The effect of daily consumption of coconut fat and soya-bean fat on plasma lipids and lipoproteins of young normolipidaemic men

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The present paper reports the influence on plasma lipids of isoenergetic diets containing 30 % of energy as fat, with a polyunsaturated : saturated fat ratio of 4·00 or 0·25, consumed for 8 weeks by twenty-five young normolipidaemic males. Approximately 70 % of the fat energy was provided by the test fats: soya-bean fat and coconut fat. During the soya-bean-fat-eating period the total plasma cholesterol level fell significantly compared with baseline values ($P < 0.001$) and during the coconut-fat-eating phase total plasma cholesterol level increased significantly compared with the soya-bean-eating period ($P < 0.001$). On the soya-bean-fat diet, high-density-lipoprotein (HDL)-cholesterol decreased by 15 % (range 6–35 %) and plasma triacylglycerols decreased by 25 % (range 13–37 %). Results of the present study show that even when the proportion of total fat in the diet is low, a high intake of linoleic acid lowers both total plasma cholesterol and HDL-cholesterol, while a high intake of saturated fat elevates both these lipid fractions. Application of regression formulas to the present findings indicates that short-chain saturated fatty acids have a neutral effect on serum cholesterol.

Recent studies in the UK suggest that atherogenesis is either accelerated or premature, or both, in Southern Asians compared with white populations. (Hughes *et al.* 1989). Coronary heart disease tends to be low in populations consuming high-carbohydrate, low-fat diets (Shaper *et al.* 1974). Although the habitual diet of Sri Lankans is high in carbohydrate, and fat contributes only 27 % of total energy, coronary heart disease is the leading cause of mortality and morbidity in middle-aged men in Sri Lanka (Shaper *et al.* 1974; Registrar General's Department, Department of Census and Statistics, 1984). Among the different hypotheses put forward to explain this high incidence of coronary heart disease is the regular intake of relatively high quantities of saturated fat in the Sri Lankan diet (Shaper *et al.* 1974). As much as 80 % of the fat content of the habitual Sri Lankan diet consists of coconut fat (CF), which is a saturated fat (Wickramanayake & Panabokke, 1961).

Vascular disease has been reported to be uncommon in Polynesian Islanders who obtain 34–63 % of their food energy from CF (Prior *et al.* 1981). However, unlike the habitual Sri Lankan diet, fish is the chief source of protein in the diet of Polynesians and fish oil fatty acids are likely to exert a favourable influence on the metabolism of lipids in this population.

Modifications of the Sri Lankan diet which would alter serum lipids and lipoproteins to profiles that are less likely to promote atherosclerosis would be beneficial. Therefore, it was felt necessary to investigate the effects of replacing CF in the habitual Sri Lankan diet with a relatively cheap and readily available polyunsaturated fat (PUSF) such as soya-bean fat. Most human experiments carried out to investigate the effect of saturated fat on plasma lipids have used lard, butter or cocoa fat. The new studies which have used CF, have used it in combination with other saturated fats. The activity of CF has, therefore, not been

adequately tested. Studies investigating the effects of replacing saturated fats in diets with PUSF have used either maize-oil or safflower-oil. Both these fats are expensive and not readily available to Sri Lankans. Moreover, the cholesterol content, carbohydrate type and quantity, and the fibre content of the experimental diets do not resemble the composition of the habitual Sri Lankan diet. The aim of the present study was to define the effects of replacing CF in the Sri Lankan diet with soya-bean fat on fasting plasma lipids of healthy normolipidaemic men.

MATERIALS AND METHODS
Subjects
Twenty-five healthy young adults, 20–26 years of age, participated in the study. They were volunteers from among the prison inmates of the Pallekalle Open Prison Camp, Pallekalle, Sri Lanka. All subjects were within 2% of normal body-weight and none of the subjects deviated more than 3% from their baseline (day 1) weight throughout the study. Physical activity was constant and none of the subjects received any medications during the study period.

Experimental design
The study was divided into two feeding periods of 8 weeks each, a period sufficient to establish the effect of each diet on plasma lipids and lipoproteins. In between the two periods there was a wash-out period of 3 weeks to allow the effects of the preceding test diet to dissipate and plasma lipids and lipoproteins to return to baseline levels. It also provided subjects relief from the difficulties of adhering to the test diet procedures.

Diets
The experimental diets consisted of foods containing one of the two fats under investigation (CF and soya-bean fat) for lunch and supper, and low-fat, high-carbohydrate foods for breakfast. Standard menus for fourteen different meals over 7 d were prepared and these meals were served in consecutive cycles every week. Both dietary regimens were isoenergetic. Foods chosen for the main meals were rice, lean meat, fish, poultry, bread, potatoes, dahl and green vegetables. The compositions (mean daily intakes) of the diets are shown in Table 1. Approximately 70% of the fat energy was from the test fats. The non-study fats (approximately 30% of the total fat) were from meat, fish, poultry, vegetables and grains. Cheese, butter and alcoholic beverages were not allowed. All meals were prepared in the prison kitchen and food from outside was not allowed. Adherence to the test diets was judged to be good on the basis of regular interviews with the prison officers and self report.

Biochemical measurements
Fasting blood samples were drawn at the beginning and at the end of each dietary period for measurement of plasma total cholesterol (TC), triacylglycerol (TG) and high-density-lipoprotein-cholesterol (HDL-C). In the last 2 weeks of each dietary period, two successive measurements of TC and TG were carried out to determine whether the lipid changes were established. The average of these two values was used to evaluate the final lipid change. TC and TG concentrations were determined by enzymic methods (Bucolo & David, 1973; Siedel et al. 1981). The inter- and intra-assay coefficients of the TC assay were both < 2·5%. The inter- and intra-assay coefficients of the TG assay were 3·5 and < 2·0% respectively. HDL-C was measured by selective precipitation with dextran sulphate and magnesium chloride (Warnick et al. 1982). The inter- and intra-assay coefficients were both < 2·5%. Plasma low-density-lipoprotein-cholesterol (LDL-C) was calculated by the method of Friedwald et al. (1972).

Table 1. *Mean composition of the diets* (*mean daily intake*)

Dietary fat...	Soya-bean-fat	Coconut fat
Energy (kJ)	10020	10150
(kcal)	2395	2425
Protein (g)	85	84
Fat (g)	78	81
Carbohydrates (g)	350	359
Cholesterol (mg)	250·0	250·0
P:S ratio	4·0	0·25

P:S, polyunsaturated:saturated fat.

Ethical considerations

The study was approved by an independent ethical committee of the Institute of Fundamental Studies. The nature, requirements, implications and potential hazards of the study were explained to sixty-two men from two dormitories in the prison camp. Forty-five individuals volunteered for the study, of which twenty-five were selected to participate. Written consent was given by every participant. All of them had complete freedom to opt out of the study group during the course of the study.

Statistical methods

Comparison of the results obtained were carried out using Student's *t* test for paired values.

RESULTS

The effects of the two diets on plasma lipids and lipoproteins are shown in Table 2. All men showed a reduction of plasma TC on the soya-bean-fat diet; the mean reduction was 21% (range 10–35%). The mean plasma TC fell from 4·64 (SD 0·37) to 3·68 (SD 0·42) mmol/l ($P < 0·001$). All subjects showed a decrease in plasma TG on the soya-bean-fat diet (mean decrease 25%; range 13–37%). The mean plasma TG fell from 1·42 (SD 0·44) to 1·06 (SD 0·42) mmol/l ($P < 0·01$). LDL-C fell during the period on the soya-bean-fat diet, by an average of 23% (range 5–45%, $P < 0·001$). The soya-bean-fat diet also lowered HDL-C. The mean reduction was 15% (range 6–35%, $P < 0·05$). Reciprocal changes were seen when CF was re-introduced. The lipids and lipoproteins increased to values which were no longer significantly different from the baseline values.

DISCUSSION

The results of this investigation are in agreement with several metabolic studies that have presented evidence that saturated fats *per se*, increase the concentrations of plasma TC, and PUSF lower plasma TC in man (Hegsted *et al.* 1965; Keys *et al.* 1965; Schafer *et al.* 1981). Controlled experiments carried out under metabolic ward conditions have shown a relationship between concentrations of dietary fat and cholesterol, and blood cholesterol. Regression formulas based on these studies have been established (Jacobs *et al.* 1979). The regression equations of Keys *et al.* (1965): Δcholesterol = 1·35 (2 ΔS − ΔP) and of Hegsted *et al.* (1965): Δcholesterol = 2·32 (ΔS − 1·3 ΔP) were applied to the data, where S and P represent the amounts of saturated (S) and polyunsaturated (P) fats as percentages of the energy content of the diet. The increase in plasma cholesterol on the CF diet compared with the soya-bean-fat diet predicted by the Keys *et al.* (1965) formula (1·34 mmol/l) is higher

Table 2. *Concentrations of plasma lipids and lipoproteins during daily consumption of soya-bean fat or coconut fat by healthy young men*

(Mean values and standard deviations)

Experimental period‡ ...	Baseline		Soya-bean fat		Coconut fat	
	Mean	SD	Mean	SD	Mean	SD
Cholesterol (mmol/l)	4·64	0·37	3·68***	0·42	4·61†††	0·39
Triacylglycerol (mmol/l)	1·42	0·44	1·06**	0·42	1·45	0·41
HDL-C (mmol/l)	1·10	0·25	0·94*	0·26	1·14	0·27
LDL-C (mmol/l)	2·95	0·43	2·27***	0·36	2·84	0·37

HDL-C, high-density-lipoprotein cholesterol; LDL-C, low-density-lipoprotein cholesterol.
Mean values were significantly different from baseline values: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.
Mean values were significantly different from soya-bean fat values; ††† $P < 0.001$.
‡ For details, see p. 548 and Table 1.

Table 3. *Fatty acid composition of the food fats (g fatty acids/100 g total fatty acids)*

Fatty acid	Coconut fat	Soya-bean fat
8:0	10·1	0·0
10:0	6·6	0·0
12:0	45·8	0·0
14:0	18·4	0·1
16:0	8·0	10·7
16:1	Trace	0·1
17:0	Trace	0·1
18:0	2·4	3·8
18:1	6·0	23·0
18:2	1·7	52·4
18:3	0·0	8·9
20:0	0·0	0·6
22:0	0·0	0·4

than the observed values of 0·93 mmol/l. The results predicted by the Hegsted *et al.* (1965) formula (1·13 mmol/l), is also higher than the observed value. In the modified equation of Keys *et al.* (1974): Δcholesterol $= 1.2 \, (2\Delta S - 1.3\Delta P)$, where S represents the proportion of saturated fatty acids containing twelve or more carbon atoms. This formula is based on the hypothesis that saturated fatty acids containing fewer than twelve C atoms have little or no effect on serum cholesterol. In view of the relatively high proportion of short-chain fatty acids in CF (Table 3), the rise in serum cholesterol predicted by the modified Keys *et al.* (1965) formula was calculated. When this formula is applied to our data there is no significant discrepancy between the predicted value (0·94 mmol/l) and the observed value (0·93 mmol/l). These observations support the hypothesis that short-chain saturated fatty acids in the diet have a neutral effect on serum cholesterol.

Under specific experimental conditions the cholesterol-elevating effect of saturated fats has been chiefly attributed to their myristic acid (14:0) component (Hegsted *et al.* 1965). The high myristic acid content of CF (Table 3) is likely to be an important factor in the setting of blood cholesterol values in the CF phase of the study.

The effect of saturated fats on plasma TG have been studied by several investigators who have reached different conclusions. The results of the present study are in agreement with

the findings of Wilson *et al.* (1971), Chait *et al.* (1974), Shepherd *et al.* (1978) and Becker *et al.* (1983) of a reduction of plasma TG with PUSF. However, Mattson & Grundy (1985) and Reiser *et al.* (1985) found no effect of PUSF on plasma TG. Chait *et al.* (1974) reported a correlation between the magnitude of the fall in TG level induced by the PUSF diet and the TC concentration during the saturated fat period. This correlation was not found in the present study. In some of these studies (Wilson *et al.* 1971), the type of fat as well as the type and intake of carbohydrate were different in the two study periods. These changes can contribute to the fall in TG. In the present study, the intake and composition of carbohydrate was the same throughout the study. Therefore, the reduction in plasma TG can be attributed to the reduction in CF intake.

The effect of PUSF on HDL-C is controversial. Some reports (Shepherd *et al.* 1978; Craig *et al.* 1980; Schafer *et al.* 1981), show that HDL-C decreases on a PUSF diet, while others report no change (Chait *et al.* 1974; Schwandt *et al.* 1982; Becker *et al.* 1983). On the other hand, Von Lossonezy *et al.* (1978) and Shore *et al.* (1981) have reported an increase in HDL-C on a PUSF diet. In the present study the PUSF diet with a P:S ratio of 4 lowered the HDL-C by an average of 15%. Reciprocal changes took place when the CF diet (P:S ratio 0·25) was re-introduced. Comparing the effects of a P:S ratio of 0·4 *v.* 4·0, in the latter case Shepherd *et al.* (1978) reported a 33% reduction in HDL-C in the four subjects in their study.

The response of HDL-C appears to be related to the P:S ratio of the diet. Schwandt *et al.* (1982) assessed the effect of a diet with a P:S ratio of 1 with a P:S ratio of 0·3 on plasma lipoproteins. In their study 37% of the energy was provided by fat. The diet with a P:S ratio of 1 effectively lowered LDL-C without affecting HDL-C. There was also no significant change in the production of thromboxane B on the two diets (results not presented).

The replacement of CF with soya-bean fat in the habitual diet of healthy normolipidaemic Sri Lankan males caused a specific fall in plasma TC and TG. However, this may not be the best dietary modification for prevention of coronary heart disease in Sri Lankans. The undoubted hypocholesterolaemic effect of soya-bean fat with its implied benefits must be weighed against the potentially harmful reduction of HDL-C. The mean plasma HDL-C concentrations of Sri Lankans have been found to be low compared with Caucasians (Mendis & Read, 1984). This may be due to the low fat and high complex carbohydrate content of the diet (Mensink & Katan, 1987). Therefore, further reduction of HDL-C as a result of replacement of CF with PUSF may have undesirable effects. However, diets with higher P:S ratios have been shown to have no effect on HDL-C (Schwandt *et al.* 1982). Further studies to determine the optimum content of PUSF in the Sri Lankan diet are needed.

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