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A Study of Blood Glucose Response Following Temperate and Tropical Fruit Ingestion in Healthy Adults

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ABSTRACT

Fruits are well known to have high nutritional values. However, the response in blood glucose level varies with different fruits. To date, data has not been compiled to rank local fruits according to their blood glucose response. Therefore, this randomised experimental study was carried out to determine the blood glucose response after consuming ten types of tropical fruits (mango, *rambutan*, *longan*, sapodilla, jackfruit, watermelon, papaya and banana of three varieties, *brangan*, *rastali* and *mas*) and four types of temperate fruits (red apple, orange, grape and green pear). A total of 72 healthy subjects randomly divided into groups of 12 to 20 subjects (mean age: 21.5$\pm$0.6 years, mean BMI: 21.13$\pm$1.49 kgm^{-2}) were requested to consume test fruits or reference food (glucose) after an overnight fasting on separate occasions. Each test fruit and the glucose contained 50g of carbohydrates. Finger-prick blood samples were obtained at 0 (fasting), 15, 30 60, 90 and 120 min after consuming each fruit. The blood glucose response was obtained by calculating area under the curve (AUC). The AUC ranged between 57.59$\pm$10 mmol.min/L and 313.2 mmol.min/L, with glucose showing the highest AUC ($p<0.05$) compared to all fruits tested. Banana gives the highest blood glucose response while green pear showed the lowest. The fruits ranked in descending order based on the AUC values were *longan*, followed by *rambutan*, grapes, watermelon, orange, papaya, jackfruit, sapodilla, mango and red apple. Tropical fruits had significantly higher AUC than temperate fruits ($p<0.05$). Overall, bananas demonstrated the largest rise in postprandial blood glucose response (62%) when compared to glucose while green pear showed the lowest response (18%). This preliminary data could be used as a recommendation to diabetic patients for optimum blood glucose control.

INTRODUCTION

Different carbohydrate-foods produce different blood glucose responses (Otto and Niklas, 1980). Considerable interest has been raised in the effects of various carbohydrate-containing foods on postprandial blood glucose response. Results obtained have been a basis for dietary recommendations for diabetic patients (Crapo, Reaven & Olesky, 1976; Bantle *et al.*, 1983). These findings led to a method of classification of carbohydrate-containing food based on their acute blood

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glucose response known as glycaemic index (Jenkins *et al*., 1981). Foods that contain carbohydrate are digested and absorbed at a slower rate, resulting in lower blood glucose. Hence, these foods may have metabolic benefits in relation to diabetic control (Ludwig, 2000). However, little attention has been given to fruits (Guevarra & Panlasigui, 2000).

Fruits consist mainly of carbohydrates and are known to have high nutritional values specifically in terms of micronutrients (Fatema *et al*., 2003). Nevertheless, the compositions vary greatly (Hoover-Plow, Savesky & Dailey, 1987). Studies have shown that high intake of fruits and vegetables may have a protective effect against cardiovascular disease (CVD) (Liu *et al*., 2000) and decrease the risk of developing diabetes (Ford & Mokdad, 2001).

The type and amount of fruits to be included in daily diets of diabetics has always been a concern (Guevarra & Panlasigui, 2000). Fatema *et al*. (2003) has reported that it is important to know the composition of fruits and their biological responses in order to rationalise the advice of including fruits in the diet of diabetic patients. In addition, Brand-Miller, Olagiuri & Foster-Powell (1997) have documented that tropical fruits may produce higher responses of postprandial blood glucose than temperate fruits.

Therefore, the objectives of this study are to determine the blood glucose response for some tropical and temperate fruits in healthy adults compared to glucose itself. This novel data could be used by dietitians and nutritionists in recommending the most suitable fruits for patients, especially individuals with diabetes.

Methods

Subjects

Four groups (A, B, C, D) consisting of 12 to 20 healthy volunteers were derived from a total of 72 subjects to participate in this study (Table 1). There were 32 males and 40 females with mean age and body mass index (BMI) of 21.5$\pm$0.6 years and 21.1$\pm$1.5 kgm^{-2} respectively. Subjects were non-smokers and not on any medication. Subjects were requested to maintain their usual daily food intake and activity throughout the study period. The purpose and protocol of the study were explained to the subjects and written consent was obtained.

Test Fruits

Subjects were grouped accordingly. 14 fruits consisting of 10 tropical fruits [mango (*Mangifera Indica*), *rambutan* (*Nephelium lappaceum*), *longan* (*Nephelium malaiense*), sapodilla (*Manilkara achras*), jackfruits (*Artocarpus heterophullus*), papaya (*Carica papaya*), watermelon (*Citrullus vulgaris*) and three varieties of banana (*Musa paradisiacal*) i.e. *Brangan*, *Rastali* and *Mas*] and four temperate fruits [red apple (*Pyrus malus*), orange (*Citrus reticula*), grape (*Vitis vinifera*) and green pear (*Pyrus communis*)] were tested in this study. Glucose (Glucolin™) dissolved in 500 ml of water was given as a reference food to compare with the test fruits. Both test fruits and glucose consisted of 50g carbohydrates. The amount of carbohydrate and the crude fibre content for each fruit was calculated using the Food Composition Table (Tee *et al.,* 1997). Table 2 shows the amount of the tested fruits which had to be consumed to provide 50g carbohydrates. All subjects managed to consume the test fruits given despite the more than average portion size.

Experimental procedures

Subjects were requested to consume test fruits or reference food (glucose) on separate occasions in the morning (0800) after 10-12 hours overnight fast. Fasting blood sample was taken by finger-pricking at time 0 and the subjects were requested to consume the test fruits with 250 ml plain water or glucose in 500ml water within 15 minutes. Further blood samples were taken at 15, 30, 60, 90 and 120 minutes after initial intake. The blood samples were obtained and analysed using glucose oxidase method (Accutrend™ - Roche Diagnostics GmbH, D-68298 Mannheim, Germany).

Data Analysis

The blood glucose values for every point of time over two hours were used to calculate the area under the curve (AUC) for each subject and each test individually by encoding in Lotus software (123; CA USA). The AUC calculation used was as described by the Food and Agriculture Organization of the United Nations (FAO, 1998). The blood glucose responses of test fruits were then calculated as follows:

Blood Glucose Response

$$= \frac{\text{AUC of test fruits}}{\text{AUC of glucose}} \times 100$$

Results were expressed as mean $\pm$ SEM. Blood glucose value at each time, AUC and blood glucose response were subjected to repeated measure ANOVA followed by Tukey's multiple range test.

RESULTS

There was no significant difference in terms of BMI and age between each subject in the group (Table 1). Table 3 shows the mean blood glucose at different time points, the AUC values and blood glucose response observed after consuming the fruits. There was a significant increase in fasting blood glucose after ingestion of all fruits and glucose ($p<0.01$). The three temperate fruits (grapes, orange and red apple) and the two tropical fruits (papaya and watermelon) reached peak blood glucose values at 15 min while the rest of the fruits including glucose peaked at 30 min.

The AUC ranged between 57.59mmol.min/L and 313.2mmol.min/L, and was significantly highest for glucose ($p<0.05$) compared to all fruits tested. Among the test fruits, the mean AUC was highest for banana while the lowest was green pear. The AUC value for banana was significantly higher than green pear, red apple, mango and sapodilla ($p<0.05$) while not significantly different compared to the rest of the fruits tested (Figure 1).

When comparing different varieties of banana, *Brangan* has the highest AUC, followed by *Mas* and *Rastali* (Figure 2). However, the differences in AUC and blood glucose response was insignificant between the three types of bananas ($p>0.05$). Nevertheless, banana showed the largest rise of blood glucose response, which was 62% when compared to glucose (100%), while green pear showed the lowest increment of only 18%. The blood glucose response of other fruits tested was *longan*, 60% followed by *rambutan* and grapes; (59%), watermelon (54%), orange (47%), papaya (45%), jackfruit (41%), sapodilla and mango (35%) and red apple (27%) respectively (Figure 3).

Tropical fruits had significantly higher AUC values and blood glucose responses than temperate fruits ($p<0.05$) and both were significantly lower than glucose ($p<0.05$) (Figure 4). The crude fibre content of the test fruits was not correlated with the AUC value ($r=-0.126$, $p>0.05$) or blood glucose response ($r=-0.035$, $p>0.05$) respectively.

DISCUSSION

This study showed that the blood glucose response produced after consuming the test fruits was significantly lower when compared with glucose ($p<0.05$). Several researchers have reported similar results and their results were attributed to

Table 1. Characteristics of human subjects according to groups given each test fruit

Group	*Test Fruits*	*n*	*Age (years)*	*BMI (kgm^{-2})*
A	Mango *Rambutan* Longan	20	21.2 ± 0.5	20.8 ± 1.4
B	Sapodilla Jackfruits Green pear	20	21.8 ± 0.8	20.5 ± 1.5
C	Banana - *Brangan* - *Rastali* - *Mas*	20	21.5 ± 1.2	21.3 ± 1.2
D	Watermelon Papaya Red apple Orange Grape	12	21.4 ± 1.5	21.0 ± 0.8
Total / Mean ± SD (Range)		72	21.5 ± 1.0 (21- 23)	20.9 ± 1.2 (19- 22)

$p > 0.05$ no significant difference of age and BMI between the groups

the type of carbohydrate content of the fruits which mainly consisted of fructose (Wolever *et al.*, 1993; Lunetta *et al.*, 1995; Guevarra & Panlasigui, 2000). Fructose is slowly absorbed and is less likely to increase blood glucose levels when compared to other monosaccharides such as glucose and lactose (Uusitupa, 1994). Fructose is rapidly cleared and metabolised by the liver in both normal and type 2 diabetic patients (Wolever & Brand-Miller, 1995). Moreover, the glycaemic index (GI) of fructose is significantly lower than that of glucose and is found to elicit lower blood glucose response (Lee & Wolever, 1998).

Our results also demonstrated that the tested fruits gave varying effects on blood glucose responses. Wolever and Brand-Miller (1995) noted that the glycaemic index of fresh fruits vary over a threefold range from 22 for cherries to 72 for watermelon. There are several factors that may affect the digestion and absorption of fruits and thus the blood glucose response. Factors such as the degree of ripeness, the type of sugars present, the presence of fibre and antinutrients and the physical state of the fruits have contributed to the response of glucose level (Guevarra & Panlasigui, 2000).

In this study, banana has the largest rise of blood glucose response while green pear showed the lowest. A possible reason for this is due to the carbohydrate content of banana which is approximately twice the amount of carbohydrate in apple, pear or orange (Hermansen *et al.*, 1992). The degree of ripeness of banana may also influence the postprandial blood glucose response (Lintas *et al.*, 1995). Over-ripe banana has been found to be digested by *a*-amylase at the highest rate, converting carbohydrate to free sugar (Englyst & Cumming, 1986). However, no difference was found in blood glucose response for

Table 2. Amount of test fruits to be consumed

Test fruits	*Amount (g) containing 50 g CHO*	*Crude fibre (g) per 50 g CHO*	*Origin*
Mango (*Mangifera Indica*)	354 (2 whole fruits)	1.4	Local
Rambutan (*Nephelium lappaceum*)	361 (12 whole fruits)	1.3	Local
Longan (*Nephelium malaiense*)	313 (24 whole fruits)	1.2	Thailand
Sapodilla (*Manilkara achras*)	271 (5 whole fruits without skin/seeds)	2.5	Local
Jackfruits (*Artocarpus heterophullus*)	686 (18 fruits without seeds)	38.4	Local
Watermelon (*Citrullus vulgaris*)	835 (6 slices without skin; LxWxT, 23.3x10x3 cm)	1.9	Local
Papaya (*Carica papaya*)	703 (4½ slices; LxWxT, 28x3x2.8 cm)	3.5	Local
Banana (*Musa paradisiacal*)			
- *Brangan*	207 (3½ fruits)	1.0	Local
- *Rastali*	230 (7 fruits)	2.3	
- *Mas*	219 (5 fruits)	3.7	
Red apple (*Pyrus malus*)	382 (3½ whole fruits)	1.0	*Fuji* (Shandong, Ltd China)
Orange (*Citrus reticula*)	552 (3½ whole fruits)	3.2	*Navel* (Australian 3107)
Grape (*Vitis vinifera*)	323 (27 whole fruits)	3.1	*Top Brand* (California)
Green pear (*Pyrus communis*)	310 (1½ whole fruits)	5.6	China

Table 3. The mean blood glucose, AUC and blood glucose response (%) of fruits under study

Test fruits	0 (min)	15 (min)	30 (min)	60 (min)	90 (min)	120 (min)	AUC (mmol.min/L)	BGR (%)
				Tropical Fruits				
Mango	3.7±0.2	4.6±0.3*	**5.8±0.4**	4.9±0.3	4.2±0.3	3.7±0.2	110.40±14**	35
Rambutan	4.2±0.2	5.8±0.2*	**7.6±0.4**	6.0±0.4	5.0±0.3	4.3±0.2	184.56±18**	59
Longan	3.8±0.2	5.6±0.2*	**7.5±0.5**	5.5±0.4	4.5±0.2	3.9±0.2	189.66±24**	60
Sapodilla	3.8+0.1	4.6+0.2*	**5.8+0.2**	5.2+0.3	3.6+0.2	3.8+0.2	110.92±15**	35
Jackfruits	3.6+0.1	4.6+0.2*	**5.7+0.1**	5.3+0.3	3.8+0.2	3.7+0.2	127.94±15**	41
Papaya	4.9+0.2	**7.9+0.3***	7.7+0.3	5.7+0.2	5.0+0.2	4.8+0.2	140.32±24**	45
Watermelon	5.0+0.2	**8.4+0.3***	7.8+0.2	6.1+0.2	5.5+0.2	5.0+0.1	170.46±23**	54
				Various type of Bananas				
- *Brangan*	4.6+0.1	7.6+0.1*	**8.1+0.1**	6.6+0.1	5.7+0.1	4.9+0.1	214.45±12**	68
- *Rastali*	4.9+0.1	6.5+0.1*	**8.5+0.2**	6.6+0.1	5.3+0.2	5.1+0.2	183.34±15**	59
- *Mas*	4.8+0.1	6.8+0.3*	**7.5+0.4**	6.6+0.4	6.0+0.3	5.1+0.2	189.45±32**	60
Mean	4.8+0.1	7.1+0.2	8.1+0.2	6.6+0.2	5.6+0.2	5.0+0.2	195.42±18**	62
				Temperate Fruits				
Grapes	5.2±0.6	**9.4±1.1***	8.8±1.5	6.3±1.0	5.0±0.6	4.7±0.4	183.60±21**	59
Orange	4.7±0.4	**8.4±1.7***	7.6±1.5	5.5±1.0	4.8±0.7	4.5±0.5	148.17±21**	47
Red apple	4.6±0.3	**6.8±0.8***	6.4±0.6	4.8±0.5	4.7±0.3	4.5±0.2	84.27±8**	27
Green pear	3.3+0.2	3.7+0.2*	**4.5+0.2**	3.6+0.1	3.2+0.1	3.0+0.1	57.59±10**	18
				Reference Food				
Glucose (Glucolin®	4.4±0.1	6.9±0.1*	**8.9±0.1**	8.0±0.1	6.1±0.1	5.6±0.1	313.20±10	100

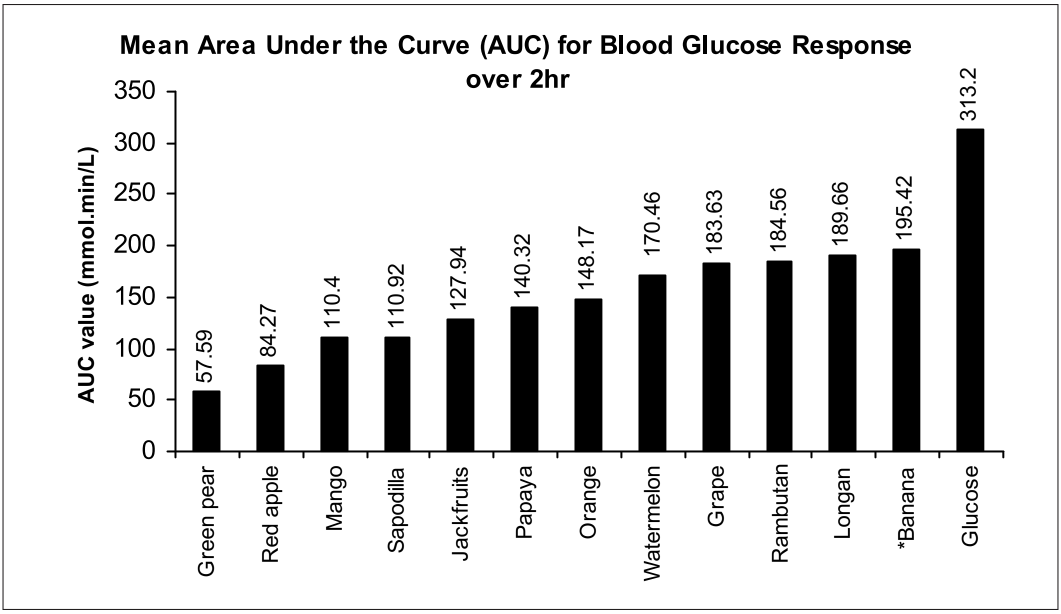
* $p<0.01$
**$p<0.05$ significantly less than glucose
Values in bold determined the peaked blood glucose response. BGR= blood glucose response

different types of bananas, indicating that all varieties of bananas have the same impact on blood glucose response.

Apple and green pear have been reported to contain more fructose and less glucose, thus demonstrating the lowest blood glucose response (Lunetta *et al.*, 1995). In this study, sapodilla and mango showed low glucose response and these results are in agreement with those shown by Guevarra & Panlasigui (2000). The presence of antinutrients such as phytic acid, tannins, lectins and saponin have been known to delay the rate of digestion and absorption (Brand-Miller *et al.*, 1997). Sapodilla contains saponin that has the properties of foaming in water while mango contains tannin and phytic acids that are found to inhibit intestinal enzymes lowering the rate of absorption thus, producing low glucose response (Guevarra & Panlasigui, 2000).

In addition, Bolton, Heaton & Burroughs (1981) and Oettle, Emmett & Heaton (1987) hypothesised that the rate of the sugar entering the bloodstream

Figure 1. Mean area under the curve (AUC) for blood glucose response over 2 hours for test fruits and glucose



[a] $p<0.05$; significantly different from glucose
[b] $p<0.05$; significantly different from banana
* Mean AUC of three types of Banana

Figure 2. Comparison of AUC and blood glucose response between different varieties of bananas

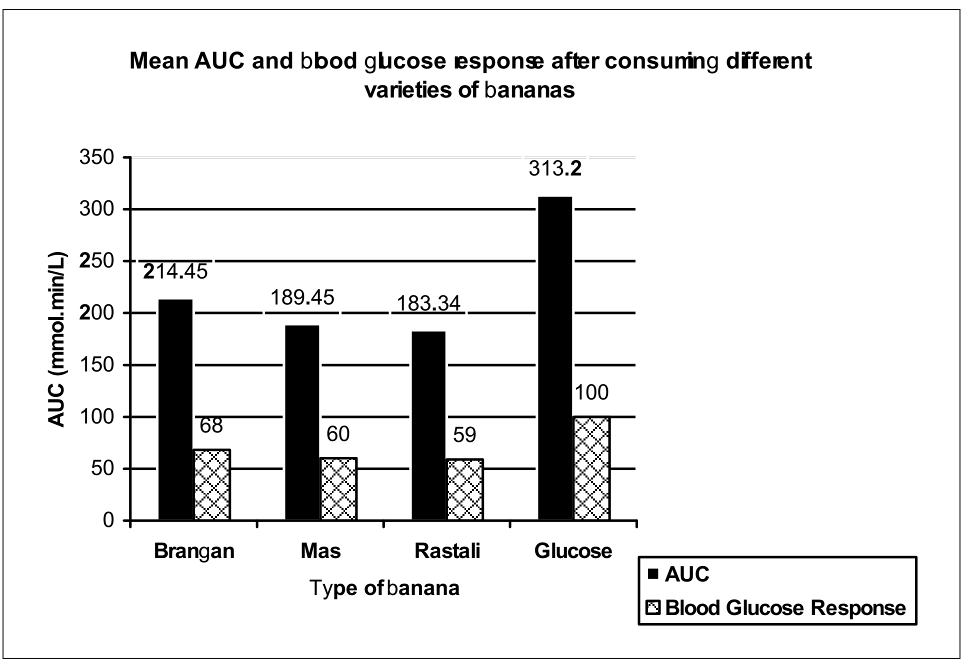


Figure 3. Mean blood glucose response (BGR) of test fruits when compared with glucose (reference food)

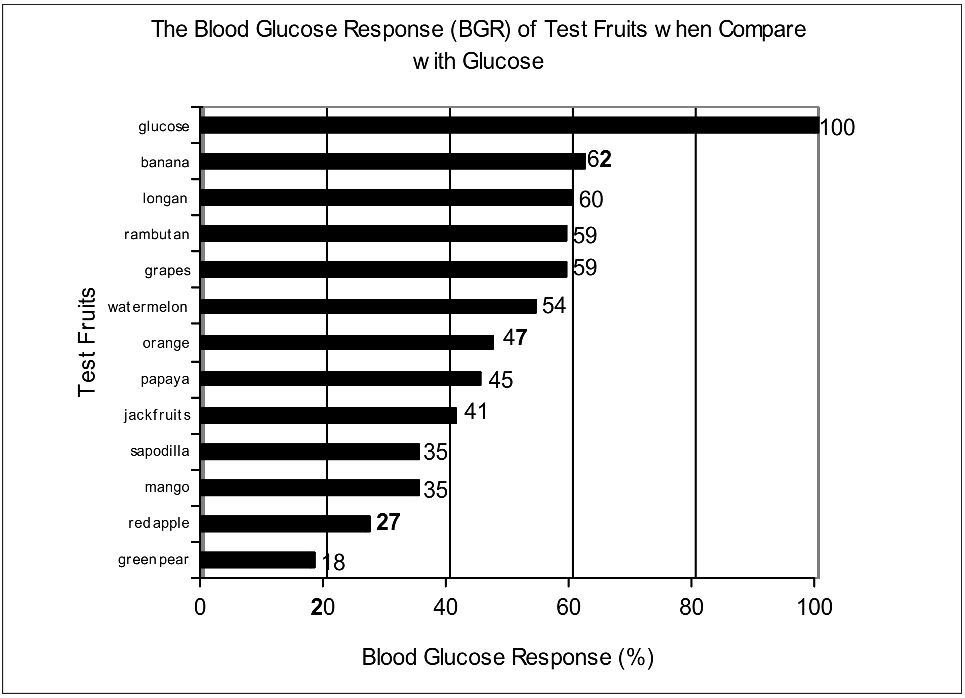
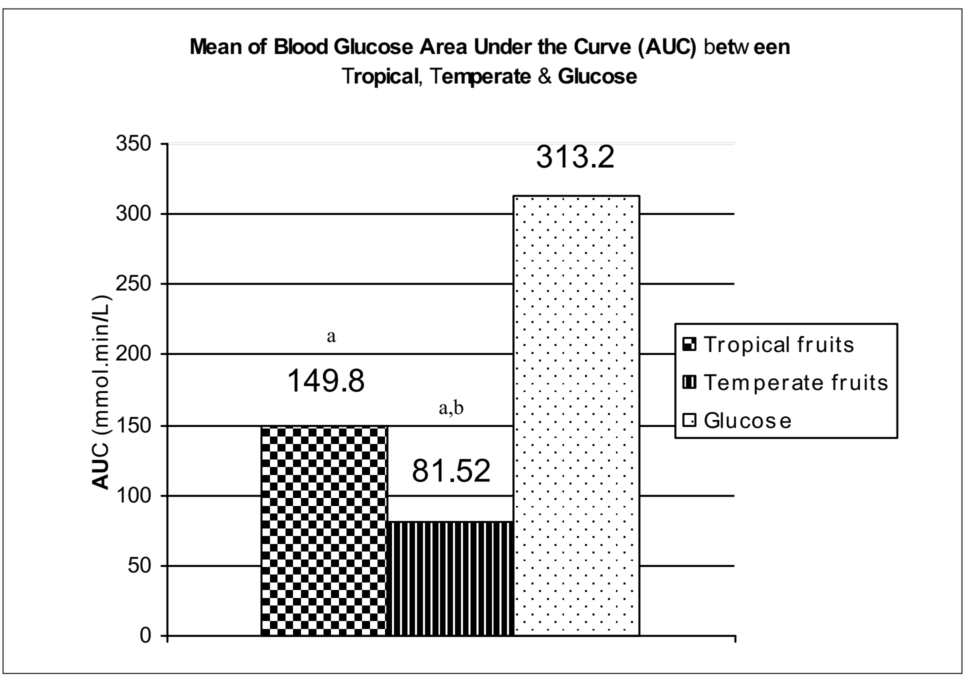


Figure 4. Mean of blood glucose area under the curve (AUC) between tropical, temperate & glucose



[a] p<0.05; significantly different from from glucose
[b] p<0.05; significantly different from tropical fruits

varies with the physical state of the fruit. Grapes, *rambutan*, *longan*, papaya and watermelon are easily chewed and thus elicit a high glucose response. Sapodilla, mango, red apple and green pear, however, require some effort in chewing due to their grainy texture. This might also contribute to its low glucose response (Guevarra & Panlasigui, 2000).

The tropical fruits demonstrated the largest rise in mean AUC value when compared to temperate fruits (Brand-Miller *et al*., 1997). Differences among the fruits may arise because of variations, particularly in monosaccharide composition and the nature of fibre (Wolever & Brand-Miller, 1995).

No significant relationship was seen between the crude fibre content of the AUC values and blood glucose response in this study despite the fact that fibre has been repeatedly shown to decrease the postprandial blood glucose (Stevens *et al*., 2002). However, our findings were in agreement with the study by Jenkins *et al*., (1981) and Lunetta *et al*., (1995). This was probably due to the types of fibre that differ within fruits. The total dietary fibres in fruits consist of soluble and insoluble fibre. The insoluble fibres such as cellulose and hemi-cellulose are rigid materials, and give the structure to plants (Anderson & Akanji, 1991). Soluble fibre like pectin, present abundantly in fruits, may form a viscous solution which has the capacity to bind to carbohydrate. This could limit the accessibility to *a*-amylase and reduce the blood glucose response (Goni, Valdivieso & Garcia-Alonso, 2000). Soluble fibre has been shown to be active on plasma glucose metabolism and consequently, demonstrate the lowering effect of blood glucose response (Riccardi & Rivellese, 1991).

CONCLUSION

Our results showed that there is a difference in blood glucose response among tropical and temperate fruits tested. Based on these results, the most suitable temperate fruits to be recommended for diabetic patients without significantly increasing the blood glucose response are green pear and red apple, while the most suitable tropical fruits are sapodilla and mango. Banana can only be eaten in moderate amounts provided that fruits are within the carbohydrate allowance. Dose-response study with various amounts of fruits for example 15 g of carbohydrate should be carried out to determine the most appropriate portion size of the fruits.

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