

Glycaemic index and glycaemic load of selected popular foods consumed in Southeast Asia

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Abstract

The objective of the present study was to determine the glycaemic index (GI) and glycaemic load (GL) values of standard portion sizes of Southeast Asian traditional foods. A total of fifteen popular Southeast Asian foods were evaluated. Of these foods, three were soft drinks, while the other twelve were solid foods commonly consumed in this region. In total, forty-seven healthy participants (eighteen males and twenty-nine females) volunteered to consume either glucose at least twice or one of the fifteen test foods after a 10–12 h overnight fast. Blood glucose concentrations were analysed before consumption of the test food, and 15, 30, 45, 60, 90 and 120 min after food consumption, using capillary blood samples. The GI value of each test food was calculated by expressing the incremental area under the blood glucose response curve (IAUC) value of the test food as a percentage of each participant's average IAUC value, with glucose as the reference food. Among the fifteen foods tested, six belonged to low-GI foods (Ice Green Tea, Beehoon, Pandan Waffle, Curry Puff, Youtiao and Kaya Butter Toast), three belonged to medium-GI foods (Barley Drink, Char Siew Pau and Nasi Lemak), and the other six belonged to high-GI foods (Ice Lemon Tea, Chinese Carrot Cake, Chinese Yam Cake, Chee Cheong Fun, Lo Mai Gai and Pink Rice Cake). The GI and GL values of these traditional foods provide valuable information to consumers, researchers and dietitians on the optimal food choice for glycaemic control. Moreover, our dataset provides GI values of fifteen foods that were not previously tested extensively, and it presents values of foods commonly consumed in Southeast Asia.

Key words: Glycaemic index: Glycaemic load: Southeast Asia

Currently, the Asian region has the largest rise in diabetes and associated chronic diseases. This is an outcome of a larger population size and changes in lifestyle and economic status. It has been estimated that diabetes and impaired glucose tolerance rates will increase by up to 60% by 2024 compared with the levels in 2007⁽¹⁾. For example, the prevalence of type 2 diabetes in Singapore increased from 1.9% in 1975 to 11.2% in 2010, and is now one of the highest in the developed world⁽²⁾. Based on observational studies, a diet producing a low glycaemic response is associated with significantly less insulin resistance and a significantly lower prevalence of the metabolic syndrome⁽³⁾, the risk of type 2 diabetes⁽⁴⁾ and the risk of coronary artery disease⁽⁵⁾ than a diet producing a high glycaemic response. Identifying lifestyle measures to improve insulin sensitivity and prevent diabetes in these Southeast Asian populations is particularly important. Although dietary interventions are the most effective and economical methods for the management and prevention of

diabetes⁽⁶⁾, there are currently limited data on the glycaemic responses of foods that are most commonly consumed in Southeast Asia.

Jenkins *et al.*⁽⁷⁾, more than two decades ago, introduced the glycaemic index (GI) as an alternative system for classifying carbohydrate-containing foods. The GI system ranks foods according to their effects on the postprandial glucose response. This system has been recommended to help guide food choice (FAO⁽⁸⁾) because low-GI foods have been shown to improve blood glucose control in people with diabetes⁽⁹⁾, leading to increased insulin sensitivity⁽¹⁰⁾ and β -cell function⁽¹¹⁾. Low- and medium-GI foods have a lower impact on blood glucose levels, and are thus the preferred choice for glycaemic control. GI values represent the glycaemic response of isoglucidic foods, and therefore they are not always representative of the glycaemic effect of typical servings of those foods⁽¹²⁾. To quantify the overall glycaemic effect of a standard portion size of foods, the concept of

Abbreviations: GI, glycaemic index; GL, glycaemic load; IAUC, incremental area under the blood glucose response curve.

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glycaemic load (GL) was introduced⁽¹³⁾. It is often necessary to consider the GL along with GI values, especially when the carbohydrate content of the food is relatively small.

The GI value of a starchy food is determined by factors such as protein and fat content, degree of milling, degree of gelatinisation, fibre type and content, and processing and storage conditions^(14,15). Consequently, there are often considerable variations in the GI value of the same food produced in different countries or by different manufacturers. Traditional Chinese or Southeast Asian foods are gaining in popularity, and are of increasing appeal worldwide. Publication of international GI values is needed for various ethnic food groups to ensure the availability of a comprehensive list for practical use. A recent review published up-to-date lists of GI values of more than 2000 different food items including a range of globally produced food groups and brands^(16,17). However, the vast majority of these published GI values are of Australian, British or Canadian origin, and some are of Danish, Indian and Japanese origin. Currently, only a few published GI and GL values are available for local Southeast Asian foods. Thus, it is necessary to determine the GI and GL values of Southeast Asian traditional foods in order to provide the local population with recommendations for an overall healthy diet.

Methods

Subjects

A total of forty-seven healthy participants (twenty-nine female and eighteen male) were recruited for the present study by means of advertisements, flyers and personal communication. Before inclusion into the study, potential participants were briefed on all aspects of the experiment and were given the opportunity to ask questions. Following the subjects' consent, a health assessment was performed, which included anthropometric measurements and a health questionnaire (giving details of food allergies/intolerance, metabolic diseases, special dietary needs, and smoking habits). Participants who met the following inclusion criteria were enrolled in the study: BMI 18.5–24.9 kg/m²; systolic blood pressure 110–120 mmHg; diastolic blood pressure 75–85 mmHg; age 21–50 years; fasting blood glucose 4–6 mmol/l; not on prescription medication; non-smoker; no genetic or metabolic diseases. BMI and body fat were determined by the body composition analyser (BC-418; Tanita). Physical activity was quantified using the questionnaire of Baecke *et al.*⁽¹⁸⁾, and only those who did not participate in competitive sports and endurance events were included.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Domain Specific Review Board of National Healthcare Group. Written informed consent was obtained from all eligible subjects before participation.

Test foods

A total of fifteen different foods were tested, including three soft drinks and twelve ready-to-eat prepared single foods or

composite foods, namely (1) Ice Green Tea (Pokka Corporation (S) Private Limited); (2) Ice Lemon Tea (F&N Foods Private Limited); (3) Barley Drink (F&N Foods Private Limited); (4) Chinese Carrot Cake (Wei Cian Foods Private Limited); (5) Beehoon (NTUC FairPrice); (6) Chinese Yam Cake (Wei Cian Foods Private Limited); (7) Pandan Waffle (Dilys Creation); (8) Chee Cheong Fun (Hock Seng Food Private Limited); (9) Lo Mai Gai (Hock Seng Food Private Limited); (10) Pink Rice Cake (Dilys Creation); (11) Curry Puff (Old Chang Kee (S) Private Limited); (12) Char Siew Pau (Tanjong Rhu Pau & Confectionery); (13) Youtiao (Koufu Private Limited); (14) Kaya Butter Toast (Just Acia Private Limited); (15) Nasi Lemak (Old Chang Kee (S) Private Limited). These foods represent a diverse range of commercial foods commonly consumed in Southeast Asia. A brief description of these foods is as follows: (1) Ice Green Tea: ready-to-drink brewed green tea; (2) Ice Lemon Tea: ready-to-drink black tea with lemon flavour; (3) Barley Drink: ready-to-drink packet drink made from pearl barley and dried winter melon; (4) Chinese Carrot Cake: turnip cake, daikon cake or radish cake, pan-fried shredded radish with plain rice flour (square-shaped slice); (5) Beehoon: rice vermicelli; (6) Chinese Yam Cake: taro cake or pan-fried shredded yam with plain rice flour (square-shaped slices); (7) Pandan Waffle: waffle batter prepared with pandan leaves, coconut milk, eggs and oil; (8) Chee Cheong Fun: rice noodle roll or steamed rice roll, plain served with sweet soya sauce; (9) Lo Mai Gai: steamed glutinous/sticky rice served with chicken meat; (10) Pink Rice Cake: teochew rice cake or Png Kueh, steamed rice pastry stuffed with pan-fried glutinous rice; (11) Curry Puff: deep-fried pastry dough stuffed with curry, chicken and potatoes; (12) Char Siew Pau: steamed barbecue pork bun; (13) Youtiao: deep-fried breadstick; (14) Kaya Butter Toast: toast with coconut jam and butter; (15) Nasi Lemak: steamed coconut milk rice with fried kuning fish, anchovies, peanuts, egg and spicy sambal sauce.

All the test foods and the reference food were given in portions containing 50 g of available carbohydrates. The glucose reference drink was made using 50 g of anhydrous glucose dissolved in 250 ml of water at room temperature. Available carbohydrate values were provided by the manufacturer or tested in our laboratory (as described in the section 'Carbohydrate, protein and fat macronutrient analyses'). The nutrient composition of the three beverages was based on the manufacturer's data, while the remaining twelve test foods were analysed in our laboratory. The glucose and test foods were freshly prepared or bought from the local supermarket or food centre in the morning on test days, and served to the participants within 30 min of preparation. Beehoon was cooked in 1 litre of boiling water for 1.5 min and served. Beehoon was the only food that required cooking, and the rest of the test foods were ready-to-eat products. The nutrient compositions of the test foods are listed in Table 1.

Study protocol

The study was a randomised, controlled, cross-over, non-blinded design. The protocol used was adopted from that



Table 1. Portion size and macronutrient composition of the test foods

	Carbohydrate (g/100 ml)	Experimental portion (ml)	Fat (g/portion)	Protein (g/portion)	Total energy (kJ/portion)
Beverages					
1. Ice Green Tea	6.0	833	0	0	837
2. Ice Lemon Tea	10.0	500	0	0	837
3. Barley Drink	7.6	658	0	2	854
Solid foods					
	Carbohydrate (g/100 g)	Experimental portion (g)	Fat (g/portion)	Protein (g/portion)	Total energy (kJ/portion)
4. Chinese Carrot Cake	15.8	316.9	81.4	8.3	4042
5. Beehoon	80.8	61.9	1.0	3.5	933
6. Chinese Yam Cake	12.8	391.5	102.6	12.6	4908
7. Pandan Waffle	33.7	148.3	45.5	11.0	2736
8. Chee Cheong Fun	18.0	277.4	26.9	5.2	1937
9. Lo Mai Gai	28.3	176.6	19.3	9.9	1728
10. Pink Rice Cake	27.1	184.8	21.2	4.3	1707
11. Curry Puff	38.6	129.6	48.9	12.7	2887
12. Char Siew Pau	32.3	154.7	25.7	10.8	1987
13. Youtiao	45.6	109.6	35.2	7.8	2293
14. Kaya Butter Toast	46.0	108.7	17.6	7.3	1623
15. Nasi Lemak	27.9	179.2	25.1	14.4	2021

described by Brouns *et al.*⁽¹⁹⁾, and is in line with procedures recommended by the FAO/WHO⁽⁸⁾ for glycaemic response studies. According to the FAO/WHO, to determine the GI of a food, tests should be repeated in six or more subjects; moreover, it has been suggested that testing in ten subjects provides a degree of power and precision⁽¹⁹⁾. Thus, each test food was tested on at least ten subjects. At each session, subjects arrived at the Clinical Nutrition Research Centre laboratory at 08.30 hours, following an overnight fast of 10 h. Subjects were advised to eat a meal of similar quantity and composition in the evening before the test session, and were asked to refrain from intensive physical activity. Upon arrival at the laboratory, subjects were first allowed to rest for 10 min. Blood samples in the fasting state were then taken 5 min apart (−5 and 0) for the analysis of blood glucose concentrations. Subsequently, subjects consumed the test/reference food along with 200 ml of water at a comfortable pace, and finished it within 15 min. Blood samples for glucose analysis were obtained at 15, 30, 45, 60, 90 and 120 min intervals following the start of the meal. Participants were advised to keep physical activity to a minimum during testing, and remain seated. Computers, work tables, reading areas and a television were provided for their use. Upon completion of all the eight sessions, participants were debriefed and compensated accordingly for their time and travel expenses.

Carbohydrate, protein and fat macronutrient analyses

Total available carbohydrate content was analysed by an enzymatic method using a Megazyme assay kit (K-ACHDF; Megazyme International). Briefly, freeze-dried and defatted samples were incubated at 80°C with heat-stable α-amylase to gelatinise, hydrolyse and depolymerise non-resistant starch, and then incubated at 60°C with protease (to solubilise and depolymerise proteins) and amyloglucosidase (to hydrolyse starch fragments to D-glucose). Then, the absorbance of the mixture was measured following enzymatic hydrolysis using a UV/visible spectrophotometer (UV-2600; Shimadzu) at a wavelength of 340 nm and 25°C, for the determination

of D-glucose and D-fructose. The percentage of total available carbohydrates (TAC) present in the food was derived from the following equation:

$$\% \text{ TAC} = \% \text{ D-glucose content} + \% \text{ D-fructose content.}$$

Protein content was determined by the Kjeldahl method (Tecator™ Digester and Kjeltec™ 8200 Auto Distillation Unit; FOSS), using a standard nitrogen-to-protein conversion factor of 6.25. Freeze-dried samples were used for all analyses. Fat content was determined gravimetrically by the solvent extraction method using the Soxtec System (Soxtec™ 2055 Manual System; FOSS).

Blood glucose analysis

A qualified technician performed the blood glucose measurements. Blood was obtained by finger prick using the Accu-Chek, sterile, single-use, lancing device (Abbott). Recent reports have suggested that capillary rather than venous blood sampling is preferred for reliable GI testing^(8,19,20). Before a finger prick, subjects were encouraged to warm their hand to increase blood flow. To minimise plasma dilution, fingertips were not squeezed to extract blood, but were instead gently massaged, starting from the base of the hand and moving towards the tips. The first two drops of expressed blood were discarded, and the following drop was used for testing. Blood glucose concentration was measured using the HemoCue Glucose 201 Analyzer (HemoCue Glucose 201 RT). HemoCue is a reliable method for the analysis of blood glucose concentration⁽²¹⁾.

Calculation of the glycaemic index and glycaemic load

The total blood glucose response was expressed as the incremental area under the blood glucose response curve (IAUC), ignoring the area beneath the baseline, and was calculated geometrically using the trapezoidal rule^(19,22). The mean, standard deviation and CV of the IAUC of each subject's repeated

reference food were calculated. The IAUC of each test food eaten by each subject was expressed as a percentage of the mean IAUC of the reference food eaten by the same subject:

$$\text{GI} = (\text{IAUC test food}/\text{IAUC reference food}) \times 100.$$

The GI value of each test food was taken as the mean for the whole group. The GL of a specific serving size of each food was calculated using the following equation:

$$\text{GL} = (\text{GI of the test food} \times \text{available carbohydrate in a serving of the test food (g)})/100.$$

The serving size of each test food was taken from the information provided by the manufacturer.

Data processing and statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (version 16.0; SPSS, Inc.), and data and figures were processed in a Microsoft Excel spreadsheet (2007). The GI values > 2 SD above the mean were considered outliers and were excluded. Levels of inter- and intra-individual variations of the three standard (glucose) tests were assessed by determining the percentage of CV. Spearman's correlation coefficient (ρ) was used to assess the relationship between the GI values and the nutrient content of each test food. Statistical significance was set at $P < 0.05$.

Results

The mean age of the participants was 23.3 (SEM 0.4) years (range 21–32 years). The mean BMI was 20.8 (SEM 0.2 kg/m²) (range 18.5–24 kg/m²). The mean body fat was 21.7 (SEM 0.2)% (range 12.1–32%). The average fasting blood glucose concentration was 4.5 (SEM 0.2) mmol/l (range 4.1–5.0 mmol/l).

The mean intra-individual CV of glycaemic responses to the three standard tests for the forty-seven participants was 16%, which is consistent with recently reported data that low mean within-subject variation (reference CV $< 30\%$) is required for accuracy⁽²³⁾. The inter-individual variation in glycaemic responses to the standard test for all the forty-seven participants was 28.7%.

The GI and GL values of all the tested foods are given in Table 2. The GI values are presented as means with their standard errors. For practical application, GI values are often grouped into categories of a low, medium or high glycaemic response. The cut-off values are as follows: low, ≤ 55 ; medium 56–69 (inclusive); high, ≥ 70 ⁽²⁴⁾. Of the test foods, six belonged to low-GI foods (Ice Green Tea, Beehoon, Pandan Waffle, Curry Puff, Youtiao and Kaya Butter Toast), three to medium-GI foods (Barley Drink, Char Siew Pau and Nasi Lemak), and the other six to high-GI foods (Ice Lemon Tea, Chinese Carrot Cake, Chinese Yam Cake, Chee Cheong Fun, Lo Mai Gai and Pink Rice Cake). From the following foods, one outlier was excluded: Barley Drink; Beehoon; Pink Rice Cake; Curry Puff; Youtiao; Kaya Butter Toast; Nasi Lemak.

There was no relationship between the GI value and the amount of protein per 50 g available carbohydrate portion (Spearman's $\rho = -0.200$) and the amount of fat per 50 g available carbohydrate portion (Spearman's $\rho = -0.327$). This is in line with the previous findings of Henry *et al.*^(12,25). Also, it was demonstrated that the amounts of protein and fat found in commonly consumed foods did not have a significant linear correlation with the glycaemic response.

Discussion

Most regions in Southeast Asia comprise three major ethnic groups, namely Chinese, Malay and Indian. There are many traditional and special foods, according to folk culture,

Table 2. Glycaemic index (GI) and glycaemic load (GL) values of the test foods (Mean values with their standard errors)

	GI		Standard serving size (g)	Carbohydrate (g per serving)	GL (per serving)	Subjects (n)
	Mean	SEM				
Beverages						
1. Ice Green Tea	50	5	250 ml	15.0	8	13
2. Ice Lemon Tea	74	7	250 ml	25.0	19	14
3. Barley Drink	62	6	250 ml	19.0	12	11
Solid foods						
4. Chinese Carrot Cake	77	8	100	15.8	12	10
5. Beehoon	35	3	100	80.8	28	11
6. Chinese Yam Cake	86	11	120	15.3	13	10
7. Pandan Waffle	46	6	80	27.0	12	11
8. Chee Cheong Fun	81	7	200	36.0	29	10
9. Lo Mai Gai	106	12	160	45.3	48	12
10. Pink Rice Cake	97	12	130	35.2	34	11
11. Curry Puff	41	4	120	46.3	19	11
12. Char Siew Pau	66	7	130	42.0	28	10
13. Youtiao	55	4	100	45.6	25	11
14. Kaya Butter Toast	49	4	120	55.2	27	11
15. Nasi Lemak	66	5	280	78.1	52	12



religion and festival. Southeast Asian foods are quite different from Western foods; indeed, they are even different from the most authentic Chinese foods. There is little information about GI and GL values of Southeast Asian foods in the literature. Southeast Asian or Chinese cooking allows for a creative and stylistic touch, and it is one important reason why Southeast Asian or Chinese foods are always absent in the international GI and GL tables. In the present study, by using a recommended standard method, we determined the glycaemic values of three popular drinks and twelve foods commonly consumed in Southeast Asia. However, Nasi Lemak, being the only composite meal, was also tested using the same standard method as used for the other foods. This enabled consistency of methodology across all the test foods. Moreover, based on our previous study⁽²⁶⁾, it has been shown that the calculated GI based on carbohydrate component produced vastly different GI values.

The GI values of the fifteen tested foods varied from 35 (Beehoon) to 109 (Lor Mai Gai). The GI of green tea was the lowest (50) among the three tested popular drinks. Based on the manufacturer's information, we have found that there are 250 mg of tea polyphenols in green tea, which may have some influence on the glycaemic response. However, Josic *et al.*⁽²⁷⁾ concluded that green tea showed no effect on the reduction in glucose and insulin levels when consumed with a breakfast meal consisting of white bread and turkey breast.

Rice noodle, which is made of rice (also known as Beehoon or rice vermicelli), has been tested in several studies. The GI value of dried rice noodles from Thailand was found to be 57 in Asian subjects⁽²⁸⁾, Guilin rice noodles 37 and Jiangxi rice noodles 40 in UK subjects⁽²⁹⁾, and Jianxi rice vermicelli 56 and Taiwan vermicelli 68 in subjects from Hong Kong⁽²⁵⁾. The GI value of rice noodles tested in the present study was 35, which matched more closely with that of Guilin or Jiangxi rice noodles found in UK subjects. These variations might be due to differences in processing conditions and ingredients used in different countries. Therefore, this reconfirms the need to test food products in the country of consumption⁽¹⁷⁾.

A high GI value was obtained for Lo Mai Gai (109) and Pink Rice Cake (97), both made of glutinous rice that has been reported to have a consistently high GI value in previous studies^(17,30). Chen *et al.*⁽³⁰⁾ found that both fried bread stick and barbecue pork bun (in Hong Kong) had a higher GI value of 69, compared with those found in the present study (55 and 64, respectively), although fat and protein levels were relatively similar.

The GI value of a single food is dependent on the composition of that food. Different elements can affect the GI of a food, such as the presence of fat⁽³¹⁾, protein⁽³²⁾ and some anti-nutrients⁽¹⁴⁾. The presence of large amounts of protein or fat may significantly reduce the glycaemic response by increasing insulin secretion or slowing gastric emptying^(33,34). In our previous study, we found that either 30 g of groundnut oil or 15 g of chicken protein could lower the GI of white rice⁽²⁶⁾. The present study indicates that there was no significant correlation of protein or fat (macronutrients) with the GI. However, Jenkins *et al.*⁽⁷⁾ reported that both fat and

protein had a negative correlation with the GI, whereas Henry *et al.*⁽¹²⁾ found a negative correlation only between protein and the GI. A larger variety of test foods might be required for any correlation to be observed. Cooking methods such as steaming and stir-frying, which are more common in Asia than in Europe and America, may also influence the nutrient composition, and thus affect the glycaemic response.

The GL of a food allows a more representative comparison of glycaemic response after consumption of a portion of the food. As with the GI, a higher GL can indicate the likelihood of greater elevation in blood glucose concentration. However, the GL takes realistic portion sizes into account, which are to be consumed in normal circumstances⁽¹⁶⁾. Good examples would be the consumption of Chinese Carrot Cake and Chinese Yam Cake; although they have high GI values, their GL values are relatively lower in comparison with other lower-GI foods.

In summary, the results of the present study provide reliable values of the GI and GL for foods commonly consumed in Southeast Asia. The identification of Southeast Asian traditional foods with lower glycaemic responses may help lower the GI of the Southeast Asian diet, and potentially be beneficial for the Asian population in the management and prevention of chronic diseases such as obesity and diabetes.

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The authors declare that there are no conflicts of interest.

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