Indian J Med Res 81, February 1985, pp 162-168

Effect of whole buckwheat (*Fagopyrum esculentum*) flour supplementation on lipid profile & glucose tolerance

R.L. Bijlani, B.M. Gandhi, M.C. Gupta, Sarita Manocha & B.N. Tandon

Department of Physiology & Human Nutrition Unit
All India Institute of Medical Sciences, New Delhi

Revised article received August 21, 1984

Serum lipid profile and glucose tolerance of volunteers consuming buckwheat (*F. esculentum*) was studied in 2 phases lasting 12 and 4 wk respectively. The pooled 4 wk results showed a significant rise in HDL cholesterol/total cholesterol ratio, VLDL cholesterol, VLDL as well as LDL triglycerides. HDL triglycerides showed a significant fall. There was a fall in fasting blood sugar while oral glucose tolerance improved. The effects of buckwheat on lipoprotein metabolism and glucose tolerance appear to be favourable.

Buckwheat (*Fagopyrum esculentum*) is a coarse millet used mostly in the form of flour[1]. The flour may be rolled and stuffed with potato (known as *paronthas*), or made into bread, pancakes, porridge or a dessert. In India, buckwheat is grown as a minor crop, and is commonly consumed in some regions during prolonged 'religious' fasts. Its crude fibre content is 8·6 per cent as compared to 0·2, 1·9, 1·6 and 1·2 per cent in case of rice, whole wheat flour, *jowar* and *bajra* respectively[2]. In recent years, several studies have suggested that dietary fiber reduces serum cholesterol[3,4]. More recent studies also indicate selective effects of fibre on certain lipoprotein fractions[5,6]. There are also reports, however, which deny any hypolipidaemic effect of fiber[7,8]. Reports on the effects of dietary fibre on glucose tolerance have been more consistent in showing improved tolerance in normal as well as diabetic subjects as a result of high fiber intake[9,10]. In view of the high dietary fibre content of buckwheat, we decided to study its effects on the lipid profile and glucose tolerance.

Material & Methods

The study was carried out on human volunteers who had been explained the nature of the study. The design of the study was in accord with the standards of the Ethics Committee of the All India Institute of Medical Sciences, New Delhi. Informed signed consent was obtained from each subject. The first phase of the study lasted 12 wk, and the second phase four wk, there being an interval of about eight wk between the two phases.

Subjects : Eight healthy young male volunteers (age 19-23 yr, weight 46-66 kg) from the student population, and two hyperlipidemic patients went on to complete phase I of the study. However, only seven of the healthy volunteers reported for the 4 wk blood sample. In the second phase, there were nine healthy young male volunteers (age 18-34 yr, weight 49-66 kg). Phases I and II had three subjects in common.

Diet : The subjects were asked to replace their cereal intake at breakfast, partially or completely, by a preparation (*i.e.*, two *paronthas*) made from 100 g whole buckwheat flour. The dough for the preparation was made in boiled potato with minimal quantity of water. It was rolled into a 3-4 mm thick round *chapatie* which was cooked, on a flat hot plate, using groundnut oil. The daily diet during the study remained the same in all other respects, asi t was prior to the study. Since the vo! unteers were dining in a hostel mess, we expected a high degree of uniformity and regularity in food intake.

Estimation of various parameters : All subjects underwent a routine clinical examination at the beginning of the study. Haemoglobin, erythrocyte sedimentation rate and some parameters of liver function were also measured at the beginning and the end of the study.

Serum lipid fractions were determined at the beginning of the study, and at 4 wk interval in phase I, and at 2 wk interval in phase II. The levels reported here are the mean of two fasting blood samples taken on consecutive days. The lipid fractions were separated by the dual precipitation method of Wilson and Spiger[11]. Cholesterol was determined by the ferric chloride method of Chiamori and Henry[12], and triglycerides according to van Handel and Zilversmit[13].

Five of the normal volunteers during each phase were also subjected to the glucose tolerance test at the beginning and the end of the study. The test was performed by oral administration of 100 g glucose in the form of 25 per cent ice-cold solution, flavoured with lemon juice. Venous blood samples were drawn for glucose estimation just before, and 0·5, 1·0 and 1·5 h after ingestion of glucose. Blood glucose was determined by the o-toluidine method[14].

The dietary fiber content of buckwheat was determined by acid and neutral detergent extraction[15].

Analysis of results : Lipid profile, fasting glucose and glucose tolerance after being on buckwheat were compared with those at the beginning of the study using the t-test for paired data, each subject serving as his own control. In addition, we also had earlier data on seven of the subjects regarding the changes in lipid profile over a period of 4 wk during the same part of the year as phase II of this study while the subjects were on a diet which was similar in all respects except that it lacked buckwheat. These figures provided additional control data for the present study.

Results

The acceptability of the buckwheat preparation was fair. It was impossible to chew the hard husk which had to be therefore swallowed whole with the aid of curds (yogurt) and water. The husk was apparently excreted unchanged in the faecal matter. No side effect except a (beneficial) loosening of the stool was reported by the volunteers while on the study.

The fibre content of whole buckwheat flour (per 100 g) was found to be as follows: neutral detergent fibre (total cell wall content), 32·6 g, and acid detergent fibre (cellulose and lignin), 17·5 g.

There was no significant change in body weight, liver function tests or haemoglobin level during either of the phases of the study.

Serum lipid profile : The serum lipid profile during the two phases is given in the Table. The pooled results of both phases have been depicted in Fig. 1. The significant changes after 4 wk of buckwheat supplementation were a rise in high-density lipoprotein cholesterol (HDL_C)/total cholesterol (Chol) ratio, very low-density lipoprotein triglycerides ($VLDL_{TG}$) and low density lipoprotein triglycerides (LDL_{TG}) and a fall in high-density lipoprotein triglycerides (HDL_{TG}). There was a distinct trend towards fall in low-density lipoprotein cholesterol (LDL_C), rise in HDL_C and hypertriglyceridemia.

When individual responses of the 16 normal volunteers and two hyperlipidemic patients were plotted, only in four out of 18 subjects serum cholesterol was found to rise, and only in three out of 18 the HDL_C/Chol ratio declined.

Comparison of changes during buckwheat supplementation with those on a comparable diet without buckwheat supplementation in some of the same subjects showed significant hypertriglyceridaemia during the control phase also (Fig. 2).

Table. Serum lipid profile in normal volunteers before and after varying periods of buckwheat supplementation (Data are mean ± SD)

Parameter	Phase I				Phase II		
	0 wk (n=9)	4 wk (n=7)	8 wk (n=8)	12 wk (n=8)	0 wk (n=9)	2 wk (n=9)	4 wk (n=9)
Cholesterol (mg/dl)	176·0±27·0	167·3±31·2	177·1±24·2	170·5±16·5	188·9±28·8	185·4±36·7	180·6±28·0
$VLDL_C$ (mg/dl)	55·9±22·9	47·6±24·7	60·9±21·4	41·1±10·4	45·3±21·1	41·2±20·6	55·1±11·8
LDL_C (mg/dl)	80·4±27·7	80·1±31·0	71·1±11·1	88·5±10·9	110·3±20·3	103·4±30·2	86·4±29·8
HDL_C (mg/dl)	39·3±7·4	39·1±7·3	44·6±6·1	40·5±5·1	33·0±11·6	40·0±8·4	38·4±5·6
HDL_C/cholesterol (%)	22·6±4·7	23·6±3·6	25·4±3·6	23·7±1·9	17·5±5·5	22·1±5·0	21·7±4·3
Triglycerides (mg/dl)	88·6±16·4	102·6±41·4	130·0±52·0	79·2±15·0	65·1±12·3	65·4±20·2	82·9±29·3
$VLDL_{TG}$ (mg/dl)	32·2±15·1	40·9±16·0	53·4±47·0	27·6±11·4	12·4±11·7	16·0±8·3	29·3±15·6
LDL_{TG} (mg/dl)	15·1±5·3	36·6±39·4	23·1±14·7	16·6±14·8	7·0±7·2	17·8±8·6	18·0±16·9
HDL_{TG} (mg/dl)	40·3±19·7	24·9±8·5	53·1±12·0	34·5±17·8	45·3±11·9	31·1±26·3	35·0±18·8

C, cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; VLDL, very low-density lipoprotein

Glucose tolerance : Fasting blood glucose was monitored in every subject during phase II. The level declined from 78·1 ± 9·2 mg/dl to 75·5±6·6 mg/dl at 2 wk, and further fell to 69·9±8·4 mg/dl at 4 wk. Neither of these changes was statistically significant, although the trend at 4 wk was suggestive ($P<0·1$).

Oral glucose tolerance test revealed a lower blood glucose level during all stages of the test performed at the end of the study (Fig. 3). The tolerance curves revealed that the rise in blood glucose was equally steep during the first half hour in both the curves, but the fall during 0·5-1·0 h was steeper after buckwheat supplementation.

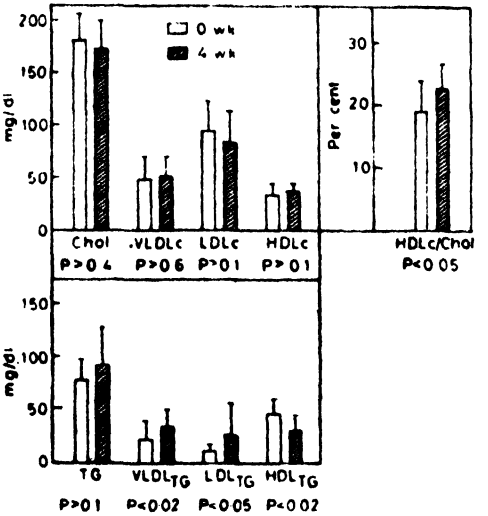

Fig. 1. Changes in lipoprotein profile in healthy volunteers after 4 wk of buckwheat supplementation (pooled results of phases I and II, n=16).

Discussion

The results of the two phases of the study (Table) revealed interesting data. During phase I, mean cholesterol declined from 176·0 mg/dl to 167·3 mg/dl at 4 wk, but again increased to 177·1 mg/dl at 8 wk. Mean HDLc/cholesterol ratio rose from 22·6 to 25·4 per cent at 8 wk, but again declined to 23·7 per cent at 12 wk. Thus it seems that the lipid profile changes brought about by dietary alteration appear by 4 wk, as reported earlier[5], and that further prolongation of the study may, in

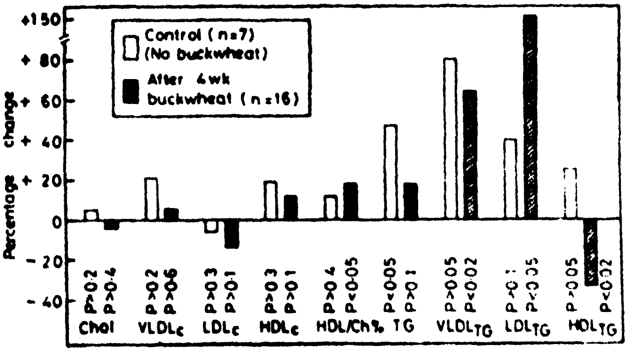

Fig. 2. Lipid profile changes during the control phase when the subjects had no buckwheat compared to the changes during the phases when they had buckwheat. The control phase subjects were in common with some of the subjects during either phase I or phase II of the buckwheat study.

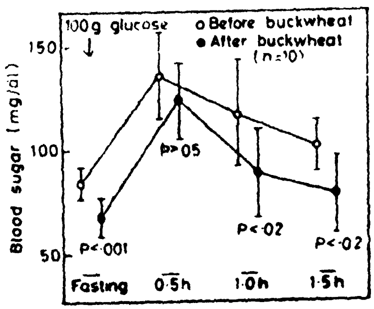

Fig. 3. Glucose tolerance test before and after prolonged buckwheat supplementation. Five subjects underwent the test during phases I and five during phase II. The changes during phases I and II represent the effects of taking buckwheat for 12 and 4 wk respectively. The results of both phases have been pooled in this graphic presentation because they were qualitatively similar.

fact, confuse the picture. It was in view of these findings that phase II of the study was designed for only 4 wk. The confusing picture emerging in the 12 wk study is perhaps due to the following at least three confounding factors introduced by prolongation of the study : (*i*) When the study continues for 12 wk, the season changes. Seasonal changes in lipid profile are well-documented[16,17]; (*ii*) it is likely that subject compliance declines towards the later part of a prolonged study; and (*iii*) the volunteers being students, the 12 wk study was designed to fit into the academic calendar. The study ended towards the end of the term when the examinations were very close. Examination stress can affect lipid profile as reported earlier[18]. While all these confounding factors appear to be important, one cannot rule out other mechanisms that bring about adaptation to the new foodstuff and restore the lipid profile to the initial phase in a prolonged study.

Bremner *et al*[19] also reported that the effects of bran on serum lipids were more significant at 2 months than at 3 months. Their other results were also similar to ours, including the tendency for LDL_c to fall, and HDL_c and triglycerides to rise. The fact that LDL_c, HDL_c and HDL_c/cholesterol have been affected more than total cholesterol is consistent with recent studies reporting selective effects on certain lipoprotein fractions[5,6]. On plotting individual responses of serum cholesterol and HDL_c/cholesterol ratio, the trend became more encouraging bringing out more clearly the trend of serum cholesterol to fall and for HDL_c/cholesterol to rise. The statistical significance of pooled results was less revealing because not only the magnitude but also the direction of response showed individual variation. A few individuals whose responses did not conform with the general pattern account for the large dispersion and poor statistical significance. More than three-fourths of the individuals responded by a fall in serum cholesterol and rise in HDL_c/cholesterol ratio, *i.e.*, by changes reported to be protective against atherosclerosis[20].

The elevation of triglycerides may be related to other dietary changes associated with buckwheat supplementation. Although the diet was not analysed, food intake before and during the study was assessed by the questionnaire method. The only difference during the study was replacement of 4 slices of bread and 10 g of butter by 2 *paronthas* containing 100 g buckwheat, 50 g potato and 20 g cooking oil. According to published Tables[2], the composition of bread and butter is as follows : carbohydrate 56 g, protein 10 g, fat 9 g, and energy 345 cal; and the composition of buckwheat *paronthas* is : carbohydrate 76 g, protein 11 g, fat 22 g, and energy 546 cal. Thus the overall caloric intake as well as fat intake during buckwheat supplementation was higher. These changes have been reported to raise serum triglyceride levels[21].

The improvement in glucose tolerance in the present study reflects a long term effect of prolonged intake of buckwheat. The fasting blood sugar was lower but the change in blood sugar 0·5 h after oral ingestion of 100 g glucose was of the same order as at the beginning of the study. This suggests that the absorption of glucose is neither impaired nor delayed. But the fall in blood sugar during the period 0·5-1·0 h was much faster after the subject had been placed on buckwheat diet for a few weeks. This suggests an enhanced sensitivity of beta cells to glucose or of peripheral tissues to insulin or both[22]. Similar long term effects of dietary fibre on glucose tolerance have been reported by others[23]. Jenkins *et al*[24] however, failed to observe a similar effect after administration of pectin for six weeks. It is possible that components of fibre other than pectin may be responsible for this effect.

One major question that cannot be answered from our data is the extent to which the observed changes can be attributed to the high fibre content of buckwheat. The amino acid composition of buckwheat protein also suggests that it may be hypolipidemic, as has been postulated for soy protein[25]. High arginine/lysine ratio which has been postulated to be the characteristic responsible for the hypolipidemic effect, is 0·44 for milk proteins, 1·12 for soy protein and 1·90 for buckwheat protein[2]. According to this criterion, buckwheat is likely to be even more hypolipidemic than soybean. There also always remains the possibility that some minor component of buckwheat, present in only minute amounts, may be responsible, at least partly, for some of the observed changes.

Acknowledgment

The study reported here was supported by a grant-in-aid from the All India Institute of Medical Sciences, New Delhi. The technical assistance of Shriyuts Nahar Singh and Gurdeep Singh is acknowledged with appreciation.

References

1. *The wealth of India*, vol. IV (Council of Scientific and Industrial Research, New Delhi) 1956 p 1.
2. Gopalan, C., Rama Sastri, B.V. and Balasubramanian, S.C. *Nutritive value of Indian foods* (National Institute of Nutrition, Indian Council of Medical Research, Hyderabad) 1971.
3. Anderson, J.W., Chen, W.L. and Sieling, B. Hypolipidaemic effects of high-carbohydrate, high-fiber diets. *Metabolism* 29 (1980) 551.
4. Mahalko, J.R., Sandstead, H.H., Johnson, L.A.K., Inman, L.F., Milne, D.B., Warner, R.C. and Haunz, E.A. Effect of consuming fiber from corn bran, soy hulls, or apple powder on glucose tolerance and plasma lipids in type II diabetes. *Am J Clin Nutr* 39 (1984) 25.
5. Asp, N.G., Bauer, H.G., Nilsson-Ehle, P., Nyman, M. and Oste, R. Wheat bran increases high density lipoprotein cholesterol in the rat. *Br J Nutr* 46 (1981) 385.
6. Kirby, R.W., Anderson, J.W., Sieling, B., Rees, E.D., Chen, W.L., Miller, R.E. and Kay, R.M. Oat-bran intake selectively lowers serum low-density lipoprotein cholesterol concentrations of hypercholesterolaemic men. *Am J Clin Nutr* 34 (1981) 824.
7. Ullrich, I.H. and Albrink, M.J. Lack of effect of dietary fiber on serum lipids, glucose and insulin in healthy young men fed high starch diets. *Am J Clin Nutr* 36 (1982) 1.
8. Liebman, M., Smith, M.C., Iverson, J., Thye, F.W., Hinkle, D.E., Herbert, W.G., Ritchey. S.J. and Driskell, J.A. Effects of coarse wheat

bran fiber and exercise on plasma lipids and lipoproteins in moderately overweight men. *Am J Clin Nutr* 37 (1983) 71.

9. Jenkins, D.J.A., Wolever, T.M.S. and Leeds, A.R. Dietary fibres, fibre analogues and glucose tolerance : Importance of viscosity. *Br Med J* 1 (1978) 1392.

10. Ray, T.K., Mansell, K.M., Knight, L.C., Malmud, L.S., Owen, O.E. and Boden, G. Long-term effects of dietary fiber on glucose tolerance and gastric emptying in noninsulin-dependent diabetic patients. *Am J Clin Nutr* 37 (1983) 376.

11. Wilson, D.E. and Spiger, M.J. A dual precipitation method for quantitative plasma lipoprotein measurement without ultracentrifugation. *J Lab Clin Med* 82 (1973) 473.

12. Chiamori, N. and Henry, R.J. Study of the ferric chloride method for determination of total cholesterol and cholesterol esters. *Am J Clin Pathol* 31 (1959) 305.

13. Van Handel, E. and Zilversmit, D.B. Micromethod for the direct determination of serum triglycerides. *J Lab Clin Med* 50 (1957) 152.

14. Pilleggi, V.J. and Szustkiewicz, C.P. In : *Clinical chemistry: principles and technics*, 2nd ed., R.J. Henry, D.C. Cannon and J.W. Winkleman, Eds (Harper and Row, Hagerstown) 1974 p 1285.

15. Arora, S.K. Analytical techniques for quality evaluation. *Forage Res* 7A (1981) 197.

16. Doyle, J.T., Kinch, S.H. and Braon, D.F. Seasonal variations in serum cholesterol concentration. *J Chronic Dis* 18 (1965) 657.

17. Bhagwan, S. and Gupta, S.P. Effect of environmental temperature on serum lipids. *Indian Heart J* 28 (1976) 108.

18. Thomas, C.B. and Murphy, E.A. Further studies on cholesterol levels in the Johns Hopkins medical students: the effects of stress at examination. *J Chronic Dis* 8 (1958) 661.

19. Bremner, W.F., Brooks, P.M., Third, J.L.H.C. and Lawrie, T.D.V. Bran in hypertriglyceridaemia : a failure of response. *Br Med J* 3 (1975) 574.

20. Kannel, W.B., Castelli, W.P. and Gordon, T. Cholesterol in the prediction of atherosclerotic disease : new perspectives based on the Framingham Study. *Ann Intern Med* 90 (1979) 85.

21. Antonis, A. and Bersohn, I. The influence of diet on serum triglycerides. *Lancet* I (1961) 3.

22. Vahouny, G.V. Conclusions and recommendations of the symposium on "Dietary Fibers in Health and Disease", Washington, D.C., 1981. *Am J Clin Nutr* 35 (1982) 152.

23. Munoz, J.M., Sandstead, H.H., Jacob, R.A., Logan, G.M. and Klevay, L.M. Effects of some cereal brans on glucose tolerance and plasma lipids of normal men. *Fed Proc* 37 (1978) 755.

24. Jenkins, D.J.A., Leeds, A.R., Houston, H., Hinks, L., Alberti, K.G.M.M. and Cummings, J.H. Carbohydrate tolerance in man after six weeks of pectin administration. *Proc Nutr Soc* 36 (1977) 60 A.

25. Nagata, Y., Imaizumi, K. and Sugano, M. Effects of soybean protein and casein on serum cholesterol levels in rats. *Br J Nutr* 44 (1980) 113.

Reprint requests : Dr R.L. Bijlani, Department of Physiology, All India Institute of Medical Sciences, Ansari Nagar, New Delhi 110029