

Original Article

Blood glucose responses of diabetes mellitus type II patients to some local fruits

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To determine the glucose responses of diabetes mellitus type II subjects to fruits, four locally available fruits (containing 25 g of available carbohydrates per serving portion) of chico, mango, pineapple, and papaya were tested among ten type II diabetic subjects, using wheat bread as the control. Results of the *in vivo* test indicated that chico and mango had significantly lower ($P \leq 0.05$) blood glucose areas compared to wheat bread. Chico and mango also had a much lower glycemic index (GI), 57 and 59, respectively, compared to pineapple, 73 and papaya, 86. Differences in glucose responses to fruits and their varying GI are attributed to the amount of fiber, type and amount of sugars found, presence of antinutrients, acidity and physical characteristics of the fruits when chewed. The high fiber content of chico (7.9%), its fructose content (5.3%), its grainy texture when chewed and the presence of antinutrients (saponin, saponin and achrasaponin) may contribute to its slow digestion and absorption. The low GI and blood glucose response of mango may be because of its fructose content (3.0%), acidity content (malic, citric and tartaric) and its phytic acid content (0.03%). Furthermore, starch, which is a possible factor contributing to low GI, is present in chico (0.8%) and mango (0.3%). Pineapple and papaya, the test fruits that elicited higher blood glucose responses and GI, have much lower fiber contents, less acids and contain glucose and sucrose sugars.

Key words: blood glucose response, fruit, glycemic index, Philippines, type II diabetes.

Introduction

A group of investigators in the mid 1980s studied the metabolic effects of various carbohydrate-containing foods fed one at a time among diabetic and non-diabetic subjects. It was shown that different foods tested had varying effects on blood sugar levels. Carbohydrate foods that were digested and absorbed at a slower rate resulted in lower blood glucose, while those that were easily digested and absorbed had higher blood glucose responses.

These observed differences and the difficulty in predicting glucose responses to various carbohydrate foods led to the determination of the glycemic index (GI) of foods. The GI is an attempt to classify or rank foods according to the extent to which foods raise the blood sugar. It is defined as the incremental area under the blood glucose response curve for a test food with 50 g of available carbohydrate, expressed as a percentage of the response in the same subject to 50 g available carbohydrate portion of a standard, such as glucose or white bread.

The GI of a food is important to people with abnormalities in blood glucose regulation, notably diabetes. Jenkins *et al.* emphasized that GI is useful in prescribing diets for diabetics, especially when they are placed on 'tight' blood glucose control in order to avoid long-term complication.¹ It was once believed that diabetic patients could exchange any food within the food exchange list, but now it is clear that even if foods have identical carbohydrate contents, the effect on blood glucose varies. The GI, together with the food exchange list, offers diabetics a wider selection of carbo-

hydrate foods. Although there are numbers of published studies providing the GI of a wide range of foods, little attention has been given to the carbohydrate content of fruits. Fruit is known to be an important carbohydrate and vitamin source and is commonly served as part of a meal or a snack.

Some studies suggest that fruits have low GI.²⁻⁴ This low GI is attributed to their fructose and fiber contents. The presence of viscous fibers, such as pectin in fruits can lower the blood glucose response, presumably by slowing the digestion and impeding the diffusion of sugars towards the absorptive mucosal surface.⁵

Diabetics were purposely employed as the subjects in this study because their diets require dietary modifications in terms of the amount and kind of dietary carbohydrate. Fruits are good sources of carbohydrates and diabetic patients, particularly the diabetes mellitus type II, are fond of eating fruits as snacks or part of their meals. However, the kind, type and amount of fruits to be included in their diets has always been a question that concerns them. It is therefore the objective of this study to address this question and determine the effects of some locally available fruits on the blood glucose level of type II diabetic patients.

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Materials and methods

Sample Preparation

Chico (*Zapota zapotilla coville*), mango (*Mangifera indica*), pineapple (*Ananas comosus*) and papaya (*Carica papaya*) were utilized in the study. At the time of purchase, the test fruits had to have the same degree of ripeness and physical appearance. The fruits were bought the day before the test and stored in a refrigerator. Table 1 shows the test fruits' origin and characteristics.

Chemical analysis

The control, wheat bread and the test fruits were analyzed for their major components namely: moisture (vacuum oven drying method), crude protein (kjeldahl method), crude fat (soxhlet method), total available carbohydrate (Clegg Anthrone method), total dietary fiber (enzymatic-gravimetric method) and ash (combustion method).

Subjects

A group of ten type II diabetic subjects (4 males and 6 females) participated in the study. They were recruited from KATUDIB (Kapatirang Tulungan ng mga Diabetico sa Bulacan), a non-government, non-profit organization of diabetics in Bulacan. Their ages ranged from 41 to 62, with mean age and body mass index (BMI) of 54.5 years and 23.1 kg/m², respectively. Their clinical characteristics are given in Tables 2 and 3. Subjects were not taking any medications and maintained their usual activity throughout the study.

In-vivo test

The fruits and bread were individually portioned to provide 25 g available carbohydrate per serving portion. Test fruits and bread were randomly assigned to each subject and were given according to a three- to four-day interval schedule for each test food.

The subjects fasted for 10-12 h the day before and arrived at six in the morning. A 24-h food recall was obtained from them upon arrival. They were instructed to urinate and to rest

for 15 min. The test food was consumed within 8-10 min, chewed with usual vigor. Tap water was served, the measure of which was constant for all the subjects.

Finger-prick capillary blood samples were taken at 0 (fasting), 30, 60, 90, 120, 150 and 180 min after consumption of test food. Eight to ten drops of blood samples were obtained by gentle pressure on the finger tip and collected into 12 × 75 mm test tubes using an autolet lancet (Stanbio Laboratory, TX, USA). Blood glucose was analyzed using the glucose oxidase method.

Blood analysis

Each test tube containing a blood sample was immersed in crushed ice before analysis. The samples were centrifuged for 15 min at a speed of 6000 r.p.m., to separate the serum. Into a 12 × 75 mm test tube, 0.10 µL of the serum was pipetted and mixed with 1 ml of glucose oxidase enzyme. The blood samples were incubated for 5 min at 37°C before reading for blood glucose values. Blood glucose was measured in mmol/L using a Premier Plus Stanbio Analyzer (Stanbio Laboratory, TX, USA) with photometric accuracy of ± 1% of the reading + 0.005 Absorbance. The values for the reference food and test foods were plotted for each subject and the incremental area was calculated geometrically per subject.

Statistical analysis

The mean GI was calculated for each patient and each test fruit. Glycemic index is the ratio between the incremental area under the 3-h glycemic response curve to a food and the incremental area under the 3-h glycemic response curve to wheat bread, multiplied by 100.

$$GI = \frac{\text{Blood glucose area under the curve of a test fruit}}{\text{Blood glucose area under the curve of the equivalent carbohydrate as white bread}} \times 100.$$

The blood glucose responses were used to calculate the total area under the curve for each subject and for each test fruit and the control. Blood glucose data were encoded in Lotus and (123; CA, USA) statistical computation was done with SAS 6.12; NC, USA.

Results were expressed as mean ± SEM. The standard errors of each mean for total incremental areas and GI were shown in order to give an idea of the dispersion of the mean. Statistical analysis and multiple comparisons between response areas were done by multiple analysis of covariance followed by Duncan's multiple range test. The level of significance was set at $P \leq 0.05$. The mean blood glucose areas of test fruits were compared by ANOVA followed also by Duncan's multiple range test and LSD test. The same procedure was conducted to compare the mean GI of test fruits.

Results and discussion

Proximate composition of test fruits

The major components of the fruits and wheat bread, as shown in Table 7, are expressed in wet weight bases. The amount (in %) based on wet weight of the product is equivalent to the amount (in g) of the component per 100 g of food as served. Results showed that chico had the highest carbohydrate content (19.1%), followed by mango (17.3%),

Table 1. Characteristics of the test fruits

Test Fruits	Origin / Variety	Characteristics
Chico	Batangas	Brownish peel color Plump, sweet delicate aroma Firm, yet yielding slightly to finger pressure No soft spots
Mango	Bulacan	Robust yellow peel Firm sweet delicate aroma No soft spots
Pineapple	Cavite	Golden-orange yellow peel, no green hue With protruding eyes Sweet delicate aroma Green stems come out easily No soft spots
Papaya	Davao	Orange peel color throughout Firm, yet yielding slightly to finger pressure Sweet delicate aroma No soft spots

Table 2. Characteristics of experimental subjects ($n = 10$)

Patient	Sex	Age (yr)	Ht (cm)	ABW (kg)	IBW (kg)	BMI	Years with diabetes	Meds.
A	M	41	165.10	63	59	23	2	Diamicon
B	F	53	154.94	53	49	22	2.5	Diet
C	M	57	158.75	64	53	25	2	Diet
D	M	58	172.72	70	65	23	3	Diabinese
E	F	60	149.86	50	45	22	6	Glibenclamide
F	F	60	157.48	62	52	15	1	Glibenclamide
G	M	49	152.40	54	47	23	3	Glibenclamide
H	F	46	149.86	50	45	22	1	Glibenclamide
I	F	58	160.02	63	54	25	3	Diet
J	F	62	160.02	55	54	21	7	Diet

ABW, actual body weight; IBW, ideal body weight; BMI, body mass index; Meds, medications.

Table 3. Ranges and means of subjects' characteristics

Variable	Range	Mean \pm SD
Age (years)	41 – 62	154 \pm 6.94
Height (cm)	149.00 – 172.72	158.12 \pm 7.06
ABW (kg*)	50 – 70	58.4 \pm 6.85
IBW (kg†)	45 – 59	52.3 \pm 6.31
BMI‡	15 – 25	23.1 \pm 1.45
Years with diabetes	1 – 7	3.05 \pm 1.98

*Actual body weight; †Ideal body weight; ‡Body mass index.

pineapple (14.1%) and papaya (9.0%). Likewise, the total dietary fiber was highest in chico (7.9%), but lowest in mango (0.7%). Papaya and pineapple had low dietary fiber values, 2.2% and 1.0%, respectively (Table 4).

The proximate composition of the test fruits was comparable with the published data in the Food Composition Table (FCT),⁶ as shown in Table 5. It was comparable in terms of moisture content, which was greater than 70%. The moisture in fruits was appreciably high, which gives them refreshing quality. Likewise, the protein (0.1–0.4%), fat (0.0–0.4%) and ash (0.1–0.2%) contents were also comparable with the FCT, that is not greater than 1%, which was just enough for the life processes of the fruits. Among the test fruits, both the FCT value and the present study showed that chico and mango contained ample carbohydrate.

Blood glucose responses and glycemic index of test fruits

The incremental areas under the curve of test fruits and wheat bread in this study showed that, compared with wheat bread, chico and mango showed a significantly ($P < 0.05$) lower blood glucose area. Likewise, the data on GI of the fruits also showed that chico (57) and mango (59) have much lower GI compared to pineapple (73) and papaya (86) (Figure 1).

Reasons for differences in mean blood glucose areas and GI values of the test fruits are due to factors that had affected the blood glucose responses.

There are several factors that may affect the digestion and absorption of fruits and thus their blood glucose responses. Factors such as the degree of ripeness, type and kind of sugars present, presence of fiber, presence of antinutrients, degree of acidity of the fruit and physical state of the fruit, all contribute to the varying responses of fruits.

The effect of ripeness or maturity on the digestion and absorption of carbohydrate in fruits had been shown by

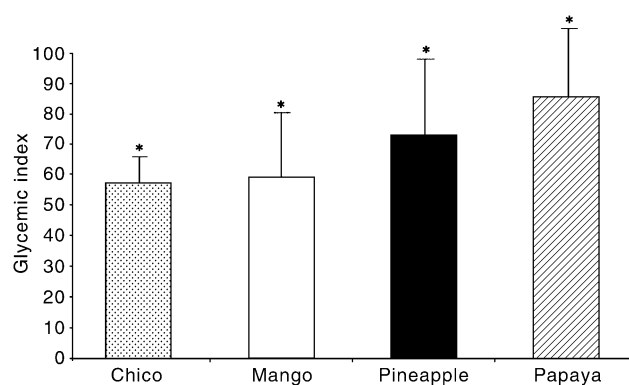


Figure 1. Mean Glycemic Index calculated for test fruits; *standard error of the mean.

studies of Wolever *et al.*,⁷ Hermansen *et al.*,⁸ Ercan *et al.*,⁹ and Lintas *et al.*¹⁰ Using bananas, their studies on ripeness had shown that digestibility increased as the fruits ripened, since their starch content decreased dramatically and was converted into free sugars. The actual sugar composition of fruits may not only be affected by maturity but also by cultivar, the soil, climatic conditions, time of harvest, the length and method of storage.¹¹

Significant differences in blood glucose responses to chico, mango, and pineapple were found in some points in time when test fruits were compared to wheat bread. This observation was comparable to the study of Wolever *et al.* where the blood glucose responses to the fruits tested were significantly lower than those after tests using bread at one or more points in time.³ Their result was attributed to the sugar content of fruits consisting mainly of fructose, sucrose, and sorbitol, all of which were found to elicit lower blood glucose responses than glucose.^{3,5,12} Wills *et al.* also showed a significant inverse relationship between GI and increasing amount of organic acids, especially malic acid.¹²

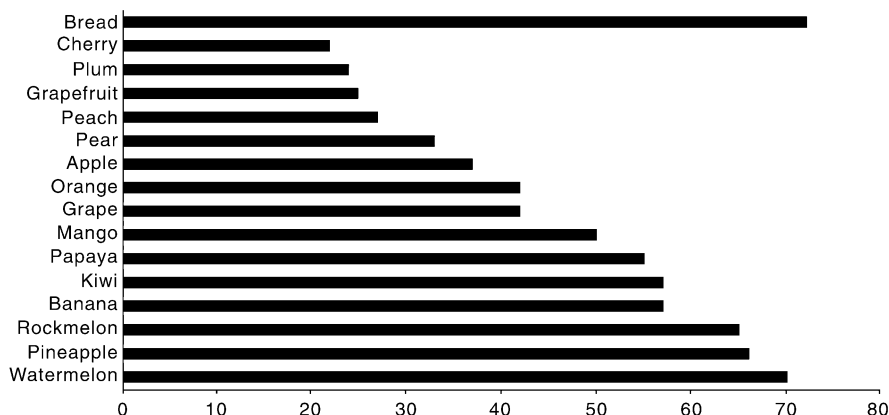
The GI of pineapple, mango and papaya in the study are comparable to values reported by other studies. From the average values calculated from published sources, Wolever and Miller had shown that the GI of fresh fruits vary over a threefold range from 22 for cherries to 72 for watermelon (Figure 2).⁷ The average values calculated from published sources showed that pineapples and papaya give a higher GI as compared to mango.^{13,4} Chico, however, had no reported scientific value for glucose response and GI.

Table 4. Proximate composition (%) of the test fruits and wheat bread

Component	Chico	Mango	Pineapple	Papaya	Wheat bread
Moisture	72.3	81.4	83.8	88.2	32.3
Crude fat	0.2	0.4	0.0	0.1	2.3
Crude protein	0.4	0.1	0.2	0.2	9.5
Ash	0.1	0.1	0.1	0.2	1.3
Available carbohydrates	19.1	17.3	14.9	9.0	50.2
Total dietary fiber	7.9	0.7	1.0	2.2	4.4
Weight (g) of a serving portion with 25g available carbohydrate	131	144	168	277	50

Table 5. Chemical composition per 100-gram edible portion of test fruits (FCT, 1997)⁶

Component	Chico <i>Zapota zapotilla coville</i>	Mango <i>Mangifera indica</i>	Pineapple <i>Ananas comosus</i>	Papaya <i>Carica papaya</i>
Moisture	73.7	82.4	86.0	86.6
Crude fat	0.9	0.2	0.2	0.3
Crude protein	0.5	0.6	0.4	0.5
Ash	0.4	0.4	0.4	0.5
Carbohydrate	24.5	16.4	13.0	12.1
Dietary fiber	7.3	2.2	1.4	1.3

**Figure 2.** Average GI values of fresh fruits calculated from published sources. (Adapted from: Wolever TMS, Miller JB. Sugars and blood glucose control. American Journal of Clinical Nutrition 1995; 62: 212s–217s)

Tropical fruits such as lemon, avocado, banana, pineapple, and papaya have been found to possess higher GI values than temperate fruits.¹⁴ Differences among the fruits may arise because of variations, particularly in monosaccharide composition and the amount and nature of fiber.⁷

There are important differences between GI of monosaccharides, notably glucose and fructose. The GI of fructose is 23, sucrose is 61 and glucose is 100. Table 6 shows the carbohydrate fractions per 100 g of the test fruits based on scientific reports.¹⁵ The data shows that mango and chico had higher amounts of sugars (13.8 g and 14.7 g respectively), compared to papaya (8.8 g) and pineapple (10.1 g). Fructose, which causes a lower glucose response compared with the other sugars, was also higher in mango (3.0 g) and chico (5.3 g). Likewise, starch is present in mango (0.3 g) and chico (0.8 g). This might also be attributed to the low glucose responses of chico and mango, as compared with the papaya and pineapple which had no starch component.

Fructose is known as fruit sugar. It is absorbed slowly and its ability to increase blood glucose is definitely less than that of the other carbohydrate sources.¹⁶ Furthermore, fructose

has no active absorption mechanism in the intestinal mucosa, but it is slowly and incompletely absorbed by facilitated digestion. Under normal conditions, fructose is converted mainly to glucose, glycogen and lactate, and to a small extent also to triglycerides. Wolever and Miller observed that natural sugars in fruit and fruit juices resulted in lower blood glucose, compared with most refined starchy carbohydrate foods, because it is rapidly cleared and metabolized by the liver in both normal and type II diabetic patients.⁷

The presence of fiber, among others, may influence the digestion and absorption of carbohydrate food and consequently its glycemic response.^{5,17–19} The total dietary fibers in fruits may include the two major types of fiber, the insoluble and soluble. The insoluble fibers, cellulose and hemicellulose are the rigid materials that give structure to plants. The viscous soluble fiber, like pectin, is found mostly in fruits. Viscous fibers are found to increase the viscosity or thickness of the mixture in the digestive tract, thus slowing the passage of food and restricting the movement of enzymes, thereby slowing digestion. The end result is a lower blood glucose response.

The total fiber content of the test fruits in this study ranged from 7.9% (chico) to 0.7% (mango). The significantly lower blood glucose response to chico compared to wheat bread may be attributed to its high level of fiber (7.9%). According to Jenkins *et al.*, foods containing more fiber could lower glycemic responses by delaying gastric emptying time.²⁰ Table 6 shows that mango also had a higher soluble dietary fiber (1.6 g) compared to papaya (1.3 g) and pineapple (0.1 g). Chico has no available data on soluble fiber, however, the high total fiber content of chico (7.9%) may also explain its low GI.

The presence in fruits of antinutrients such as phytic acid, tannins, lectins, enzyme inhibitors, saponins, etc. can also delay digestion and produce low blood glucose response.^{17, 21} Chico contains saponin, saponin and achrasaponin which might lead to lower glucose response. Mango also contains phytic acid (0.03 g/100 g), which might also explain its low blood glucose response. The antinutrient tannin is a complex polyphenolic compound found to inhibit intestinal enzymes and transport systems concerned with carbohydrate assimilation. Phytic acid, also an antinutrient, is an inositol hexaphosphate able to bind very strongly to positively charged ions like iron, zinc, magnesium and calcium. Saponin is a glycoside characterized by its properties of foaming in water solution. Chico and mango had a low glucose response, which may be because of the presence of antinutrients that delay their rate of digestion and absorption.

Miller *et al.*¹⁴ hypothesized that the higher the acidity and osmotic strength (number of molecules per mL) of the fruit, the lower the glucose response and GI factor. Table 7 shows the organic acids per 100 g edible portion of the test fruits from a scientific report.¹⁵ It shows that the most widely occurring and abundant organic acid in test fruits are citric and malic acids. Mango had a combination of malic, citric and tartaric acid. This can also explain the low glucose response and GI in mango. Pineapple and papaya contain only two organic acids, malic and citric. The concentrations of organic acids in fruits can be extremely variable depending also on factors such as growing and storage conditions,

ripeness, amount of sunlight received and even time of the day when fruits are picked.

Another mechanism that might explain the differences in blood glucose responses and GI in fruits is suggested by Oettle *et al.*²² and Bolton *et al.*²³ They hypothesized that the speed with which the sugars in a fruit enter the bloodstream varies with the physical state of the fruit. Fruits that are easily chewable, like grapes, release their juices and sugars easily, or collapse into fluid mush, like ripe bananas, may leave the stomach and be absorbed more quickly. Fruits, like apples and raisins, when chewed, retain their solidity and their juices and sugars are not absorbed as quickly.

The test fruit, papaya, has the characteristic of being easily chewed and thus elicits a high glucose response and GI. Chico, however, requires some effort in chewing due to its grainy texture, thus this might also attribute to its low glucose response and GI.

Summary and conclusion

In this study, an attempt has been made to determine the glucose response and GI of several fruits in order to determine their appropriateness as part of a dietary prescription for diabetic patients. Results showed differences in the glucose response and GI among the fruits tested and these may be attributed to the different amount of starches and sugars, as well as the presence of fiber and antinutrients. The acidity and physical characteristics of the fruits may also contribute to their varying glucose responses and GI.

It is concluded that chico and mango, being classified under the intermediate GI foods,¹⁴ can be eaten by diabetics without significantly increasing their blood glucose levels. Pineapple and papaya, being classified under the high GI foods,¹⁴ can be eaten in moderate amounts by diabetic patients, provided they are within the carbohydrate allowance, or they can be combined with other low GI foods to decrease their glycemic indices.

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Table 6. Carbohydrate fraction per 100-gram edible portion of test fruits (Holland, Unwin and Buss, 1992)¹⁵

Test fruits	Total carbohydrate			Individual sugars		Fiber fractions	
	Starch	Sugars	Glucose	Fructose	Sucrose	Soluble	Insoluble
	g	g	g	g	g	g	g
Chico	0.8	14.7	6.7	5.3	2.7	N	N
Mango	0.3	13.8	0.7	3.0	10.1	1.6	0.5
Pineapple	0	10.1	2.0	2.5	5.5	0.1	0.6
Papaya	0	8.8	2.8	2.8	3.1	1.3	0.2

N, The nutrient is present in significant quantities but there is no reliable information on the amount.

Table 7. Organic acids per 100-gram edible portion of test fruits (Holland, Unwin and Buss, 1992)¹⁵

Test fruits	Malic (g)	Citric (g)	Tartaric (g)	Oxalic (g)
Chico*	—	—	—	—
Mango	0.1	0.4	0.1	Tr
Pineapple	0.2	0.8	—	Tr
Papaya	0.1	0.1	—	—

* No data available.

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