## Original Article

# Concurrent management of postprandial glycaemia and nutrient intake using glycaemic glucose equivalents, food composition data and computer-assisted meal design

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A computer system, called SERVE-NZ Nutririon Management System, for use in diabetes management, addresses the problem of concurrently controlling postprandial glycaemic response and nutrient intake in meals containing a number of foods, is described. It converts the weight and relative glycaemic potency of each food to its content of glycaemic glucose equivalents (GGE) – the amount of glucose theoretically inducing the same blood glucose response as would the specified quantity of food. Glycaemic glucose equivalents in a meal can be simply obtained by adding the GGE content of all foods in the meal to give a figure for the maximal glycaemic impact of the meal. Glycaemic glucose equivalents may be calculated using food composition databases that include available carbohydrate, common standard measure weights and glycaemic index values. If GGE is treated as a nutrient, an output of the total nutrient profile of a food or meal, and its glycaemic impact as GGE, can be obtained simultaneously. Application of a nutritional software system incorporating GGE values to management of glycaemic loadings and nutrient intakes over five meals within a day is demonstrated. The system may be a useful aid in self-management of glycaemia, as it will identify quantities of foods that can be consumed without exceeding the predetermined glucose tolerances of individuals. The graphical presentation of GGE and nutrient composition of meals may be a useful visual aid in educating clients with diabetes. The GGE values on food labels would provide easily understood guidance, not obtained from glycaemic index values, to the maximum number of items or quantity of a food that an individual should eat at a time. In its present basic form the calculation of GGE is most likely to slightly overestimate glycaemic impact, so it presents a worst-case prediction.

**Key words: carbohydrate, diabetes, food composition data, glycaemia, glycaemic glucose equivalents, nutrition software.**

### Introduction

Dietary control of diabetes mellitus has proved to be difficult because it is a complex syndrome in which risk factors such as obesity, immediate effects such as hyperglycaemia and complications such as atherosclerosis are all influenced by nutrient intake. Hyperglycaemia is responsible for both acute and insidious medical problems that characterize the syndrome, so means of controlling it have been an important focus of diabetes management. However, the best way of maintaining glycaemic control is still under debate,[1–3] and there is the ever-present challenge of controlling glycaemia while simultaneously maintaining an appropriate nutrient balance.

Diabetes management has traditionally used the carbohydrate exchange system, in which foods of similar composition and carbohydrate content are exchanged. However, such food exchanges do not take into account large differences in the glycaemic potency of foods that result from factors such as monosaccharide composition of available carbohydrate, the effect of food structure on digestion and other food matrix effects.[4]

The glycaemic index (GI) was therefore developed as a physiological basis for carbohydrate exchange,[5] and is a measure of the blood glucose response to *carbohydrate within a food* as a percentage of the response to an equicarbohydrate dose of glucose. Usually, enough of a food is fed to provide 50 g of carbohydrate, and the blood glucose response is compared with the response to 50 g of glucose or to white bread providing 50 g of available carbohydrate.

Glycaemic index is therefore a measure of the relative effects of equal weights of available carbohydrates, so use of it should be restricted to comparing available carbohydrates or foods containing the same amounts of available carbohydrate per edible weight. However, because of the enormous range of available carbohydrate content per edible weight of carbohydrate foods, many dietitians and consumers alike have found GI difficult to apply. Data sets in which GI and available carbohydrate content are combined to allow glycaemic comparisons of entire carbohydrate foods across a spectrum of food compositions would facilitate food exchanges for control of postprandial glycaemia.

New data sets based on GI and available carbohydrate for use in managing postprandial glycaemia have recently been

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proposed.[6,7] One of them, the relative glycaemic potency (RGP), is simply the GI value adjusted for the carbohydrate content of a food, and is defined as:

$$\text{RGP} = \frac{\text{incremental area under the blood glucose response curve for a food}}{\text{corresponding area after consuming an equal weight of glucose}} \times 100.$$

The RGP gives a classification of whole foods according to their immediate impact on blood glucose levels, and produces a different ranking of foods than that obtained with GI. It allows a direct comparison of the glycaemic impact of foods on a weight-for-weight basis. In principle, it does what dietitians are presently attempting to do in dietary management of glycaemia when they apply GI to food categories. Use of GI and available content combined for use as a continuous variable appears to be valid, as recent clinical trials have shown that the glycaemic response to a food can be reliably predicted from its carbohydrate content and glycaemic index.[8,9]

The RGP is used to compare equal weights of foods. However, as different foods are usually not consumed in equal weights, and as RGP relates whole-food weight to glucose weight, RGP can most usefully be used to calculate the amount of glucose that would be equivalent in glycaemic impact to a given weight of food; in other words, to determine the glycaemic glucose equivalent (GGE) content of the food. Glycaemic glucose equivalent values allow different amounts of different foods to be compared directly according to their impact on glycaemia. They enable the relative glycaemic impact of meals to be expressed because the GGE content of different foods consumed at the same time may, in theory, be added to give a measure of the glycaemic impact of a meal.

Perhaps one of the most important attributes of GGE is that as a quantity in grams it may be treated in the same way as would a nutrient, allowing the glycaemic impact of a food and its nutrient composition to be presented simultaneously in a food or meal analysis, thus facilitating the task of simultaneously managing glycaemia and nutrition. The GGE therefore lends itself to use in computer-based diet management systems, which are likely to be increasingly used in modern dietetics.

This paper describes the derivation of GGE and how they may be applied, in conjunction with food composition data, to the management of glycaemia and diabetes.

## Method

A set of RGP values (Table 1) was constructed for all New Zealand foods for which a GI value had been measured or to which a value could be reasonably assigned from the international tables of glycaemic index.[10] Glycaemic index values were entered into the New Zealand Food Composition Database, and RGP values calculated for each food using the formula:

$$\text{RGP} = (\%\text{CHO}/100) \bullet \text{GI}_f$$

where %CHO is the available carbohydrate content[9] and $GI_f$ is the glycaemic index of a food.

As RGP is blood glucose response as a percentage of the response to an equal weight of glucose, it amounts to glucose equivalents per 100 g of a food. The GGE content per gram of a food is therefore $RGP_f/100$ and the GGE content of a weight (W) of food:

$$\text{GGE} = (\text{W} \bullet \text{RGP}_f/100)\ \text{g}.$$

The GGE content of a given quantity of specific food is thus defined as the weight of glucose in grams that would induce the same glycaemic response as the given quantity of the food.

As the weight of a food is often difficult for consumers to estimate, it is more practical to work in common standard measures (CSM), such as cups, spoons, servings, and to calculate GGE as:

$$\text{GGE} = \text{no. CSM} \bullet \text{CSMwt} \bullet \text{RGP}/100$$
$$\text{or GGE} = \text{no. CSM} \bullet \text{CSMwt} \bullet (\%\text{CHO}/10\,000) \bullet \text{GI}_f \qquad 1$$

where no. CSM is the number of common standard measures and CSMwt is the weight of a CSM of the food. The GGE content of one CSM of each food is given in the last column of Table 1.

As RGP, and therefore GGE, content will be low for foods containing low levels of carbohydrate, and which may therefore have a correspondingly high fat content, each of the foods in Table 1 was assessed to see whether it would qualify as being both a carbohydrate food and acceptably low in fat. The criteria used were that 55% or more of the energy in the food should be present as available carbohydrate and not more than 30% of the energy should be in the form of fat. Foods satisfying both criteria are identified in Table 1 with a tick.

Calculations of the GGE content of meals can be simply performed by computer using a nutrition management system, such as SERVE-NZ, linked to a food composition database. As CSMwt, %CHO, and $GI_f$ are part of the New Zealand Food Composition database, all that is required to calculate the nutrient profile of a food or meal, and its equivalent glycaemic impact, is the identity of a food and the amount of it, either in grams or number of CSM. As GGE represent a theoretical quantity of glucose associated with an amount of food, for the purposes of the calculation they can be treated in exactly the same way as a nutrient. The computer program was therefore designed to calculate GGE equivalent to each food quantity, whether entered as a weight or as CSM, and to give a simultaneous profile of the macronutrient content and glycaemic impact of the meal. Output is provided as a screen containing a histogram of the macronutrient content of the food and its GGE content (Fig. 1).

## Results

Glycaemic glucose equivalents values calculated from CSMwt, GI and %CHO, for CSM of New Zealand Foods are given in Table 1 (GGE/CSM). The list at present contains only about 100 values because it is limited mainly to foods that were thought to correspond reasonably to those in the International Tables of Glycaemic Index, and for which %CHO values were available in the New Zealand Food Composition Database. The GGE content per gram of each food is not given because it is simply RGP/100. The RGP and GI values differ considerably, because RGP is a measure of glycaemic response to a whole food relative to response to an

**Table 1.** Glycaemic glucose equivalents (GGE) and precursor values for New Zealand foods

| Key † | Food | | %CHO | GI | RGP | Nature of CSM | CSMwt (g) | GGE/CSM (g) |
|---|---|---|---|---|---|---|---|---|
| | *Bakery products* | | | | | | | |
| A54 | Bagel, plain | ✓ | 47 | 72 | 34 | bagel | 74 | 25 |
| A4 | Biscuit, digestive, plain | | 63 | 58 | 37 | biscuit | 14 | 5 |
| * | Biscuit, golden fruit | — | 66 | 77 | 51 | biscuit | 13 | 7 |
| A7 | Biscuit, oatcake | | 57 | 54 | 31 | biscuit | 15 | 5 |
| A63 | Biscuit, shortbread | | 56 | 64 | 36 | biscuit | 14 | 5 |
| A12 | Biscuit, wafer, cream | | 62 | 76 | 47 | biscuit | 9.5 | 5 |
| A16 | Bread, currant | ✓ | 47 | 47 | 22 | med. slice | 34 | 8 |
| A43 | Bread, multigrain ‘light’ | ✓ | 44 | 52 | 23 | med. slice | 28 | 6 |
| A42, | Bread, multigrain ‘heavy’ | ✓ | 37 | 52 | 19 | med. slice | 28 | 5 |
| * | Bread, Burgen, dark rye | ✓ | 39 | 45 | 18 | slice | 38 | 7 |
| * | Bread, Burgen mixed grain | ✓ | 41 | 55 | 23 | slice | 38 | 9 |
| * | Bread, ‘fibre white’ | ✓ | 47 | 77 | 36 | med. slice | 28 | 10 |
| * | Bread, Molenberg | ✓ | 45 | 75 | 34 | med. slice | 30 | 10 |
| A40 | Bread, roll, white, soft | ✓ | 49 | 70 | 34 | roll | 51 | 18 |
| A52 | Bread, roll, wholemeal | ✓ | 43 | 69 | 30 | roll | 70 | 21 |
| A18 | Bread, white, sliced | ✓ | 43 | 70 | 30 | med. slice | 26 | 8 |
| A23 | Bread, wholemeal | ✓ | 37 | 69 | 26 | med. slice | 28 | 7 |
| A25 | Bun, currant | ✓ | 49 | 47 | 23 | bun | 80 | 18 |
| A77 | Cake, sponge, plain | ✓ | 60 | 46 | 28 | slice | 89 | 25 |
| A30 | Chapati, high fat | | 44 | 57 | 25 | chapati | 36 | 9 |
| A31 | Chapati, low fat | ✓ | 40 | 57 | 23 | chapati | 36 | 8 |
| A32 | Crispbread, rye | ✓ | 64 | 65 | 42 | biscuit | 6 | 3 |
| A101 | Croissant | | 39 | 67 | 26 | small | 57 | 15 |
| A34 | Doughnut, ring | | 44 | 76 | 33 | doughnut | 42 | 14 |
| A96 | Muffin, toasted | ✓ | 41 | 55 | 23 | muffin | 80 | 18 |
| | *Beverages, non-alcoholic* | | | | | | | |
| C46 | Juice, apple | ✓ | 9.8 | 41 | 4 | cup | 261 | 11 |
| C 12 | Juice, grapefruit, unsweet. | ✓ | 7.9 | 48 | 4 | cup | 256 | 10 |
| C14 | Juice, orange, unsweet. | ✓ | 7.7 | 52 | 4 | cup | 256 | 10 |
| C18 | Lucozade | ✓ | 15.6 | 95 | 15 | cup | 264 | 39 |
| | *Breakfast cereals* | | | | | | | |
| D1 | Bran cereal | ✓ | 37 | 42 | 16 | cup | 45 | 7 |
| D32 | Corn flakes, Kellogg’s | ✓ | 85 | 84 | 71 | serving | 30 | 21 |
| D4 | Muesli, toasted, sweet | | 53 | 43 | 23 | cup | 110 | 25 |
| D9 | Porridge, prepared (milk and water) | | 10.5 | 61 | 6 | cup | 260 | 17 |
| D10 | Rice, puffed, ‘Ricies’ | ✓ | 78 | 89 | 69 | cup | 14 | 10 |
| D11 | Wheat, puffed | ✓ | 64 | 74 | 47 | cup | 14 | 7 |
| D20 | Wheat biscuit, ‘Weet-Bix’ | ✓ | 62 | 70 | 43 | biscuit | 15 | 7 |
| | *Cereals* | | | | | | | |
| E3 | Barley, pearl, boiled | ✓ | 25 | 25 | 6 | cup | 165 | 10 |
| E2 | Barley, whole grain flakes | ✓ | 58 | 66 | 38 | cup | 90 | 35 |
| E19 | Macaroni, boiled | ✓ | 17 | 45 | 8 | cup | 149 | 11 |
| E23 | Oat bran | ✓ | 55 | 55 | 30 | cup | 120 | 36 |
| E42 | Rice, brown, boiled | ✓ | 29 | 55 | 16 | cup | 206 | 33 |
| E27 | Rice, white, boiled | ✓ | 27 | 58 | 16 | cup | 216 | 34 |
| E31 | Spaghetti, boiled | ✓ | 20 | 41 | 8 | cup | 148 | 12 |
| | *Dairy* | | | | | | | |
| F28 | Ice cream, vanilla | | 22 | 61 | 13 | cup | 143 | 19 |
| F40 | Milk, fluid, standard | | 4.5 | 27 | 1 | cup | 258 | 3 |
| F55 | Yoghurt, fat red., unsweetened | ✓ | 4.9 | 33 | 2 | small carton | 150 | 2 |
| | *Fast foods* | | 0 | | 0 | | | |
| H61 | Fish, fingers, baked | | 20.3 | 38 | 8 | finger | 25 | 2 |
| H49 | Sausage, deep fried | | 6.9 | 28 | 2 | sausage | 79 | 2 |
| | *Fruit* | | | | | | | |
| L17 | Apple, dessert, flesh, raw | ✓ | 10.7 | 38 | 4 | apple | 121 | 5 |
| L22 | Apricot, canned, syrup | ✓ | 27 | 64 | 17 | cup | 272 | 47 |
| L26 | Apricot, dried | ✓ | 49 | 31 | 15 | 10 halves | 35 | 5 |
| L23 | Apricot, raw | ✓ | 9.3 | 57 | 5 | apricot | 54 | 3 |
| * | Banana, raw, green | ✓ | 26 | 38 | 10 | banana | 128 | 13 |
| L32 | Banana, raw | ✓ | 24 | 58 | 14 | banana | 128 | 18 |
| L45 | Cherries, eating, raw | ✓ | 14 | 22 | 3 | cup | 150 | 5 |
| L81 | Grapefruit, flesh, raw | ✓ | 10.1 | 25 | 3 | grapefruit | 170 | 4 |
| L82 | Grape (black or white) | ✓ | 15.8 | 46 | 7 | grape | 5.4 | 0 |
| L89 | Kiwifruit, raw | ✓ | 9.3 | 52 | 5 | kiwifruit | 100 | 5 |

**Table 1.** continued

| Key † | Food | | %CHO | GI | RGP | Nature of CSM | CSMwt (g) | GGE/CSM (g) |
|---|---|---|---|---|---|---|---|---|
| L101 | Mango, raw | ✓ | 14.6 | 55 | 8 | mango | 176 | 14 |
| L106 | Melon, rock, raw | ✓ | 6.3 | 65 | 4 | cup | 168 | 7 |
| L113 | Orange, juice, fresh | ✓ | 9.2 | 50 | 5 | cup | 258 | 12 |
| L114 | Orange, raw | ✓ | 7.7 | 44 | 3 | orange | 128 | 4 |
| L191 | Pawpaw, Australian | ✓ | 6.9 | 58 | 4 | slice | 140 | 6 |
| L125 | Peach, canned | ✓ | 22 | 47 | 10 | cup of slices | 260 | 27 |
| L139 | Pear, eating, flesh, raw | ✓ | 11.6 | 42 | 5 | pear | 148 | 7 |
| L144 | Pineapple, raw | ✓ | 11.4 | 66 | 8 | slice | 110 | 8 |
| L155 | Plum, raw | ✓ | 13.9 | 39 | 5 | plum | 49 | 3 |
| L161 | Raisins | ✓ | 64 | 64 | 41 | cup | 154 | 63 |
| L173 | Sultanas | ✓ | 75 | 56 | 42 | cup | 153 | 64 |
| L177 | Watermelon, raw | ✓ | 5.1 | 72 | 4 | cup | 213 | 8 |
| | *Nuts and seeds* | | | | | | | 0 |
| Q14 | Peanuts | | 8 | 14 | 1 | cup | 156 | 2 |
| | *Recipes* | | | | | | | |
| R159 | Cake, banana, not iced | | 43 | 47 | 20 | slice | 85 | 17 |
| R22 | Cake, sponge, low fat | ✓ | 49 | 46 | 23 | slice | 89 | 20 |
| R38 | Crumpet | ✓ | 38 | 69 | 26 | crumpet | 40 | 11 |
| R162 | Muffin, bran | ✓ | 36 | 60 | 22 | muffin | 80 | 17 |
| R96 | Pizza, cheese and tomato | | 19 | 60 | 11 | slice | 100 | 11 |
| | *Snack foods* | | | | | | | |
| * | Apricot bar, 'Mother Earth' | — | 75 | 50 | 38 | bar | 50 | 19 |
| U5 | Meusli bar | | 55 | 61 | 34 | bar | 32 | 11 |
| U18 | Popcorn, candied | ✓ | 71 | 55 | 39 | cup | 8 | 3 |
| U10 | Potato crisps, plain | | 48 | 54 | 26 | packet | 50 | 13 |
| | *Soups* | | | | | | | |
| V33 | Soup, pea, homemade | | 6.5 | 60 | 4 | serving | 260 | 10 |
| V13 | Soup, tomato, condensed | | 14 | 38 | 5 | cup | 267 | 14 |
| V14 | Soup, tomato, prep w/water | | 7 | 38 | 3 | cup | 258 | 7 |
| | *Sugar, confectionery and sweet spreads* | | | | | | | |
| W6 | Mars bar | | 63 | 68 | 43 | bar | 60 | 26 |
| W4 | Chocolate bar, plain | | 61 | 49 | 30 | small bar | 40 | 12 |
| W11 | Honey | ✓ | 80 | 73 | 58 | tablespoon | 21 | 12 |
| W45 | Jellybean | ✓ | 92 | 80 | 74 | jellybean | 2 | 2 |
| W24 | Sugar, white (sucrose) | ✓ | 100 | 65 | 65 | teaspoon | 4 | 3 |
| | Maltose | ✓ | 100 | 105 | 105 | teaspoon | 4 | 4 |
| | Lactose | ✓ | 100 | 46 | 46 | teaspoon | 4 | 2 |
| | Fructose | ✓ | 100 | 23 | 23 | teaspoon | 4 | 1 |
| | *Vegetables* | | | | | | | |
| X138 | Beans, broad, boiled | ✓ | 8.6 | 79 | 7 | cup | 170 | 12 |
| X10 | Beans, haricot, boiled | ✓ | 15 | 38 | 6 | cup | 180 | 10 |
| X141 | Beans, red kidney, boiled | ✓ | 16 | 27 | 4 | cup | 187 | 8 |
| X17 | Beetroot, boiled | ✓ | 9.8 | 64 | 6 | cup | 180 | 11 |
| X33 | Carrot, boiled, drained | ✓ | 5.5 | 71 | 4 | carrot | 49 | 2 |
| X43 | Corn, sweet, boiled | ✓ | 21 | 55 | 12 | cob | 128 | 15 |
| X151 | Kumara, baked | ✓ | 23 | 44 | 10 | kumara | 114 | 12 |
| X53 | Lentils, red, cooked | ✓ | 10.4 | 26 | 3 | cup | 209 | 6 |
| X69 | Parsnip, boiled | ✓ | 12.3 | 97 | 12 | parsnip | 160 | 19 |
| X76 | Peas, chick, cooked | | 10.3 | 33 | 3 | cup | 173 | 6 |
| X78 | Peas, green, boiled, | ✓ | 7.1 | 48 | 3 | cup | 165 | 6 |
| X96 | Potato, mashed, milk & butter | ✓ | 14.5 | 70 | 10 | cup | 209 | 21 |
| X154 | Potato, microwaved | ✓ | 21.1 | 81 | 17 | potato | 90 | 15 |
| X94 | Potato, Rua, flesh, boiled | ✓ | 18 | 56 | 10 | potato | 114 | 12 |
| X102 | Potato, fries | ✓ | 28 | 75 | 21 | cup | 60 | 13 |
| X103 | Potato, instant | ✓ | 14.7 | 83 | 12 | cup | 241 | 29 |
| X147 | Pumpkin, boiled, drained | ✓ | 4 | 75 | 3 | cup | 220 | 7 |
| X148 | Pumpkin, flesh, baked | ✓ | 9.1 | 75 | 7 | cup | 217 | 15 |
| X123 | Swede, boiled, drained | ✓ | 3.7 | 72 | 3 | cup | 150 | 4 |
| X105 | Sweet potato, boiled | ✓ | 18.9 | 54 | 10 | cup | 235 | 24 |
| X150 | Taro, corms, cooked | ✓ | 27 | 54 | 15 | cup | 142 | 21 |
| X132 | Yam, boiled, drained | ✓ | 27 | 34 | 9 | cup | 144 | 13 |

* Values provided by Dr A.Chisholm, Nutrition Department, Otago University, New Zealand.
† Key to food in the New Zealand Food Composition Database.
—, data not available to calculate whether or not it qualifies for a ✓.
CHO, available carbohydrate content; CSM, common standard measure; CSMwt, CSM weight; GI, glycaemic index; RGP, relative glycaemic potency.
✓Foods containing < 30% energy as fat and at least 55% energy as available carbohydrate.

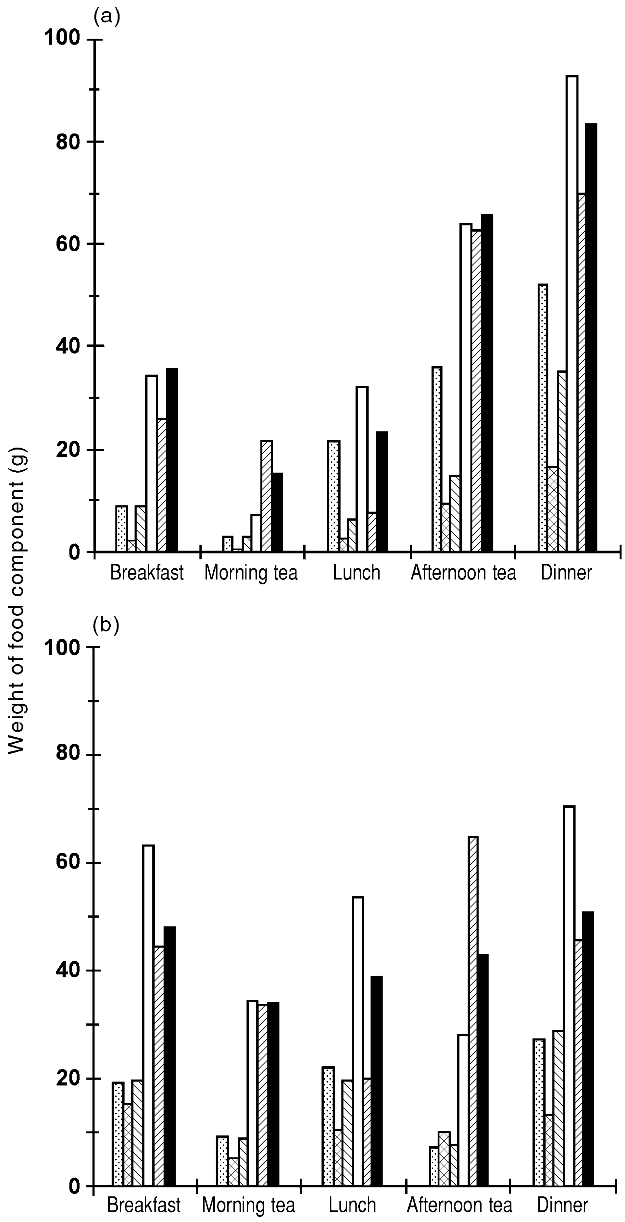


**Figure 1.** Profiles of nutrient content, and glycaemic potency expressed as glycaemic glucose equivalents (GGE), for five meals during 1 day: (a) before modifying; and (b) after modifying to redistribute glycaemic loading and reduce fat intake by 30%: fat ( ), fibre ( ), protein ( ), starch ( ), sugars ( ), GGE ( ).

equal weight of glucose, while GI is expressed on the basis of response to food carbohydrate relative to response to glucose.

The majority of foods in Table 1 qualified as high carbohydrate/acceptable fat according to the criteria that specify that at least 55% of energy should come from carbohydrate and no more than 30% of energy should come from fat. In other words, most of them can be regarded as carbohydrate foods to which it is prudent to apply combined GI-food composition data such as RGP and GGE in diabetes management.

The use of values for no.CSM, CSMwt, %CHO, and GI in calculating the theoretical GGE content of five hypothetical meals over 1 day, using equation 1, is shown in Table 2. The food intakes shown in Table 2 result in a very uneven pattern of glycaemic loadings throughout the day, which is immediately evident in the graphic output from the SERVE-NZ Nutrition Management System (Fig. 1). The meal plan was therefore revised to redistribute GGE levels between meals, and at the same time reduce the fat content of the meal by about 30%. The revised meal plan, shown in Table 3, was achieved by redistributing carbohydrate intakes, choosing carbohydrate-rich foods of low RGP and removing butter. The result was a more even glycaemic loading (Fig. 2) with virtually no change in total GGE intake (unmodified, 223 GGE/day; modified, 215 GGE/day), a 30% reduction in fat intake (unmodified, 121 g/day; modified, 85 g/day) and a slight increase in total carbohydrate intake (unmodified, 418 g/day; modified, 459 g/day). Thus control of glycaemia was in theory greatly improved without decreasing carbohydrate intake.

## Discussion

The system presented here is aimed at facilitating the dietary management of glycaemia and diabetes by simultaneously providing information on the glycaemic impact of a food or diet and its nutrient content. It makes management of diabetes more quantitative by taking into account the glycaemic potency of whole foods, their carbohydrate content, their nutrient composition, and the quantities in which they are consumed, and it presents the information in an easily understandable visual format.

The usefulness of GGE stems from the fact that the content of GGE can be calculated in spreadsheets for any quantity, in weight or CSM, of one or more specified foods, as long as GI or RGP values are available to use with CSMwt and percentage CHO. By linking the spreadsheets to food composition tables, a nutritional profile of a meal and its glycaemic impact as glucose equivalents can be presented together.

Glycaemic glucose equivalents, unlike GI, are not limited to comparisons of foods containing equal amounts of CHO because they are not indices based on equi-carbohydrate comparisons. And although GI is promoted as ‘a classification of foods according to their blood glucose responses’[11] or ‘simply a ranking of foods according to their immediate effect on blood sugar levels’[12] it in fact relates to *carbohydrates* as affected by being in a food, not to foods per se, so the foregoing statements are not strictly correct, and have been misunderstood by some users of GI. Furthermore, as GI is a ratio unrelated to food weights it cannot be applied on its own to predicting the relative glycaemic effects of different weights of different foods. The GI is a valuable datum measured under specific clinical conditions, but it needs to be used carefully in dietetics.

As most consumers think in terms of familiar amounts such as cups and spoons, a user-friendly system must be able to present food data in CSM. Glycaemic glucose equivalents is user-friendly to the extent that the GGE content of any amount of food, including CSM amounts, can be presented. The values for GGE per CSM in Table 1 would allow a person for whom a tolerated level of glucose has been established to know approximately how much of a food item they could consume. The theoretical glycaemic impact of any food product such as a muesli bar or a slice of bread, when expressed as GGE as in Table 1, would inform a person who has been advised not to eat more than 30 g of GGE at a time, that they should restrict themselves to about one bagel to

**Table 2.** Glycaemic analysis of meals over the course of a day: A. unmodified meals

| | CSM | CSM wt (g) | No. CSM | Total wt (g) | %CHO | GI | RGP | GGE |
|---|---|---|---|---|---|---|---|---|
| *Breakfast* | | | | | | | | |
| Bagel, plain | 1 piece | 74 | 1 | 74 | 47.1 | 72 | 34 | 25.1 |
| Juice, apple, FreshUp | 1 cup | 261 | 1 | 261 | 9.8 | 41 | 4 | 10.5 |
| Butter, salted | 1 teaspoon | 5 | 2 | 10 | 1.0 | 46 | 0 | 0.0 |
| | | | | | | **Total for breakfast** | | **35.6** |
| *Morning tea* | | | | | | | | |
| Biscuit, digestive, plain | 1 biscuit | 14 | 1 | 14 | 63.0 | 58 | 37 | 5.1 |
| Juice, orange, unsweetened | 1 cup | 256 | 1 | 256 | 7.7 | 52 | 4 | 10.3 |
| | | | | | | **Total for morning tea** | | **15.4** |
| *Lunch* | | | | | | | | |
| Soup, cream of tomato | 1 cup | 260 | 1 | 260 | 5.5 | 38 | 2 | 5.4 |
| Butter, salted | 1 teaspoon | 5 | 3 | 15 | 1.0 | 46 | 0 | 0.0 |
| Bread, roll, white, soft | 1 roll | 51 | 1 | 51 | 49.7 | 70 | 35 | 17.7 |
| | | | | | | **Total for lunch** | | **23.2** |
| *Afternoon tea* | | | | | | | | |
| Bun, currant | 1 bun | 80 | 1 | 80 | 49.3 | 47 | 23 | 18.5 |
| Biscuit, oatcake | 1 biscuit | 15 | 4 | 60 | 57.4 | 54 | 31 | 18.6 |
| Juice, grapefruit, unsweetened | 1 cup | 256 | 2 | 512 | 7.9 | 48 | 4 | 19.4 |
| Biscuit, wafer, plain cream | 1 biscuit | 9.5 | 2 | 19 | 62.1 | 76 | 47 | 9.0 |
| Butter, salted | 1 teaspoon | 5 | 3 | 15 | 1.0 | 46 | 0 | 0.0 |
| | | | | | | **Total for afternoon tea** | | **65.6** |
| *Dinner* | | | | | | | | |
| Bread, roll, white, soft | 1 roll | 51 | 1 | 51 | 49.7 | 70 | 35 | 17.7 |
| Soup, cream of tomato | 1 cup | 260 | 2 | 520 | 5.5 | 38 | 2 | 10.9 |
| Spaghetti, boiled | 1 cup | 148 | 1 | 148 | 20.1 | 41 | 8 | 12.2 |
| Fish fingers, grilled | 1 finger | 25 | 3 | 75 | 20 | 28 | 6 | 4.2 |
| Peas, green, boiled, drained | 1 cup | 165 | 1 | 165 | 7.1 | 48 | 3 | 5.6 |
| Ice cream, vanilla, econ | 1 cup | 143 | 0.5 | 71.5 | 21.4 | 61 | 13 | 9.3 |
| Butter, salted | 1 teaspoon | 5 | 4 | 20 | 1.0 | 46 | 0 | 0.1 |
| Apricot, canned, syrup | 1 cup | 272 | 0.5 | 136 | 27 | 64 | 17 | 23.5 |
| | | | | | | **Total for dinner** | | **83.5** |

%CHO, available carbohydrate content; CSM, common standard measure; CSMwt, CSM weight; GGE, glycaemic glucose equivalents; GI, glycaemic index; RGP, relative glycaemic potency.

avoid excessive postprandial glycaemia. Glycaemic glucose equivalents could therefore be useful on food labels and provide consumers with the opportunity to experiment with variety within individually predetermined intake limits.

Similarly, the software for calculating GGE in conjunction with food composition data will be able to be used in formulating diets that comply with individual tolerances to food carbohydrates. As soon as the tolerance of an individual to glucose has been established, meals can be formulated and tested to ensure that the GGE delivered do not exceed that individual's predetermined upper limit.

In its present basic form, the calculation of GGE probably overestimates the glycaemic impact of meals, because at this stage the influence of factors such as carbohydrate quantity,[8] fat content[13] and acidity,[14] which may lower glycaemic response per gram of food, are not taken into account. The theoretical glucose equivalents represented by GGE therefore probably present a worst-case prediction of the relative postprandial glycaemic response to a food, so they err on the side of safety.

Glycaemic glucose equivalents are derived partly from GI values so they suffer from some of the same inadequacies as currently afflict GI,[7] and a good deal of further work is required to address the problems. There is a need for thorough revaluation of GI and carbohydrate data on which RGP values are based, to minimize compounded errors. The CSM sizes need to be reassessed and, where necessary, aligned with present serving sizes. Specific data are required for local foods, and how these equate to non-local foods can be assessed to assign GI values to the local foods examined. Clinical validations should be performed to define the applicability of GGE values under various circumstances. For instance, the impact of meal composition and size on glycaemic response needs further research, which could provide correction factors to apply during calculation of the GGE content of meals. The power of the approach presented here in management of acute glycaemic responses will be increased as research is undertaken to discriminate between rapid- and slow-acting GGE. The model should therefore have great heuristic value in diabetes research as further work is undertaken to address some of the above questions aimed at defining how it may best be applied in managment of glycaemia.

As presented here, GGE are an alternative way of achieving what many dietitians and their clients are attempting with difficulty at present — to manage glycaemia and diabetes by combining GI, carbohydrate and food composition data.

This paper has presented a model for applying information technology to the problem of concurrently managing glycaemia and nutrient intakes in diabetes management, that should work in theory. Although at present limited by the availability of data, it is proposed as an opportunity for the future.

**Table 3.** Glycaemic analysis of meals over the course of a day: B. Meals shown in Table 2 modified to distribute glycaemic loading more evenly throughout the day and reduce fat content by 30%

| | CSM | CSM wt (g) | No. CSM | Total wt (g) | %CHO | GI | RGP | GGE |
|---|---|---|---|---|---|---|---|---|
| *Breakfast* | | | | | | | | |
| Meusli | 1 cup | 110 | 1 | 110 | 53 | 43 | 23 | 24.48 |
| Bread, multigrain, light | 1 slice | 28 | 2 | 56 | 44 | 52 | 23 | 12.80 |
| Juice, apple, FreshUp | 1 cup | 261 | 1 | 261 | 9.8 | 41 | 4 | 10.49 |
| | | | | | | **Total for breakfast** | | **48.40** |
| *Morning tea* | | | | | | | | |
| Bun, currant | 1 bun | 80 | 1 | 80 | 49 | 47 | 23 | 18.54 |
| Biscuit, digestive, plain | 1 biscuit | 14 | 1 | 14 | 63 | 58 | 37 | 5.12 |
| Juice, orange, unsweetened | 1 cup | 256 | 1 | 256 | 7.7 | 52 | 4 | 10.25 |
| | | | | | | **Total for morning tea** | | **33.90** |
| *Lunch* | | | | | | | | |
| Soup pea, homemade | 1 cup | 260 | 1 | 260 | 6.5 | 60 | 4 | 10.14 |
| Bread, multigrain, light | 1 slice | 28 | 2 | 56 | 44 | 52 | 23 | 12.90 |
| Biscuit, oatcake | 1 biscuit | 15 | 2 | 30 | 57 | 54 | 31 | 9.30 |
| Orange | 1 orange | 190 | 1 | 190 | 78.0 | 44 | 3 | 6.44 |
| | | | | | | **Total for lunch** | | **37.78** |
| *Afternoon tea* | | | | | | | | |
| Bun, currant | 1 bun | 80 | 1 | 80 | 49.3 | 47 | 23 | 18.54 |
| Juice, grapefruit, unsweetened | 1 cup | 256 | 1 | 512 | 7.9 | 48 | 4 | 19.40 |
| Apple | 1 apple | 121 | 1 | 121 | 10.9 | 38 | 4 | 4.96 |
| | | | | | | **Total for afternoon tea** | | **42.90** |
| *Dinner* | | | | | | | | |
| Soup, cream of tomato | 1 cup | 260 | 1 | 520 | 5.5 | 38 | 2 | 10.87 |
| Spaghetti, boiled | 1 cup | 148 | 1 | 148 | 20.1 | 41 | 8 | 12.20 |
| Fish finger, grilled | 1 finger | 25 | 3 | 75 | 20 | 28 | 6 | 4.20 |
| Peas, green, boiled, drained | 1 cup | 165 | 1 | 165 | 7.1 | 48 | 3 | 5.62 |
| Banana, raw | 1 banana | 128 | 1 | 128 | 24 | 58 | 14 | 17.81 |
| | | | | | | **Total for dinner** | | **50.78** |

%CHO, available carbohydrate content; CSM, common standard measure; CSMwt, CSM weight; GGE, glycaemic glucose equivalents; GI, glycaemic index; RGP, relative glycaemic potency.

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