J. Food Sci. Technol., 1996, Vol. 33, No. 2, 124-128

Effect of Supplementation of *Spirulina* on Hypercholesterolemic Patients

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The effect of *Spirulina* on hypercholesterolemic patients was carried out in Coimbatore city. Thirty ischaemic heart disease patients without any complications of the disease and with blood cholesterol levels above 250mg/dl were selected for the study and divided into three groups of 10 each for supplementation of *Spirulina*. Subjects in groups A and B received 2g and 4g *Spirulina* per day, respectively for three months. Group C served as control. The study has revealed that *Spirulina* plays a key role in weight reduction, lowering the blood cholesterol levels and improving the lipid profile of patients.

Keywords: *Spirulina fusiformis*, Hypercholesterolemia, Lipid profile, Blue green algae.

Spirulina fusiformis is a multicellular filamentous blue green microalgae (cyanobacteria) known for its potential to bring about a nutritional revolution in the developing countries, where it grows naturally in highly alkaline lakes. (Muratee 1993). Several countries have started growing it commercially. It is gaining popularity in recent years, as a food supplement, because of its remarkable ability to synthesize high quality concentrated food more efficiently than any other algae (Challem 1981; Umesh and Seshagiri 1984). It is an excellent food source, providing the highest amount of proteins (65-71%) with all the essential and non-essential amino acids as well as various vitamins and minerals, including the B complex and chelated minerals in a balanced proportion along with the pigments (MCRC brochure 1990; Venkataraman 1993).

Studies have shown that it has high levels of beta carotene, gamma linolenic acid, iron and vitamin B_{12} (Seshadri and Umesh 1992; Venkataraman 1992). Furthermore, it has a thin cell wall and its digestion and absorption are easy (Iwata et al. 1990).

Extensive research on toxicological aspects has been carried out under the UNIDO (1980) programme in Mexico for a ten year period. This study has proved conclusively that *Spirulina* is a safe food with absolutely no side effects. Other long term and short term toxicological tests on animals and human beings have indicated similar results (Kumari et al. 1981; NIN 1988).

Recently, *Spirulina* has made an important breakthrough in tackling the problem of hypercholesterolemia and in animal experiments, it has proved that *spirulina* had positive effects in reducing serum total cholesterol and elevating high density lipoprotein (HDL) cholesterol levels (Chen et al. 1981; Devi and Venkataraman 1983; Kato et al. 1984; Chokkukannan et al. 1993). The present study was carried out to determine whether *Spirulina* could exert these effects on human subjects.

Materials and Methods

Thirty patients who were overweight with the blood cholesterol levels ranging from 250-400 mg/dl in the age group of 40-60 years attending the government hospitals, Coimbatore city formed the subjects for this study. From all the 30 subjects, the background informations like socio-economic pattern, dietary practices and health details were elicited through a detailed questionnaire. The data from this questionnaire revealed that the occurrence of ischemic heart disease was more (21 out of 30 subjects) in the age group of 46 to 55 years with sedentary life style and in non-vegetarians with high saturated fat intake.

They were divided into three groups of 10 subjects each for supplementation of *Spirulina*. Subjects in group A received 2g of *Spirulina* per day and those in group B received 4g of *Spirulina* per day for three months, while the group C served as control. The tablets commercially available as *Multinal* supplied by the "New Ambadi Estates Private Limited" (a member of Murugappa Group), Madras were used in the study.

The subjects in group A were administered two tablets twice a day and the subjects in group B received two tablets, four times a day for a period of three months.

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The biochemical parameters monitored in this study were serum cholesterol, triglycerides (TG), high density lipoprotein (HDL), low density lipoprotein (LDL), very low density lipoprotein (VLDL), body weights and the final levels of liver enzymes such as serum glutamic oxaloacetic transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT). All the above estimations were carried out initially and after three months supplementation for all the 30 subjects. But the blood cholesterol level was estimated three times, viz., at initial, intermediate and final points.

Blood cholesterol level was determined by Zak's method (Varley et al. 1980), and measurement of TG and HDL cholesterol were made by the enzymatic method, LDL cholesterol and VLDL cholesterol were calculated by Friedewald formula (Friedewald 1972)and the final levels of the liver enzymes SGOT and SGPT were estimated by using the method of Rietman and Frankel (Wooton 1964).

Results were statistically analysed as per the methods of Snedecor and Cochran (1967) and Gupta (1981).

Results and Discussion

Body weight

Mean initial weights of subjects from groups A, B and C were 62.7, 62.1 and 61.0 kg, respectively and at the end of three months, the respective mean weights were 60.5, 59.9 and 60.3 kg. There were no significant differences between the reductions observed in two experimental groups, but the reductions were highly significant, when compared to the control group (Table 1).

Serum cholesterol

The mean initial serum cholesterol levels of groups A, B and C were found to be 282.1, 309.8, 280.8 mg/dl, respectively. Clear declining trends of the cholesterol levels were observed in the experimental groups during the end of second month. At the end of third month, the values were 218.8, 206.1 and 269.0 mg/dl, respectively for the three groups. It was noted that the subjects receiving four grams supplementation of *Spirulina* recorded the maximum reduction of serum cholesterol, which was statistically highly significant (Table 2). The differences between the groups B and C as well as A and C were also highly significant ($P \leq 0.01$).

TABLE 1. BODY WEIGHT CHANGES IN THE SUBJECTS (n = 10)

Groups	Body weight, kg Initial	Final	Difference	Groups compared	't' test
A	62.7± 5.39	60.5± 5.0	2.2± 0.87	A vs B	0^{NS}
B	62.1± 5.56	59.9± 5.30	2.2± 0.87	A vs C	4.48**
C	61.0± 5.22	60.3± 5.18	0.7± 0.60	B vs C	4.48**

** - highly significant ($p \leq 0.01$)
NS - Not significant ($p > 0.05$)

TABLE 2. CHANGES IN THE SERUM CHOLESTEROL LEVELS OF THE SUBJECTS (n=10)

Groups	Serum cholesterol, mg/dl Initial	Inter-mediate	Final	Diffe-rence	Groups com-pared	't' test (between initial & final)
A	282.1± 16.59	242.7± 16.49	218.8± 14.78	63.3± 7.58	A vs B	10.11**
B	309.8± 28.70	239.9± 25.33	206.1± 27.36	103.7± 10.11	A vs C	18.21**
C	280.8± 21.07	275.0± 22.45	269.0± 22.08	11.8± 4.75	B vs C	26.02**

** - highly significant ($p \leq 0.01$)

TABLE 3. CHANGES IN THE SERUM TRIGLYCERIDE LEVELS OF THE SUBJECTS (n =10)

Groups	Serum triglycerides, mg/dl Initial	Final	Difference	Groups compared	't' test
A	220.1± 34.20	171.9± 35.94	48.2± 5.62	A vs B	0.86^{NS}
B	222.5± 33.57	171.8± 33.56	50.7± 7.36	A vs C	22.02**
C	218.1± 31.72	213.2± 33.20	4.9± 2.66	B vs C	18.49**

** - highly significant ($p \leq 0.01$)
NS - Not significant ($p > 0.05$)

Serum triglycerides

The mean initial serum triglyceride level observed in groups A, B and C were 220.1, 222.5 and 218.1 mg/dl respectively and at the end of three months, the triglyceride levels were reduced to 171.9, 171.8 and 213.2 mg/dl, respectively. The differences observed between the two experimental groups were not statistically significant among themselves, but both the experimental groups registered highly significant differences, when compared to the control group (Table 3).

High density lipoprotein (HDL) cholesterol

The mean initial serum HDL cholesterol levels in groups A, B and C were 46.1, 44.6 and 45.5 mg/dl and at the end of third month, the values

increased to 51.4, 50.3 and 47.6 mg/dl, respectively. The differences between the two experimental groups were not statistically significant, but the differences were highly significant, when compared to the control group (Table 4).

Low density lipoprotein (LDL) cholesterol

Mean initial serum low density lipoprotein (LDL) cholesterol levels in groups A, B and C were 192.0, 220.5 and 191.8 mg/dl, respectively and at the end of three months, the levels were reduced to 132.8, 121.7 and 178.7 mg/dl, respectively. The highest reduction in LDL cholesterol was observed in the group supplemented with four grams of *Spirulina*. All the comparisons made among the three groups showed highly significant differences ($P \leq 0.01$) (Table 5).

Very low density lipoprotein (VLDL) cholesterol

The mean initial levels of the VLDL cholesterol for the three groups were almost similar viz., 44.0, 44.7 and 43.5 mg/dl, respective;ly. All the three mean values were above the normal levels of 35 mg/dl. It was encouraging to find that *Spirulina* supplementation had brought down the VLDL cholesterol levels to 34.4 mg in group A and 34.3 mg in group B, while a very slight reduction of 0.8 mg was recorded in group C. The differences

TABLE 4. CHANGES IN THE HDL CHOLESTEROL LEVELS OF THE SUBJECTS (n = 10)

Groups	HDL cholesterol, mg/dl Initial	Final	Difference	Groups compared	't' test
A	46.1±	51.4±	5.3±	A vs B	0.63^{NS}
	4.95	4.48	1.42		
B	44.6±	50.3±	5.7±	A vs C	5.57**
	3.61	3.20	1.41		
C	45.5±	47.6±	2.1±	B vs C	6.27**
	3.91	4.25	1.14		

** - highly significant ($p \leq 0.01$)
NS - Not significant ($p > 0.05$)

TABLE 5. CHANGES IN THE LDL CHOLESTEROL LEVELS OF THE SUBJECTS (n = 10)

Groups	LDL cholesterol, mg/dl Initial	Final	Difference	Groups compared	't' test
A	192.10±	132.8±	59.2±	A vs B	10.81**
	15.90	14.50	6.63		
B	220.5±	121.7±	98.8±	A vs C	16.94**
	27.19	25.39	9.51		
C	191.8±	178.7±	13.1±	B vs C	24.69**
	20.18	21.32	5.49		

** - highly significant ($p < 0.01$)

TABLE 6. CHANGES IN THE VLDL CHOLESTEROL LEVELS OF THE SUBJECTS (n = 10)

Groups	VLDL cholesterol, mg/dl Initial	Final	Difference	Groups compared	't' test
A	44.0±	34.4±	9.6±	A vs B	1.04^{NS}
	6.86	10.92	1.91		
B	44.7±	34.3±	10.4±	A vs C	13.91**
	6.75	6.75	1.50		
C	43.5±	42.7±	0.8±	B vs C	18.83**
	6.41	6.65	0.54		

** - highly significant ($p \leq 0.01$)
NS - Not significant ($p > 0.05$)

observed between the two experimental groups were not statistically significant, while both the experimental groups registered high siginificant differences in VLDL cholesterol reduction, when compared to the control group (Table 6).

Serum glutamic oxalo acetic transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT)

The mean final SGOT and SGPT levels observed among the three groups of subjects were found to be normal (Table 7), showing *Spirulina* supplementation did not cause any damage to the heart and the liver.

The results of the present study reveal that *Spirulina* plays a very impressive role in weight reduction, in lowering the blood cholesterol levels and in improving the lipid profiles of individuals. *Spirulina* contains 5 to 6% essential fatty acids of which gamma linolenic acid and linolenic acid account for approximately 30% (Grattan 1989). It can prevent fat and cholesterol accumulation. Gamma linolenic acid is approximately 170-fold more effective in lowering the plasma cholesterol level than linolenic acid (Nichols and Wood 1986).

Gamma linolenic acid is not present very much in the diet. However, linolenic acid can be converted to gamma linolenic acid in the presence of an enzyme Delta-6-desaturase. This enzyme is not active in some individuals. Moreover, it is inhibited by a high saturated fat in the diet. But, *Spirulina* has got preformed gamma linolenic acid and linolenic acid (Seshadri and Seshagiri 1986; Richmond 1988; Hendrickson 1989).

TABLE 7. ACTIVITY OF LIVER ENZYMES

Groups	SGOT, units/dl	SGPT, units/dl
A	21.1	16.7
B	19.4	15.5
C	21.1	18.6

It can be concluded that supplementation of *Spirulina* tablets resulted in very significant beneficial effects including weight reduction, fall in the levels of blood cholesterol, TG, LDL, VLDL cholesterol and elevation of HDL cholesterol. Four grams of *Spirulina* supplementation had exerted more beneficial effects than the two grams, in reducing serum cholesterol and LDL cholesterol levels.

In addition, *Spirulina* has a higher content of all essential and non-essential amino acids including L-phenylalanine and L-tyrosine, which directly influence the levels of neurotransmitters (norepinephrine and dopamine) in the brain, which control appetite (Challem 1981; Lee 1984). This might be one of the reasons for weight reduction, resulting from *Spirulina* supplementation. The polyunsaturated fatty acids that are present in *Spirulina* help to reduce serum cholesterol levels on a long term basis. By virtue of this three-fold effect, weight and cholesterol reduction could be achieved (Seshadri and Seshagiri 1986).

Acknowledgements

The authors express heartfelt gratitude to New Ambadi Estates Private Limited, Algal Division, Madras (A member of Murugappa Group) for sponsoring the present investigation through a free supply of *Spirulina* tablets. They are grateful to Dr. Marimuthu, Dean, Coimbatore Medical College, Dr. Santharam, Medical Superintendent, ESI hospital, Coimbatore and Dr. Sundaresan, Madras for encouragement and facilities. Also sincere thanks are due to Dr. L.V. Venkataraman, Central Food Technological Research Institute, Mysore, for valuable advice and guidance.

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Received 11 January 1995; revised 19 January 1996; accepted 27 January 1996