Zeitschrift für
Ernährungswissenschaft Z Ernährungswiss 23:136–142 (1984)

The effect of dietary saturated fat versus polyunsaturated fat on serum cholesterol and phospholipid concentrations in rabbits with partial ileal bypass

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Summary

Rabbits were fed semipurified diets containing either corn oil or coconut fat. Dietary coconut fat significantly elevated serum total cholesterol and phospholipid concentrations. Rabbits with partial ileal bypass (PIB) had significantly lower serum cholesterol and phospholipid values, irrespective of whether the diet contained corn oil or coconut fat. The effect on serum lipids of the type of fat was similar in control and PIB animals. Since PIB rabbits are known to excrete extremely high amounts of steroids with the feces, we suggest that our data point to a lack of interaction of the type of dietary fat with the fecal excretion of steroids.

Zusammenfassung

In der vorliegenden Arbeit erhielten die Kaninchen eine halbgereinigte Diät, die entweder Maisöl oder Kokosöl als Fettträger hatte. Das Kokosöl in der Diät verursachte einen signifikant gestiegenen Cholesterin- und Phospholipidspiegel im Serum. Kaninchen mit einer teilweisen Dünndarmumlegung (PIB) zeigten signifikant erniedrigte Serumcholesterin- und Phospholipidkonzentrationen, unabhängig davon, ob die Diät Kokosöl oder Maisöl enthielt. Die Sorte des Nahrungsfettes hatte einen ähnlichen Effekt auf die Serumlipide bei Kontrolltieren sowie bei Tieren mit einer PIB. Da bekannt ist, daß Kaninchen mit einer PIB einen sehr hohen Gehalt an Steroiden mit dem Kot ausscheiden, vermuten wir, daß keine Wechselwirkung zwischen Art des Nahrungsfettes und der Steroidausscheidung besteht.

Introduction

It has been well established that the replacement of saturated fatty acids in the diet by polyunsaturated fatty acids lowers serum cholesterol concentrations in experimental animals and man (6, 10, 11, 12, 13, 17, 20). One of the underlying mechanisms most frequently proposed is that dietary

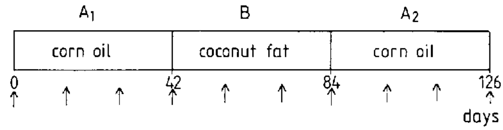

Fig. 1. Experimental design. Arrows indicate the days on which blood samples were taken.

polyunsaturated fats enhance the fecal excretion of acidic and neutral steroids, thereby giving rise to an increased conversion of cholesterol into fecal steroids (8, 10, 16, 17). Partial ileal bypass (PIB) is a surgical procedure occasionally used for the treatment of hypercholesterolemia (5, 19). The main effect of PIB, which involves bypass of the distal one-third of the small intestine, is the interruption of the enterohepatic cycle of bile acids, resulting in an enhanced fecal excretion of bile acids and thus a drain on the body cholesterol pool (5, 14). PIB has also been shown to increase the excretion of neutral steroids with the feces (5, 14). Since PIB represents a condition of extreme steroid drainage, it could be hypothesized that such treatment would cause nonresponsiveness to the serum-cholesterol lowering effect of dietary polyunsaturated fats. In the present study we have tested this hypothesis by feeding semipurified diets containing either saturated fat (coconut fat) or polyunsaturated fat (corn oil) to rabbits with or without PIB.

Materials and methods

Animals, experimental design and diets

In this experiment, female rabbits of the New Zealand White strain, aged about 11 months, were used. PIB was performed at the age of about 5 months. The animals

Table 1. Composition of the experimental diets.

Ingredient	(g/100 g) Corn oil diet	Coconut fat diet
Casein	21	21
Corn starch	17	17
Dextrose	21	21
Molasses	5	5
Corn oil	10	1
Coconut fat	–	9
Saw dust	18	18
Salts, minerals, vitamins[1])	8	8

[1]) This mixture consisted of (g/100 g diet): dicalcium phosphate, 2.9; sodium chloride, 0.6; magnesium carbonate, 0.3; magnesium oxide, 0.2; potassium bicarbonate, 1.8; vitamin premix, 1.2, and mineral premix, 1.0. The composition of the vitamin and mineral premixes have been described elsewhere (21). The diets were offered as pellets.

were kept individually in stainless steel cages (45 × 35 × 60 cm) with wire mesh bases constructed of galvanized steel in a room with controlled lighting (10 hours/day), constant temperature (18 °C) and humidity. Before the experimental period the animals were fed a commercial, pelleted rabbit diet (LK-01®, Hope Farms, Woerden, The Netherlands). According to the manufacturer, the diet consisted of (g/100 g): crude protein, 18.8; crude fat, 3.3; carbohydrates, 56.2; fiber, 14.8.

On day 0 of the experiment (after blood sampling) the animals were transferred to the semipurified diet containing corn oil for 42 days. Successively, the rabbits were fed the diet containing coconut fat for 42 days, and the corn-oil diet again for another 42 days. The design of the experiment is shown in figure 1. The A-B-A design was chosen in order to eliminate time and sequence effects. In the experiment 8 control and 4 PIB animals were used; during the course of the experiment two rabbits died. The composition of the experimental diets is given in table 1. Food and water were provided ad libitum.

Partial ileal bypass (PIB) surgery

Operations were performed under general anesthesia induced by an oxygen: nitrous oxygen: fluothane (1:1:0.01 by vol.) mixture. Thirty minutes before intubation the animals were sedated by the intramuscular administration of a mixture (10:0.2; w/w) of fluanison: fentanyl (Hypnorm®, Duphar B.V., Amsterdam, The Netherlands). A mid-line-laparotomy was performed and the entire small intestine was measured along the mesenteric border with a calibrated umbilical tape from the ligament of Treitz downwards to the ileocecal valve. The distal one-third of the small-bowel was by-passed, and the proximal two-third was anastomosed end-to-side to the cecum in one layer, using interrupted atraumatic polyglycolic acid suture (6-0 Dexon®, Cyanamid, London, GB). The closed end of the by-passed distal ileum was sutured to the anterior tenia of the cecum and mesenteric defects were closed. The laparotomy was subsequently closed in three layers, using atraumatic polyglycolic acid suture interrupted for the fascia and atraumatic catgut intracutaneously for the skin.

Blood sampling and lipid analyses

Blood samples in the fasting state were taken between 08.00 and 10.00 hours from a marginal ear vein into tubes without anticoagulant. In the serum total cholesterol was determined enzymatically using the kit (Monotest) supplied by Boehringer Mannheim GmbH, FRG. Serum phospholipids were determined enzymatically using the kit (Phospholipids B-Test Wako) supplied by Wako Pure Chemical Industries Ltd, Osaka, Japan.

Table 2. Body weight of the rabbits fed the experimental diets.

	Body weight (kg)	
	Control animals (n = 7)	PIB animals (n = 3)
Start period A_1	3.51 ± 0.17	3.27 ± 0.21
End period A_1	3.87 ± 0.21	3.53 ± 0.32
End period B	3.91 ± 0.19	3.70 ± 0.46
End period A_2	4.27 ± 0.28	4.15 ± 0.37

Results are expressed as means ± SE. For experimental design and explanation of the dietary periods, see figure 1.

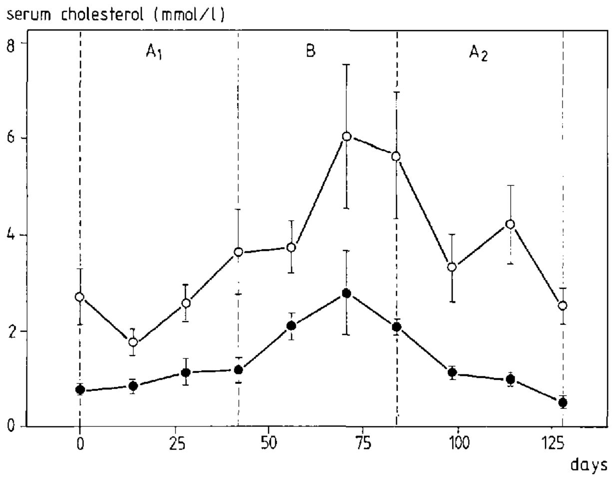

Fig. 2. Time course of the concentration of serum cholesterol in control (○, n = 7) and PIB rabbits (●, n = 3). Results are expressed as means ± SE. For experimental design and explanation of dietary periods, see figure 1.

Results

The initial body weights of the control and PIB rabbits were not significantly different (table 2). During the course of the experiment the rabbits were still growing, body-weight gain in the two groups being similar.

Figure 2 shows that during all stages of the experiment serum cholesterol values in the PIB rabbits were significantly lower than in the control rabbits. Transfer from the diet containing corn oil to the coconut-fat diet

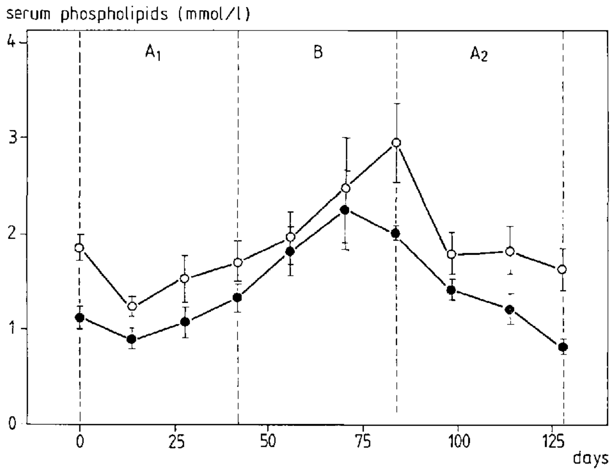

Fig. 3. Time course of the concentration of serum phospholipids in control (○, n = 7) and PIB rabbits (●, n = 3). Results are expressed as means ± SE. For experimental design and explanation of dietary periods, see figure 1.

caused an increase in serum cholesterol in both experimental groups. Switching back to the diet containing corn oil induced a rapid decline in serum cholesterol and values similar to those during the first dietary period were seen (fig. 2). Similar results were obtained earlier with rabbits (3).

The pattern of serum phospholipids closely resembled that observed for cholesterol. Concentrations of phospholipids in the serum of the PIB rabbits were lower than in the control animals during the entire experiment, but the difference did not reach statistical significance on all time intervals (fig. 3). The semipurified diet containing corn oil caused a rapid but transient decrease in serum phospholipids when compared with the initial value, which was determined in serum taken while on the commercial diet (fig. 3). Replacement of corn oil by coconut fat increased serum phospholipids in both control and PIB rabbits. In the third dietary period serum phospholipid concentrations declined again.

The observed effects on serum lipids by changes in the diet should be corrected for time-dependent drifts. Our switch-back design afforded such a correction. Table 3 shows the effects of the type of dietary fat on serum cholesterol and phospholipids after correction. Dietary coconut fat caused a significant increase in the concentrations of cholesterol and phospholipids in the serum when compared with corn oil. There was no statistically significant difference between control and PIB rabbits with regard to their cholesterolemic response to the nature of the dietary fat (table 3).

Figure 4 shows that in rabbits fed semipurified diets containing either corn oil or coconut fat the levels in the serum of total cholesterol and phospholipids are closely associated. Exactly the same relationship was found earlier in rabbits on diets differing in the protein component (2). A very strong correlation between serum cholesterol and phospholipids was also found in calves (1).

Discussion

The hypocholesterolemic action of dietary polyunsaturated fats when compared to saturated fats has been well established in experimental animals and man (10, 17). The present study confirms this. The mechan-

Table 3. Serum cholesterol and phospholipid responses to coconut fat versus corn oil after corrections for time and sequence effects.

	Serum lipid response (mmol/l)	
	Control animals (n = 7)	PIB animals (n = 3)
Serum cholesterol	2.13 ± 0.75	1.36 ± 0.22
Serum phospholipids	0.78 ± 0.24	0.92 ± 0.13

The serum lipid response was calculated per animal as (mean value in period B) – (½ times mean value in period A_1 + ½ times mean value in period A_2). Results are expressed as means ± SE. For experimental design, see figure 1.

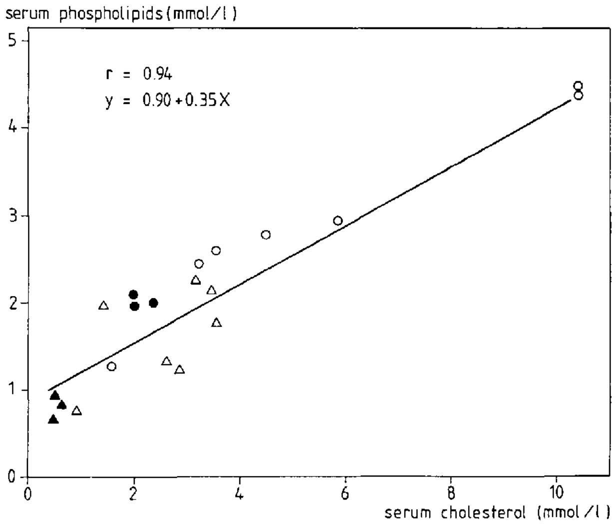

Fig. 4. Relationship between serum cholesterol and phospholipid concentrations in control (open symbols) and PIB rabbits (closed symbols) on semipurified diets containing either coconut fat (circles) or corn oil (triangles). Serum lipid values refer to the beginning (Day 84) and end (Day 128) of period A_2 (see fig. 1).

ism(s) by which polyunsaturated fatty acids lower serum cholesterol remains controversial (17). Several studies have pointed to enhanced excretion of steroids with the feces (8, 10, 16, 17) which would be in line with the observed increased turnover rate of serum cholesterol (15). Other studies failed to demonstrate an effect on fecal steroid excretion by the type of dietary fat in humans (7) and rabbits (4).

Exclusion of the distal section of the small intestine, where absorption of bile acids takes place (9), has been shown to drastically increase the fecal excretion of acidic steroids and also of neutral steroids by rabbits (5) and man (14). If polyunsaturated fats lower serum cholesterol through an enhanced excretion of steroids, one would anticipate that in rabbits with PIB, who have extremely high rates of fecal steroid excretion, the cholesterolemic effect of polyunsaturated fats versus saturated fats is smaller or even absent when compared with normal animals. We found that this was not the case. The effect of coconut fat versus corn oil was similar in control and PIB animals, and this was so for both serum cholesterol and phospholipid concentrations (table 3). Thus our data would substantiate the lack of effect of the type of dietary fat on fecal steroid excretion reported by various investigators (7). Possibly, the differential effect of saturated and polyunsaturated fats on serum cholesterol is related to redistribution of cholesterol between serum and tissues (4, 17) or to lipoprotein structure (17, 18).

References

1. Beynen AC, Van Gils LGM, Den Engelsman G (1983) Z Ernährungswiss 22:97
2. Beynen AC, Terpstra AHM (1983) Comp Biochem Physiol 76B, 737

3. Beynen AC, West CE (1981) Z Tierphysiol, Tierernährg u. Futtermittelkde 46, 233
4. Bieberdorf FA, Wilson JD (1965) J Clin Invest 44, 1834
5. Buchwald H (1964) Circulation 29, 713
6. Bronte-Stewart B, Antonis A, Eales I, Brock JF (1956) Lancet 1, 521
7. Brussaard JH, Katan MB, Hautvast JGAJ (1983) Eur J Clin Invest 13, 115
8. Connor WE, Witiak DT, Stone DB, Armstrong ML (1969) J Clin Invest 48, 1363
9. Dietschy JM, Wilson JD (1970) New Engl J Med 282, 1241
10. Glueck CJ (1979) Am J Clin Nutr 32, 2703
11. Groen J, Tjiong BK, Kamminga CE, Willebrands AF (1952) Voeding 13, 556
12. Kinsell LW, Partridge J, Boling L, Margen S, Michaels G (1952) J Clin Endocrinol 12, 909
13. Lambert GF, Miller JP, Olsen RT, Frost DV (1958): Proc Soc Exp Biol Med 97, 544
14. Moore RB, Frantz Jr ID, Buchwald H (1969) Surgery 65, 98
15. Nestel PJ (1970) Clin Sci 38, 593
16. Nestel PJ, Havenstein N, Whyte HM, Scott TJ, Cook LJ (1973) New Engl J Med 288, 379
17. Paul R, Ramesha CS, Ganguly J (1980) Adv Lipid Res 17, 155
18. Spritz N, Mishkel MA (1969) J Clin Invest 48, 78
19. Van Niekerk JLM, Hendriks T, De Boer HHM (1984) Neth J Med 27, 18
20. Wigand G (1960) Acta Med Scand 166 (Suppl 351):1
21. West CE, Deuring K, Schutte JB, Terpstra AHM (1982) J Nutr 112:1287

Received April 18, 1984

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