Effects of Dietary Gum Phospholipid on Lipid Metabolism in Broiler Chicks

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ABSTRACT : This experiment was to determine the usefulness of gum safflower phospholipid as a feed ingredient. Forty female broiler chicks were divided into four groups and fed experimental diets containing following fats and oils; beef tallow (Tallow), the blend of safflower oil and palm oil (SP-oil), gum rapeseed phospholipid (Rap-PL), or gum safflower phospholipid (Saf-PL) for 21days. There were no differences in growth performances among the treatments. Abdominal fat weight tended to be reduced in the chicks fed phospholipids. The activity of hepatic acetyl-CoA carboxylase was significantly reduced in the Rap-PL and Saf-PL as compared to that of Tallow. Feeding dietary phospholipids resulted in a slight reduction in total fat and triglyceride contents in the breast and thigh muscles. In addition, total fat and triglyceride contents in the thigh muscle were significantly decreased by dietary Saf-PL as compared to those of Tallow. These results suggested that dietary gum phospholipids, either from rapeseed or safflower, had desirable effects of lowing abdominal and muscle fats, and could be used as a feed ingredient for broiler diets. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 506-510*)

Key Words : Gum Safflower Phospholipid, Gum Rapeseed Phospholipid, Abdominal Fat, Acetyl-CoA Carboxylase, Triglyceride, Thigh Muscle, Broiler Chicks

INTRODUCTION

Dietary phospholipids were reported to effectively lower serum cholesterol levels in rats (Clark et al., 1981; Iwata et al., 1991; Iwata et al., 1992; Jimenes et al., 1990; O'Mullane and Hawthorne, 1982). Hypocholesterolemic effects of the dietary phospholipid may be attributed to decreased cholesterol secretion from the liver, or to increased uptake of high density lipoprotein into the liver (Murata et al., 1982). In a previous study, we found that feeding safflower phospholipid (either gum or purified type) to laying hens significantly reduced liver total lipid and serum cholesterol levels, and suggested that crude safflower phospholipid could be used as a feed ingredient for layer rations (An et al., 1997). Recently, the increased fat accumulation in modern broiler chickens has become a major concern for producers as well as consumers. Moreover, the abdominal fat is a wasteful byproduct to the poultry processor and cause problems in waste management of the plant. Dietary phospholipids may be a valuable ingredient to reduce abdominal fat pads in broiler chicks.

Phospholipids, mainly soybean lecithin, are widely utilized not only as hypocholesterolemic agents but also as additives in the food industry or for nonfood applications (Van Nieuwenhuyzen, 1981). Gum phospholipid, which is a by-product of edible oil extraction, contains about 50% neutral lipid. However, it is not widely used at present. The objective of this study was to evaluate the usefulness of gum phospholipids as a feed ingredient for broilers.

MATERIALS AND METHODS

Day-old forty female broiler chicks (Chunky strain) were weighed and divided into 4 groups. The broilers were raised on the floor in a windowless house under continuous lighting and room temperature of 32℃ and fed the commercial diet for 3 weeks. At 21 days of age, the birds were divided into four groups of ten birds each, and fed experimental diets containing following fats and oils; beef tallow (Tallow), the blend of safflower oil and palm oil (SP-oil), gum rapeseed phospholipid (Rap-PL), or gum safflower phospholipid (Saf-PL). The composition of experimental diets is presented in table 1. SP-oil, safflower oil : palm oil (8:2, vol/vol), contains comparable amounts of linoleic acid to that of safflower phospholipid. The phospholipid fractions and fatty acid composition of test fats and oils are given in table 2. Feed and water were provided *ad libitum*. The birds were weighed individually on a weekly basis, and feed consumption was recorded daily.

At 42 days of age, six chicks from each treatment were killed by decapitation, and each tissue (abdominal fat, liver, and breast and thigh muscles) was immediately removed. An aliquot of liver was homogenized in 0.25 M sucrose containing 1 mM EDTA-2Na, and the liver homogenates were prepared according to the method of Utter and Keech (1963).

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Table 1. Composition of experimental diets[1]

	Tallow	Sp-oil	Rap-PL	Saf-PL
Ingredients:				
Corn and fish meal	610	602	641	639
Soybean meal	202	220	134	140
Beef tallow	52			
Safflower oil and palm oil (8:2)		52		
Gum rapeseed phospholipid			52	
Gum safflower phospholipid				52
Soyprotein	50	41	83	80
Sucrose	4		17	16
Calcium phosphate, dibasic	45	47	39	39
Calcium carbonate	23	24	20	20
Sodium chloride	6	6	6	6
Mineral mixture[2]	0.5	0.5	0.5	0.5
Vitamin mixture[3]	1	1	1	1
Choline chloride	1.5	1.5	1.5	1.5
DL-methionine	2.5	2.5	2.5	2.5
L-arginine, monohydrochloride	1.5	1.5	1.5	1.5
L-lysine, monohydrochloride	1	1	1	1
Total	1,000	1,000	1,000	1,000
Calculated values:				
ME (MJ/kg)	13.3	13.3	13.2	13.2
CP (%)	19.9	19.9	19.9	19.9
Ether extract (%)	7.7	7.7	7.8	7.8
Crude fiber (%)	2.3	2.4	2.0	2.0
Calcium (%)	2.3	2.4	2.0	2.0
Available phosphorus (%)	0.89	0.93	0.77	0.77
Linoleic acid (%)	1.4	4.4	2.9	4.8

[1] Abbreviation used: SP-oil, safflower oil and palm oil (8:2); Rap-PL, gum rapeseed phospholipid; Saf-PL, gum safflower phospholipid.

[2] Supplied mg/kg of diet: maganese, 30; copper, 5; iodine, 1; zinc, 30; iron, 25; cobalt, 0.2.

[3] Supplied mg/kg of diet: retinol palmitate, 14.44; cholecalciferol, 0.02; tocopherol, 20; menadione, 3; thiamin hydrochloride, 4; riboflavin, 5; calcium pantothenate, 10; niacin, 12; pyridoxine hydrochloride, 4; biotin, 0.4; folic acid, 1; cyanocobalamin, 0.01; lactose, 926.

The liver homogenates were centrifuged at 6,000 *g* at 4℃ for 10 min and their supernatant fractions were recentrifuged at 105,000 *g* at 4℃ for 60 min. The resulting supernatants (cytosolic fractions) were used for assaying lipogenic enzymes. Acetyl-CoA carboxylase (EC 6.4.1.2) activity was assayed by the $H^{14}CO_3^-$ fixation method (Qureshi et al., 1980). Fatty acid synthetase activity was assayed by the [^{14}C]CoA incorporation method (Hsu et al., 1965). The protein content of the solutions was determined by the method of Lowry et al. (1951), using bovine serum albumin as a standard. Enzyme activity was expressed as nanomoles of substrate converted to product per min per mg of protein at 37℃.

The total lipids of the liver, serum and muscles were extracted by Folch et al. (1957), and then separated to various lipid fractions by thin layer chromatography on silica gel chromatorod. Each lipid fraction was quantified by IATRO SCAN (TH-10 TLC/FID analyzer, Iatron Ltd.).

The contents of moisture, crude protein and ether extract were determined by the method of the AOAC (1990).

All data were statistically analyzed using ANOVA, and significant differences among obtained means were determined using Duncan's multiple range test at the 5% probability level (Duncan, 1955).

RESULTS AND DISCUSSION

Growth performances were presented in table 3. Body weight gain and feed consumption tended to be higher in the chicks fed SP-oil diet. However, the differences were not significant statistically. Feed conversion ratio appeared to be improved in Rap-PL as compared to those of other diet groups. Relative liver weight in phospholipid diet groups were higher than that in the others, among which Rap-PL group

Table 2. Phospholipid fractions and fatty acid composition of dietary fats in experimental diets[1]

	Tallow	Sp-oil	Rap-PL	Saf-PL
Phospholipid fractions (g/100g)				
Phosphatidylcholine			16.5	12.2
Phosphatidylethanolamine			7.8	8.3
Phosphatidylinositol			12.2	16.2
Phosphatidic acid			9.2	5.0
Lysophosphatidylcholine			10.7	2.7
Others			6.0	11.8
Neutral lipid	99.0	99.3	38.8	44.7
Fatty acid composition (g/100g)				
C14:0	3.0	0.3		0.1
C16:0	26.5	12.8	9.1	14.9
C18:0	19.7	2.9	1.7	4.3
C18:1 ω9	47.6	21.1	48.7	10.7
C18:2 ω6	3.2	61.8	32.4	68.3
C18:3 ω3		0.3	7.8	0.2
C20:0		0.3	0.4	0.6
C20:1 ω9		0.2	0.9	0.3
C22:0		0.3	0.3	0.5

[1] Abbreviation used: SP-oil, safflower oil and palm oil (8:2); Rap-PL, gum rapeseed phospholipid; Saf-PL, gum safflower phospholipid.

Table 3. Effects of dietary phospholipids on performance in female broilers[1,2]

	Tallow	Sp-oil	Rap-PL	Saf-PL	Pooled SEM
Final body weight (g)	2,002	2,095	2,004	2,009	13
Daily feed consumption (g)	137	148	135	140	
Feed/gain ratio	1.94	1.94	1.90	1.95	
Liver weight (g/100 g BW)	1.84^{c}	1.95^{bc}	2.10^{a}	2.02^{ab}	0.03
Abdominal fat weight (g/100 g BW)	2.46^{a}	2.36^{a}	1.81^{b}	2.24^{ab}	0.09
Right breast meat weight (g/100 g BW)	6.26	6.03	6.57	6.33	0.08
Right thigh meat weight (g/100 g BW)	6.99^{ab}	7.04^{ab}	7.36^{a}	6.77^{b}	0.07

[a,b,c] Values with different superscripts within a row differ significantly ($p<0.05$).

[1] Abbreviation used: SP-oil, safflower oil and palm oil (8:2); Rap-PL, gum rapeseed phospholipid; Saf-PL, gum safflower phospholipid.

[2] Values are presented as means (n=6, each group).

showed the highest value. Relative abdominal fat weight tended to be lower in the chicks fed the phospholipids. Especially, abdominal fat weight in Rap-PL diet group was significantly reduced as compared to that of Tallow group.

Table 4 shows the liver and plasma contents of various lipid fractions and the activities of hepatic lipogenesis related enzymes. The activity of hepatic acetyl-CoA carboxylase (ACC) was reduced in the Rap-PL and Saf-PL groups as compared to that of the Tallow group. No significant differences in the fatty acid synthetase were observed among treatments. Ide and Murata (1994), Ide et al. (1992a, b, 1994) demonstrated that diets containing a soybean phospholipid or egg yolk phospholipid compared to those containing soybean oil or fat blend simulating fatty acid composition of soybean phospholipid profoundly reduces various parameters for triglyceride synthesis such as the activities of enzymes in fatty acid synthesis in rat liver homogenate and the rate of incorporation of [1-^{14}C]acetate in fatty acid in isolated hepatocytes. In this study, liver triglyceride content was not changed by phospholipids feeding regardless of a decrease in hepatic ACC activity.

The present study used gum phospholipids containing high phosphatidylethanolamine (PE). It has been demonstrated that ethanolamine moiety of dietary PE is hydrolyzed in the small intestine and then absorbed (Ikeda et al., 1987). Ethanolamine acts as a precusor of PE in cells. The first step of this pathway involves phosphorylation by a kinase that has a broad specificity (i.e., it phosphorylates ethanolamine as well as choline) (Porter and Kent, 1990). Porter and Kent (1990) showed that ethanolamine/choline kinase is the

Table 4. Effects of dietary phospholipids on the activities of lipogenesis related enzymes and the contents of various lipid fractions in the liver and serum in female broilers[1,2]

	Tallow	Sp-oil	Rap-PL	Saf-PL	Pooled SEM
Lipogenesis related enzyme (nmol/min/mg protein)					
Acetyl-CoA carboxylase	2.51[a]	2.20[ab]	1.44[b]	1.82[b]	0.20
Fatty acid synthetase	1.82	1.77	1.73	1.79	0.04
Liver (mg/g)					
Triglyceride	9.97	21.93	16.94	21.21	1.89
Phospholipid	36.30[a]	31.73[b]	31.29[b]	31.12[b]	0.71
Cholesterol	3.46	3.42	3.51	3.30	0.04
Serum (mg/100ml)					
Triglyceride	23.2[ab]	15.8[b]	27.6[a]	19.4[b]	1.5
Phospholipid	372	403	459	381	14
Cholesterol	112	113	109	101	1

[a,b,c] Values with different superscripts within a row differ significantly ($p<0.05$).

[1] Abbreviation used: SP-oil, safflower oil and palm oil (8:2); Rap-PL, gum rapeseed phospholipid; Saf-PL, gum safflower phospholipid.

[2] Values are presented as means (n=6, each group).

Table 5. Effects of dietary phospholipids on the contents of moisture, crude protein, ether extract and various lipid fractions in the breast and thigh meats in female broilers[1,2]

	Tallow	Sp-oil	Rap-PL	Saf-PL	Pooled SEM
Breast meat					
Moisture (g/100g)	74.5	74.6	74.8	74.6	0.1
Crude protein (g/100g)	21.7	22.1	21.8	21.9	0.1
Ether extract (g/100g)	0.5	0.5	0.5	0.4	0.0
Triglyceride (mg/g)	1.73	1.97	1.29	1.17	0.14
Phospholipid (mg/g)	2.25	2.72	2.61	2.52	0.11
Cholesterol (mg/g)	0.64[b]	0.68[ab]	0.66[ab]	0.70[a]	0.01
Thigh meat					
Moisture (g/100g)	74.5	74.3	74.7	74.8	0.1
Crude protein (g/100g)	18.5	18.1	17.8	18.5	0.1
Ether extract (g/100g)	4.7[a]	4.7[a]	4.2[ab]	3.7[b]	0.1
Triglyceride (mg/g)	30.90[a]	30.39[a]	27.90[a]	21.18[b]	1.05
Phospholipid (mg/g)	12.50[ab]	11.41[b]	12.42[ab]	13.65[a]	0.33
Cholesterol (mg/g)	0.82[b]	0.99[a]	0.98[a]	0.94[a]	0.02

[a,b,c] Values with different superscripts within a row differ significantly ($p<0.05$).

[1] Abbreviation used: SP-oil, safflower oil and palm oil (8:2); Rap-PL, gum rapeseed phospholipid; Saf-PL, gum safflower phospholipid.

[2] Values are presented as means (n=6, each group).

same enzyme, and choline and ethanolamine were mutually competitive inhibitor. Thus phosphorylation of choline may be diminished in the presence of high ethanolamine concentration and less phosphorylation is produced, leading to a relatively high synthesis of PE *versus* phosphatidylcholine (PC). It is possible that lower availability of newly synthesized PC would lead to slower synthesis of very low density lipoprotein (VLDL) (Yao and Vance, 1989). Liver triglyceride content tended to be higher in chicks fed the gum phospholipids as compared with those fed tallow, regardless of a decline of hepatic ACC activity. In addition, chicks fed the gum phospholipids had lower liver phospholipid levels as compared with those fed the tallow. Furthermore, the gum safflower phospholipid contained less proportion of PC than the gum rapeseed phospholipid, and liver triglyceride content of Saf-PL group tended to be lower and plasma triglyceride concentration was significantly higher than that of the Rap-PL diet group. Hence a PE/PC ratio in dietary fats might be responsible for the VLDL secretion from the liver in broiler chicks.

The contents of moisture, crude protein, ether extract and various lipid fractions in breast and thigh muscles are shown in table 5. Contents of moisture and crude protein in breast and thigh meats were not

affected by dietary treatments. Feeding of dietary phospholipids resulted in a slight reduction in ether extract and triglyceride contents in the breast and thigh meats. In addition, there were significant decreases in ether extract and triglyceride contents in the thigh by feeding Saf-PL. Muscle triglyceride contents decreased in the Saf-PL group, although plasma triglyceride levels were not affected by the dietary treatment. This may be due to the decrease in the activity of lipoprotein lipase by which hydrolysis is a prerequisite for the uptake of plasma lipoprotein triglyceride into tissues. Phospholipid contents in the thigh was greatest in chicks fed Saf-PL diet. Cholesterol contents in the breast and thigh were least for chicks fed Tallow diet. Therefore, it has been suggested that the decrement in the proportion of crude fat in the meat was attributed to the appreciably more reduction of triglyceride than the amount of phospholipid and cholesterol increased.

This study demonstrated that hepatic ACC activity was declined by dietary gum phospholipid, and gum rapeseed phospholipid feeding resulted in the decrease in abdominal fat weights in broiler chicks. In addition, feeding of gum safflower phospholipid resulted in a decrease in fat contents of poultry carcasses. These findings indicated that the gum rapeseed and/or safflower phospholipids, a by-product of edible oil extraction, could be used as a feed ingredient for broiler diet.

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