Glycemic Differences between White and Whole Grain Bread but No Differences in Glycemic Response between Sandwiches made with these Breads, Implications for Dietetic Advice

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Abstract

**Objective:** Strategies to prevent and control diabetes are important with an increasing number of people at risk. Recommendations to consume whole grain foods or basing food choices on Glycemic Index (GI) may be useful in this regard.

**Methods:** We undertook a randomized crossover study in which 120 healthy young adults consumed white bread and whole grain bread sandwiches. The commercially produced breads were chosen to have similar available carbohydrate contents per sandwich (26 and 27 g, respectively) but published Gls that represented high (75) and low (49) GI products. Participants were randomly assigned a filling of jam (n=42), cheese (n=36), or nut-based spread (n=42). The amounts of carbohydrate in the fillings were 12g (jam), 1g (cheese), and 11g (nut-based spread). On different days, each participant consumed a white or whole grain sandwich containing their assigned filling. Blood glucose responses were measured at intervals over two hours.

**Results:** The glycemic responses between white and whole grain sandwiches, represented by incremental area-under-the-blood-glucose-curve (iAUC) were not different. For white and whole grain sandwiches, respectively, the iAUCs (mmol/L.min) were: jam 125 vs 109, P=0.26; cheese 71 vs 53, P=0.06; and nut-based spread 94 vs 72, P=0.12. The lack of postprandial glycemic difference between sandwiches was in contrast to the GI difference between bread types (P=0.03). In regression analysis, the choice of filling had a greater influence over the postprandial response than the type of bread.

**Conclusions:** The data are consistent with American Diabetes Association advice to monitor the amount of carbohydrate intake. Nevertheless, there are attributes other than glycemia to recommend whole grains.

Keywords: Postprandial; Whole grain; Sandwich; Glycemia; Diabetes

Abbreviations: GI: Glycemic index; iAUC: incremental Area Under Curve

Background

Controlling postprandial glycemia is regarded as an important goal in the management of diabetes [1]. One technique with potential to influence postprandial glycemia is food choice based on the glycemic index (GI) [2]. In determining the GI of a food, postprandial glycemia is measured following consumption of a portion of food containing a fixed amount of available carbohydrate. A high GI food is characterized as one that induces marked fluctuations in blood glucose concentrations. Specifically, a rapid rise and a high peak blood glucose value, followed by a rapid decline and undershoot, in which blood glucose falls below the baseline value [3]. On the other hand, a low GI food is typified as producing more gradual changes in blood glucose concentration over a longer time period. Differences in the shape of the curves and the overall rise or increment in blood glucose above the fasting value over the postprandial period forms the metabolic basis of the GI concept [4].

However, individual foods are often combined and eaten as meals, such that glycemic responses found for individual foods may not reliably reflect glycemic differences when other foods are co-ingested [5]. Whilst others have found good correspondence between expected and measured glycemic responses to mixed meals [6], our experience has been that published GI values for individual foods overestimate the GI of mixed evening meals [7]. It was suggested many years ago that the GI concept, when based on single foods, would have limited clinical utility if the effects of individual food challenges were not predictable in a meal setting [8]. This has implications for giving GI advice, advice that generally consists of replacing high GI foods with low GI foods, for example, exchanging white bread for whole grain bread [9]. In theory, using the GI values of individual breads, considerable differences in postprandial glycemic excursions would be expected. However, it is also possible that the addition of spread and fillings ameliorates the difference.

Our aims therefore were to compare the postprandial responses to sandwiches made from either high GI white bread or low GI whole grain bread and to assess whether the type of filling modified the postprandial blood glucose relationship between bread types.

**Methods**

A convenience sample of 120 male and female student’s aged 19-38 y were recruited. The study had a randomized crossover design in which each participant consumed a white and a whole grain bread sandwich. The breads were commercially available (Goodman Fielder...
New Zealand Limited, Auckland, New Zealand) and were chosen for their GI and carbohydrate contents. The whole grain bread was Vogels Soy and Linseed with a low GI of 49 reported on the packet. This bread has a grain composition of wheat flour with added kibbled soya beans (7%), linseeds (7%), and wheat and rye whole grains (7%). The white bread was Natures Fresh that did not have a GI value, so a value of 75 was assigned based on the recommendation given in the International Tables of Glycemic Index for white bread [10]. In order to match available carbohydrate content, the white bread was sandwich (thin) sliced and the whole grain bread was toast (thick) sliced. Margarine was spread on each slice of bread because margarine or butter are customarily used when making sandwiches. Three fillings were used, processed Cheddar cheese slices (Fonterra Brands NZ Ltd. Auckland, New Zealand); Nutella, a hazelnut and chocolate spread (Ferrero, Lithgow, Australia); and Rose’s raspberry jam (HJ Heinz Co Australia Ltd., Southbank, Australia). The fillings were chosen to represent high fat (cheese), high carbohydrate (jam) and a mix of fat and carbohydrate (Nutella). Participants were randomly assigned to one of the fillings such that approximately 40 people consumed sandwiches containing each of the fillings. The available carbohydrate contents of the breads and fillings were taken off the nutrition information panels on the packaging. In addition, a commercial laboratory undertook proximate analyses of the two breads to verify the information. The GIs of the breads were also tested in a subset of 20 participants in which a 50 g glucose beverage was tested twice and portions of white and whole grain bread containing 50 g available carbohydrate, once. Two capillary blood samples were taken for the determination of baseline blood glucose concentration using Hemocue meters (Hemocue AB, Angelholm, Sweden). The correct functioning of the Hemocue instruments was checked daily using a manufacturer’s control. Immediately following, the test or reference food was consumed within 10 minutes and blood sampled at 15, 30, 45, 60, 90 and 120 minutes; participants remained seated for the duration. Postprandial glycaemia was assessed as the incremental Area Under The Curve (iAUC) calculated using the trapezoidal method and ignoring the area below baseline [11]. The GI of the breads was calculated for each person by expressing the iAUC of the test food relative to the iAUC of the glucose reference and the average of the group taken as the bread GI.

The testing was conducted over a four-week period. Bread GI testing in the subset of 20 participants was carried out early morning after an overnight fast. There were three start times for testing postprandial glycaemia following the consumption of sandwiches, 7:15 am (n=46), 12:15 pm (n=53) and 3:00 pm (n=21). Participants were allocated to one of the times and tested both sandwiches (white and whole grain) at the same start time but two weeks apart. The numbers of participants assigned cheese, jam and Nutella, respectively, were 13, 18 and 15 (7:15 am), 16, 16 and 21 (12:15 pm) and 7, 8 and 6 (3:00 pm). Participants assigned to the morning test were asked to fast overnight whilst those scheduled in the afternoon were asked to fast for three hours prior to the start time. Participants were also asked to avoid drinking alcohol and to refrain from strenuous physical activity prior to the tests. The sandwiches were made using two weighed slices of the commercially available breads using electronic scales reading to the nearest 1 g (Salter, Model 3010, Tonbridge, Kent, England). Five to six grams of margarine was weighed and spread onto each slice of bread and the appropriate filling added, either jam or Nutella (weighed, 20-21 g) or two cheese slices (unweighed, nominally 40 g). A baseline capillary blood sample was taken, the sandwich was consumed within 10 minutes, blood was sampled at 15, 30, 45, 60, 90 and 120 minutes, and postprandial iAUC was calculated as described previously.

This study was conducted according to Declaration of Helsinki guidelines and all procedures involving human participants were approved by the Human Ethics Committee of the University of Otago. Written informed consent was obtained from all participants.

**Statistical Analysis**

Analyses were performed using STATA (version 12.0) and a two-sided 0.05 level of significance. Standard deviations derived from earlier studies in our laboratory were used to calculate that a sample size of 40 people had 80% power to detect a difference of 25% in iAUC. A difference of this magnitude represents a difference between the cut-points of low (55) and high (69) GI classification that may be of clinical relevance. The iAUCs were log-transformed, and arithmetic means and 95% confidence intervals (CI) were back-transformed to provide geometric means and 95% CIs. Comparisons in iAUC between sandwiches were tested with a Students t-test using paired data. Multivariate mixed model regression analysis with participant ID treated as a random factor was performed to compare the effect of bread type (white versus whole grain) and filling type (jam, cheese, and Nutella) on log-transformed iAUC. Beta coefficients and standard errors (SE) were then back-transformed to the original scale.

**Results**

The mean (SD) age of the participants was 23 (3.6) y with a mean body mass and body mass index (BMI) of 65 (12.0) kg and 26 (3.5) kg/m², respectively. The available carbohydrate contents of the breads were 32 (10.0) g (whole grain) and 43 (10.0) g (white). The nominal serve masses of two slices of bread were 61 g (white) and 85 g (whole grain). Hence, the nominal serves contained 26 and 27 g available carbohydrate for the white and whole grain breads, respectively. When weighed, the mean (SD) mass of two slices of white and whole grain bread used to make the sandwiches were 61 (6.1) and 90 (5.1) g, respectively. The composition of the sandwiches is shown in Table 1. The amount of carbohydrate provided by the fillings was 12 g (jam), 1 g (cheese), and 11 g (Nutella). Data for postprandial glycaemia are given in Table 2. The difference in GI between white and whole grain bread was statistically significant (P=0.03). There were no statistically significant differences in iAUC between sandwiches made with white and whole grain bread.

Time of eating the sandwiches was included in the model as a covariate but this made no difference to the outcome.

In multivariate analysis comparing between bread types,

**Table 1: Nutrient composition of the sandwiches.**

<table>
<thead>
<tr>
<th>Sandwich filling</th>
<th>Jam</th>
<th>Cheese</th>
<th>Nutella</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread type</td>
<td>White</td>
<td>Grain</td>
<td>White</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>1030</td>
<td>1310</td>
<td>1340</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>5.7</td>
<td>10.2</td>
<td>12.8</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>8</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>14.1</td>
<td>14.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>38</td>
<td>39</td>
<td>27</td>
</tr>
</tbody>
</table>

**Table 2: Mean (95% CI) Glycemic Index for bread and blood glucose incremental area under the curve (iAUC; mmol/L*min) for sandwiches.**

<table>
<thead>
<tr>
<th>Bread alone (n=20), Jam (n=42), Cheese (n=36), Nutella (n=42)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread Glycemic Index</td>
<td>72 (61, 85)</td>
</tr>
<tr>
<td>Jam sandwich iAUC</td>
<td>125 (98, 159)</td>
</tr>
<tr>
<td>Cheese sandwich iAUC</td>
<td>71 (52, 99)</td>
</tr>
<tr>
<td>Nutella sandwich iAUC</td>
<td>94 (68, 128)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bread alone (n=20), Jam (n=42), Cheese (n=36), Nutella (n=42)</th>
<th>P</th>
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</table>
irrespective of the filling (n=120), an effect of bread type was found (Table 3). An effect of filling was also found, with the beta coefficient for jam being considerably larger than the beta coefficient for white bread. Incremental blood glucose concentrations plotted against time are shown in Figure 1. Averaged over the 2-hour time period, the mean difference in incremental blood glucose between white and whole grain sandwiches was 0.20 (95% CI: 0.09, 0.32) mmol/L.

**Discussion**

The magnitude of difference in iAUC between sandwiches made with white and whole grain breads was relatively small and was not statistically significant. This finding was unexpected given that the breads had been selected to have a large difference in GI, the white being chosen as a high GI bread (>70) and the whole grain a low GI bread (<55). These breads represent products towards the upper and lower ends of the GI scale of bread available in New Zealand supermarkets. Indeed, our data for the GI of bread tested in the subset of 20 participants was consistent with the white bread being a high GI product (GI 72; 95% CI 61, 85) and the whole grain bread a low to medium GI product (GI 56; 95% CI 46, 69). Differences in the glycemic response to sandwiches were found when comparing among fillings, but this was expected given the different carbohydrate contents that the fillings contributed to the sandwiches. Whilst whole grain bread was associated with a smaller glycemic response than white bread sandwiches in the overall sample (n=120), this difference was not found when analysing within each sandwich filling (Table 2). The lack of statistical significance could be due to a smaller sample (n~40 per filling) as there was a tendency for the whole grain sandwiches to have smaller glycemic responses than the equivalent white bread sandwiches. Whether potential differences in glycemia of this magnitude are of clinical relevance is questionable. In our group of participants without diabetes, the mean difference in blood glucose concentration for sandwiches made with different bread types over the two-hour postprandial period was 0.20 mmol/L. We are unaware of any clinical implication for difference as small as this although the magnitude may be greater in people with diabetes.

The purpose of recommending foods based on GI to people with diabetes is to help control glycaemia by influencing the postprandial glycemic response. Postprandial glycaemia has been found to be a predictor of cardiovascular events in people with type 2 diabetes [12] and an independent risk factor for intima-media thickness [13]. In some studies the use of GI to guide food choice has been found to improve metabolic markers for people with diabetes [14-16]. However, our data and that of others [5,7,17] raise questions as to how GI determinations on individual foods are translated into practical advice when foods are combined and eaten in a realistic manner. A health information and patient-support network for people with diabetes in the United Kingdom suggest that the GI concept can be useful if portion control is taken into consideration [18]. Similarly, the American Diabetes Association recognize that both the amount and the type of carbohydrate influence blood glucose, suggesting that carbohydrate be monitored by carbohydrate counting or by choice [19]. Our data are consistent with this advice from the diabetes organizations in that the sandwich with the highest carbohydrate content (jam) induced the highest blood glucose readings. The cheese sandwich contained a smaller amount of carbohydrate than the jam sandwich and induced a lower blood glucose response; but it had a higher fat and energy content than the jam sandwich, highlighting the need to consider a number of nutritional qualities when making food choices.

Apart from the absolute iAUC, some evidence is suggestive that the shape of the glycemic response curve may have clinical relevance. High GI foods have been characterized as producing an undershoot in which blood glucose concentrations decline rapidly and fall below the baseline value [3], a phenomenon with purported negative health consequences. For the bread and sandwiches we tested there was no indication of an undershoot within the a priori 120 minute postprandial period.
timeframe. Another perception, that low GI foods produce longer sustained glycemia, was not supported in our data, nor was it upheld after the examination of a large University of Sydney dataset [20]. On the contrary, from inspection of Figure 1 it can be seen that the postprandial response to the white and whole grain bread sandwiches tracked each other closely and that even the initial rise in blood glucose concentration did not differ between bread types. This is consistent with results obtained from a number of studies in which it was found that sugary foods were more likely to induce an undershoot than starchy foods irrespective of GI [20]. From our data and from the University of Sydney dataset [20], it cannot be concluded that high GI products, or foods made with high GI ingredients, characteristically differ in all aspects of their glycemic response profiles compared with low GI products, particularly for foods within the same food category.

Despite the lack of difference in postprandial glycemia between our white and whole grain sandwiches, we would still recommend whole grain for its better nutritional profile. Interventions studies involving adults, whole grain intakes have been inversely associated with risk of developing type 2 diabetes, arguably independent of GI or glycemic load [21]. Magnesium and cereal fiber in particular are nutritional qualities of whole grain diets associated with reduced risk of developing dysglycemia and type 2 diabetes [22,23].

Factors weighing against the use of whole grain could be cost, availability, taste preference and energy content. In order to match the carbohydrate content of the bread types, the mass of whole grain bread (90 g) was higher than that of white bread (61 g). A higher fat and protein content associated with the larger portion resulted in the white grain sandwich containing more energy than the corresponding white bread sandwiches. Many low GI products, such as biscuits, cakes and muesli bars are high in fat, sugar and energy and thus may not be suitable for people aiming to control weight or diabetic progression. Guidance on the appropriate use of GI are available [24].

The strength of the study was the large sample and a crossover design, both being conducive to finding meaningful differences in iAUC. Testing at different times of the day could be regarded as a limitation because GI testing is usually undertaken in the morning following an overnight fast. However, the testing time was standardized to each participant and from a practical viewpoint; sandwiches are eaten at different times of the day. Despite the breads themselves inducing different glycemic responses, the addition of spread and fillings removed this difference. Our data indicate that any expectation of a substantial improvement in postprandial glycemia attainable from choosing breads based on GI may be overestimated when food combining and sandwich fillings are taken into account. Although there is compelling evidence in favor of whole grain intake, from a glycemic viewpoint, our findings are consistent with the American Diabetes Association advice, that people with diabetes carefully monitor the amount of carbohydrate consumed.

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References