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Research Article

Glycemic Response to Common Serving Size of Selected Carbohydrate Rich Foods

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Abstract

Dietary management of obesity largely focuses on the quality and quantity of carbohydrate (CHO) intake to maintain blood sugar levels close to normal. The index that measures the effect of type and amount of food on metabolic response is postprandial glycemia. Glycemic response to specific food quality and quantity affects the postprandial metabolic pathways leading to carbohydrate utilization and fat storage. In the present study, to classify food according to their hyperglycemic quality, glycemic response to equi-quantity of commonly consumed carbohydrate, rich foods were compared with that of white bread (reference) in healthy volunteers. Venous blood samples were drawn in the fasting state (0 min) and at 30, 60, 90 and 120 min after consuming 100g portions of the test food and white bread. Glycemic Bread Equivalent (GBE), which reflects the weight of bread that would induce a glycemic response equal to that induced by the test food, was highest for biscuit (167g), followed by Chapatti (122g), Puffed rice (67g), Potato (52g), and least for Rice (20g). GBE/100g values have been used to calculate the predicted glycemic response to common serving sizes of the selected foods. While, expressed in GBE/serving size (GBE/SS), the sequence of hyperglycemic impact changed to be highest for one medium potato, followed by one medium wheat Chapatti, one cup of Rice, two biscuits and least for one cup puffed rice. These values are of significance in identifying foods that result in prolonged post-prandial hyperglycemia leading to increased insulin demand and subsequent fat storage.

Keywords: Food quality, Carbohydrate quantity, Serving size, Glycemic response

Introduction

Obesity epidemic is posing great challenges to the health and economic systems of the developing countries (Khandelwal & Reddy 2013, George, Rajaram, Shanmugam 2013). The higher adiposity in obese individuals further leads to metabolic derangements at the tissue level that culminate into type 2 diabetes. Hence, obesity and diabetes management is often similar and overlapping. In both cases, postprandial

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metabolism favouring fat storage needs to be curtailed by facilitating normal insulin secretion and action.

Many complex biochemical and molecular events have been implicated in hyperglycemia-induced tissue damage (Ceriello et al 2004, Brownlee 2001, Lebovitz 2001). The postprandial glycemic response to foods is a function of the quality and quantity of carbohydrates present (Singhania & SenRay 2012). Several studies have shown that the total amount and nature (composition, portion size, preparation method, consumption, and digestion rate) of the carbohydrates consumed are all important determinants of postprandial glucose levels, and low carbohydrate can reduce post prandial hyperglycemia at least in the short-term. (Mayfield & Havas 2005, Franz 2001, Arora & McFarlane 2005, Beebe 1987)

Glycemic bread equivalent (GBE) is an index that compares the postprandial glycemic response to given quantity of test food, with that of the same amount of white bread (Monro & Williams 2000). A GBE value directly represents the weight of bread that can induce glycemic response equal to that induced by the test food. Since GBE values are expressed in gram units for the whole foods, the GBE for 100g food can be used to predict GBE for common serving sizes (Monro 2005). The present study elucidates the effect of food quality on postprandial glycemic response to different carbohydrate rich foods.
The paper also provides insights on relevance of portion control in glycemic management for obesity.

Experimental methods

Clinically healthy adult volunteers of both sexes, in the age range of 25-65y with BMI < 25kg/m^2, and fasting blood sugar levels <100mg/dL were enrolled on the basis of consent to adhere to the experimental conditions. Individuals suffering from infectious disease, hormonal problems, sub-clinical signs and symptoms of diabetes (acanthosis nigricans, etc) or under any medications were excluded. Written Informed consent was taken from all the subjects. Ethics committee approval for the study protocol was obtained from local committee Registered under section 25 of the Companies Act, 1956, Mumbai, India.

Food Selection: Commonly consumed foods like Rice (white, short grain, milled steamed), Potato (boiled), Indian whole wheat bread (Chapatti, roasted, no fat), biscuit (Britannia Mariegold), and puffed rice were selected and the preparation methods were standardized. The foods were always prepared/procured fresh on the morning of the test (Table1). The test foods were served without any accompaniments to analyze their individual effects on glycemia and insulinemia.

Table 1: The amount of raw ingredients used for the preparation of test food portions

Food products	Ingredients	Raw weight	Cooked weight	Cooking procedure
Bread, white (Britannia)	White bread	100	100	
Chapatti (Whole wheat Indian flatbread)	Wheat flour, whole	72	100	Flour kneaded into dough using water, rolled into thin chapatti, roasted both sides on a pan
	Water	60ml	100	

Marie biscuit	Britannia Marigold	100	100	
Rice	Rice, milled, white, short grain	34	100	Raw milled rice, washed and cooked in thrice the amount of water for about 20 min
	Water	102		
Rice , puffed	Puffed rice	100	100	
Potato, white, boiled	Potato, raw, with peel	125g	100	Raw potato washed in water and boiled in microwave for 6 min, then peeled

Experimental design: After an overnight fast (10-12hours), the volunteers were fed 100g of the test foods or reference food (white bread) on different days. All subjects were fed reference food on the first day followed by test foods in random order on different occasions. The tests were conducted in the morning starting at 8am or 9am with a gap of at least 7 days between each test. Subjects were given 10 minutes to complete ingestion of the given test food portion, and were asked to chew the food thoroughly. Otherwise, depending on the individual eating pattern, size of ingested food particles and thereby absorption time would vary. 250ml of water was also provided with the meals. The postprandial glycemic effect of the test foods and bread were recorded for 2 hr by collecting blood at every half an hour. Subjects were asked to refrain from performing any vigorous physical activity during the study period.

Blood sampling: Venous blood was analyzed for the blood glucose level using Glucometer (Sugar scan manufactured by HMD Biomedical Inc.). Blood samples were taken in the fasting state (0 min) and at 30, 60, 90, and 120 min after the ingestion of both references food and test food on different occasions. The incremental area under curve (IAUC) of each test food and bread were calculated to determine the GBE value for each subject, and mean values were reported. The net IAUC is based on simple application of the trapezoid rule to all the blood glucose increments above baseline.

$$\text{GBE}/100\text{g} = \frac{\text{IAUC blood glucose response to a specified food}}{\text{IAUC response to glucose equal in weight to the food}} \times 100$$

IAUC- Incremental Area Under the Curve

Chemical Analysis: The selected foods were analyzed for sugars (total, reducing, non- reducing sugar, hydrolyzed starch) using Lane-Eynon Method (1923), fat using Soxhlet method (Cohen 1971), moisture content by vacuum oven method (Ranganna 1986) and dietary fiber by AOAC (18th Edition 2007, 985.29) method.

Statistical Analysis: The results are expressed in Mean ± SE. Statistical Package for Social Sciences (SPSS version 12.0) was used in all analyses. The mean differences between the AUC glycemic response for different test foods and standard were determined using one way ANOVA.

Results

The Blood glucose response to 100g of the test foods were compared with an equal quantity of standard food—White bread.

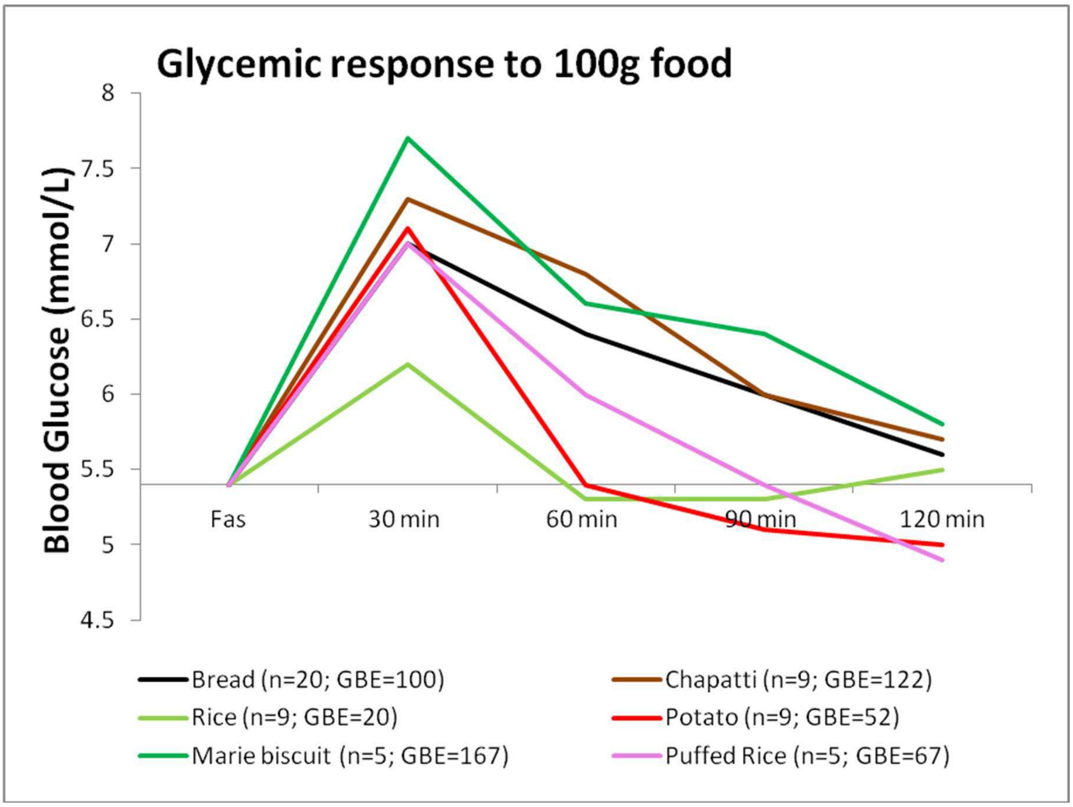

Figure 1: Blood glucose response to 100 g of test foods and bread

Figure 1, shows that 100g of biscuit and Chapatti induced much higher glycemic AUC compared to standard food, white bread. The GBE/100g of puffed rice, apparently very light and often recommended as low calorie snack item, was also found to be high. The glycemic response to potato and rice, the most commonly restricted food for any metabolic disorders including weight management, was found to be much lower than that of bread indicating that the overall glycemic response to foods do not depend on the GI of the same food, but varies to a large extent depending on the quality of the whole food (e.g. moisture content (Table 2), processing techniques used, etc). The mean total AUC glucose response to 100g of white rice was significantly lower ($p<0.01$) than that of white bread. The glucose AUC for 100g chapatti was significantly higher than that of rice ($p<0.01$) and potato ($p<0.01$).

Table 2: Proximate composition of the test foods selected for the study

Food product	Moisture	Fat	Total starch		Soluble sugar	TDF
	(g %) Mean±SD	(g %) Mean ±SD	Dry wt. (%)	Wet wt. (%) Mean±SD	Wet wt. (%)	(g %)

Bread, white	36.8 ± 0.5	0.6 ± 0.05	52.6	33.6 ±0.6	2.5±0.8	4.0
Chapatti	33.3 ± 2.5	2.2 ± 0.7	47.9	34.1 ±5.7	-	5.9
Biscuit	4.5 ± 0.9	9.9 ± 0.3	46.2	43.2 ±2.2	29.4±2.2	1.4
Rice (cooked)	74.3 ± 2.2	0.7 ± 0.02	86.4	21.0 ±0.8	-	3.6
Puffed Rice	8.3 ± 1.6	0.1 ± 0.02	29.8	27.4 ±0.8	-	1.5
Potato (boiled)	64.2 ± 2.7	0.1 ± 0.01	44.1	16.4 ±2.2	-	1.5

Mean values for all parameters except TDF analyzed in triplicates

GBE/serving

Expressing the food quality in terms of GBE has an advantage as it is expressed in gram units, unlike the glycemic index which is in percentages and not responsive to the changing doses (Monro & Williams 2000). Using the GBE values for 100g of test foods, the glycemic bread equivalent for common serving sizes (GBE/SS) could be calculated, which will have more practical application in diet counseling.

Table 3: Glycemic bread equivalent values for common serving sizes

Food	HH measure/ 100g	HH measure/ Serving	Amount (g)/ Serving	GBE /100g	GBE /serving
Chapatti	3 med.	1 med.	30	122	36.6
Biscuit	18 ½ no	2 in no.	11.5	142	16
Rice (cooked)	¾ cup	1 cup	130	20	26
Puffed Rice	6 cups	1 cup	17	67	11
Potato (boiled)	1 big	1 whole	100	52	52

HH- Household

When the predicted glycemic response to common serving sizes of the foods was calculated using GBE/100g values, the picture changed dramatically (Table 3). Potato was found to have the highest GBE/ serving followed by chapatti and rice. Marie biscuit and puffed rice were found to have much lower glycemic response when served as snack item- serving size as compared to 100g portion.

The serving size of staple food like rice or chapatti will never be equal to serving size of biscuit or puffed rice, usually consumed in lower quantity as snack item. Therefore, equi-quantity based comparison is more relevant to items belonging to the same food group, but may not be useful for the comparison among different food groups. In such case, one more terminology as GBE/SS (serving size) can be used to compare the food among different food groups, and will be useful for creating food exchange list within the same food group.

Discussion

When the GBE values for common serving sizes relevant to the test foods were calculated, the quality based relation of food with quantity emerged (Table 3). The moisture content of the selected foods strongly influenced the total amount (volume) of energy nutrient consumed at one time.

Rice (100g / 3/4th cup), having high Glycemic Index (Miller, Pang, & Bramall 1992), would be expected to induce a higher glycemic response, but its response is equivalent to that induced by 20g bread only; much lower than that of biscuit and chapatti (Figure 1). This is mainly due to the high water content of cooked rice and type of starch present (SenRay & Singhania 2011)

The postprandial glycemic AUC of 100g potato was found to be much lower than that of the same quantity of other test foods (Figure 1). Starch granules of potato absorb large volume of water and swell, leading to increased surface area for action of amylase enzyme. So, the presence of higher amylopectin starch and faster enzyme action is responsible for rapid breakdown and utilization of potato starch, resulting in a less prolonged glycemic response, which, combined with higher moisture content of potato gave a smaller postprandial AUC (Singhania & SenRay 2012a).

Chapatti and Biscuit constitute products made from wheat. The composition of wheat starch includes higher proportion of amylose (25%) chains leading to the slow and sustained release of blood glucose in postprandial period. However, the higher fiber and protein content of the whole wheat flour makes it a better choice than biscuit which is made from refined wheat flour (Singhania & Senray 2012b). 100g Marie biscuit induced significantly higher glycemic response than the same amount of bread ($p<0.01$), rice ($p<0.01$), puffed rice ($p<0.01$) and potato ($p<0.01$).

Biscuit contains high amount of starch due to very low moisture content of final crispy product. Free sugars in biscuits add to the hyperglycaemic an effect of the higher starch content. It contains a least amount of fiber and a highest amount of fat (Table 2) as compared to the other test foods, making it a poor choice for obese, as well as for diabetic population. The only consideration is that biscuit is rarely consumed in large quantities (100g) at one time. Here GBE/SS is more relevant since it is eaten as a snack and not as a main dish.

Foods with high volume: weight ratio such as biscuit and puffed rice, have light and porous nature and are generally consumed in lesser quantities at one time. But most often, doctors and nutritionist encourage the consumption of these snacks to patients for their apparent lightness. The high postprandial glycemic impact of these foods on equi-quantity basis indicates a possible negative metabolic impact of consuming them freely. Using GBE/SS, the present study shows that it is permissible to enjoy a limited serving of these snacks (Table 3) without over indulging. Equi-quantity based comparison (GBE) which has much more advantages over the use of traditional GI values, can be used for predicting responses to normal serving size of the products.

Rice and potato being high moisture containing product have high volume and hence, give bulk and satiety with comparatively diluted energy supply, which is the main focus in dietary management of obese individual and other metabolically imbalanced individual. Rice is a staple food eaten with accompaniments. Due to a lower fiber content and poor overall nutritive value, the ideal accompaniments may be foods with higher micronutrient density, such as pulses or vegetables which can attenuate the peaks in glycemic response further (Singhania & Senray 2012c).

Like white rice, chapatti is also a common staple item consumed with accompaniments such as vegetables and pulses. For decades now, chapatti prepared from whole wheat flour has been given preference over white rice. Doctors and nutritionists have advised patients that rice contains only starch and is fattening. Study results show that the predicted glycemic response to regular serving size of chapatti (30g) is much higher than that of rice (Table 3). Also, the normal serving size of one chapatti may not satiate the hunger of an individual but a bowl of white rice can. This emphasizes the importance of bulk and starch density on consumption pattern. There is no doubt that the nutritive value of chapatti by itself continues to be superior to plain rice. But rice, being in the same food group and consumed as the main meal, has lesser postprandial glycemic impact with higher satiety level than the whole wheat chapatti. It appears to be a myth that rice consumption should be restricted strictly for weight watchers or diabetic person; rather it may be a better option than plain wheat chapatti. Sen Ray & Paharia (2013) have shown that rice is favourable as compared to equi-quantity bread even in diabetic individuals having compromised insulin status, due to the lower glycemic and insulinemic impact of cooked rice.

Conclusion

GBE values facilitate the direct comparison of glycemic responses to equal quantities of the whole foods as consumed by the individual. Since the values are expressed in gram units, they can be placed alongside other nutrients in the food exchange list. GBE values for 100g foods can be used to estimate the glycemic response to common serving size or any given doses, unlike the GI. This will enable the consumer to use them while choosing foods based on food quality, as well as quantity in practical situations.

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