

Effect of mycoprotein on blood lipids¹⁻³

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ABSTRACT This metabolic study was designed to investigate the effects of mycoprotein on blood lipids. Mycoprotein is a food produced by continuous fermentation of *Fusarium graminearum* (Schwabe) on a carbohydrate substrate. Two groups of subjects with slightly raised cholesterol concentrations took part in the 3-wk study. The experimental group was fed mycoprotein in place of meat and the control diet contained meat. There was no change in plasma cholesterol in the control group but there was a 13% reduction in the mycoprotein group. Low-density lipoprotein (LDL) increased in the control group by 12% and decreased by 9% in the mycoprotein group. High-density lipoprotein (HDL) decreased by 11% in the control group but increased by 12% in the mycoprotein group. In each case the group ANOVA differences between variables were statistically significant. It is clear from these results that lipid variables are advantageously altered by mycoprotein consumption. *Am J Clin Nutr* 1990;52:646-50.

KEY WORDS Mycoprotein, *Fusarium graminearum*, blood lipids, lipoproteins, metabolic study

Introduction

Mycoprotein is a food produced by continuous fermentation of *Fusarium graminearum* (Schwabe) on a carbohydrate substrate (glucose). The process includes a short heat-treatment stage to reduce the RNA content by activating the endogenous RNAase enzymes, after which the mycoprotein is filtered and then formed into a variety of food products. The development of mycoprotein is described in detail elsewhere (1, 2).

Mycoprotein contains high-quality protein, a low amount of largely unsaturated fatty acids, and a significant quantity of dietary fiber. It can be textured and flavored to resemble meat or be presented in other forms as an alternative source of protein and other nutrients, which, at the same time, are delicious. It is approved for use as food by the UK authorities and has been on sale to the UK public since January 1985. It is sold under the trade name Quorn (Marlow Foods, Marlow, Buckinghamshire, UK) and is available through major food retailers in a variety of recipe dishes, pies, and flans. Quorn mycoprotein is the main protein ingredient in such products, has a shelf life similar to that of meat, can be frozen, and does not shrink on cooking.

The introduction of Quorn mycoprotein was a rare event in that it was a totally new foodstuff, and this work was undertaken to investigate its effects on blood lipids, lipoproteins, apolipoproteins A-I (apo A-I) and B (apo B), glycemic vari-

ables, blood pressure, and body weight over a 3-wk period. Previous animal studies (3-6) gave some indication of possible effects on blood lipids, and a previous human study, not specifically designed to investigate lipid concentrations, gave some indication that there might be an effect (7). Previous studies of ours demonstrating an effect of fiber on blood lipids influenced the design of this study, because the fiber component of mycoprotein is quite considerable and also of an unusual composition (cell walls contain chitin and β -glucan) (8, 9).

Methods

Materials

In this study subjects consumed Quorn mycoprotein in the form of commercially available pies and recipe dishes (preprepared main courses) as well as dishes prepared daily, which centered around textured and flavored mycoprotein pieces (chunks, slices, scallops, and bread-crumbs-coated pieces). The mycoprotein was supplied as two alternative types: white (chicken flavor) or brown (beef flavor), both with nonmeat flavors.

The various mycoprotein pieces were produced from the mycoprotein filter cake by the addition of a small amount of egg albumen as a binder, flavor, and for the brown mycoprotein, color. The analysis of the two types of mycoprotein as fed appears in **Table 1**. The fiber content of mycoprotein (25% of dry matter) is attributable to its wall component, approximately one-third of which is chitin (poly *n*-acetyl glucosamine) and two-thirds is β -glucan.

Subjects

Two hundred fifty staff and students of King's College London were screened by finger-prick blood sample (Reflotron, Boehringer Mannheim GmbH, Mannheim, FRG) to determine total-cholesterol concentrations. Of those with total cholesterol between 5.2 and 6.2 mmol/L, 22 subjects were found suitable to participate in the study, having no indication of dia-

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TABLE 1
Nutrient composition of mycoprotein per 100 g

	White	Brown
Energy (kcal)	91	95
Energy (MJ)	0.381	0.399
Total fat (g)	3.3	3.1
Saturated fatty acids (g)	0.5	0.5
Polyunsaturated fatty acids (g)	1.6	1.5
Monounsaturated fatty acids (g)	0.4	0.4
Protein (g)	13.2	13.5
Carbohydrate (g)	1.9	3.1
Dietary fiber (g)	5.3	5.5

betes mellitus or thyroid disorder and not using lipid-lowering drugs or other substances that would affect lipid metabolism. All subjects underwent further screening to establish that the first cholesterol reading was valid. Of the 22 subjects 5 decided not to take part because of demands of the study, and seventeen subjects (12 female, 5 male, age 19–48 y, body mass indices 16.9–32.1 kg/m²) participated. All subjects were healthy and none were taking any medication. This study was approved by the King's College ethical committee.

Methods

Subjects were randomly assigned to two parallel groups (nine eating mycoprotein and eight eating control diet) and all subjects were asked to record their habitual diet to establish individual energy intakes before the metabolic study began. Pre-study dietary intakes are shown in Table 2 and are only slightly lower than intakes during the study. Slightly more energy was given during the study period, because experience has demonstrated that subjects eat more food when it is prepared for them.

It was not possible to calculate either dietary cholesterol or individual fatty acid intakes during the pre-study period because subjects consumed a diverse range of commercially prepared foods for which only basic macronutrient information is available from manufacturers. The total energy and macronutrient composition of the mycoprotein and control diets were

TABLE 2
Prestudy dietary intake*

Energy		
(kcal/d)	1808 ± 413	
(MJ/d)	7.6 ± 0.1	
Total fat		
(g/d)	71.1 ± 22.3	
(% energy)	35.2 ± 6.8	
Protein		
(g/d)	64.5 ± 15.1	
(% energy)	14.3 ± 1.2	
Carbohydrate		
(g/d)	238.0 ± 62.6	
(% energy)	49.7 ± 7.3	
Dietary fiber (g/d)	22.6 ± 10.0	
Alcohol		
(g/d)	2.6 ± 3.7	
(% energy)	1.0 ± 1.3	

* $\bar{x} \pm SD$.

TABLE 3
Dietary intakes during study*

Variable	Mycoprotein diet	Control diet
Energy		
(kcal/d)	1945 ± 114	1874 ± 105
(MJ/d)	8.1 ± 0.03	7.8 ± 0.03
Total fat		
(g/d)	75.0 ± 7.3	70.3 ± 8.5
(% energy)	34.5 ± 2.7	33.5 ± 3.8
Protein		
(g/d)	78.7 ± 5.1	79.9 ± 8.4
(% energy)	16.6 ± 1.3	17.2 ± 1.7
Carbohydrate		
(g/d)	255.0 ± 21.0	247.0 ± 20.0
(% energy)	49.0 ± 2.7	49.5 ± 3.0
Dietary fiber (g/d)	38.6 ± 5.4	27.4 ± 4.5
Mycoprotein (g/d)†	190.6 ± 16.8	0
Cholesterol <i>mgms/day</i>	113.0 ± 37	164.0 ± 59

* $\bar{x} \pm SD$.

† Nutrient content is included in dietary intakes.

calculated but were not always identical because of the characteristics of mycoprotein (Table 3).

Table 4 shows that all fatty acids in the two diets were very closely balanced. Fatty acid values were taken from food tables (10), and where no values were available, gas-liquid-chromatography analysis was undertaken on preprepared main courses from both control and mycoprotein diets (11, 12).

Table 3 shows that there was a difference in dietary cholesterol intake (mycoprotein is cholesterol free), but because the overall intake was low this probably had little effect, if any, on blood cholesterol. The ratio of polyunsaturated to saturated fatty acids (P:S) of the two diets showed virtually no difference. Subjects eating mycoprotein received on average 191 g mycoprotein/d distributed over lunch and dinner, and the control group was given equicaloric amounts of meat-containing foods.

TABLE 4
Fatty acid content of diets*

Chain length	Mycoprotein diet	Control diet
4:0	0.68 ± 0.29	0.57 ± 0.10
10:0	0.66 ± 0.19	0.54 ± 0.08
12:0	1.11 ± 0.43	0.90 ± 0.19
14:0	2.80 ± 0.49	2.72 ± 0.38
16:0	11.75 ± 0.62	11.96 ± 1.18
18:0	4.29 ± 0.66	4.27 ± 0.65
Other saturates	1.43 ± 0.34	1.40 ± 0.27
Total saturates	22.72 ± 2.33	22.36 ± 2.01
16:1	0.89 ± 0.16	1.12 ± 0.21
18:1	21.49 ± 5.48	19.92 ± 3.63
Other monounsaturates	0.95 ± 0.19	0.84 ± 0.12
Total monounsaturates	23.33 ± 5.55	21.88 ± 3.61
18:2	12.65 ± 3.13	11.42 ± 4.14
18:3	1.31 ± 0.33	0.62 ± 0.10
Other polyunsaturates	0.16 ± 0.05	0.18 ± 0.05
Total polyunsaturates	14.12 ± 3.06	12.22 ± 4.24

* $\bar{x} \pm SD$.

TABLE 5
Blood lipid results

	Initial value	Final value	Change	Final value adjusted for covariance
<i>mmol/L</i>				
Cholesterol				
Mycoprotein	5.54 ± 0.47*	4.81 ± 0.45†	-0.74‡	4.75§
Control	5.31 ± 0.27	5.37 ± 0.52	0.05	5.43
SED			0.234	0.233
HDL				
Mycoprotein	0.58 ± 0.14	0.65 ± 0.15	0.064¶	0.717‡
Control	0.74 ± 0.14	0.65 ± 0.15**	-0.084	0.575
SED			0.030‡	0.0359
LDL				
Mycoprotein	4.16 ± 0.41	3.78 ± 0.46††	-0.38‡	3.73‡
Control	3.91 ± 0.29	4.39 ± 0.44††	0.48‡	4.45‡
SED			0.226	0.226
Triglycerides				
Mycoprotein	1.78 ± 0.43	0.83 ± 0.28††	-0.931	0.760
Control	1.47 ± 0.24	0.70 ± 0.18††	-0.766	0.785
SED			0.1058	0.0766

* $\bar{x} \pm SD$.

†**†† Significantly different from initial: † $P < 0.01$, ** $P < 0.001$, †† $P < 0.05$.

‡§ Significantly different from control: ‡ $P < 0.01$, § $P < 0.05$, † $P < 0.001$.

|| Standard error of difference.

Because of the characteristics of mycoprotein, it was impossible that subjects could be blinded to diet. All food and drink over the 3-wk experimental period was provided prepared and preweighed. All main meals were eaten under supervision in a metabolic unit and all snacks were provided but sometimes were eaten outside. The mycoprotein was given in a diverse number of prepared dishes usually with some type of sauce, as a bread-crumbs-coated product, or in salad marinade.

The only intended difference in nutrient composition between the two experimental groups was in the dietary fiber composition of the mycoprotein group, which had 11.2 g/d more than the control group had. The sources of dietary fiber in both dietary groups was identical (cereals, vegetables, and fruits) except for that obtained from mycoprotein.

A questionnaire was devised to establish if there was any difference between the mycoprotein and control groups for the following variables: fluid intake, intestinal discomfort, frequency of defecation, fecal bulk and consistency of feces (see Appendix). The questionnaire was administered at the end of the 3-wk experimental period.

Subjects fasted overnight before blood sampling, which was done on two separate occasions within 3 d before and after the metabolic study. The following variables were measured: body weight, blood pressure [random-zero sphygmomanometer (13)], total cholesterol (enzymatic CHOD-PAP method, Boehringer Mannheim), triglycerides (Peridochrom GPO-PAP method, Boehringer Mannheim), low-density lipoprotein [LDL, calculated by the Friedwald formula (14)], high-density lipoprotein (HDL, HDL precipitant, Boehringer Mannheim), apo A-I and apo B (immunoturbidimetric assay, Orion Diagnostica, Espoo, Finland), insulin (enzyme-linked immunosorbent assay, Boehringer Mannheim), glucose (GOD-PAP, Boehringer Mannheim), and glycated hemoglobin (test combination HbA1, Boehringer Mannheim).

Statistical analysis

Three types of statistical analysis were performed on the data. Within each treatment group the initial values (before) were compared with the final values (after) with a paired *t* test. The two groups were compared by analysis of variance (ANOVA) of the change over the period. The final values for the two groups were compared by analysis of covariance (ANCOVA), using the initial value as a covariate (GENSTAT 5, Rothamstead Experimental Station, Harpenden, UK).

Results

There was no change in mean body weight throughout the study and no significant change in either systolic or diastolic blood pressure and glycemic or insulinemic variables. Table 5 shows the main lipid variables measured. Total cholesterol was reduced by 13% (ANOVA, $P < 0.01$) in the mycoprotein group whereas no change occurred in the control group. There was a 9% reduction in LDL in the mycoprotein group but a 12% increase in the control group (ANOVA, $P < 0.01$). HDL increased by 11% in the mycoprotein group but decreased by 11% in the control group (ANOVA, $P < 0.001$). In both groups triglycerides were reduced by 53%.

Table 6 shows the apo A-I and apo B results, which showed no overall statistically significant changes between the two treatment groups. However apo A-I within the mycoprotein group fell significantly by 8% (ANOVA, $P < 0.05$) and apo B fell significantly by 14.8% (ANOVA, $P < 0.01$). ANCOVA for the blood results showed very similar results to the straightforward ANOVA between treatment groups (Tables 5 and 6).

Tables 3 and 4 show that there were no major differences in mean nutrient intakes between the groups except for the intended 29% increase in dietary fiber in the mycoprotein group. The small differences that did occur were, no doubt, because subjects were eating real food and not formula diets.

Results of the questionnaire administered at the end of the study are shown along with the questionnaire in the appendix. There was no perceived difference in fluid intake. Six of nine subjects experienced some flatulence on the mycoprotein diet,

TABLE 6
Apolipoprotein results

	Initial value	Final value	Change	Final value adjusted for covariance
Apo A-I (g/L)				
Mycoprotein	1.86 ± 0.11*	1.70 ± 0.12†	-0.157	1.748
Control	1.97 ± 0.21	1.94 ± 0.31	-0.031	1.889
SED‡			0.0887	0.0951
Apo B (g/L)				
Mycoprotein	0.94 ± 0.12	0.81 ± 0.15§	-0.138	0.783
Control	0.84 ± 0.16	0.78 ± 0.12	-0.066	0.801
SED			0.068	0.065
Apo B/Apo A-I				
Mycoprotein	0.51 ± 0.09	0.48 ± 0.11	-0.031	0.46
Control	0.84 ± 0.12	0.40 ± 0.05	-0.035	0.42
SED			0.04	0.04

* $\bar{x} \pm SD$.

†§ Significantly different from initial: † $P < 0.05$, § $P < 0.01$.

‡ Standard error of difference.

but this only lasted for the first few days in most subjects. There may have been a slight perceived increase in the frequency of defecation on the mycoprotein diet in some subjects, and fecal bulk was reported to have increased more in the mycoprotein group.

Discussion

Despite the practical difficulties in conducting a metabolic study of this type, the objectives were met very successfully. Overall the mycoprotein dishes were well liked and in individual instances where this was not so, acceptable substitutes were always found. The major problem with any metabolic study is maintaining motivation, and this was achieved by continuous personal contact with the subjects, which although time consuming and difficult, is of the utmost importance.

These results demonstrate that mycoprotein had beneficial effects on cholesterol (13% reduction) and also on the major lipid fractions (Table 5). The 11% increase in HDL in the mycoprotein group is contrasted by the 11% reduction in HDL in the control group, and the 9% reduction in LDL in the mycoprotein group is contrasted by the 12% increase in LDL in the control group. The apo B results, although not statistically significant, show a trend similar to that of the lipid and lipoprotein fractions. This effect on both cholesterol and the lipid fractions is not always demonstrated with a lipid-lowering food: dietary fat manipulation often has a cholesterol-lowering effect but the lipid fractions are not always advantageously affected (15, 16). The types of dietary fibers known to lower blood cholesterol (mainly soluble fibers) also do not always show the desired effect on lipid fractions (17–22).

The dramatic reduction of plasma triglycerides in both control and mycoprotein groups was probably due to the nutritionally balanced diet given to both groups. The fat as a percentage of total energy in both diets was only slightly lower than in subjects' habitual diets (Table 3), which would not account for the effect on triglycerides. The increase in LDL and reduction in HDL on the control diet may be a result of the change from subjects' habitual diets to a carefully controlled, different diet.


There was some initial flatulence, probably because of the fermentation of the dietary fiber found in the mycoprotein, but this effect varied according to the habitual dietary fiber intake of the individual, being less in those individuals with higher fiber intake.

Because all nutrients in the different diets were strictly controlled, the results point to dietary fiber having had this desirable effect on blood lipids. The exact mechanisms can only be postulated at this stage, but literature on the subject of dietary fiber and lipids does show that cholesterol degradation may be altered and that dietary fiber may bind neutral sterols, bile acids, and cholesterol in the intestine (23). The amino acid content of the two diets could not be balanced and, indeed, this is usually only possible when a formula diet is used. The change from an animal to a vegetable protein source could possibly have an effect on the blood lipid profile, but it is impossible to calculate all individual amino acids at the present time because of the lack of detailed information. We are therefore unable to state whether the displacement of animal protein by a vegetable source resulted in a lower amount of available arginine, which is necessary for the production of LDL molecules (24).

The fiber alone may not be the only active hypocholesterolemic substance in mycoprotein (3). Potent inhibitors of cholesterol synthesis in the form of *d*- α -tocotrienol have been identified in barley and other cereals (25). *d*- α -Tocotrienols are widely found in a variety of plants and may offer an avenue of further investigation. Tocotrienols differ slightly from tocopherols at three double bonds from the isoprenoid chain, which seem to be essential for the inhibition of cholesterol synthesis (25).

We show here that it is possible to reduce blood lipids by eating mycoprotein. There is ample evidence to show that low- and/or modified-fat diets have an effect on plasma lipids (15, 16). It is also well established that a variety of fiber products will normalize lipids (17–22). Various types of soy bean preparations were investigated in great detail (26–28); the lipid-lowering effect of soy is probably due to the very high protein content of the soy isolates, because the fiber content of such isolates is low. Two studies using purified dietary fiber from soy did not reduce plasma cholesterol (29, 30).

The ideal blood-lipid-normalizing diet should be low in total fat with a moderate proportion of polyunsaturated and monounsaturated fatty acids and should possibly also include some marine oils (31). The carbohydrate content of the diet should be between 50% and 60% of total energy, automatically lowering the percentage of energy coming from fat (31). The carbohydrate should be whole grain and high in soluble fiber, ie, contain oats, barley, and rye. Foods with added purified fibers (gum fibers and pectin) can be of use (32).

Mycoprotein can now be added to a range of foods that can be included in a lipid-lowering or lipid-normalizing diet because it is not only low in fat but has a high P:S and also contains considerable amounts of dietary fiber. A single dietary change dependent on one food is an impractical regimen that is certain to fail, but a multiple approach which includes a variety of lipid-normalizing foods offers the greatest chance of success. 

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APPENDIX

Questionnaire used at the end of the study and replies to questionnaire

Question	Mycoprotein group		Control group	
	Yes	No	Yes	No
1 Did you drink more fluid during this study?	3	6	3	5
2 Did you experience any intestinal discomfort at any time during the study and if so do you think it was due to the food you were given?	6*	3	1	8
3 Did you notice any changes in frequency of defecation during this study?	5†	4	2‡	6
4 Did your fecal bulk increase during the study?	4	5§	2	6
5 Did you notice any changes in the consistency of your feces?	4¶	5	2¶	6

* Mainly flatulence, which only lasted for first few days in most people.

† More, 3; less, 2.

‡ More, 1; less, 1.

§ Decreased, 1.

|| Decreased, 3.

¶ Half softer, half harder.