ORIGINAL ARTICLE

Glycaemic, Insulinaemic and Nonesterified Fatty Acid Responses of Rice and Chapati in Type 2 Diabetes Mellitus Subjects

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Abstract:

To observe the plasma glucose, insulin and nonesterified fatty acid (NEFA) responses on consumption of rice and chapati, 17 type 2 diabetic subjects, consumed equi-carbohydrate amount of two varieties of rice, two varieties of traditional wheat flour bread and white bread as the reference food. Blood sample was drawn eight times between 0h and 3h to measure glucose, insulin and NEFA. Plasma glucose response to both varieties of chapati was significantly lower as compared to that of WB and BR32 rice. Rice BR32 showed higher glycemic response than boiled water chapati. The different glycaemic responses of rice and chapati were reflected in their glycaemic index or GI [BR32: 94±11, BR25: 98±10, NWC: 90±9 and BWC: 88±8]. NWC showed significantly lower GI than that of rice BR25 (p< 0.01) and GI of BWC is significantly lower than both BR32 and BR25 rices (p< 0.03, 0.001). Rice BR25 showed lower insulin response (iAUC) compared to WB (p<0.01). NEFA responses were also higher in WB and rice BR25 compared to both NWC (p< 0.01, 0.04) and BWC (p<0.01, 0.05). These types of response may be beneficial for diabetic patients and populations in general. From the standpoint of NEFA response BR25 variety of rice seems to be a better choice compared to BR32.

Introduction:

Considerable attention is needed regarding the quantity and nature of carbohydrate for a healthy diet. The latest trend is towards liberalization of carbohydrate intake, which should constitute 50% to 60% of total calories[1]. Special caution, however, is required to define the nature of carbohydrate due to the central importance of maintaining normoglycaemia and due to the need for adjustment of drug regimens in consideration of a particular diet.

Carbohydrate content varies from one food to another. So, a method of ranking the carbohydrate containing food has been proposed on the basis of the incremental blood glucose responses and glycaemic index (GI), produced for a given amount of food[2]. Glucose, in turn,

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triggers insulin secretion from the pancreatic beta cells, and insulin action and secretion are also modulated by changes of plasma nonesterified fatty acid in response to glucose. Since insulin is now known to be atherogenic, a low GI at the expense of hyperinsulinaemia may not always be useful[3]. Nonesterified fatty acids have been found to be a risk factor for diabetes and may also have a direct effect on hypertension[4]. Randle suggested that an increased availability of free fatty acids, resulting in a decrease in the muscles glucose uptake, may also stimulate gluconeogenesis, inhibit insulin-stimulated glucose utilization in muscles and promote hepatic production of glucose and VLDL triglyceride, worsen glucose tolerance and have direct toxic effect on beta cells[5]. Elevated plasma NEFA concentrations antagonize insulin action and thus may play a critical role in the development of insulin resistance in type 2 diabetes. Thus, plasma NEFA elevation may be mechanistically linked to the cluster of metabolic abnormalities seen in type 2 diabetes, including hyperglycaemia, hyperinsulinaemia and dyslipidaemia. So, in addition to GI, the amount of insulin and NEFA secreted in response to food are also important in the management of diabetes and its vascular complications. Thus ranking of food based on their insulinaemic and NEFA responses, along with the glycemic response, is necessary. Measurement of Insulinaemic index (II) and NEFA index (NEFAI) may be the two indicators of this response.

Rice is the staple food in the daily meal of Bangladeshi population and it is the main carbohydrate source for these people. Rice is also a common carbohydrate source in many other countries. The Bangladeshi diets are heavily dependent on rice, constituting up to 80% of the daily energy intake[6]. There are, however, different varieties of rice available in Bangladesh and various techniques are used for their processing. To prepare a diet plan for diabetic and cardiovascular patients in the local perspective we need to grade these rices according to their glycaemic, insulinaemic and NEFA responses. In recent years our group has undertaken a long-term program to assess the GI and insulin index of common dietary components of Bangladesh. As a part of this series Larsen studied BR25 rice with various processing techniques (parboiled and nonparboiled) in human subjects and animals, and she found that rice had low glycaemic and insulinaemic indices than those of white bread[7]. The response to pressure parboiled (PP) rice was significantly lower than that of the non-parboiled (NP) and traditionally parboiled (TP) ones. She also found that the overall glycemic responses to rice were approximately 25% higher in the Bangladeshi subjects when compared to Danish subjects. NEFA, however, was not studied in her study.

The present work is the second one in the series and, in addition to rice, wheat flour bread (commonly known as chapati), the second most commonly consumed food has been investigated. Chapati is the main diet in a vast number of areas of Indian subcontinent and it is specially advised to people with diabetes and cardiovascular diseases. Chapati is prepared in different ways depending on particular custom and culture. In the present work two commonly consumed varieties of rice (BR32 and BR25) and two varieties of chapatti – one prepared with normal temperature water (NWC) and another prepared with boiled water (BWC) have been investigated for their glucose, insulin and NEFA responses.

Material and method:

Subjects:

Seventeen Type 2 diabetic subjects (eight male, nine female) were included in this study. The subjects were non-obese (BMI 23±2 kg/m^2, waist-hip ratio 1.03±0.02, M±SD) with mild to moderate hyperglycaemia (M±SD, HbA_{1c} 707±0.7% and fasting glucose value 7.0±2.5 mmol/l). The (M±SD) age of the subjects was 42±5. The participants were selected from the Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM), Dhaka Outpatient Department. Diabetes was diagnosed and classified by the WHO criteria (WHO Expert Committee 1999)[8]. Patients with acute or chronic complications of diabetes mellitus and those using insulin, oral contraceptives or steroids were excluded. Pregnancy was also an exclusion criterion. All participants gave their written consent after being fully informed about the nature of the study.

Study design:

Detailed family history was taken, and clinical and biochemical findings were recorded in a predesigned case record form. The body weight in kilogram was measured by using appropriate scales (Detect-Medic, Detect Scales INC, USA). Body Mass Index and waist-hip ratio of the subjects were calculated by appropriate formula. The subjects were requested to fast overnight (8-10 hours) and suggested not to take medicine. An intravenous cannula was inserted into a superficial vein in the forearm, fasting blood samples were drawn and meal was served. The meal was consumed within 15 minutes along with 200 ml water. Blood samples were then collected at 15, 30, 45, 60, 90 120, 150 and 180 minutes. Separated serum was preserved at –70°C for future biochemical analysis.

Test meals:

The test materials were collected from the Grain Quality Control Department, BRRI, Gazipur, Dhaka, Bangladesh. All the test materials were chemically analyzed for their dry matter, amylose, carbohydrate, fat and protein contents. The subjects were given test meals which contained 50 gm available carbohydrate and to get this amount of carbohydrate the amount of

Table I: Clinical, sociodemographic and anthropometric characteristics of the study subjects

Parameters	Values
Age (years, M±SD)	42±5
BMI (M±SD)	23±2
Waist-hip ratio (M±SD)	1.03±0.02
Female : Male	52:48
Rural : Urban	3:14
Duration of diabetes (Months, M±SD)	6.2± 3
FPG (mmol/l, M±SD)	7.0±2.5
Annual income (median-range) in US Dollars	2068 (1034-6206)
$HbA_{1}c$ (%, M±SD)	7.7±0.7

test meals required were as follows: Pressure parboiled BR32- 183 gm and BR25- 187 gm, NWC- 73 gm, BWC- 73 gm and White Bread- 78 gm. The meals were served along with 200 ml of water.

Chemical analysis of the test meals:

All chemical analyses were done in duplicates. Dry matter (DM) was determined by oven drying at 105^0C for 20 hours, and available carbohydrate was determined as total starch by an enzymatic-colorimetric method[9]. Protein (N*6.25) was analyzed using a Kjell-Foss 16200 Autoanalyzer.

Laboratory methods:

Plasma glucose was measured by glucose-oxidase method (Sera Pak, USA), HbA_{1c} by dedicated HPLC (BioRad, USA), NEFA by colorimetric method (Randox, UK) and plasma insulin was measured by a microparticle enhanced fluorescent immunoassay (EIMA) technique (Abbott Laboratories, USA).

Statistical Analysis:

All analyses were done using the Statistical Package for Social Science (SPSS) software for Windows. Integrated plasma values (iAUC) of glucose, insulin and NEFA over the three hour time period were calculated by area under the curve (AUC) using a mathematical model[10]. The glycaemic index (GI) was calculated by using the formula:

$$GI = \frac{\text{Incremental blood glucose area after food intake}}{\text{Corresponding area after equi carbohydrate portion of reference food}} \times 100$$

To compare difference between the means Bonferroni t-test, Mann-Whitney 'U' tests and Paired t-test were done as and where appropriate.

Results:

Table I shows the clinical,sociodemographic and anthropometric characteristics of the study subjects and Table II shows the chemical composition of the test meals.

Glycaemic responses and GI values of the study subjects:

There were no significant differences in the absolute fasting plasma glucose values of the study subjects among the test meals. The reference food WB showed statistically higher glycaemic response (as measured by iAUC) in

Table II: Physical and chemical characteristics of the test meals used in the study (percentage of DM)

Test meal	Rice BR32	Rice R25	Wheat flour
Dry matter[1]	88.49	88.20	91.37
Protein[1]	9.56	9.56	14.12
App Amylose content[1]	26	26.9	21.6
Carbohydrates available[1]			
Dietary fibres[2]	1.6	1.2	10.6
Resistant starch[3]	6.6	2.6	2.3

[1] Determined as is on milled rice samples; [2] Non-starch polysaccharides and lignin; [3] Determined as is on cooked milled rice samples.

comparison to NWC and BWC [iAUC, 1828±278 in Bread vs 1651±241 in NWC ($p < 0.002$) and 1603±299 in BWC ($p<0.001$)]. There was no significant difference in the glycaemic response of WB with that of the rice varieties. Rice BR32 showed higher glycaemic response than BWC [iAUC, 1730±302 in BR32 vs 1603±299 in BWC ($p<0.04$)], although it showed no statistical difference with NWC. Rice BR25 showed higher glycaemic response than NWC and BWC [iAUC, 1801± 308 in BR25 vs 1651±241 in NWC ($p<0.01$) and 1603±299 in BWC ($p<0.001$). But there was no statistical difference in the glycemic responses in between the rice varieties. (iAUC, 1730±302 in BR32, 1801±308 in BR25) as well as in between the chapati varieties (iAUC, 1651±241 in NWC and 1603±299 in BWC).

Results expressed as mean±SD; Bonferroni 't' test was performed to test the difference between means. $P < 0.05$ was taken as the level of significance;

The overall GI value is 7.29% higher in rice than chapati.

The glycaemic responses of rice and chapati are reflected in their GI values, and BR32 shows higher GI values compared to that of BWC (BR32 94±1, BWC 88±8; $p< 0.03$) showed in Table-III. Rice BR25 shows higher GI in comparison to both NWC and BWC [BR25 98±10 vs NWC 90±9 ($p< 0.01$) and BWC 88±8 ($p< 0.001$)]. The rice and chapati varieties also did not show any significant difference among themselves in their GI values. The overall GI value to rice is approximately 7.29% higher than that of the chapati.

Insulin responses and Insulin Index of the study subjects after feeding the test foods:

Absolute increment of insulin values [median (range), µIU/ml] was calculated in response to test foods. White bread showed no significant difference in insulin response compared to the two rice varieties and chapati varieties [3294 (1447-7119) in WB, 3769(1101-8218) in BR32, 2452 (1164-6588) in BR25, 3063 (910-7706) in NWC and 3045 (1108-7107 in BWC]. The two rice and chapati varieties did not show any difference in insulin response values among themselves. The same responses were reflected in their index values [median (range)] [93 (56-162) in BR32, 82 (55-141) in BR25, 106 (50-155) in NWC, 93 (51-174) in BWC].

Table III: Effect on glycaemic status of the study subjects (n=17) after feeding the different test and reference foods

Test foods	**Plasma glucose (mmol/l*180 min)**									**GI**
	0 min	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	
Bread	7.0±1.2	8.0±1.5	9.5±1.5	10.8±1.9	11.4±1.7	12.2±1.4	10.6±1.9	9.3±1.9	8.4±1.8	
BR32	7.3±1.0	8.3±1.2	9.2±1.6	10.1±1.7	10.9±1.8	11.1±2.1	9.7±2.0	8.9±1.9	7.9±1.8	94±11
BR25	7.2±0.7	8.3±1	9.2±1.1	10.1±1.6	11.5±2.1	12.2±2.4	10.3±2.1	9.0±2.2	8.2±2.2	98±10
NWC	7.0±0.7	7.9±0.8	9.0±1.1	9.7±1.5[a]	11±2.0	10.8±2.5	9.4±1.9	8.1±1.4	6.5±0.8	90±9[c*]
BWC	7.1±0.9	7.5±1.2	8.7±1.8	9.8±2.4	10.3±2.5	10.2±2.4	9.3±2	8±1.4	7.2±1.3	88±8

N= number of subjects; AUC= area under curve; GI= Glycemic index.

NEFA responses and NEFA Index:

NEFA response as measured by iAUC [median (range), µmol/l] was higher in rice BR25 [65085 (26115-108975)] compared to that of NWC [54450 (33000-70215, $p<0.04$)] and BWC [54120 (30000-73155), $p< 0.05$]. Rice BR32 did not show any difference with any type of chapati in the NEFA response. Reference food WB also showed higher NEFA response in comparison to both chapati varieties [70875 (36030-89505), $p<0.01$]. There was no significant difference in the NEFA responses among the rice and chapati varieties. NEFA Index (NI) of rices did not show statistically significant difference compared to NWC and BWC [median (range); 100 (48-167), 90 (51-207), 87 (45-133) and 82 (57-122) in BR32, BR25, NWC1 and BWC respectively]. The two rice and chapati varieties also showed no difference in between themselves.

Discussion:

Rice and wheat are by far the most important starchy foods for human consumption. Rice is suitable for use in low glycaemic diets having beneficial properties in the dietary management of type 2 diabetic subjects. Interestingly, it is widely believed particularly in Asia that diabetic subjects should limit their rice intake due to a positive association between a high intake of rice and the risk of developing diabetes. As starch is the principal component of rice, the physicians and dieticians with substantial restriction of this major carbohydrate source advise diabetic patients. To rationalize the advice of rice and chapati (traditional wheat flour bread) in diabetic (as well as cardiovascular) patients, it is important to know their chemical composition and their biological responses. The substitution of calories and other nutrients may then be done on the basis of patient choice, socioeconomic capability and availability in the market.

Glycaemic Index (GI) is a useful tool in measuring the biological response of a food in relation to glycaemic status. The present study evaluates the GI of rice and chapati in type 2 diabetic subjects. In line with the popular impression, the results suggest that, two varieties of chapati produces lower glycaemic responses compared to rice and white bread (the reference food) (Table-III) and this needs to be kept in mind when providing dietary advice to diabetic patients and calculating their calorie requirements. It is interesting to note that though the GI of chapati prepared from normal temperature water (NWC) produce apparently higher GI than the chapati prepared from boiled water (BWC), but the difference is not significant. When the rice varieties (BR25 and BR32) cooked for the same length of time, BR25 produces higher GI than BR32 but statistically the difference is also not significant. The results clearly demonstrated that the chapati varieties investigated in this study, independent of processing and physico-chemical properties, were less glycaemic compared to white bread and rice. Thus, the chapati independent of processing is better recommended than rice and refined western bread as carbohydrate source in the diabetic diet and the two varieties of chapati can be interchangeable.

Insulin is the central hormone in maintaining blood glucose homeostasis. In type 2 diabetes mellitus the absolute level of insulin may be low, normal or higher in the blood although there is always a relative insulin deficiency. In spite of life saving role of the hormone the higher level of insulin in blood (hyperinsulinaemia) has been shown to be associated with increased atherosclerosis leading to cardiovascular disorders[11]. Due to this atherogenic role of insulin it is desirable to control the blood glucose of patients keeping the insulin levels as normal as possible. In this context, plasma insulin measurement in the present study has an important implication. The results showed that the absolute insulin values at different point of time did not differ significantly between the test meals. The insulin responses (as iAUC) and the insulin index are also not differing significantly among the test foods (Table-III). So, it may be stated that the insulin secretory capacity was not influenced by the test foods.

The amount of insulin secretion in response to NEFA is also centrally important in the management of diabetes. Elevated NEFA affects both insulin action and insulin secretion, these effects contributing to the pathogenesis of glucose intolerance. Increased circulating concentrations of NEFA reduce peripheral insulin sensitivity due to presence of glucose-fatty acid cycle and also increase hepatic glucose output due to promotion of gluconeogensis. A reduction in circulating NEFA leads to an increase in insulin mediated glucose uptake[12]. The study evaluates the NEFA index of rice and chapati. Rice BR25 shows higher NEFA response compared to chapati. From the view of NEFA it can also be concluded that chapati is a better choice as a diabetic diet.

Chemical analysis of the test foods shows that protein and dietary fiber contents are higher in wheat flour than the rice varieties and it is known that protein appears to have an impeding effect on the glycaemic response to starchy foods. Holt et al observed a negative correlation between protein content and glycaemic score[13].

Chapati used in the present study also shows the negative correlation of GI with protein content of the wheat flour. Available carbohydrate content is also higher in wheat flour than rice BR25. The rice used has high amylose content (26%), but the amylose content is lower in wheat flour (21.6%). Previous studies showed that high amylose content lower the starch digestion rate, measured as glycaemic and insulinaemic response to rice (Larsen et al 1999). In the present study the intermediate amylose containing wheat flour produces low GI. These beneficial effects of chapatti are not fully known' possibly due to its high dietary fiber content, lower available carbohydrate content (70% in wheat flour vs. 77% in BR25 and 83% in BR32) and higher protein content (14.12% in wheat flour vs. 9.56% in BR32 and BR25).

A major finding in this study is the overall inferiority of the WB, which showed significant higher glycaemic and insulinaemic as well as NEFA responses in comparison to rice and chapati. It further demonstrates the superiority of traditional food habits, in comparison to processed foods of the modern days.

'Chapati' is a better choice from the standpoint of glycaemic, insulinaemic, and NEFA responses and also from the findings of chemical analysis of the test foods. The overall GI of chapatti is 7.29% higher than rice. So, dieticians and physicians can give option to diabetics to take rice instead of chapati with more calorie burn or can take rice mixed with other low glycaemic foods.

It is now necessary to explore the effects of these food groups after a chronic consumption as well as to investigate other nutritional aspects before a rational dietary management policy can be developed for diabetic patients as well as for population in general.

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References:

1. Vinik A, Wing RR, Lauterio TJ. Nutritional management of the person with diabetes. In: Porte D Jr, Sherwin RS, (editors). Ellenberg and Rifkin's Diabetes Mellitus, Fifth edition. Stamford Connecticut: Appleton and Large, 1996. pp- 609-652.
2. Wolever TMS, Jenkins DJA, Jenkins AL, et al. The glycemic index: methodology and clinical implications. Am J Clin Nutr 1991; 54: 846-54.
3. Stout RW. Diabetes and atherosclerosis, the role of insulin. Diabetes Care 1990; 13: 631-654.
4. Anne FC, Beverly B, Dominique S, et al. High free fatty acid concentration: an independent risk factor for hypertension in the Paris prospective study. International J Epidemiol 1998; 27: 808-813.
5. Randle PJ, Garland PB, Hales CN, et al. The glucose fatty-acid cycle: its role in insulin sensitivity and the metabolic disturbances of diabetes mellitus. Lancet 1963; 1: 785-789.
6. Choudhury OH. A review of literature on nutrition studies in Bangladesh. Dhaka: Bangladesh Institute of Development Studies,1992.
7. Larsen HN. Rice, effects of variety, parboiling and population – and the glycemic index. PhD Thesis 1997. Research Department of Human Nutrition, The Royal Veterinary and Agricultiral University, Copenhagen, Denmark.
8. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Report of the expert committee on the diagnosis and classification of diabetes mellitus. Diabetes Care 1999; 20: 1183-97.
9. Bach Knudsen KE. Carbohydrate and lignin contents of plant materials used in animal feeding. Anim Feed Sci Tech 1997; 67: 319-338.
10. Tai MM. A mathematical model for the determination of total area under glucose tolerance , and other metabolic curve. Diabetes Care 1994; 17: 152-4.
11. Kaplan NM. Hypertension and diabetes. In: Porte D Jr, Sherwin RS (editors). Ellenberg and Rifkin's Diabetes Mellitus, Fifth edition. Stamford Connecticut: Appleton and Large, 1996. pp-1097-1104.
12. Caroline MA, Malcolm N. Fatty acid and insulin secretion. Diabetes, Obesity & Metabolism 2000; 2: 213-221.
13. Holt SHA, Brand Miller JC, Petocz. An insulin index of foods: the insulin demand generated by 1000-kJ portions of common foods. Am J Clin Nutr 1997; 66: 1264-1276.