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Honey and Type 1 Diabetes Mellitus

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1. Introduction

Type 1 diabetes mellitus is by far the most common metabolic and endocrinal disease in children (Peters & Schriger, 1997). The major dietary component responsible for fluctuations in blood glucose levels is carbohydrate. The amount, source (Jenkins et al., 1981; Gannon et al., 1989) and type (Brand et al., 1985) of carbohydrate appear to have profound influence on postprandial glucose levels. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction and failure of various organs especially the eyes, kidneys, nerves, heart and blood vessels (American Diabetes Association, 2001).

The glycemic effect of any foodstuff is defined as its effect on blood glucose level postprandially. Both the glycemic index (GI) and the peak incremental index (PII) are used to assess the glycemic effect of different food stuffs (Jenkins et al., 1981). Jennie et al (2003) who studied the use of low glycemic index diets in the management of diabetes found that diets with low glycemic indices (GI), compared with conventional or high-GI diets, improved overall glycemic control in individuals with diabetes, as assessed by glycemic index, peak incremental index, reduced HbA1c and fructosamine. They concluded that using low-GI foods in place of conventional or high-GI foods has a clinically useful effect on postprandial hyperglycemia similar to that offered by pharmacological agents that target postprandial hyperglycemia. Similarly, the American Diabetes Association (2002) stated that the use of low-GI foods may reduce postprandial hyperglycemia.

Honey is the substance made when the nectar and sweet deposits from plants are gathered, modified and stored in the honeycomb by honey bees. It is composed primarily of the sugars glucose and fructose; its third greatest component is water. Honey also contains numerous other types of sugars, as well as acids, proteins and minerals (White et al., 1962; White, 1980; White, 1975). The water content of honey ranges between 15 to 20% (average 17.2%). Glucose and fructose, the major constituents of honey, account for about 85% of the honey solids. Besides, about 25 different sugars have been detected. The principal oligosaccharides in blossom honeys are disaccharides: sucrose, maltose, turanose, erlose. Trace amounts of tetra and pentasaccharides have also been isolated (Bogdanov, 2010). The protein and amino acid content of honey varies from 0.05 to 0.3 %. The honey proteins are mainly enzymes (White, 1975). Honey also contains varying amounts of mineral substances ranging from 0.02 to 1.03 g/100 g (White, 1975). Among honey benefits are its anti-

inflammatory (Al Waili & Boni, 2003), anti- oxidant (Frankel et al., 1998; Gheldof & Engeseth, 2002; Gross et al., 2004) and anti-microbial effects (Molan, 1992; Steinberg et al., 1996; Molan, 1997; Theunissen et al., 2001). Further-more, several studies have shown that honey produced an attenuated postprandial glycemic response when compared with sucrose in both patients with diabetes and normal subjects (Ionescu-Tirgoviste et al., 1983; Shambaugh et al., 1990; Samanta et al., 1985; Al Waili, 2004; Agrawal et al., 2007).

C-peptide is considered to be a good marker of insulin secretion and has no biologic activity of its own (Ido et al., 1997). Measurement of C-peptide, however, provides a fully validated means of quantifying endogenous insulin secretion. C-peptide is co-secreted with insulin by the pancreatic cells as a by-product of the enzymatic cleavage of proinsulin to insulin. Consequently, serum C-peptide level can be used as a true indicator of any change in the insulin level, which is the main determinant of plasma glucose level.

Several studies were performed in healthy and in type 2 diabetic patients to evaluate the effects of honey on the insulin and C-peptide levels, and the results were controversial (Bornet et al., 1985; Elliott et al., 2002; Watford, 2002; Al-Waili, 2003).

2. Aim of the study

The aim of this work was to compare the effects of honey, sucrose and glucose on plasma glucose and C-peptide levels in children and adolescents with type 1 diabetes mellitus.

3. Subjects and methods

3.1 Subjects

Twenty patients with type 1 diabetes mellitus, aged 3–18 (mean 10.95 years) and ten healthy non-diabetic children and adolescents, aged 1–17 (mean 8.5 years) were studied. All subjects were within 68–118% and 77–125% of their ideal body weight and height, respectively. The mean BMI of patients and controls were 22.60 and 23.15, respectively. All patients with diabetes had a mean glycosylated hemoglobin of 9.9% (range = 7–15%). The sex ratio in patients and controls was 1:1. The patients were recruited from the regular attendants of the children clinic of the National Institute of Diabetes in Cairo, Egypt. The study was approved by the local ethical committee, and an informed written consent was obtained from at least one parent of each subject before the study. All patients were receiving three insulin injections per day, each consisting of a mixture of a medium-acting insulin (isophane NPH) and a short-acting soluble insulin (human Actrapid).

3.2 Methods

All patients were primarily diagnosed with type 1 insulin-dependent diabetes mellitus by measuring the serum level of C-peptide on presentation [the patient was considered suffering from insulin-dependent diabetes mellitus type 1 if the C-peptide level was below 0.4 ng/dl (Connors, 2000)]. All subjects were subjected to the following:

1. Anthropometric measures including weight in kg and height in cm which were plotted against percentiles for age and sex.
2. Oral sugar tolerance tests using glucose, sucrose and honey in three separate sittings: After an overnight fast (8 h) and omission of the morning insulin dose, a calculated amount of each sugar (amount = weight of subject in kg X 1.75 with a maximum of 75 g) (William & Ruchi, 2005) was diluted in 200 ml water and then ingested over 5 min in a

random order, on separate mornings 1 week apart. The honey dose for each patient was calculated based on the fact that each 100 gm of the honey used in this study contained 77.3 gm sugars. So if a patient weighs for example 20 kg, he/she should receive 20 x 1.75 = 35 gm sugar which will be present in (35 x 100) ÷ 77.3 = 45.3 gm honey. Venous blood was sampled just before ingestion and then every 30 min postprandial for 2 h thereafter. Samples were left to clot, centrifuged and glucose assay was performed chemically on the Synchron CX5 autoanalyzer (Beckman instruments Inc.)[1].

3. Measurement of fasting and postprandial serum C- peptide level: Venous blood samples were withdrawn from each subject at 0 (fasting) and 2 h postprandial after ingestion of each individual sugar. The samples were then centrifuged and serum was stored in aliquots at – 20°C. At the end of the study, samples were calibrated for C-peptide using the biosource c-pep-easia[2], which is a solid phase enzyme amplified sensitivity immunoassay performed on a microtiter plate. A fixed amount of C-peptide labeled with horseradish peroxidase (HRP) competes with unlabeled C-peptide present in the calibrators controls and samples for a limited number of binding sites on a specific antibody. After 2 h incubation at room temperature, the microtiter plates were washed to stop the competition reaction. The chromogenic solution (TMB-H2O2) was added and incubated for 30 min. The reaction was stopped with the addition of stop solution, and the microtiter plate was then read at the appropriate wave length. The amount of substrate turnover was determined colorimetrically by measuring the absorbance which was inversely proportionate to the C-peptide concentration. A calibration curve was plotted and C-peptide concentration in samples was determined by interpolation from the calibration curve.
4. Calculation of glycemic and peak incremental indices (see example figure 3.1):

$$\text{Glycemic index of the food (Jenkins, 1987)} = \frac{\text{Area under glycemic curve of test food}}{\text{Area under glycemic curve of glucose}}$$

- Area under curve (AUC) refers to the area included between the baseline and incremental blood glucose points when connected by straight lines. The area under each incremental glucose curve is calculated using the trapezoid rule (note: only areas above the baseline are used).
- Peak incremental index (PII) (Samanta et al., 1985) is defined as the ratio of the maximal increment of plasma glucose produced by sugar to that produced by glucose

$$\text{Peak incremental index} = \frac{\text{Maximal increment produced by the sugar tested}}{\text{Maximal increment produced by glucose}}$$

Maximal increment is the difference between the peak point and the fasting point.

3.3 Statistical analysis

Standard computer program SPSS for Windows, release 13.0 (SPSS Inc., USA) was used for data entry and analysis. All numeric variables were expressed as mean ± standard deviation (SD). Comparison of different variables in various groups was done using student t-test and Mann–Whitney test for normal and non-parametric variables, respectively. Wilcoxon signed

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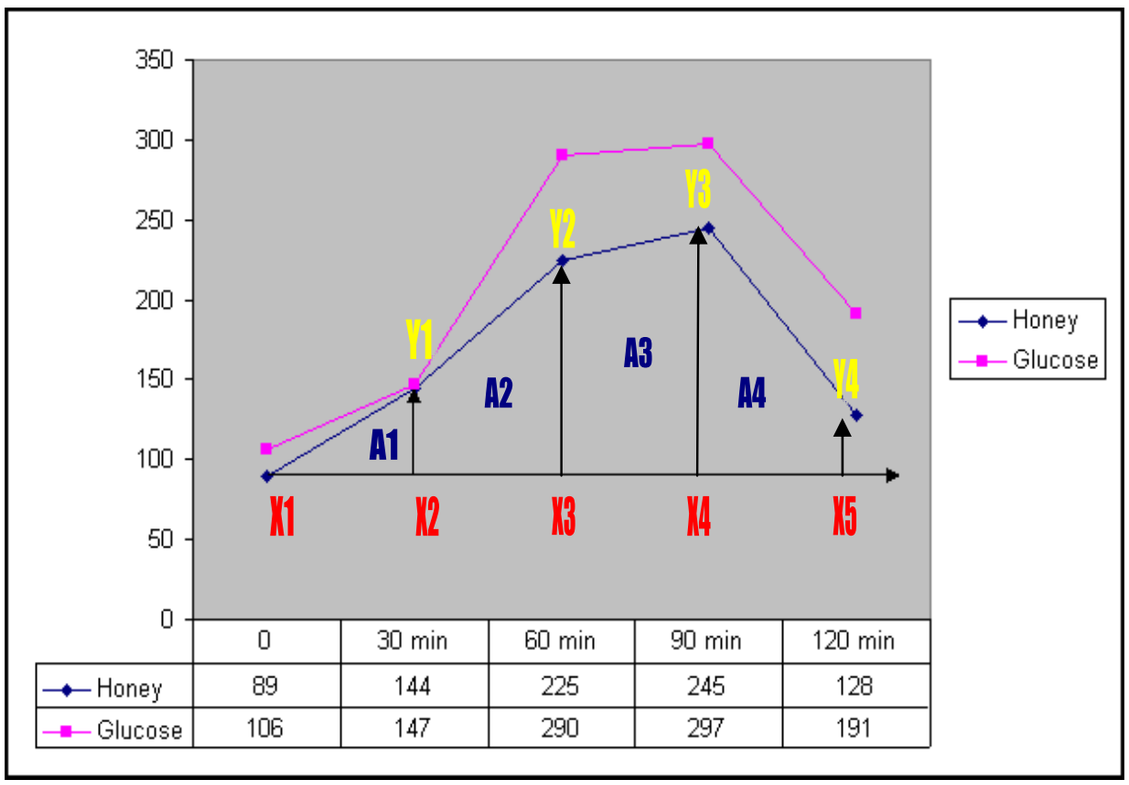
rank tests were used to compare multiple readings of the same variables. Chi-square ($\chi 2$) test was used to compare frequency of qualitative variables among the different groups (Daniel, 1995).



	0	30 min	60 min	90 min	120 min
Honey	89	144	225	245	128
Glucose	106	147	290	297	191

Fig. 3.1 Oral glucose tolerance curve of one of our patients

For calculation of the area under honey curve (AUC) $=A_1+A_2+A_3+A_4$

A_1 is a triangle = 1/2 base x height = $1/2(X_2 - X_1) \times (Y_1 - X_2) = ½(30) \times (144 – 89) = 15 \times 55 = 825$

A_2 is a trapezoid = 1/2 sum of the parallel sides (heights) x base

$= 1/2[(Y_1 - X_2) + (Y_2 - X_3)] \times (X_4 - X_5) = 1/2[(144 – 89) + (225 – 89)] \times 30 = 1/2(55 + 136) \times 30 = 1/2(191) \times 30 = 95.5 \times 30 = 2865$

A_3 is a trapezoid = 1/2 sum of the parallel sides (heights) x base

$= 1/2[(Y_2 – X_3) + (Y_3 - X_4)] \times (X_4 - X_3) = 1/2[(225 – 89) + (245 – 89)] \times 30 = 1/2(136 + 156) \times 30 = 1/2(292) \times 30 = 146 \times 30 = 4380$

A_4 is a trapezoid = 1/2 sum of the parallel sides (heights) x base

$= 1/2[(Y_3 – X_4) + (Y_4 - X_5)] \times (X_3 - X_2) = 1/2[(245 – 89) + (128 – 89)] \times 30 = 1/2(156 + 39) \times 30 = 1/2(195) \times 30 = 97.5 \times 30 = 2925$

$AUC = A_1 + A_2 + A_3 + A_4 = 825 + 2865 + 4380 + 2925 = 10995$

4. Results

No significant difference was found between patients (diabetics) and controls (non-diabetics) as regards the age and anthropometric measures (table 4.1). The mean age of subjects in the diabetic and non- diabetic groups was 11.3 and 8.5 years, respectively, with no statistically significant difference between groups (P > 0.05). The mean weight %, height % and body mass index did not also differ significantly between diabetics and non-diabetics (93.6%, 99.2%, 22.6 versus 94%, 98.2%, 23.1, respectively; P > 0.05). The mean plasma glucose level at 0 (fasting) and 30 min postprandial (i.e. 30 min after intake of glucose, sucrose or honey) did not differ significantly between subjects in both groups (diabetics and non-diabetics) (Tables 4.2 - 4.5) (P > 0.05). In non-diabetics (control), as shown in tables 4.2 and 4.3, the mean plasma glucose level 60, 90 and 120 min after intake of honey became significantly lower than after either glucose or sucrose (P< 0.05). Similarly, as shown in tables 4.4 and 4.5, there was a statistically significant decrease of plasma glucose in diabetics at 60, 90 and 120 min after honey intake, when compared with either glucose or sucrose (P< 0.05). The glycemic index (GI) and the peak incremental index (PII) of either sucrose or honey did not differ significantly between patients and controls (P > 0.05). On the other hand, both the GI and PII of honey were significantly lower when compared with sucrose in patients and controls. In non-diabetics, the glycemic index (GI) of honey was 0.69 compared to 1.32 for sucrose, with statistically significant difference (P< 0.05). In diabetics, the GI of honey was also significantly lower than that of sucrose (o.61 versus 1.19, respectively; P< 0.001) (table 4.6; figure 4.1). The PII of honey in non-diabetics was 0.61, compared to 1.25 for sucrose (P< 0.05). In diabetics, the PII of honey was also significantly lower than that of sucrose (0.60 versus 1.10, respectively; P< 0.001) (table 4.7; figure 4.2).

The mean (±SD) fasting C-peptide of patients and controls were 0.15 (±0.13) and 1.91 (±0.77) ng/ml, respectively (P< 0.001). All diabetic patients had a basal C-peptide level less than 0.7 ng/ml. In diabetics, although honey intake resulted in increase in the mean level of C-peptide, yet this increase was not statistically significant when compared with either glucose or sucrose (P> 0.05) (Table 4.8; figure 4.3). On the other hand, in non-diabetics, honey produced a statistically significant higher C-peptide level, when compared with either glucose or sucrose (P< 0.05) (Table 4.8; figure 4.4).

Variable	Diabetics	Non-diabetics	P
Age (yr)	11.30 ± 4.80	8.50 ± 5.38	>0.05
Weight %	93.60 ± 13.82	94.00 ± 14.28	>0.05
Height %	99.20 ± 13.01	98.20 ± 11.14	>0.05
BMI	22.59 ± 5.50	23.14 ± 2.90	>0.05

P > 0.05 is non significant
BMI: Body Mass Index

Table 4.1 Age and anthropometric measures in diabetics and non-diabetic controls (mean ± SD)

Time (min)	Glucose	Honey	P
0	75.20 ± 17.45	72.30 ± 9.09	> 0.05
30	86.00 ± 19.88	83.30 ± 9.52	> 0.05
60	102.90 ± 24.47	88.80 ± 10.04	< 0.05
90	103.60 ± 21.24	88.50 ± 8.64	< 0.05
120	91.10 ± 20.74	81.00 ± 8.30	< 0.05

Table 4.2 Mean plasma glucose (±SD) (mg/dl) in non-diabetics (control) following equivalent amount of glucose or honey (P < 0.05 is significant)

Time (min)	Sucrose	Honey	P
0	68.50 ± 12.59	72.30 ± 9.09	> 0.05
30	83.80 ± 13.56	83.30 ± 9.52	> 0.05
60	101.60 ± 11.45	88.80 ± 10.04	< 0.05
90	105.40 ± 18.03	88.50 ± 8.64	< 0.05
120	93.60 ± 17.25	81.00 ± 8.30	< 0.05

Table 4.3 Mean plasma glucose (±SD) (mg/dl) in non-diabetics (control) following equivalent amount of sucrose or honey (P < 0.05 is significant)

Time (min)	Glucose	Honey	P
0	206.05 ± 95.79	208.10 ± 92.76	> 0.05
30	257.55 ± 92.79	247.75 ± 99.44	> 0.05
60	339.80 ± 96.86	285.50 ± 86.29	< 0.05
90	328.05 ± 99.75	272.25 ± 85.33	< 0.05
120	297.90 ± 106.86	236.75 ± 76.80	< 0.05

Table 4.4 Mean plasma glucose (±SD) (mg/dl) in diabetics following equivalent amount of glucose or honey (P < 0.05 is significant)

Time (min)	Sucrose	Honey	P
0	198.30 ± 77.762	208.10 ± 92.76	> 0.05
30	268.25 ± 78.78	247.75 ± 99.44	> 0.05
60	320.35 ± 67.17	285.50 ± 86.29	< 0.05
90	323.65 ± 71.27	272.25 ± 85.33	< 0.05
120	310.15 ± 92.63	236.75 ± 76.80	< 0.05

Table 4.5 Mean plasma glucose (±SD) (mg/dl) in diabetics following equivalent amount of sucrose or honey (P < 0.05 is significant)

	Sucrose	Honey	
	GI	GI	P
Non- diabetics	1.32 (0.85–1.92)	0.69 (0.43–1.43)	< 0.05
Diabetics	1.19 (0.31–3.08)	0.61 (0.15–1.92)	< 0.001

Table 4.6 Glycemic index (GI) mean (range) of sucrose and honey (glycemic index of glucose = 1) (P < 0.05 is significant; P < 0.001 is highly significant)

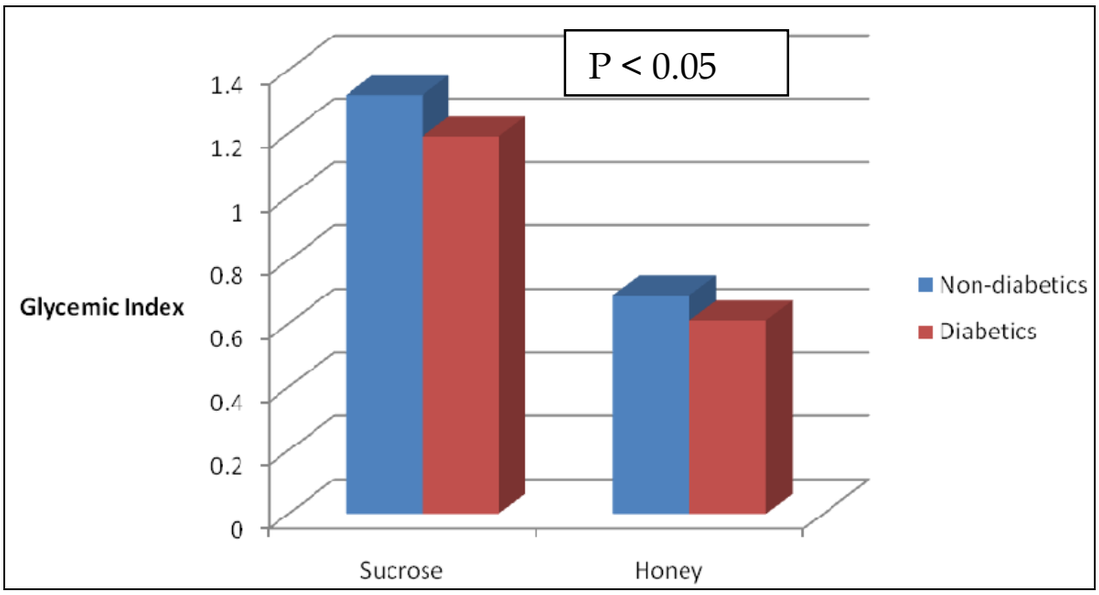


Fig. 4.1 Glycemic index of sucrose and honey

	Sucrose	Honey	P
	PII	PII	
Non- diabetics	1.25 (0.50–1.82)	0.61 (0.30–1.10)	< 0.05
Diabetics	1.10 (0.65–2.98)	0.60 (0.20–1.60)	< 0.001

Table 4.7 Peak incremental index (PII) mean (range) of sucrose and honey (peak incremental index of glucose = 1) (P < 0.05 is significant; P < 0.001 is highly significant)

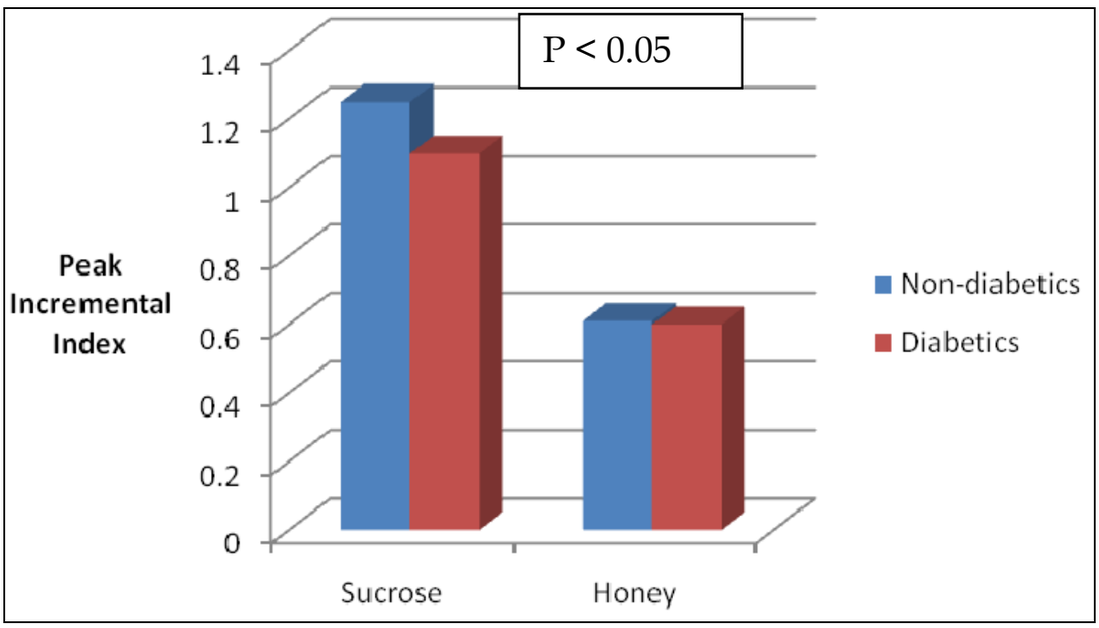


Fig. 4.2 Peak incremental index of sucrose and honey

Group	C-peptide (ng/ml)			P
	After glucose	After sucrose	After honey	
Non-diabetics	3.96 ± 0.84	3.99 ± 1.10	5.50 ± 1.15	P < 0.05
Diabetics	0.29 ± 0.53	0.32 ± 0.53	0.47 ± 1.09	P > 0.05

Table 4.8 Mean C-peptide (±SD) (ng/ml) following equivalent amount of glucose, sucrose or honey in non-diabetics and diabetics (P < 0.05 is significant)

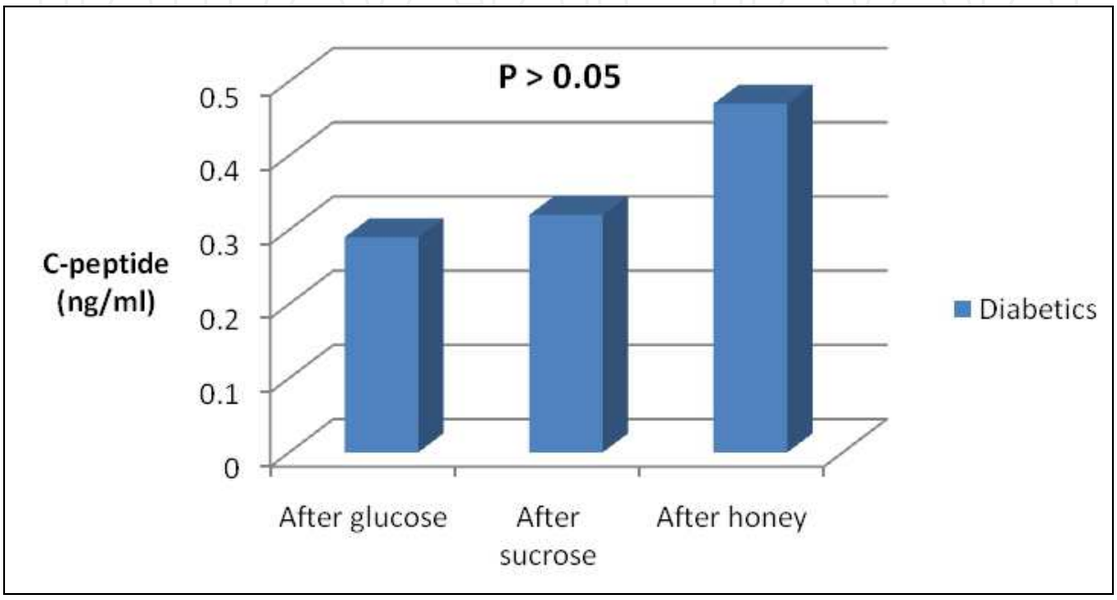


Fig. 4.3 C-peptide following equivalent amount of glucose, sucrose or honey in diabetics

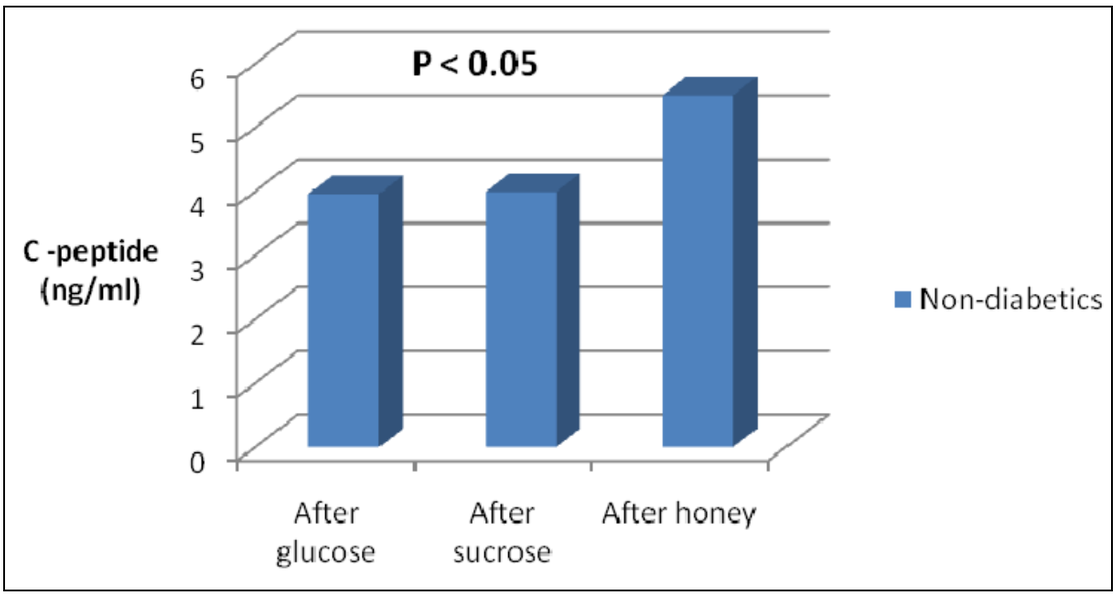


Fig. 4.4 C-peptide following equivalent amount of glucose, sucrose or honey in non-diabetics

5. Discussion

As shown in many studies, sustained hyperglycemia is a risk factor for both micro vascular and macro vascular (as cardiovascular) complications in type 2 diabetes mellitus (Laakso & Lehto, 1997; Bretzel et al., 1998 as cited from Oizumi et al., 2007), while postprandial hyperglycemia has also been considered a risk factor for cardiovascular complications (Tominaga et al., 1999; Risso et al., 2001; Chiasson et al., 2002; Hanefeld et al., 2004; Nakagami et al., 2004 as cited from Oizumi et al., 2007). Many experimental and epidemiological studies have shown that increased postprandial plasma glucose levels may have equally or even more harmful effects than fasting hyperglycemia (Tominaga et al., 1999; Risso et al., 2001; Nakagami et al., 2004 as cited from Oizumi et al., 2007), and the reduction of postprandial plasma glucose levels delays the development of cardiovascular complications (Chiasson et al., 2002; Hanefeld et al., 2004 as cited from Oizumi et al., 2007).

Jenkins (1987) defined the glycemic index as the ratio between the blood glucose areas produced after ingestion of a studied sugar compared to the blood glucose area produced after glucose ingestion itself. He stated that the glycemic response to food affects the insulin response which in turn is also potentiated by other non-glucose dependent factors in this food (Ostman et al., 2001). On the other hand, FAO/WHO (1998) defined the glycemic index as the incremental blood glucose area (0–2 h) following ingestion of 50 g of available carbohydrates (no fibers or resistant starch included), expressed as a percentage of the corresponding area following an equivalent amount of carbohydrate from a standard reference product. Samnata et al (1985) defined the peak incremental index of a certain sugar as the ratio between the maximal increments of the glucose level after ingestion of the sugar compared to the maximal increment produced after ingestion of glucose. He also mentioned that both the glycemic and the peak incremental indices are closely related, highly dependent and positively correlated to the plasma glucose produced after ingestion of any given sugar. Therefore, any change in the plasma glucose level after ingestion of a certain sugar will markedly affect both the glycemic index and the peak incremental index. Hence, the glycemic and the peak incremental indices measure how fast and how much a food raises blood glucose levels. Foods with higher index values raise blood sugar more rapidly than foods with lower index values do in case of the glycemic index and much more in case of peak incremental index.

In our study, no statistically significant differences were found between diabetic patients and non-diabetic controls regarding the glycemic and the peak incremental indices of the studied sugars. Similarly, Samnata et al (1985), who studied the glycemic effect of glucose, sucrose and honey in 12 normal volunteers, eight patients with insulin-dependent diabetes mellitus (IDDM) and six patients with non-insulin-dependent diabetes mellitus (NIDDM), found no significant differences between the normal volunteers and diabetic patients regarding the glycemic and peak incremental indices of both sugars. Since the glycemic index (GI) is the ratio between the area under curve (AUC) of the studied sugar and the AUC of glucose, and the peak incremental index (PII) is the ratio between the maximal blood glucose increment of the studied sugar and that of glucose; it may be expected that both GI and PII will be the same in both diabetics and non-diabetics. Our study showed that honey has statistically significant lower glycemic and peak incremental indices than sucrose and glucose in both patients and controls (< 1 with honey, 1 with glucose being the reference sugar and >1 with sucrose). In agreement, Kaye et al (2002), who published the international table of glycemic index and glycemic load values, found that the GI of honey (0.55 ± 0.05) was lower than that of sucrose (1.10 ± 0.21). Also, Shambaugh et al (1990) found that sucrose caused higher blood sugar readings than honey in normal volunteers. In the study of

Samnata et al (1985), honey ingestion in both diabetics (IDDM) and non-diabetics also resulted in a significantly lower PII compared to the glucose and sucrose. In the study done byAl-Waili (2004), honey compared with dextrose and sucrose caused a lower elevation of plasma glucose levels (PGL) in both diabetics (IDDM) and normal subjects. In an attempt to explain his results, he stated that the mild reduction of plasma glucose levels obtained by honey might be a result of the fructose content of honey which requires metabolic transformation in the liver, a slow process conferring relatively low-GI on these sugars (Jenkins et al., 1981; Wolever et al., 1991). Also, Watford (2002) demonstrated that very small amounts of fructose, which is the main component of honey, could increase hepatic glucose uptake and glycogen storage, as well as reduce peripheral glycemia which could be beneficial in diabetic patients. In the study performed by Agrawal et al (2007), honey was found to produce an attenuated postprandial glycemic response especially in subjects with glucose intolerance. They referred these results to the possibility that the glucose component of honey might be poorly absorbed from the gut epithelium. Also, Tirgoviste et al (1983) studied blood glucose and plasma insulin responses to various carbohydrates in type 2 diabetes, and they found that the increase in plasma glucose was significantly higher after administration of more refined carbohydrates such as glucose than after the complex ones such as honey. Meanwhile, Oizumi et al (2007) and Arai et al (2004) found that consumption of a palatinose (a disaccharide found in honey)-based balanced formula suppressed postprandial hyperglycemia, glycemic and peak incremental indices and produced beneficial effects on the metabolic syndrome–related parameters (namely, the lipid profile and visceral fat accumulation) in diabetic patients. They stated the reason of this observation to be due to the fact that although palatinose is completely absorbed, yet it has the specific characteristics of delayed digestion and absorption as reported by Dahlquist et al (1963) and Lina et al (2002).

Our results showed that honey, compared to glucose and sucrose, caused a significant elevation in the C-peptide levels in non-diabetic subjects. Meanwhile, in diabetic patients, the plasma C-peptide levels did not differ significantly between the three types of sugars. To our knowledge, no similar work was done to study the effects of honey on C-peptide levels in type 1 diabetes mellitus. However, several studies were performed in healthy and in type 2 diabetic patients to evaluate the effects of honey on the insulin and C-peptide levels, and the results were controversial. In the study of Al Waili (2003), inhalation of honey solution, when compared with hyperosmolar dextrose and hypoosmolar distilled water, resulted in a significant elevation of plasma insulin and C-peptide in both normal individuals and in patients with type 2 diabetes mellitus. However, in 2004, the same author found that honey ingestion, when compared with sucrose, caused a greater elevation of insulin and C-peptide in type 2 diabetic patients, while in healthy subjects dextrose ingestion caused a significant elevation of plasma insulin and C-peptide when compared with honey. The author hypothesized that honey may have the ability to stimulate insulin production and secretion from the pancreas than do sucrose in type 2 diabetes mellitus. On the other hand, Bornet et al (1985) reported no significant changes in plasma insulin levels after honey ingestion compared to sucrose in type 2 diabetics. Liljeberg et al (1999) found that high-GI foods induced a greater elevation of blood insulin than did low glycemic index meals (like honey). Elliott et al (2002) tried to explore whether fructose consumption might be a contributing factor to the development of obesity and the accompanying metabolic abnormalities observed in the insulin resistance syndrome and they found that honey intake caused a significant lowering of plasma insulin and C-peptide in normal subjects when compared to sucrose and dextrose. They related their findings to the fructose content of honey which does not stimulate insulin secretion from pancreatic beta cells and that consumption of foods and beverages containing

fructose produced a smaller postprandial insulin excursions than did consumption of glucose-containing carbohydrates (Glinsmann & Bowman, 1993). Also, Watford et al (2002) stated that very small amounts of fructose, which is the main component of honey, could increase hepatic glucose uptake and glycogen storage, as well as reduce peripheral glycemia and thus insulin levels. Ionescu-Tirgoviste et al (1983) studied the blood glucose and plasma insulin responses to some simple carbohydrates (glucose, fructose, lactose) and some complex ones (apples, potatoes, bread, rice, carrots and honey) in 32 type 2 (non-insulin-dependent) diabetic patients, and they found that increases in plasma insulin were significantly higher after the more refined carbohydrates (glucose, fructose and lactose) than after the more complex ones (apples, potatoes, rice, carrots and honey, P less than 0.01).

We hypothesize that honey might have a direct stimulatory effect on the healthy beta cells of pancreas; an effect which may be related to the non-sugar part of honey. This hypothesis is based on the finding that honey caused significant postprandial increase in the C-peptide level despite its lower glycemic and peak incremental indices when compared to either glucose or sucrose. On the other hand, the lack of significant increase in C-peptide levels among diabetic patients might be due to the minimal residual function of the patient's pancreatic beta cells, which is beyond their capacity of further postprandial response. This proposal is backed up by the findings of Pozzan et al (1997) who investigated the relation between the fasting C-peptide level and the ability to respond to a particular stimulus, and they reported that there is a positive significant correlation between the basal value (BV) and the peak value (PV) of C-peptide in insulin dependent diabetic patients and that positive responses need a minimal basal level of 0.74 ng/ml. In all our studied patients, the basal C-peptide level was less than 0.7 ng/ml. Also other authors found significant correlations between the basal and the maximum C-peptide values after a stimulus. However, they reported different basal values which can respond to stimulation. Such values were 0.09 (Clarson et al., 1987), 0.18 (Eff et al., 1989) and 0.39 ng/ml (Faber & Binder, 1977). The variation in these levels was probably due to the different ages and different diabetes duration of the studied populations (Pozzan et al., 1997).

6. Conclusions and recommendations

1. Honey has a lower glycemic and peak incremental indices compared to glucose and sucrose in both type 1 diabetic patients and non-diabetics. Therefore, we recommend using honey as a sugar substitute in type 1 diabetic patients.
2. In spite of its significantly lower glycemic and peak incremental indices, honey caused significant post- prandial rise of plasma C-peptide levels when compared to glucose and sucrose in non-diabetics; indicating that honey may have a direct stimulatory effect on the healthy beta cells of pancreas. On the other hand, C-peptide levels were not significantly elevated after honey ingestion when compared with either glucose or sucrose in type 1 diabetic patients. Whether or not ingestion of honey in larger doses or/and for an extended period of time would have a significant positive effect on the diseased beta cells, needs further studies.

7. References

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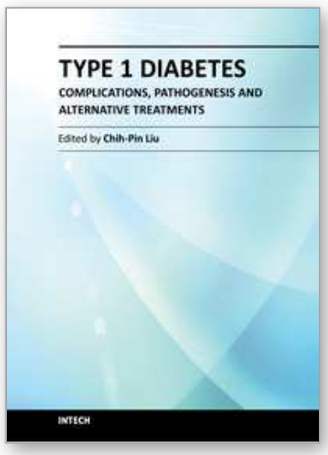

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This book is intended as an overview of recent progress in type 1 diabetes research worldwide, with a focus on different research areas relevant to this disease. These include: diabetes mellitus and complications, psychological aspects of diabetes, perspectives of diabetes pathogenesis, identification and monitoring of diabetes mellitus, and alternative treatments for diabetes. In preparing this book, leading investigators from several countries in these five different categories were invited to contribute a chapter to this book. We have striven for a coherent presentation of concepts based on experiments and observation from the authors own research and from existing published reports. Therefore, the materials presented in this book are expected to be up to date in each research area. While there is no doubt that this book may have omitted some important findings in diabetes field, we hope the information included in this book will be useful for both basic science and clinical investigators. We also hope that diabetes patients and their family will benefit from reading the chapters in this book.

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