Lipid Compositional Changes in Calves Fed Excess Iodine

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ABSTRACT

Calves were fed milk replacer containing .57, 10, or 200 ppm iodine (from ethylenediaminedihydriodide) to determine the effects of excess dietary iodine on composition of lipids in blood plasma, liver, and heart. High iodine intakes had no effect on plasma total lipids or lipid classes, but caused lipid class concentration changes in liver and heart. Both 10 and 200 ppm iodine increased concentration of liver phosphatidylethanolamine and heart phosphatidylcholine, cholesterol, and total lipids, and the 200 ppm intake also increased concentration of liver phosphatidylcholine, total lipids, and heart phosphatidylethanolamine. Both iodine treatments tended to increase all the other minor lipid classes in liver and heart as well. Both 10 and 200 ppm iodine treatments increased some of the n–3 polyunsaturated fatty acids in the major phospholipids of plasma, liver, and heart. For the preruminant calf, liver and heart may be more useful than blood plasma for indicating excess iodine effects on lipid metabolism.
(**Key words**: iodine, lipids, calves)

INTRODUCTION

Dietary concentration of iodine can have a marked influence on lipid metabolism in animals (1, 6, 12). In humans, plasma lipid changes accompany both hypothyroid and hyperthyroid conditions and plasma cholesterol (C) is commonly used as an index of thyroid disorder (12, 17). Lascelles and Setchell (12) found that hypothyroidism, produced in pregnant ewes by feeding thiouracil, increased plasma C, and phospholipids. Similar blood lipid changes for hypothyroidism also have been reported for dogs (4) and rhesus monkeys (5). In contrast, lowered plasma C concentrations have been found in dairy cows with hyperthyroidism (6, 13) or in cows provided high iodide intakes in which symptoms of iodine toxicity developed but not hyperthyroidism (6).

No information appears to be available about the preruminant calf on the effects of high dietary iodine on lipid metabolism. To study the effect, an ongoing experiment (8) on iodine tolerance was used. Three dietary iodine groups were selected: control milk replacer, .57 ppm iodine (in DM, with no added iodine), 10 ppm iodine (high), and 200 ppm iodine (very high), obtained by adding ethylenediaminedihydriodide (EDDI) to the control diet. The objective was to determine if excess dietary iodine altered lipid metabolism in the preruminant calf, as indicated by lipid compositional changes in blood plasma, liver, and heart.

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MATERIALS AND METHODS

Blood plasma, liver, and heart samples were obtained for lipid analyses from calves killed at the end of the iodine tolerance investigation (8). In that 6-wk study, 3-d-old calves were fed basal milk replacer containing (in DM) either .57 (control), 10, 50, 100, or 200 ppm iodine (EDDI). The basal diet, without added iodine, contained .57 ppm iodine; this was used as the control diet, although it was higher than the NRC (16) allowance of .25 ppm. Only the 200 ppm iodine intake reduced weight gains, DM intake, feed efficiency, and DM digestibility (8). At the 100 and 200 ppm iodine intakes, calves showed typical symptoms of iodine toxicity, i.e., nasal discharge, excessive tear and saliva formation, and coughing from tracheal congestion (8). Thyroxine concentrations in calf blood were not measured to indicate if excess iodine had produced hyperthyroidism. However, this was unlikely, since Hillman and Curtis

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(6) reported that cows given excess dietary iodine showed typical signs of chronic iodine toxicity without developing hyperthyroidism. For the present study, the blood plasma and tissue samples were taken from three calves (age 45 d), each from the control and the 10 and 200 ppm treatments. The composition of the milk replacer (DM basis) was: sweet whey (8.8%), skim milk powder (69.0%), tallow (16.6%), coconut oil (2.0%), emulsifiers (1.0%), $MgSO_4 \cdot 7H_2O$ (1.0%), $CaCl_2$ (.7%); the diet was fortified (.9%) with all known required trace elements and vitamins (8). Iodine contents of blood plasma (μg/ml) and tissues (ppm, fresh tissue) for the control, 10 ppm, and 200 ppm groups were: plasma, .14, .32, 4.0; liver, .17, .32, 1.7; and heart, .11, .26, .93.

For lipid analyses, tissue samples were weighed, pulverized at dry ice temperature, and then extracted for lipids with chloroform and methanol (2:1) according to Kramer and Hulan (11). The same extraction procedure was used for blood plasma. The lipid classes were isolated and quantified (9) by three-directional TLC, with methylheptadecanoate internal standard, using silica gel H plates (Analtech Inc., Newark, DE), converted to their methyl esters (11) and analyzed by GLC using fused silica capillary columns (10). We used a randomized, one-way design with five treatments and three calves per treatment. Data were subjected to ANOVA by the general linear models procedure of SAS (18). Treatment means were separated by Duncan's multiple range test using 5% probability.

RESULTS AND DISCUSSION

Total Lipids and Lipid Classes in Blood Plasma, Liver, and Heart

Elevation of dietary iodine from .57 ppm to 10 or 200 ppm (with EDDI) had no effect on concentrations of the major phospholipids, C, cholesteryl esters (CE), triglycerides (TG), or total lipids in calf blood plasma (Table 1). Because calves in the 200 ppm lot showed typical symptoms of iodine toxicity, the development of this disorder apparently had no effect on plasma composition of the major lipid classes. Our plasma C data contrast with those obtained by Hillman and Curtis (6) for lactating dairy cows. They found that chronic iodine (EDDI) toxicity caused markedly reduced serum C, whereas here, the calf plasma C concentrations were unaffected. The reasons are not readily apparent but may have been related to differences in which ruminants and preruminants utilize acetate and glucose for cholesterogenesis (7) and differential effects of excess iodine on the processes.

Although not reflected by plasma lipid concentrations, excess dietary iodine did cause lipid class changes in calf liver and heart (Table 1). High iodine intake (10 ppm) increased liver phosphatidylethanolamine (PE) and heart phosphatidylcholine (PC), C, and total lipids. Very high iodine (200 ppm) also caused these changes and, in addition, increased liver PC and total lipids and heart PE. Virtually all of

TABLE 1. Major lipid classes in calf blood plasma, liver, and heart.[1]

Tissues and lipid classes[2]	Dietary iodine, ppm in DM .57	10	200	SE
Blood plasma				
PC	.79	.88	.74	.07
CE	.76	.81	.72	.06
C	.18	.21	.18	.03
SP	.14	.13	.13	.02
TG	.06	.08	.05	.02
Total lipids	2.1	2.2	1.9	.2
Liver				
PC	9.4^{b}	10.0^{ab}	10.8^{a}	.3
PE	4.3^{b}	5.0^{a}	5.1^{a}	.2
C	1.6	1.6	1.8	.1
SP	1.4	1.6	1.6	.2
TG	.85	.92	1.1	.1
CL	.66	.73	.82	.08
Total lipids	20.3^{b}	22.4^{ab}	23.5^{a}	.8
Heart				
PC	4.9^{b}	5.8^{a}	5.7^{a}	.2
PE	2.7^{b}	3.3^{ab}	3.7^{a}	.2
SP	1.1	1.3	1.3	.1
CL	1.0	1.2	1.4	.2
C	1.0^{b}	1.4^{a}	1.3^{a}	.1
TG	.92	1.0	1.2	.3
Total lipids	13.0^{b}	15.5^{a}	16.3^{a}	.7

^{a,b}Means on the same line (for each tissue) with different superscripts differ ($P<.05$).

[1]In milligrams per milliliter plasma or per gram fresh tissue. Means for 3 calves per dietary treatment.

[2]Lipid classes: CE = cholesteryl esters; C = unesterified cholesterol; PC = phosphatidylcholine; SP = sphingomyelin; PE = phosphatidylethanolamine; TG = triglyceride; CL = cardiolipin.

TABLE 2. Fatty acid composition of major lipids in blood plasma, liver, and heart.[1]

Tissue lipid[3] and iodine intake	Fatty acids[2]									
	16:0	18:0	18:1 n–9	18:2 n–6	20:4 n–6	22:4 n–6	18:3 n–3	20:5 n–3	22:5 n–3	22:6 n–3
Plasma PC										
.57 ppm	15.8	26.0	16.5	27.2	2.0	.22	.48	.10	.42[b]	.27[b]
10 ppm	15.3	27.8	15.8	28.7	2.3	.29	.54	.11	.54[a]	.32[b]
200 ppm	16.1	26.1	15.5	26.5	2.6	.32	.57	.15	.64[a]	.44[a]
SE	1.2	1.5	.7	1.4	.3	.04	.04	.03	.03	.03
Plasma CE										
.57 ppm	8.6	1.1	5.5	70.7	1.7	0	3.0	.14	0	0
10 ppm	7.6	.74	5.7	73.4	1.8	0	3.2	.16	0	0
200 ppm	8.3	.80	5.4	72.2	1.9	0	3.3	.22	0	0
SE	.7	.15	.3	2.3	.2		.2	.04		
Liver PC										
.57 ppm	16.4	28.0	16.2	19.0	6.2	.89	.70[b]	.35	1.7[b]	1.6[b]
10 ppm	16.8	30.2	15.0	19.5	5.6	.87	.69[b]	.32	1.8[b]	1.5[b]
200 ppm	16.3	27.3	15.3	19.9	6.5	.98	.93[a]	.43	2.6[a]	2.2[a]
SE	.6	1.9	1.0	.5	.4	.05	.05	.05	.2	.1
Liver PE										
.57 ppm	7.6	32.2	15.5	14.1	15.4	1.3	.51	.37[b]	2.3[b]	2.0[b]
10 ppm	7.3	33.9	14.1	14.2	16.1	1.4	.50	.39[b]	2.6[ab]	2.1[b]
200 ppm	7.5	31.8	14.6	14.5	16.0	1.5	.59	.52[a]	2.9[a]	2.8[a]
SE	.4	2.0	1.0	.4	.5	.2	.04	.03	.2	.2
Heart PC										
.57 ppm	30.5	9.0	16.3	29.8	4.2	.13[b]	.35[b]	.24	.34[b]	.08[b]
10 ppm	27.7	8.6	17.4	29.4	4.8	.28[a]	.50[a]	.32	.74[a]	.17[a]
200 ppm	29.8	9.1	15.3	30.8	5.2	.31[a]	.55[a]	.31	.68[a]	.19[a]
SE	2.2	.3	.9	.8	.5	.03	.03	.04	.05	.02
Heart PE										
.57 ppm	4.4	34.0	7.3	22.8	18.2	.45[b]	.35	.95	1.2[b]	.45[b]
10 ppm	3.5	32.4	7.9	23.3	18.5	.67[a]	.33	1.10	2.1[a]	.79[a]
200 ppm	3.8	33.7	6.6	23.7	18.7	.63[a]	.32	1.03	1.8[a]	.74[a]
SE	.4	1.6	.6	.7	.7	.04	.04	.07	.2	.06

[a,b]Means on the same row with different superscripts differ ($P<.05$).

[1]Averages for 3 calves per dietary treatment. Relative abundance of major fatty acids in weight percent.

[2]Number of carbon atoms:number of double bonds; n–x, where n is the chain length of the fatty acid, and x is the number of carbon atoms from the last double bond to the terminal methyl end.

[3]PC = phosphatidylcholine; CE = cholesteryl esters; PE = phosphatidylethanolamine.

the lipid class data for liver and heart showed a trend for an increase in concentration as the iodine intake was elevated. These tissue lipid changes were not the result of growth differences. Although average daily gain (ADG) was lower for calves receiving 200 ppm iodine, ADG for 10 ppm iodine was the same as for the controls (8). Excess dietary iodine may have increased PE [located in the inner layers of cell membranes (1, 2)] by enhancing endoplasmic reticular synthesis of PE (14), whereas PC [located primarily in outer cell membranes (1, 2)] presumably was increased by iodine promoting either PE conversion to PC (14) or of PC uptake from plasma lipoproteins (2, 15). The higher concentration of both PC and C in heart tissue as iodine intake was increased from .57 to 10 ppm reflected the tendency for a constant C to PC ratio in tissues (20).

The mechanisms of iodine toxicity in animals have not been clarified and additional research will be required to determine whether the phospholipid and C alterations found here were contributing to the toxicity or were a result of its development. A causative effect would be expected if the phospholipid changes appreciably altered the architecture of membrane lipids.

Fatty Acid Composition of the Major Lipids in Blood Plasma, Liver, and Heart

The 10 and 200 ppm iodine treatments did not change the concentration of fatty acids (Table 2) making up the major lipids in plasma, liver, and heart (i.e., 16:0,[2] 18:0, 18:1 n–9, 18:2 n–6, 20:4 n–6 fatty acids). However, for all lipids analyzed, except plasma CE, there were increases for some of the n–3 polyunsaturated fatty acids (PUFA) and occasionally for 22:4 n–6. Only the highest iodine treatment promoted the n–3 increases in liver PC and PE, whereas in heart PC and PE increases in the n–3 PUFA were caused by both of the high iodine intakes. Higher concentrations of 22:5 n–3, 22:4 n–6, and 22:6 n–3 could have resulted from enhanced C_{20}-elongase and $\Delta 4$-desaturase activities (19). However, calculation of precursor to product ratios for PUFA involved in the various metabolic reactions indicated that this did not occur (not shown). More likely, excess dietary iodine increased utilization of these fatty acids during phospholipid synthesis or during reacylation or transacylation reactions (2, 14). The increased concentrations of 22:5 n–3 and 22:6 n–3 in liver and heart might be implicated in altered prostanoid metabolism in those tissues as these fatty acids are known to competitively inhibit 2-series prostanoid production from arachidonic acid (3).

CONCLUSIONS

Feeding preruminant calves excess iodine in milk replacer, at concentrations 40 and 800 times the NRC allowance (.25 ppm, in DM) had no effect on lipid classes in blood plasma, but in liver and heart increased concentrations of the major phospholipids and some of their n–3 PUFA. For the preruminant calf, these lipid changes in liver and heart may be more useful than blood plasma lipid analyses for determining the effects of excess iodine intakes on lipid metabolism.

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[2]Number of carbon atoms:number of double bonds; n–x, where n is the chain length of the fatty acid, and x is the number of carbon atoms from the last double bond to the terminal methyl end.

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