Short Communication

Glycemic index of common Malaysian fruits

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The objective of the present study was to measure the glycemic index of durian, papaya, pineapple and watermelon grown in Malaysia. Ten (10) healthy volunteers (5 females, 5 males; body mass index 21.18±1.7kg/m²) consumed 50 g of available carbohydrate portions of glucose (reference food) and four test foods (durian, papaya, pineapple and watermelon) in random order after an overnight fast. Glucose was tested on three separate occasions, and the test foods were each tested once. Postprandial plasma glucose was measured at intervals for two hours after intake of the test foods. Incremental areas under the curve were calculated, and the glycemic index was determined by expressing the area under the curve after the test foods as a percentage of the mean area under the curve after glucose. The results showed that the area under the curve after pineapple, 232±24 mmol×min/L, was significantly greater than those after papaya, 147±14, watermelon, 139±8, and durian, 124±13 mmol×min/L (p<0.05). Similarly, the glycemic index of pineapple, 82±4, was significantly greater than those of papaya, 58±6, watermelon, 55±3, and durian, 49±5 (p<0.05). The differences in area under the curve and glycemic index among papaya, watermelon and durian were not statistically significant. We conclude that pineapple has a high glycemic index, whereas papaya is intermediate and watermelon and durian are low glycemic index foods. The validity of these results depends on the accuracy of the data in the food tables upon which the portion sizes tested were based.

Key Words: glucose, durian, papaya, pineapple, watermelon

INTRODUCTION

The concept of the glycemic index (GI) was introduced as a means of classifying carbohydrate containing foods based on the blood glucose response after food consumption.[1] The GI is defined as the incremental area under the blood glucose response curve (AUC) after a portion of food containing 50g of the available carbohydrate is expressed as a percentage of the response after 50g of glucose is taken by the same subject.[2] High GI diets may have undesirable health effects by promoting hyperglycemia and hyperinsulinemia.[3,4] Recent studies report that a high diet GI may increase risk of cardiovascular disease (CVD) [5-7] and type 2 diabetes.[8-11] On the other hand, low GI diets have been suggested to have health benefits.[3,4,12,13] Low GI diets have been shown to improve blood glucose control in patients with diabetes,[14-16] and may help in the reduction of body weight,[17,18] and risk factors for CVD.[7,14,19,20] As the awareness of the GI concept is widespread, dietitians and nutritionists must be able to understand the GI concept and provide nutrition counseling to their patients.

Fruits are good sources of carbohydrates, vitamins and minerals and are considered important for good health. Studies suggest that fruits containing viscous fibers may help control glucose responses by slowing the digestion and absorption process.[21] Various kinds of fruits are grown in plenty in the rich Malaysian soil throughout the year. The Malaysian food pyramid recommends including 2 servings of fruit per day. Although Malaysians include a wide variety of fruits in their diet, the GI of many of these fruits has not been determined. Hence, we determined the glycemic index of durian, papaya, pineapple and watermelon.

MATERIALS AND METHODS

Setting

Study was conducted at the dietetics department, School of Health Sciences, Universiti Sains Malaysia using internationally recognized GI methodology.[22,23]

Subjects

Healthy men and non-pregnant, non-lactating women aged 18-75 years were recruited from the Unversiti Sains Malaysia campus and screened by height, weight, blood

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Table 1. Composition of test meals [32, 33]

Food	Portion size (g)	Protein (g)	Fat (g)	Dietary Fiber† (g)	Fructose (g)	Glucose (g)	Sucrose (g)	Av. Carbohydrate (g)
Durian	207	5.6	7.0	7.9	‡	‡	‡	50.0
Papaya	943	14.0	0.9	17.0	16.1	16.1	17.8	50.0
Pineapple	543	2.7	0.5	7.6	12.5	10.0	27.5	50.0
Watermelon	893	5.4	1.8	3.6	16.4	9.3	24.3	50.0

† Data obtained from United States Department of Agriculture's (USDA) online nutrient database[24]; ‡ No data available

pressure and medical examination. Exclusion criteria were: known history of AIDS or hepatitis, inflammatory bowel disease, diabetes or heart conditions (angina, arrhythmia or heart failure); history of an acute medical or surgical event within the last 6 months; BMI > 23kg/m^2; use of medications; those who cannot or will not comply with the experimental procedures. Ten healthy subjects (5 females and 5 males) with a mean age of 31.4±6.3years and a mean body mass index of 21.2±1.7kg/m² took part in this study. However, the participation of two subjects was discontinued by the investigators partway through the study (before they had completed tests of durian and papaya) because they became pregnant; therefore, the GI values of durian and papaya were determined in the remaining 8 subjects. The research protocol was approved by the institutional ethics review committee and informed consent was obtained from all subjects.

Test foods and reference food

The four tropical fruits selected for study were durian (*Durio zibethinus*), papaya (*Carica papaya*), pineapple (*Ananas comosa*) and watermelon (*Citrulius vulgaris – red variety*). These test foods had the same degree of ripeness at the time of purchase. The test foods were purchased from the local fruit shop one day before use. Glucose (Glucolin™) was used as the reference food.

In-vivo test and blood sample analysis

We studied the subjects on 7 different occasions in the morning after 10-12 hour overnight fasts. No restrictions were placed on the meal that was eaten prior to the test. On three occasions, subjects consumed 50g of glucose dissolved in 400ml water. On the other four occasions the subjects consumed a portion of one of the 4 test foods containing 50g of available carbohydrate, defined as total carbohydrate by difference minus dietary fiber. As the dietary fiber information is not available in the nutrient composition of Malaysian food table, we obtained the data from the United States Department of Agriculture's (USDA) online nutrient database.[24] All test foods were served with a drink of 250ml water. Each subject consumed the test foods over a 10 to 13min period. Finger prick capillary blood samples were taken fasting and at 15, 30, 45, 60, 90 and 120 min from when the subject first started eating. Blood samples were drawn into 1.5ml eppendorf tubes containing fluoride oxalate and were quickly centrifuged to obtain plasma, which was stored at -20°C prior to analysis of glucose using an auto analyzer (Spectra-E, Vitalab- Clinical Chemistry Analyser) which uses the glucose oxidase method.

Data analysis

Statistical analyses was conducted using Microsoft Excel Spread Sheets and the Statistics Program for Social Sciences (SPSS, version 12.1.0) computer software package. Incremental areas under the blood glucose response curves (AUC), ignoring area beneath the fasting level, were calculated geometrically.[2] The mean, SD and coefficient of variation (CV = 100×SD /mean) of AUC values for repeated glucose tests for each subject were calculated. The AUC for each food was expressed as a percentage of the mean AUC for glucose taken by the same subject and the resulting values averaged to give the food GI. The GI value of pineapple for one of the subjects was > 2SD greater than the mean and as a result, was regarded as a outlier and discarded.[2] The AUC values and GI values of each subject were subjected to repeated measures ANOVA and, after demonstrating significant heterogeneity, the significant differences between individual means was assessed using Tukey's test to adjust for multiple comparisons. The criterion for significance was 2-tailed $p<0.05$. Pearson's product-moment correlation analysis was employed to explore a potential correlation between dietary fiber, fructose and GI. Results were expressed as mean±SEM.

RESULTS

The composition of the test meals are shown in Table 1 and expressed in terms of the portion size that was fed to each subject. Among the test foods, durian contained the highest amount of fat, while papaya contained the most

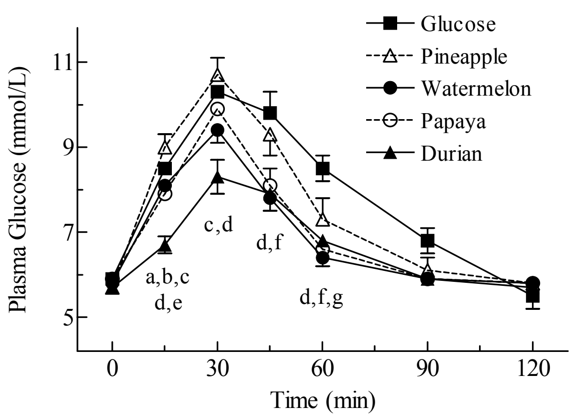

Figure 1. Mean plasma glucose response of test foods and the reference food. Values are means+/-SEM (n=8-10). Comparison of glucose concentrations ($p<0.05$): a, durian vs. papaya ; b, durian vs. watermelon; c, durian vs. pineapple; d, durian vs. glucose; e, papaya vs. pineapple; f, watermelon vs. glucose; g, papaya vs. glucose.

Table 2. Incremental area under the curve (AUC) and glycemic index (GI) values of glucose and the test foods

	Area Under the Curve (mmol×min/L)	Glycemic Index (%)
Glucose	259±15[a]	100[a]
Pineapple	232±24[a]	82±4[b]
Papaya	147±14[b]	58±6[c]
Watermelon	139±8[b]	55±3[c]
Durian	124±13[b]	49±5[c]

Values are means±SEM; [ab] Means with different letter superscripts differ significantly, $p<0.05$.

Table 3. Comparison of GI values of the test foods obtained in this study with that of the GI values present in the international table [28]

Foods	GI (International Table)	Subjects (number)	GI (this study)	Subjects (number)
Durian	‖	‖	49 ± 5	8
Papaya	59 ± 1	10	58 ± 6	8
Pineapple	59 ± 8	11	82 ± 4	9
Watermelon	72 ± 13	8	55 ± 3	10

Values are means±SEM; ‖ No data available

protein and dietary fiber. The sucrose content of pineapple is comparatively higher than other test foods. However, there was no available data on the types of sugar found in durian.

The plasma glucose responses after the consumption of glucose and the four test foods are shown in Figure 1. The CV of the AUC of repeated glucose trials taken by 10 subjects was 20.9±4%. The mean AUC after glucose consumption was significantly greater than those after papaya, watermelon and durian (Table 2). Mean AUC after pineapple consumption, was not significantly different from that of glucose, but was significantly greater than those after papaya, watermelon and durian (Table 2). Prior to the removal of the outlier, the GI value of pineapple was 90±9. After discarding the outlying value, the mean GI value for pineapple (82±4) was still significantly greater than those for papaya (58±6), watermelon (55±3) and durian (49±5) ($p<0.05$; Table 2). Comparison of GI values of the test foods obtained in this study with that of the GI values present in the international table is shown in Table 3.

DISCUSSION

Many factors may influence the GI of fruits. These factors include the type of sugars, degree of ripeness, fiber content, presence of anti nutrients, and acid content.[25-27] Our study showed that the AUC and GI of pineapple were higher than the other three fruits. In addition our GI value for pineapple, 82±4, is significantly higher than the value of 59±8 given in the International GI Tables [28] by unpaired t-test (p=0.03). The dissimilarity of the GI values of the same type of fruits grown in different places may be due to the growing conditions or to differences in the sugar composition of the individual fruits. As a fruit ripens, the nutrient composition changes.[29] A fruit that ripens early in the season will have a different nutrient content from one of the same cultivated variety that ripens later in the season. In addition nutrient composition is influenced by time of harvest, period of storage and the method of storage.[29] Thus, it is difficult for food composition tables to accurately state nutrient composition data. The sugar composition of the fruits grown in Malaysia is not yet determined; therefore, the data that is given in Table 1 may not represent what was in the fruits we used in this study. On the other hand, dietetic professionals plan diets based on information given in such food composition tables, so the results shown here are relevant to "real life" situations. AUC and GI values for durian are comparatively lower than the other fruits. This may be due to the presence of fiber and the high fat content of durian. The dietary fiber present in foods could influence the digestion and absorption of the carbohydrate they contain and consequently their blood glucose responses.[21] However there was no relationship detected between the dietary fiber content of the fruits and their respective glycemic index values (r=-0.03, p=0.9). Fat on the other hand does not have a direct effect on blood glucose response, but it may influence glycemic response indirectly by delaying gastric emptying, and thus, carbohydrate absorption.[30] Recently Moghaddam et al found that across the range of 0 – 30g, protein and fat present in liquid test meals reduced the blood glucose responses independently from each other in a linear, dose-dependent fashion.[31] However, Moghaddam et al noted that the same effects might not apply to solid meals. The type of sugar that is present in durian is unknown. There is also no reported scientific value with regard to the GI of durian and as a result this might be the first study to determine the GI of durian.

Our GI value for papaya obtained in this study, 58±6, was almost identical to that reported in the International GI Tables, 59±1.[28] The relatively low GI value of papaya may be due to the presence of fiber and the 14 g of protein found in portion size used in the study.[31] However, the GI value of watermelon in this study, 55±3, tended to be lower than that given in the International table, 72±13, although the difference is not statistically significant. The proportion of fructose present in watermelon is slightly higher than that of glucose; this may explain why the GI value of watermelon is low. Fructose has a lower blood glucose response (GI = 19±2) than glucose (GI = 99±3) because fructose is absorbed by a saturable facilitated diffusion process and must be converted to glucose by the liver before entering the blood circulation.[28] Though there was excellent correlation between the fructose content of the fruits and their respective GI values (r = -0.8), it was not significant (*p*=0.4).

Further work is needed to confirm whether the GI values of pineapple and watermelon from Malaysia differ from those in other countries, and to determine why these differences exist. In addition, the composition of sugars present in durian is not known. We conclude that, using portion sizes based on food tables, durian and watermelon grown in Malaysia can be classified as low GI foods, papaya as an intermediate GI food, and pineapple as a high GI food. The accuracy of these results depends upon accuracy of the nutritional composition of the fruits as given in food tables.

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AUTHOR DISCLOSURES

Dr. Wolever is President and part-owner of Glycemic Index Laboratories, Inc., a contract research organization; President and part-owner of Glycaemic Index Testing, Inc., a corporation which provides services related to the measurement of the glycemic index of foods; received grant/research support from Cargill, Inc. and ILSI Europe; is a consultant for McCain Foods; and received honoraria for consulting/speaking from the Dutch Sugar Bureau and Mars Inc. Dr. Wolever is co-author of a range of popular books on the glycemic index under the general title of The Glucose Revolution: Authoritative Guide to the Glycemic Index, published by Marlowe & Co., NY; he is also author of a scientific book entitled: The Glycaemic Index: A Physiological Classification of Dietary Carbohydrate, published by CABI, UK. S Daniel Robert, Aziz Al-safi Ismail and Than Winn, no conflicts of interest.

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馬來西亞常見水果的昇醣指數

本研究的目的是測量產於馬來西亞的榴蓮、木瓜、鳳梨和西瓜的昇糖指數。10 位健康的志願者(5 位男性、5 位女性；身體質量指數 21.18±1.7kg/m²)在禁食一夜之後以隨機的順序分別食用 50g 純葡萄糖(參考食物)和 4 種測試水果(榴蓮、木瓜、鳳梨和西瓜)。葡萄糖在不同時間共測試三次，每種受測水果被測試一次。食用這些測試水果後的 2 小時期間，測量飯後血糖。先計算血糖曲線面積，再由測試食物血糖曲線下面積為葡萄糖平均面積的百分比決定昇醣指數。結果顯示鳳梨曲線下面積(232±24 mmol×min/L)顯著大於木瓜(147±14)、西瓜(139±8)和榴蓮(124±13) ($p<0.05$)。同樣的，鳳梨的昇醣指數(84±4)也顯著大於木瓜(58±6)、西瓜(55±3)和榴蓮(49±5) ($p<0.05$)。木瓜、西瓜和榴蓮曲線下面積和其個別 GI 值間並未達統計顯著差異。我們推斷鳳梨有高的昇醣指數，而木瓜居中，西瓜及榴蓮為低昇醣指數食物。因為需用食物成分表來推算食物份量，本研究結果的效度仰賴食物成分表上資料的正確性。

關鍵字：葡萄糖、榴蓮、木瓜、鳳梨、西瓜。