose	4.0
Soybean oil	8.6
Casein	24.3
$CaCO_3$	4.3
$Ca_3(PO_4)_2$	4.0
K_2HPO_4	0.4
DL-methionine	0.3
NaCl	0.4
Vitamin mixture	1.2
Trace mineral mixture	2.0

Composition of vitamin mxiture (per 100 g):
vitamin A, 71000IU; vitamin D, 6000IU; α-tocopherol, 300IU; vitamin K_3, 15.9 mg; thiamine-chloride, 84 mg; riboflavin, 165 mg; Ca-panthothenate, 305 mg; nicotinic acid, 870 mg; pyridoxine-chloride, 243 mg; folic acid, 165 mg; vitamin B_{12}, 0.3 mg: inositol, 6.0 mg: biotin, 3.0 mg: ascorbic acid, 2000 mg; and choline-chloride, 25000 mg.
Composition of trace mineral mixture: $MnSO_4.H_2O$, 0.9%; KI, 0.004%; $ZnSO_4$, 0.54%; $FeSO_47H_2O$, 0.50%; $CuSO_4$, 0.025%; MnO_3, 0.0025%; Na_2SeO_3, 0.022%; $CoCl_26H_2O$, 0.02%; and $MgSO_4$, 12.5%.

Results

Calculated metabolizable energy (ME) intake and body weight gain are presented in Table 2. Body weight gain was shown to decrease slightly by addition of cellulose to the basal diet but there was no statistical significance. Total egg production for 20 days was significantly increased by cellulose feeding in the force-fed quails. Feeding of cellulose significantly increased abdominal fat weight in force-fed quails.

Liver weight and liver composition are given in Table 3. Liver weight was not reduced by cellulose feeding in the quails fed *ad libitum*. In the force-fed quails, liver weight and liver weight per 100 g body weight were significantly reduced by cellulose feeding. Liver moisture content and NFDM content were significantly elevated and liver lipid content was significantly depressed by cellulose feeding in the force-fed quails. A decreasing trend in liver lipid content was demonstrated

TABLE 2. *Effects of Dietary Cellulose on Food Intake, Body Weight Gain, Egg Production and Abdominal Fat Weight*

Treatment		Number of chicks	Feed intake (g/day)	Calculated ME intake (kcal/day)	Body weight gain (g/day)	Egg production (g/20 days)	Abdominal fat weight (g/100g bw)
Feeding	Cellulose (%)						
Ad libitum	0	15	13.9±1.4[2)]	50.4±5.2	0.3±0.5^{a}	80.4±28.4^{a}	0.45±0.30^{a}
Ad libitum	5	15	15.3±1.3	52.9±4.3	0.1±0.3^{a}	90.6±29.8^{a}	0.58±0.33^{a}
Force-fed[1)]	0	9	19.1±0.3	69.3±1.3	2.2±0.7^{b}	83.8±22.6^{a}	1.94±0.94^{b}
Force-fed[1)]	5	10	20.0±0.9	68.8±3.0	1.5±0.4^{b}	109.9±15.7^{b}	3.35±0.59^{c}

1) Excessive food (approximately 130% level of the group fed *ad libitum*) was force-fed 3 times per day.
2) Standard deviation of the mean.
a,b,c Means within same column not sharing a common superscript are significantly different ($P < 0.05$).

TABLE 3. *Effects of Dietary Cellulose on Liver Weight and Liver Composition*

Treatment		Liver weight		Liver composition (%)			Liver lipid
Feeding	Cellulose (%)	(g)	(g/100g bw.)	Moisture	Lipid	NFDM[1)]	(g)
Ad libitum	0	4.02±0.71^{a}	3.66±0.48^{a}	63.4±6.5^{a}	16.2±8.1^{a}	20.4±4.0^{a}	0.66±0.39^{a} (100)[2)]
Ad libitum	5	4.22±0.81^{a}	3.63±0.60^{a}	64.8±4.9^{a}	13.5±6.1^{a}	21.7±3.3^{a}	0.57±0.35^{a} (86)
Force-fed	0	8.36±1.43^{b}	5.90±0.90^{b}	51.8±6.0^{b}	30.5±8.6^{b}	17.7±2.2^{b}	2.53±1.22^{b} (100)
Force-fed	5	6.55±1.43^{c}	4.67±0.90^{c}	59.9±7.8^{ab}	19.2±10.3^{a}	20.9±3.3^{a}	1.37±1.06^{a} (52)

1) Non-fat dry matter.
2) Values in parenthesis indicate % of the chicks fed without cellulose.
a, b, c Means within same column not sharing a common superscript are significantly different ($P < 0.05$).

TABLE 4. *Effects of Dietary Cellulose on Plasma Concentration of Glucose, NEFA and β-Lipoprotein*

Treatment		Plasma glucose (mg/100 ml)	Plasma NEFA[1)] (μEq/100 ml)	Plasma β-lipoprotein (mg/100 ml)
Feeding	Cellulose (%)			
Ad libitum	0	272±21[a]	61±13[a]	353± 95[a]
Ad libitum	5	264±18[a]	73±12[a]	423±120[a]
Force-fed	0	282±21[a]	99±17[b]	546±100[b]
Force-fed	5	290±19[a]	151±30[c]	697±152[c]

1) Non-esterified fatty acid.
a, b, c Means within same column not sharing a common superscript are significantly different ($P < 0.05$).

by the feeding of cellulose in comparison with liver lipid content in the quails fed basal diet *ad libitum.* In force-fed quails, liver lipid content was significantly depressed to approximately two-thrids that of the basal group by the feeding of cellulose. A most marked change was observed in the amount of lipid in liver of chicks force-fed the cellulose-added diet which was significantly decreased to approximately one-half that of the basal group.

No marked changes were observed in plasma glucose level as shown in Table 4. Plasma concentration of NEFA and β-lipoprotein were significantly increased by cellulose feeding in force-fed quails.

Discussion

It has already been confirmed that crude fiber in the diet has growth-promoting effects in poultry. Davis and Briggs (15) observed that the addition of 5 to 15 per cent of cellulose to a purified fiber-free diet resulted in a significant increase in growth. Similar results were reported by Saito *et al.* (16). The abdominal fat weight increased in cellulose-fed quails may indicate that carcass fat content was increased by cellulose feeding, since it has been reported that a high significant correlation was obtained between abdominal and carcass fat content in laying hens (17). The above results are apparently different from the well-known effect of crude fiber which prevents carcass fat deposition (18). The reason for this discrepancy is not solved in this experiment, but it may be attributable to the difference in feeding patterns (force-feeding and conventional feeding).

Liver lipid content was decreased, though not statistically significantly, by cellulose feeding in the quails fed *ad libitum,* which is in agreement with our previous paper (13) that liver lipid content was depressed by the feeding of cellulose for 32 days in growing chicks. Furthermore, it has been clearly demonstrated in the present experiment that liver lipid accumulation was markedly accelerated by the feeding of fiber-free basal diet and was significantly prevented by the feeding of cellulose. Several reports have dealt with factors affecting liver lipid content in fatty liver syndrome. It has been considered that hereditary characteristics, environmental condition, physiological condition and nutrition affect liver lipid accumulation. Garlich (19) reported that there were differences in liver lipid attributable to variety of laying hens. In environmental conditions, high temperature (20, 21), housing in cages (22) and exercise (23) has been shown to affect liver lipid content. Sunde (24) reported that laying hens had higher liver lipid content than that of non-layers and that administration of estrogen induced liver lipid accumulation. Administration of thyroid powder has been shown to reduce liver lipid in chicks (25). Jensen *et al.* (26) have suggested that geographical conditions and mineral content in tap water affect liver lipid in laying hens.

Caloric intake has been considered to be one of the most effective factors among various factors inducing liver lipid accumulation (3, 5, 27), though nutritional factors such as dietary carbohydrate source (21, 28–30), dietary lipid source (31), protein content in food (32), amino acids (20, 33), vitamins (22, 33, 35) and minerals (36) have influence on liver lipid accumulation in chicks. Furthermore, Hamilton and Garlich (37) reported that aflatoxin caused an increase in fat content of livers. However, we have not obtained any data within the limit of the publications which we searched that dietary crude fiber contributed to preventing liver lipid accumulation in chicks. In the present study, there is no reason to consider that nutritional factors other than addition of cellulose have contributed to prevent liver lipid accumulation since lipotropic factors such as methionine, vitamins and minerals, were administered excessively to the quails. Therefore, it becomes clear that the feeding of cellulose is effective in preventing the liver lipid accumulation in force-fed quails. It is evident from changes of plasma concentration of NEFA and β-lipoprotein that cellulose affects on lipid metabolism in quails.

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