JOURNAL OF PURE AND APPLIED MICROBIOLOGY, June 2012. Vol. **6**(2), p. 773-780

Glycaemic Index and Blood Glucose Responses of Type 2 *Diabetes mellitus* and Healthy Subjects to Rice and Beans Meal

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(Received: 28 September 2011; accepted: 10 December 2011)

The study was carried out to determine the blood glucose response and glycaemic index (GI) of rice/beans for diabetics and non-diabetics. The subjects comprised of 10 diabetics and 6 non-diabetics. Feeding of glucose was repeated twice and test meal was administered only once. The meals (test meal) contained 50 grams of carbohydrate and are made up of rice, beans, tomatoes and palm oil with meat, while 50 grams of glucose was used as the standard food. The GI for rice and beans was taken as the average of the 10 values for type-2 diabetic subjects and 6 values for the controls. Glycaemic index of rice/beans was 59 in the type-2 diabetic while it was 60 in the healthy individuals. The glycaemic loads of this meal were 29.5 and 30 for diabetic and healthy subjects respectively. The glycaemic index of rice and beans is within the moderate group while the glycaemic load of the meal is high. Processing of food and how they interact with each other may have profound effect on the glycaemic index of the meal. It is recommended that rice and bean should be eaten by diabetics when the grains are intact rather than when mashed.

Key Words: Rice, Beans, Type 2 diabetes, Glucose, Glycaemic index, Glycaemic load, Blood glucose response.

Cowpea (*Vigna unguiculata* [L.] Walp) commonly referred to as black eye peas in the United States of America, is a staple food crop of significant economic importance worldwide. This crop serves to bridge the hunger gap between the planting and harvesting periods of the main food crops. Cowpea is regarded as a popular and an important indigenous African food legume crop by many rural communities living in less developed countries of tropical and sub-tropical Africa, most especially West and Central Africa and this region represents over 66% of the 12.5 million hectares grown worldwide with an annual production of over 3 million tones of grains worldwide (Singh *et al.*, 1997). Part of the popularity of cowpea as a food staple for people in the semi-arid and humid tropical regions of Africa stems from the fact that it is relatively drought-tolerant, performing well under conditions where most other food legumes do not. Its unique ability to fix nitrogen even in very poor soils with low organic matter also contributes to its widespread use among farmers (Singh *et al.*, 1997).

Cowpea has the potential to contribute to food security and poverty reduction in West Africa. The demand for cowpea in this region is increasing because of high population growth, mainly from the urban areas, and also because of poverty and the demand for low-cost food. The high protein content (20-25%) of cowpea and its use as a staple in the diets of Sahelian and coastal populations make it also a crop with high potential

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for food security in these regions. Cowpea is especially rich in lysine, but is deficient in sulfurous amino acids. Compared to other legumes, methionine and tryptophan levels are high. Except for total sulfurous amino acids, and to a lesser extent isoleucine, levels of essential amino acids are at least as high as those in soybean. The protein which is rich in lysine but poor in methionine and cystine can be used to complement cereal proteins which have low lysine but high methionine and cystine (Bressani, 1975) or the quality of cowpea products can be increased significantly by combining it with milk protein and/or other sources known for their high methionine and cystine content (Boulter *et al.*,. 1975).

In Nigeria cowpea is usually eaten with other foods such as rice, yam maize, cocoyam, bread, plantain and vegetables as part of the diet. In many areas, rice and beans are often served side by side or mixed together. Either way, they are considered a meal, because other ingredients such as meat, fish, crayfish or chicken are added. Recently, cowpea has been cited for imparting specific positive health potentiating responses (hypocholesterolaemic response, prevention of diabetes and colonic cancer, and weight control) when properly positioned in the diet. Dietary fibre's viscous and fibrous structure can control the release of glucose with time in the blood, thus helping in the proper control and management of diabetes mellitus and obesity (Creutzfeldt 1983; Jenkin *et al.,* 1982).

The glycaemic index (GI), a classification of food based on the blood glucose response relative to a starchy food, for example, white bread, or a standard glucose solution, has been proposed as a therapeutic principle for diabetes mellitus by slowing carbohydrate absorption (Creutzfeldt 1983; Jenkin *et al.,* 1982). Low-GI foods, for example, high-dietary fibre foods, have been shown to reduce postprandial blood glucose and insulin responses and improve the overall blood glucose and lipid concentrations in normal subjects and patients with diabetes mellitus (Collier *et al.,* 1988; Fontvielle *et al.,* 1988; Brand *et al.,* 1991; Wolever *et al.,* 1992a and b).

The general objective of the present study is to determine the glycaemic index and load of cowpea and rice as a common meal in Nigeria. The specific objectives are to determine: (a) the insulin index of the meal in non-diabetic and diabetic human subjects; (b) the GI of rice and cowpea from non-diabetic and diabetic human subjects; (c) the Glycaemic load in non-diabetic and diabetic human subjects.

METHODS

Study participants

Non-diabetic (n 6) and diabetic (n 10) human subjects (type 2, non-insulin-dependent diabetes mellitus) were physically examined by a medical doctor and evaluated by an endocrinologist on the basis of the following criteria: non-diabetics: fasting blood glucose 4–7 mmol/l, aged 35–60 years, no physical defect and non-smokers; diabetics: fasting blood glucose 7·5–11·0 mol/l, aged 35–60 years, no intake of drugs other than diabetics, no complications and non-smokers. Each subject was interviewed for physical activity. The participants gave their consent after being fully informed about the experimental nature of the study. The diabetic subjects on drugs were instructed to avoid the drugs for one week before the commencement of the study. To ensure compliance, blood glucose level was monitored thrice that week. Information on age, sex, anthropometric measurements and the type of drugs used and how long they have been diagnosed were collected from the subjects. All procedures were described in a protocol submitted to and approved by the scientific and ethical committee of Ahmadu Bello University Teaching Hospital, Shika - Zaria, Nigeria.

Protocol of the study

Inclusion criteria

Eligible subjects were between the ages of 35 and 75, must be physician diagnosed with type 2 diabetes for at least six (6) months and currently controlling their blood glucose levels using dietary methods, exercise and/or through the use of oral hypoglycemic agents such as Metformin for at least three(3)months.

Exclusion criteria

Exclusion criteria included: the presence of unresolved health issues (e.g. hypertension not controlled by medication), evidence of condition(s) that would influence the participant's ability to complete the study such as gastrointestinal disease, weight changes of e"10% of the participants body weight within a 6 month period, women who are either pregnant or breastfeeding, allergy to beans, and the inability to follow study protocol.

Using a randomized cross-over design, the control and test foods were fed in random order on separate occasions after an overnight fast. The control and test foods contained 50 g available carbohydrates. The participants were told to fast overnight (8 -10h) before the start of the study. Glucose was used as a reference food. Feeding of glucose was repeated twice and test meal was administered only once. The meals (test meal) contained 50 grams of carbohydrate and are made of rice, beans, tomatoes and palm oil with meat, while 50 grams of glucose was used as the standard food. The percentage composition of carbohydrate, protein and fat of the test meal was within recommended range as advised by World Health Organization (WHO, 1985; WHO, 1990).

On the day of the metabolic studies, fasting venous blood was drawn from each subject, then the standard food (glucose) or the test food (rice and beans) meal was served. They were instructed to consume the entire meal within 10-15 minutes, after the meal was consumed the time was noted as 0 time. At 30, 60, 90, 120 and 150 minutes, 2mls of venous blood samples were collected. The blood samples were allowed to clot for 10-15 minutes at room temperature and the serum was separated immediately from the blood using a centrifuge. Blood glucose levels were analyzed on the same day using glucose oxidase method (Trinder, 1969). Both non-diabetic and diabetic participants were treated the same way.

Calculation of Glycaemic Index (GI) and Glycaemic Load (GL)

The area under the glucose response curve for each food, ignoring area below the fasting level, was calculated (Wolever *et al.*, 1991). The GI of each food was expressed as the percentage of the mean glucose response of the test food divided by the standard food taken by the same subject. Each subject's individual GI for each food was calculated. The GI for rice and beans was taken as the average of the 10 values for type-2 diabetic subjects and 6 values for the controls. The glycaemic load was calculated as carbohydrate content of food in percentage multiplied by the glycaemic index.

Statistical Analyses

The blood glucose responses, incremental value and peak value of the reference and the meal were compared using a paired student's t test within the group. Unpaired student's t test was used between the diabetics and control subjects. Significant level was taken as $p<0.05$.

RESULTS

The mean ages of the study group in both diabetic and control subjects were 51.30±2.64years and 52.33±2.75years respectively. There was no significant difference between them. The body mass index of the diabetic and the control groups were 31.46±1.78kg/m^2 and 28.27±1.66kg/m^2 respectively and they were also similar. The mean duration of the disease in the type-2 diabetics was 3.10 ±0.41 years (Table 1).

In the diabetics, the blood glucose response to glucose and rice/beans were significantly lower from 30-150 minutes while rice/beans had insignificant effect on blood glucose in the healthy group (Tables 2). The incremental value of glucose and rice/beans in type-2 diabetics was significantly lower at 30, 60, 90, and 120 and 150 minutes after rice beans consumption while it was not significant in the healthy subjects (Table 2). When the incremental value of the diabetic and

Table 1. Parameters of participants with glycaemic index and glycaemic load of Rice/beans meals fed to diabetic and control subjects

	Age (years)	BMI (Kg/m^2)	Duration	Glycaemic index	Glycaemic load
Diabeticsubjects	51.30±2.64	31.46±1.78	3.10±0.40	58.99±8.76	29.5
Control Subjects	52.33±2.75	28.27±1.66	N/A	60.22±18.31	30.0

Values are means ± SD. N/A = Not applicable

Table 2. Blood glucose responses and increments to glucose and rice/beans meal in diabetic and healthy subjects

Time (Min)	Diabetic Subjects				Control Subjects			
	Glucose Solution		Rice/Bean Meal		Glucose Solution		Rice/Bean Meal	
	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)
0	6.70±1.09	6.22±0.86	4.20±0.20	4.27±0.25				
30	11.37±1.08[a]	4.67±0.61[b]	9.61±1.06[a]	3.39±0.63[b]	6.63±1.06	2.43±0.93	6.12±0.64	1.85±0.46
60	14.51±1.45[c]	7.87±0.99[d]	11.19±1.31[c]	4.97±0.62[d]	7.28±0.71	3.08±0.59	5.43±0.33	1.17±0.46
90	15.11±1.82[e]	8.41±1.11[f]	10.63±1.46[e]	4.41±0.93[f]	6.57±0.86	2.37±0.75	5.70±0.19	1.43±0.18
120	13.32±1.82[g]	6.62±1.21[h]	10.00±1.41[g]	3.78±0.85[h]	6.18±0.91	1.98±0.83	5.33±0.29	1.27±0.23
150	12.38±1.77[k]	5.68±1.22[m]	8.90±1.46[k]	2.68±0.85[m]	4.70±0.33	0.50±0.44	4.92±0.26	0.65±0.14

Values in mmol/L are means ± SD. Values in the same row with same superscripts are significantly different ($p<0.5$). Blood glucose concentration at time 0 min corresponds to Fasting blood sugar (FBS). Incremental glucose means increment in blood glucose concentration over fasting blood glucose.

healthy subjects for rice/beans were compared it was significantly lower from 60-150 minutes in healthy than diabetic subjects. The diabetic subjects got to the peak of blood glucose response at 90 minutes when glucose was taken and it was 60 minutes when rice/beans was eaten, while the healthy subjects was at 60 and 30 minutes after consumption of glucose and rice/beans respectively (Table 2). The maximum increase in blood glucose after consumption of glucose and rice/beans in diabetic subjects was 8.41±1.11mmol/L and 4.97±0.62mmol/L respectively and it was significantly lower when rice /beans was consumed; while it was 3.08±0.59mmol/L and 1.85±0.46mmol/L for glucose and rice/beans respectively in healthy subjects ($p<0.05$) and the difference was highly significant. The maximum increase was significantly lower in healthy than diabetic subjects after consumption of rice/beans. Glycaemic index of rice/beans was 59 in the type-2 diabetic while it was 60 in the healthy individuals. The glycaemic load of this meal was 29.5 for diabetic and healthy subjects (Table 1).

The two-hour postprandial blood glucose in type-2 diabetic subjects after glucose solution and test meals were consumed was 13.32±1.82mmol/L and 10.00±1.41mmol/L and the difference was significantly lower when rice/beans was eaten, but in the healthy subjects, it was 6.18±0.91mmol/L for glucose and 5.33±0.29 mmol/L for the test meal. These values were significantly different when they were compared statistically from each other.

DISCUSSION

Rice and beans is a common meal combination for the rich, poor, educated and none-educated Nigeria. The glycaemic index of rice and beans is within the moderate group. It has been shown by some studies that the actual form in which legumes are usually eaten that is whole cooked seeds is a source of inaccessible fractions that contribute to physiologically indigestible starch bulk (Tovar *et al.*,., 1992a; Botham *et al.*,., 1995). In this study it was expected that the combination of rice and beans would give a low Glycaemic index but it turned out to be medium GI. It is the same rice that gave low GI (Alegbejo *et al.*,

2009) that was used with beans but the combination gave a medium range. This could be due to the moisture content, and the cooking time which probably result in differences in the degree of starch gelatinization and consequently the GI values. The rice and beans were cooked together, but the rice was added just towards the last twenty minutes of the cooking. This indicates that processing of food and how they interact with each other may have profound effect on the glycaemic index of a meal. Previous studies showed that beans, lentils, and legumes had low GI values. The mechanism of the low GI of these food products seem to be because of the soluble fiber, and anti-nutrients available in the foods (Wolever and Bourne, 1990). It was reported by Feskens *et al.* (1991) that consumption of legumes rich in soluble dietary fibre was inversely associated with risk of glucose intolerance. In controlled experiments, diets high in soluble fibre-rich foods (Mann, 1984) or foods with a low glycaemic index are associated with improved diurnal blood glucose profiles as well as long term overall improvement in glycaemic control as evidenced by reduced levels of glycated haemoglobin (Brand *et al.*, 1991).

The GI value of meal may change over time if changes are made in the ingredients or processing methods. Those carbohydrates that have low or moderate glycaemic would also be suitable for diabetes management (Jenkins *et al.*, 1981; Brand-Miller *et al.*, 2003). The Glycaemic load of this meal was high in both diabetics and healthy subjects and it has been reported by several large-scale, observational studies from Harvard University that the long-term consumption of a diet with a high glycaemic load (GL= GI × dietary carbohydrate content) is a significant independent predictor of the risk of developing type 2 diabetes (Salmeron *et al.*, 1997a, Salmeron *et al.*, 1997b) and cardiovascular disease (Liu *et al.*, 2000).

For many years, cereal-legume mixtures, have been recommended as ideal combination to ensure intake of all essential amino acids, especially in vegetarian/developing world diets. A major problem with the glycaemic index diet in most studies is that it ranks foods individually, not based on how they interact with each other. This can result in inaccuracies, because most people do not consume one type of food at a time, but rather a meal of many different types of food. The absorption rate of carbohydrates is based on a number of other factors, including how ripe the food is, how much is eaten, how the food is prepared and any other existing health problems.

The results of controlled clinical trials suggest that increasing bean consumption improves serum lipid and lipoprotein profiles. A meta-analysis that combined the results of 11 clinical trials found that increasing the consumption of dry beans resulted in modest (6-7%) decreases in total cholesterol and LDL-cholesterol (Anderson and Major, 2002). Several characteristics of beans may contribute to their cardioprotective effects. Beans are rich in soluble fiber, which is known to have a cholesterol-lowering effect. Elevated plasma homocysteine levels are associated with increased cardiovascular disease risk, and beans are good sources of folate, which helps to lower homocysteine levels (Anderson and Major, 2002). Beans are also good sources of magnesium and potassium, which may decrease cardiovascular disease risk by helping to lower blood pressure (Anderson and Major, 2002). The low-glycemic index values of beans means that they are less likely to raise blood glucose and insulin levels, which may also decrease cardiovascular disease risk. Though in this study the blood glucose was significantly lower in the diabetics when compared to the healthy subjects, yet the Glycaemic index was moderate. It is necessary to always mentioned the Glycaemic load and the index of this food when mixed with the other foods and that processing may affect the indices of the meal.

A confounding factor of the studies conducted thus far is the use of single foods versus complete meals as the initial or first meal. The fat and protein quantity and quality are known to influence the rate of glucose absorption from a mixed meal (Jenkns *et al.*, 1995). Therefore, the dynamics of immediate and subsequent meal glycemia are more complicated if the initial meal is a complete, mixed meal. It seems that serving a single food as the initial meal would simplify data interpretation except for the fact that, under free living conditions, people rarely, if ever, consume a single, stand-alone food as a meal or snack. The physiological properties of a food change in relation to other components present in a meal, therefore it is important to examine the effects of whole grain and legume consumption as part of a complete meal. Barely 1/3 of studies conducted thus far utilize complete meals for the initial or first meal. Although there is often good agreement between these studies and those utilizing single foods, Wolever *et al.* 1988 showed that lentils fed as a single food decreased glucose area under the curve at a subsequent meal relative to whole wheat bread whereas lentils as part of a complete meal did not.

The effect of food structure was examined by Ja¨rvi *et al.* (1999) in a study where the dietary fibre content was kept constant but the overall dietary glycaemic index (dietary GI) differed between two diets, achieved largely by altering the food structure. O'Dea *et al.*, (1980) found that ground rice meals elicited much higher peak responses of glucose and insulin than meals consisting of whole grains of rice. An effect on glycaemic response is also found when comparing mixed meals having different grain structures. A meal consisting of parboiled rice, whole beans, and bread containing whole wheat grains elicited areas under the plasma insulin and blood glucose response curves that were 39 and 42% lower, respectively, compared with a meal of sticky rice, ground beans and bread made from wholemeal flour (Ja¨rvi *et al.*, 1995). Disruption of intact legumes also has an effect on the rate of carbohydrate digestion. Cooked white kidney beans, lentils and yellow peas had substantially lower *in vitro* starch digestion rates (50–75% lower) compared with ''dry milled and cooked'' pulses (Wu¨rsch *et al.*, 1986). The slower rate of digestion was attributed to the starch being entrapped in fibrous thick celled walls. Similarly, the rate of starch hydrolysis was five-fold greater when using ground cooked lentils compared with cooked mashed whole lentils, while blending the lentils after cooking gave an intermediate rate (Wong and O'Dea, 1983). In this study the subjects chewed the meal before swallowing and also the beans were well cooked. *In vivo*, higher glycaemic and/or insulinaemic responses were found following meals of ground pulses compared with intact pulses (O'Dea and Wong, 1983; Golay *et al.*, 1986).

Thus, food with an intact botanical structure such as rice and beans may delay or render some of the starch unavailable for absorption, indicating that structural disruption of cereal grains and pulses has an effect on carbohydrate metabolism independent of the fibre content.

In the study by Granfeldt *et al.*, (1994), an intact grain structure elicited lower glucose and insulin responses than the ground meals. Thus, the effect on measures of carbohydrate metabolism is determined by the structure and possibly particle size appears to be appreciably greater than the effect of starch type.

REFERENCES

1. Singh, B.B., Mohan, D.R. Raj, K.E. Dashiell, and Jackai, L.E.N. Pages x–xii *in* Advances in cowpea research. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS) 1997. IITA, Ibadan, Nigeria.
2. Bressani, F. Legumes in human diet and how they might improved. *In nutritional Improvement of Food Legumes by Breeding*. M. Miilner (ed). A Wiley Interscience Publication. John Wiley and Sons; New York 1975; Pp. 15-42.
3. Boulter, D, Evan,I.M, Thompson, A. Yarwood,A. The amino acid composition of *vigna unguiculata* meal in relation to nutrition. In proceedings of symposium of Nutritional Improvement of food Legumes by Breeding, edited by M. Milner, 3-5 July 1972, United Nations protein advisory group 1975; New York USA.
4. Creutzfeldt, W. Introduction. In Delaying Absorption as a Therapeutic Principle in Metabolic Diseases, p. 1 [W Creutzfeldt and RU Folsch, editors]. New York, NY 1983: Thiem-Stratton.
5. Jenkins, D.J.A., Ghafari, A., Wolever, T.M.S., *et al.*, Relationship between rate of digestion of foods and post-prandial glycemia. *Diabetologia*, 1982; **22:** 250–255.
6. Collier, G.R., Giudici, S., Kalmusky, J, *et al.*, Low glycemic index starchy foods improve glucose control and lower serum cholesterol in diabetic children. *Diabetes Nutrition Metabolism* 1988; **1**: 11–19.
7. Fontvieille, A.M., Acosta. M., Rizkalla, S.W., *et al.* A moderate switch from high to low glycemic index foods for three weeks improves the metabolic control of type I (IDDM) diabetic subjects. *Diabetes Nutr. Metab.*, 1988; **1**: 139–143.
8. Brand, J. C., Colagiuri, S., Crossman, S., Allen, A., Roberts, D. C. K. and Truswell, A. S. (1991).

Low-glycemic index foods improve long-term glycaemic control in NIDDM. *Diabetes Care*, 1991; **14**: 95-101.

9. Wolever, T.M.S., Jenkins, D.J.A. and Vuksan, V. Beneficial effect of low-glycaemic index diet in overweight NIDDM subjects. *Diabetes Care*, 1992a; **15:** 562-566.

10. 10. Wolever, T.M.S., Jenkins, D.J.A. and Vuksan, V. Beneficial effects of a low-glycaemic index diet in type 2 diabetes. *Diabetic Medicine*, 1992b; **9**: 451-458.

11. 11. W. H. O. WHO study group of Diabetes Mellitus. Technical report series 727, WHO Geneva 1985.

12. W. H. O. Diet Nutrition and the preventing of chronic diseases. Report of WHO expert Committee. Technical report series 797, WHO Geneva, 1990.

13. Trinder, P. Determination of glucose in the blood using glucose oxidase with an alternative oxygen acceptor. *Ann. Biochem.*, 1969; **6**: 24-27.

14. Wolever, T.M.S., Jenkins, D.J.A., Jenkins, A.L. and Josse, R.G. The glycaemic index, methodology and clinical implications. *Am. J. Clin. Nutr.*, 1991; **54**: 846-854.

15. Tovar, J., Björck, I.M. and Asp, N.G. (1992). Incomplete digestion of legumes starches in rats: A study of precooked inaccessible starch fractions. *J Nutri.*, 1992; **122**: 1500-1507.

16. Botham, R. L., Cairns, P., Morris, V. J., Ring, S. G., Englyst, H. N. and Cummings, J. H. A physicochemical characterization of chick pea starch resistant to digestion in the human small intestine. *Carbohydrate Polymers* 1995; **26**: 85–90.

17. Alegbejo, J. O., Ameh, D. A., Ogala W. M. and Ibrahim, S. Glycaemic responses and Glycaemic load of parboiled long grain rice with vegetable/ carrot sauce in healthy and type-2 diabetic subjects. *Biological and Environ. Sci. J Trop.*, 2009; **6(3)**:38- 42.

18. Wolever, T.M.S. and Boume, G.H (eds). The glycemic index. Aspects of some vitamins, minerals and enzymes in health and diseases. *World Rev. Nutr. Diet*, 1990; **62**: 120–185.

19. Feskens, E.J.M., Bowles, C.H. and Kromhout, D. Carbohydrate intake and body mass index in relation to the risk of glucose intolerance in an elderly population. *Am. J. Clin. Nutr.*, 1991; **54**: 136-140.

20. Mann, J.I. Lines to legumes: changing concepts of diabetic diets. *Diabetic Medicine,* 1984; **l**: 19l -199.

21. Jenkins, D. J. A., Wolever, T. M., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., Bowling, A.C., Newman, H.C., Jenkins, A.L. and Goff, D.V. Glycaemic index of foods: a physiological basis for carbohydrate exchange. *Am. J. Clin. Nutr.*, 1981; **34(3)**: 362-366.

22. Brand – Miller, J., Haynes, S., Petocz, P. and Colaquiri, S. Low glycaemic index diets in the management of diabetes: a meta analysis of randomized control trial. *Diabetes Care*, 2003; **26(8)**: 2261 -2267.

23. Salmeron, J., Aseherio, A., Rimm, E.B., Colditz, G.A., Spiegelman, D., Jenkins, D.J., Stampter, M.J., Wing, A.l. and Willet, W.C. Dietary fibre, glycaemic load/index and risk of NIDDM in men. *Diabetes Care*, 1997a; **20(4)**: 545-550.

24. Salmeron, J., Manson, J.E., Stamper, M.J., Colditz, G.A., Wing, A.l. and Willett, W.C. Dietary fibre, glycaemic load and risk of non-insulin dependent diabetes mellitus in women. *J. Am. Med. Assoc.*, 1997b; **227:** 472-477.

25. Liu, S., Willett, W., Stampfer, Hu, F., Franz, M. Sampson, L. and Heinekens, C. A prospective study of dietary glycaemic load, carbohydrate intake, and risk of coronary heart disease in US Women. *Am. J. Clin. Nutr.,* 2000; **71**: 1455-1461.

26. Anderson J.W., Major A W. Pulses and lipaemia, short- and long-term effect: potential in the prevention of cardiovascular disease. *Br. J. Nutr.,* 2002; **88** Suppl 3:S263-271.

27. Jenkins, D. J. Josse, R. G. Jenkins, A. L. Wolever, T. M. and Vuksan, V. Implications of altering the rate of carbohydrate absorption from the gastrointestinal tract. *Clin. and invest. Med.*, 1995; **18(4):** 296-302.

28. Wolever, T.M., Jenkins, D.J., Ocana, A.M., Rao, V.A and Collier, G.R. Second-meal effect: low-glycemic-index foods eaten at dinner improve subsequent breakfast glycemic response. *Am. J. Clin. Nutr.,* 1988; **48(4):** 1041-1047.

29. Jarvi, A.E., Karlstrom, B.E., Granfeldt, Y.E., Bjorch, I.E., Asp, N.G. and Vessby, B.O. Improved glycaemic control and lipid profile and normalized fibrinolytic activity on a low glycaemic index diet in type 2 diabetic patients. *Diabetes Care*, 1999; **22**: 10–18.

30. O'Dea, K., Nestel, P.J and Antonoff, L Physical factors influencing postprandial glucose and insulin responses to starch. *Am. J. Clin. Nutr.,* 1980; **33**: 760–765.

31. Jarvi, A. E., Karlstrom, B. E., Granfeldt, Y. E., Bjorck, I. M., Vessby, B. O. and Asp, N. G. The influence of food structure on postprandial metabolism in patients with non-insulin-dependent diabetes mellitus. *Am. J. Clin. Nutr., 1995;* **61(4)**: 837-842.

32. Wu¨rsch, P., Del Vedovo, S. and Koellreutter,

B. Cell structure and starch nature as key determinants of the digestion rate of starch in legume. *Am. J. Clin. Nutr.*, 1986; **43**: 25–29.

33. Wong, G.S and O' Dea, K. Importance of physical form rather than viscosity in determining the rate of starch hydrolysis in legumes. *Am. J. Clin. Nutr.*, 1983; **37**: 66-70.

34. Golay, A., Coulston, A.M., Hollenbeck, C.B., Kaiser, L.L, Wursch, P. and Reaven, G. M. Comparison of metabolic effects of white beans processed into two different physical forms. *Diabetes Care*, 1986; **9**: 260–266.

35. Granfeldt, Y., Liljeberg, H., Drews, A., Newman, R. and Bjorck, I. Glucose and insulin responses to barley products: influence of food structure and amylose-amylopectin ratio. *Am. J. Clin. Nutr.*, 1994; **59**: 1075–1082.