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Glycemic and Insulinemic Responses to Commonly Consumed Potatoes in Bangladeshi Type 2 Diabetic Subjects

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Abstract: Glycemic and Insulinemic responses to potato and sweet potato by estimating their Glycemic Index (GI) and insulinemic index (measured by c-peptide) from Bangladeshi origin were investigated in Type 2 Diabetic Mellitus (T2DM) patients. Based on serving size in the Bangladeshi society the GL of those two food items were also calculated. About 10 T2DM subjects (male 5, female 5, age 44±3.16 years, BMI 24±3.85, HbA_1c 6.78±1.79%, M±SD) studied under a cross-over design, consumed equi-carbohydrate amount of the vegetables and white bread (WB, as reference food) with a run in period of 7 days between the consecutive items. The test meals (potato, sweet potato and WB) containing 50 g of total carbohydrate) were given to the participants for ingestion within 10 min with 200 mL water. Serum levels of glucose were estimated at 0, 15, 30, 45, 60, 90, 120, 150 and 180 min, respectively. GI and GL (serving size of the food 22 g for both potato and sweet potato, respectively in Bangladesh) were calculated by standard formulas. Serum glucose was measured by glucose-oxidase, c-peptide was used as the marker of insulin and was measured by chemiluminescent ELISA and HbA_1c (glycosylated hemoglobin) by High-Performance Liquid Chromatography (HPLC) method. Classification of GI was taken from the international table (GI: high = 70, medium 56-69 and low = 55; GL: high = 20, medium 11-19 and low = 10). Both plain potato and sweet potato showed significantly higher serum glucose response compared to that of reference food (iAUC (M±SD): 234±65 in bread vs 361±81 in Potato and 416±47 in sweet potato; p<0.015 and 0.001, respectively). The similar glycemic response between plain potato and sweet potato was reflected in their GI values: 162±50 and 191±66, respectively. The basal values of serum insulin in all the 3 groups were matched. The substantially higher glycemic response and GI values in potato and sweet potato were not the consequence of a suppressed insulin response. The GL of potato and sweet potato were 8 and 11, respectively. Considering the economical aspect, crop production, high satiety, therapeutic advantage and for food diversity potato can be recommended for healthy as well as T2DM subjects especially for their low fat and high micronutrient content and beneficial effects in insulin response for some verities observed in this study. In spite of high GI, considering potential source of carbohydrate current consumption can possibly increased from a minor vegetable to the most important vegetable in the diet, as a mixed meal or and an occasional partial substitute for rice.

Key words: Glycemic index, glycemic load, insulinemic index, potato, sweet potato, type 2 diabetic mellitus, carbohydrate

INTRODUCTION

In the context of emerging epidemics of Type 2 Diabetic Mellitus (T2DM) even in developing countries (WHO, 2010), the quantitative and qualitative aspects of carbohydrate in diet are getting increasing attention for the prevention of this disorder and other NCD's related metabolic syndrome. The Glycemic Index (GI) is now being used as an useful concept for ranking the biological response to dietary carbohydrates (Foster-Powell *et al.*, 2002) and subsequently, the Glycemic Load (GL) has been introduced as a practical tool for everyday nutritional education to the subjects (Foster-Powell *et al.*, 2002; Galgani *et al.*, 2006). It is also now recognized that insulin response should also be included as a major indicator when evaluating the biological response to carbohydrate rich diets as hyperinsulinemia constitute a major risk factor for cardiovascular diseases. It has been further realized that GI, GL and insulin response (which can be evaluated in terms of insulinemic index or II) need to be

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studied in different environmental, racial and cultural settings due to the substantial dependence of the chemical composition of and biological response to carbohydrate containing foods on these variables.

Potato is the major source of energy in many societies and it is a versatile, carbohydrate-rich, high potassium and low sodium food, early digestible, prepared and served in a variety of ways. The GI of potato has been studied in Australia, New Zealand, Romania canada, Kenya and Indian population and widely scattered results have focused depending on the variety of potato preparation and population studied (high GI in Australia Canada and New Zealand; medium GI in Romania and low to high GI in Kenya and India, respectively (Foster-Powell *et al*., 2002) compared with the reference food white bread.

The insulinemic response to potato has already been studied rarely (Crapo *et al*., 1981). Bangladesh is among the top 10 countries with highest number of diabetic population in the world (Wild *et al*., 2004). Although, rice is the staple source of energy in this country, potato is the commonest vegetable consumed singly or mixed with almost all types of food items and sweet potato also consumed in mixed vegetables, especially as snacks but less than plain potato. The average consumption of potato in Bangladesh has been reported as 9.8 kg/capita/year (Scott and Bouis, 2010) and its prices almost half that in rice. To ease the increasing demand on rice and to promote food diversity, it is important to further popularize potato as a more staple source of carbohydrate in the country. In spite of its importance in the Bangladeshi diet, no study has so far been conducted on the glycemic and insulinemic response of potato in any group of Bangladeshi subjects. The present study was designed to explore these responses for potato and sweet potato which consumed as a snack also (with only boiled preparation) in Bangladeshi type 2 diabetes mellitus subjects.

MATERIALS AND METHODS

Study subjects: Subjects were selected from Out Patients Department (OPD) of Bangladesh Institute of Research and Rehabilitation on Diabetes, Endocrine and Metabolic Disorders (BIRDEM). A total number of 10 T2DM subjects (5 males and 5 female) took part in the study. Diabetes was diagnosed and classified by the WHO criteria. Subjects were requested to maintain their usual daily food intake and activity throughout the study period. The purpose and protocol of the study were explained to the subjects and written consent was obtained.

Tested foods and its preparation: The study included 2 test meals (potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batatas*)) and WB as reference food. Both test foods and reference food consisted of 50 g available carbohydrates. To get 50 g available carbohydrate the weight of white bread, potato sweet potato were 65, 221 and 177 g, respectively.

For test food fresh potato and sweet potato were purchased from the local Dhaka city market in bulk quantities sufficient to conduct all tests. First washed, weighed (221 and 177 g, respectively) and with intact skin boiled with water until getting soft, large potatoes were halved before cooking. Sufficient water added for boiling. After boil water drained, skinned off and samples were then taken into a plate. The test meals were served at room temperature. As reference food freshly baked white bread was sliced and portioned to the calculated weight (65 g). Each portion was bagged individually and stored frozen.

On the days of trial, white bread portions were removed from the freezer 45 min before serving and allowed to thaw at room temperature.

Experimental procedure: On the 1st day after selection and taking consent detailed socio-demographic data, family history of the patients and medical history were taken and physical and clinical examinations were done on the first day of the visit using a pre-tested questionnaire. Anthropometric measurements included height, weight; waist circumference and hip circumference were taken. Thereafter, subjects were required to go through the study protocol on 4 separate occasions (one trial for test food and 2 repeated trial for the reference food) in the morning after a 10-12 h overnight fasting and advised not to take any kind of medicine or smoke on the previous day except the prescribed one.

The test of the reference food repeated once to obtain at least two values in each subject, thus the precision was improved (Brouns *et al*., 2005). Test and reference meals were given to patients under a cross-over design with a wash out period of 7 days to avoid the 2nd meal effect (Wolever *et al*., 1988). Patients were advised to rely on recommended standard carbohydrate diet and also instructed not to eat legumes in the meal preceding the fast. An intravenous cannula was inserted into a superficial vein in the forearm on the day of experiment, drawing the fasting (0 h) blood sample of the patient, subjects were requested to consume the test food with 250 mL plain water (during the protocol of the test potato) or the glucose in 250 mL water (during the protocol of the reference food) in random order at a comfortable place within 10 min. Further blood samples were drawn at 15, 30, 45, 60, 90, 120, 150 and 180 min after the initial intake of sample. Patients took their prescribed medicine at the beginning of the meal. All the information and data obtained were recorded in a predesigned case record form.

Blood sample was allowed to centrifuge at 3000 rpm for 15 min. The plasma separated was allocated in the labeled eppendrof tubes and preserved at -70°C until biochemical analysis. C-peptide-glucose ratio was calculated with calculating values of glucose and c-peptide in study participants at zero and 180 min. These ratio evaluated c-peptide (equivalent to insulin) status of the patients in response to their glucose responses after ingestion of test foods.

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Serum glucose was estimated by glucose-oxidase (GOD-PAD) method using reagents from SERA PAK, USA (Trinder, 1969). Insulin (measured by c-peptide as a marker of insulin) was determined by ELISA method using kits from DRG Diagnostics (Germany) and glycosylated hemoglobin (HbA1c) was measured by High-Performance Liquid Chromatography (HPLC) method.

Ethical consideration: The protocol was approved by the Ethical Review Committee of the Diabetic Association of Bangladesh.

Statistical analysis: All analysis was done using the Statistical Package for Social Science (SPSS) software for Windows. The incremental Areas Under the Curve (iAUC) was calculated by the standardized criteria (Wolever *et al.*, 1991) ignoring any area below the baseline. The average iAUC for the two white bread tests was used as the reference value and each subject's individual GI for each food was calculated. To compare difference between means, one way ANOVA test was performed where appropriate. All parametric variables were expressed as M±SD and non-parametric data were expressed in percentage value. About $p<0.05$ was considered as the statistically significant.

RESULTS AND DISCUSSION

Characteristics of the study population: Table 1 shows the characteristics of the participants. Participants consisting of ten T2DM subjects (male 5, female 5; age 44±3 years, mean±SD). The mean BMI of the study subject were±SD, 24±3 while the mean waist-hip ratio was found to be 0.92±0.02. The average HbA_1c was 6.8±1.9 for the study subjects. All the participants represent medium socio-economic class.

Table 1: Clinical and socioeconomic characteristics of study subjects (n =10)

Parameters	Values
Age (years, M±SD)	44±3
BMI (M±SD)	24±3
Male:Female	1:1
Waist-Hip Ratio (WHR, M±SD)	0.92±0.02
Annual income in US $ (median-range)	771-3429
HbA_1c (M±SD)	6.8±1.8

Values are expressed as Mean±SD except range and ratio

Glycemic response to the food items: Both potato and sweet potato showed significantly higher serum glucose response compared to that of WB (increment area under the curve (M±SD): 234±65 vs. 361±81 and 416±47 in white bread, potato and sweet potato; $p<0.01$ and <0.001, respectively)). However, both, potato and sweet potato blood glucose dynamics increased but not differed in the level of significance with WB at any time points minutes Table 2. The glycemic response of sweet potato was reflected in the higher GI values (162±50 and 191±66 for potato and sweet potato, respectively). The GL calculated on the basis of Bangladeshi serving size were 8 and 11 for potato and SP, respectively (Table 2).

C-peptide response to the food items: The basal values of serum insulin in all the 3 groups were matched. The substantially higher glycemic response and GI values in potato and sweet potato were not the consequence of a suppressed insulin response (180 min: 2.7 (1.1-5.8), 1.8 (0.5-3.1) and 2.8 (1.0-4.3) in case of bread, potato and sweet potato, respectively).

This was also supported by the 180 min c-peptide: glucose ratio (0.34 (0.16-0.97), 0.25 (0.05-0.51) and 0.34 (0.15-0.58) in case of WB, potato and sweet potato, respectively). The serum C-peptide value increased at 180 min compared to 0 min in case of sweet potato but in potato there was a lower response and it significantly differed from WB (Table 3). Study Homa%B and Homa%S were calculated and no significant difference has observed among the groups.

Popularization of potato in Bangladeshi diet is important both from economic and nutritional view points. It will require intensive coordinated effort as it involves changing a deep rooted cultural habit related to rice based diets. However, the impact of such transition on NCDs need also be considered when planning campaigns. There are common beliefs among Bangladeshi people that potatoes are much more diabetogonic than rice, so any public health campaign must incorporate proper evidence generated from local potatoes and local population on the risk and benefit of these two products. The GI values obtained for potato was 162 that somewhat higher than those previously reported for boiled white potatoes compared with white bread as reference food (80-144 in

Table 2: Serum glucose response of the subjects (n = 10) at different times point after consuming the test foods

Test foods	Serum glucose (mmol L^{-1}) 0/0' min	15 min	30 min	45 min	60 min	90 min	120 min	150 min	180 min	iAUC (mmol L^{-1} at 3 h)	GI	GL
Bread	7.5±1.6	7.4±1.5	8.2±1.7	9.3±1.9	10.0±1.7	10.2±1.3	8.8±1.3	7.8±1.5	7.2±1.1	234±65	-	-
	(100)	(99±3)	(109±10)	(124±10)	(134±8.7)	(138±13)	(119±11)	(105±7)	(97±7)	-	-	-
Potato	7.3±1.6	7.5±1.4	9.4±1.7	10.4±2.4	11.2±2.4	10.7±2.1	9.2±1.9	8.1±1.3	6.8±1.5	361±81*	162±50	8
	(100)	(103±12)	(131±29)	(143±22)	(154±19)	(147±15)	(127±18)	(113±13)	(94±13)		-	-
Sweet potato	7.3±1.0	7.5±1.4	8.8±2.0)	10.4±2.2	11.8±1.7	11.7±1.2	10.0±1.2	8.4±1.1	6.9±1.0	416±47***	191±66	12
	(100)	(101±7)	(119±13)	(141±18)	(160±15)	(159±13)	(137±13)	(115±16)	(93±11)		-	-

Results expressed as mean±SD; *p<0.05 and **p<0.01 ***p<0.001 were taken as the level of significance as compared to reference food in one-way ANOVA. Potato and sweet potato has 221 and 177g/100 g of carbohydrate, respectively. To calculate GL serving size 22g/serve; iAUC, Increment area under the curve

Table 3: C-Peptide status of the study subjects (n = 10) after feeding different test meals

[a]Test foods	Serum C-peptide (ng mL^{-1}) 00 min	180 min	AICP of C-pep	HOMA B% 0 min	180 min	HOMA S% 0 min	180 min	C-peptide: Glucose 0 min	180 min
Bread	1.6	2.7	1.1	167.2±77.2	252.2±132.1	18.4±6.3	12.4±6.1	0.20	0.34
	(0.75-3.0)	(1.1-5.8)	(0.2-2.8)	-	-	-	-	(0.07-0.5)	(0.16-.97)
Potato	2.7	1.8	-0.70	246.7±96.4	213.9±103.8	12.9±7.8	17.5±6.8	0.41	0.25
	(0.95-4.1)	(0.50-3.1)	(-2.7 -1.6) a*	-	-	-	-	(0.11-0.54)	(0.05-0.51)
Sweet potato	1.9	2.8	1.25	187.6±77.6	213.6±81.7	14.8±6.4	14.4±8.9	0.25	0.34
	(1.1-3.8)	(1.0-4.3)	(-1.8-2.5)	-	-	-	-	(0.13-0.58)	(0.15-.58)

Results expressed as median (range) and mean±SD; *p<0.05 and **p<0.01 ***p<0.001 was taken as the level of significance; as compared to reference food in one-way ANOVA. [a]Bread, Plain potato, Sweet potato. AICP; absolute incremental changes of C-peptide over basal values. HOMA %B, Insulin secretory capacity by Homeostasis Model Assessment; HOMA %S, Insulin sensitivity by homeostasis model assessment

Australia (Brand-Miller *et al*., 1998; Soh and Brand-Miller, 1999), 83-90 in Canada (Wolever *et al*., 1994, Wolever and Jenkins, 1986), 100 in New Zealand (Perry *et al*., 2000), 59 in Romania (Ionescu-Tirgoviste *et al*., 1983) and 33-108 in India (Kanan *et al*., 1998)). In some case, the GI range of potato were 59-100 (Ionescu-Tirgoviste *et al*., 1983; Perry *et al*., 2000), 78-101 (Soh and Brand-Miller, 1999) as against reference food glucose. The GI for sweet potato was 191 which is also very high compared with 63 in Australia (Thorburn, 1986), 84 in Canada (Wolever *et al*., 1994) and 111 in New Zealand (Perry *et al*., 2000). This discrepancy between studies may be due partly to various cooking method (adding salt, amount of cooking water) moisture content of food, temperature for degree of starch gelatinization (Crapo *et al*., 1981) and also the cutting pieces of potato applied in different studies.

Moreover, the glycemic load reported in the current study were 8 and 12 for potato and sweet potato and these findings reflect the GL category as low and lower limit of medium, respectively due to existing dietary habit in Bangladesh. However, in various types of diet vegetables (i.e., potato) are used as a mixed meal and it is evident that GL values can be applied to mixed meals or whole diets by calculating the weighted GL value of the meal or diet (Wolever and Jenkins, 1986) and it also useful in predicting the acute impact on blood glucose and insulin response within the context of mixed meals (Galgani *et al*., 2006). Furthermore in case of insulin response of the tested root vegetables, it is indicated that at the same time insulin secretion showed down regulation for potato and increased slightly for sweet potato in the expense of similar level of blood glucose that can play the beneficial role to prevent NCDs. This postprandial insulin pattern is also supported by other study (Crapo *et al*., 1981). Therefore, to achieve a prescribed goal in carbohydrate (200 g) or number of exchanges (12 serves) or meet the current nutritional advice to increase the intake of starchy foods such as potatoes could well contribute to an exceptionally medium to high glycemic load, this in turn may not increase rather minimize insulin demand specially for T2DM subjects.

So, this is relevant for epidemiological studies investigating the role of carbohydrates in non-communicable chronic diseases.

CONCLUSION

In conclusion considering the economical aspect, crop production, high satiety, therapeutic advantage and for food diversity potato can be recommended for healthy as well as T2DM subjects especially for their low fat and high micronutrient content and beneficial effects in insulin response for some verities observed in this study.

In spite of high GI, considering potential source of carbohydrate current consumption can possibly increased from a minor vegetable to the most important vegetable in the diet as a mixed meal or and an occasional partial substitute for rice. However, before think as a staple food or exchange with rice extensive long term studies need to be conducted to promote potato as a good alternative diet. Lastly different verities of potatoes GI needs to be explored in further studies to find out the commercially viable low/medium GI potatoes.

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REFERENCES

Brand-Miller, J.C., C. Allwan, K. Mehalski and D. Brooks, 1998. The glycaemic index of further Australian foods. Proc. Nutr. Soc. Aust., 22: 110-110.

Brouns, F., I. Bjorck, K.N. Frayn, A.L. Gibbs, V. Lang, G. Slama and T.M.S. Wolever, 2005. Glycaemic index methodology. Nutr. Res. Rev., 18: 145-171.

Crapo, P.A., J. Insel, M. Sperling and O.G. Kolterman, 1981. Comparison of serum glucose, insulin and glucagon responses to different types of complex carbohydrate in noninsulin-dependent diabetic patients. Am. J. Clin. Nutr., 34: 184-190.

Foster-Powell, K., S.H.A. Holt and J.C. Brand-Miller, 2002. International table of glycemic index and glycaemic load values. Am. J. Clin. Nutr., 76: 5-56.

Galgani, J., C. Aguirre and E. Diaz, 2006. Acute effect of meal glycemic index and glycemic load on blood glucose and insulin responses in humans. Nutr. J., 5: 22-28.

Ionescu-Tirgoviste, C., E. Popa, E. Sintu, N. Mihalache, D. Cheta and I. Mindu *et al.*, 1983. Blood glucose and plasma insulin responses to various carbohydratesin type 2 (non-insulin-dependent) diabetes. Diabetologia, 24: 80-84.

Kanan, W., R.L. Bijlani, U, Sachdeva, S.C. Mahapatra, P. Shah and M.G. Karmarker, 1998. Glycaemic and insulinaemic responses to natural foods, frozen foods and their laboratory equivalents. Indian J. Physiol. Pharmacol., 42: 81-89.

Perry, T., J. Mann, K. Mehalski, C. Gayya, J. Wilson and C. Thompson, 2000. Glycaemic index of New Zealand foods. N. Z. Med. J., 113: 140-142.

Scott, G.J. and H.E. Bouis, 2010. Sustainability of potato consumption in developing countries: The case of Bangladesh. International Potato Center. Program Report 95-96. http://www.cipotato.org/publications/program_reports/95_96/program6/prog64.asp.

Soh, N.L. and J. Brand-Miller, 1999. The glycaemic index of potatoes: The effect of variety, cooking method and maturity. Eur. J. Clin. Nutr., 53: 249-254.

Thorburn, A., 1986. Digestion and absorption of carbohydrate in Australian aboriginal, pacific Island and western foods. Ph.D. Thesis, Human Nutrition Unites, University Sydney of Australia.

Trinder, P., 1969. Determination of glucose in blood using glucose oxidase with an alternative oxygen receptor. Ann. Clin. Biochem., 6: 24-27.

WHO, 2010. Noncommunicable diseases and mental health news. World Health Organization. http://www.who.int/nmh/newsletter_apr2010.pdf.

Wild, S., G. Roglic, A. Green, R. Sicree and H. King, 2004. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. Diabetes Care., 27: 1047-1053.

Wolever, T.M. and D.J. Jenkins, 1986. The use of the glycemic index in predicting the blood glucose response to mixed meals. Am. J. Clin. Nutr., 43: 167-172.

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

Wolever, T.M., D.J. Jenkins, A.L. Jenkins and R.G. Josse, 1991. The glycemic index: Methodology and clinical implications. Am. J. Clin. Nutr., 54: 846-854.

Wolever, T.M.S., L. Katzman-Relle, A.L. Jenkins, V. Vuksan, R.G. Josse and D.J.A. Jenkins, 1994. Glycaemic index of 102 complex carbohydrate foods in patients with diabetes. Nutr. Res., 14: 651-659.