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Natural Honey Lowers Plasma Glucose, C-Reactive Protein, Homocysteine, and Blood Lipids in Healthy, Diabetic, and Hyperlipidemic Subjects: Comparison with Dextrose and Sucrose

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ABSTRACT This study included the following experiments: (1) effects of dextrose solution (250 mL of water containing 75 g of dextrose) or honey solution (250 mL of water containing 75 g of natural honey) on plasma glucose level (PGL), plasma insulin, and plasma C-peptide (eight subjects); (2) effects of dextrose, honey, or artificial honey (250 mL of water containing 35 g of dextrose and 40 g of fructose) on cholesterol and triglycerides (TG) (nine subjects); (3) effects of honey solution, administered for 15 days, on PGL, blood lipids, C-reactive protein (CRP), and homocysteine (eight subjects); (4) effects of honey or artificial honey on cholesterol and TG in six patients with hypercholesterolemia and five patients with hypertriglyceridemia; (5) effects of honey for 15 days on blood lipid and CRP in five patients with elevated cholesterol and CRP; (6) effects of 70 g of dextrose or 90 g of honey on PGL in seven patients with type 2 diabetes mellitus; and (7) effects of 30 g of sucrose or 30 g of honey on PGL, plasma insulin, and plasma C-peptide in five diabetic patients. In healthy subjects, dextrose elevated PGL at 1 (53%) and 2 (3%) hours, and decreased PGL after 3 hours (20%). Honey elevated PGL after 1 hour (14%) and decreased it after 3 hours (10%). Elevation of insulin and C-peptide was significantly higher after dextrose than after honey. Dextrose slightly reduced cholesterol and low-density lipoprotein-cholesterol (LDL-C) after 1 hour and significantly after 2 hours, and increased TG after 1, 2, and 3 hours. Artificial honey slightly decreased cholesterol and LDL-C and elevated TG. Honey reduced cholesterol, LDL-C, and TG and slightly elevated high-density lipoprotein-cholesterol (HDL-C). Honey consumed for 15 days decreased cholesterol (7%), LDL-C (1%), TG (2%), CRP (7%), homocysteine (6%), and PGL (6%), and increased HDL-C (2%). In patients with hypertriglyceridemia, artificial honey increased TG, while honey decreased TG. In patients with hyperlipidemia, artificial honey increased LDL-C, while honey decreased LDL-C. Honey decreased cholesterol (8%), LDL-C (11%), and CRP (75%) after 15 days. In diabetic patients, honey compared with dextrose caused a significantly lower rise of PGL. Elevation of PGL was greater after honey than after sucrose at 30 minutes, and was lower after honey than it was after sucrose at 60, 120, and 180 minutes. Honey caused greater elevation of insulin than sucrose did after 30, 120, and 180 minutes. Honey reduces blood lipids, homocysteine, and CRP in normal and hyperlipidemic subjects. Honey compared with dextrose and sucrose caused lower elevation of PGL in diabetics.

KEY WORDS: • ***cholesterol*** • ***C-peptide*** • ***C-reactive protein*** • ***dextrose*** • ***diabetes mellitus*** • ***homocysteine*** • ***honey*** • ***hyperlipidemia*** • ***hypertriglyceridemia*** • ***insulin*** • ***plasma glucose*** • ***sucrose*** • ***triglyceride***

INTRODUCTION

THE CONSUMPTION OF SUGARS such as sucrose or fructose has been associated with a number of undesirable metabolic effects.[1] Several studies have shown an inverse association between dietary sucrose and high-density lipoprotein-cholesterol (HDL-C).[2] A diet high in sucrose (*i.e.,* >20% of energy) is associated with elevation of levels of plasma triglycerides (TG).[3] High dietary sucrose may chronically increase blood pressure, and increase concentrations of circulating insulin.[4] Fructose appears to be the primary nutrient mediator of sucrose-induced insulin resistance and glucose intolerance.[5] Potentiation of postprandial lipidemia by fructose is seen in both diabetic and nondiabetic subjects.[6]

C-reactive protein (CRP) is an acute-phase reactant. Cardiac risk factors such as obesity, smoking, hypertension, and chronic periodontal disease are associated with elevated CRP levels. CRP functions as a pro-atherosclerotic factor as well as a risk marker.[7] It has been shown that antioxidants and vitamin E reduce the concentration of CRP.[8,9]

Homocysteine, an amino acid that is produced in the human body, impairs the generation and decreases bioavailability of the endothelium-derived relaxing factor nitric ox-

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ide (NO). Individuals with lower homocysteine have reduced cardiovascular event rates.[10] Homocysteine is considered to be an important risk factor for cancer as well as for cardiovascular diseases.[11] Increased homocysteine concentrations are associated with an increased risk for incidence of nephropathy and proliferative retinopathy.[12]

Honey is one of the oldest known medicines. It was valued highly in the Middle East and is mentioned in the Holy Quran and The Holy Bible. Honey is a natural product of bees of the genera *Apis* and *Meliponinae*. Honeybees have enzymes called invertases that catalyze the hydrolysis of sucrose in the nectar to a glucose–fructose mixture. Honey, in fact, is primarily a mixture of these three sugars. Honey has been used for treatment of respiratory diseases, urinary diseases, gastrointestinal diseases, skin ulcers, wounds, eczema, psoriasis, and dandruff.[13,14] Oral administration of pure small- or large-bee honeys in 5 mL/kg doses did not produce a significant increase in glucose levels in normal and alloxan-diabetic rabbits.[15] Recently, we have found that honey increased blood vitamin C level, β-carotene, uric acid, glutathione reductase, serum iron, copper, zinc, hemoglobin, and packed cell volume in normal subjects.[16] Honey reduces liver enzymes, blood urea, and fasting blood sugar.[16] Moreover, honey reduces plasma prostaglandin (PG) E_2, PGF_2-alpha, and thromboxane B_2 concentrations in normal individuals.[17] Honey increased NO in saliva collected from normal individuals.[18] Intravenous delivery of honey causes improvement of renal and hepatic functions, bone marrow function, and lipid profile.[19] It reduces alanine transaminase, aspartate transaminase, TG, cholesterol, blood urea nitrogen, and blood glucose, and elevates serum protein, serum albumin, hemoglobin, and white blood cell count.[16] Therefore, honey, in contrast to other delivery forms of sugars, appears to have desirable effects on various metabolic parameters.

Maintaining normal levels of serum homocysteine, CRP, lipids, and insulin is highly desirable for cardiovascular health. This study investigated effects of natural honey on plasma glucose level (PGL), plasma insulin and C-peptide, CRP, homocysteine, and blood lipids in normal, hyperlipidemic, and diabetic subjects and compared natural honey with dextrose and artificial honey.

SUBJECTS AND METHODS

Experiment 1: Effects of honey or dextrose on blood glucose level, and plasma insulin and C-peptide in healthy subjects

Eight healthy subjects, 25–42 years old, five men and three women, were selected randomly from our medical staffat the Dubai Specialized Medical Center and Medical Research Laboratories. Complete physical examination and laboratory tests were performed. Each subject was studied twice with an interval of 1 week between the tests. On the first occasion, after 14 hours of fasting, PGL and plasma insulin and C-peptide were estimated. The subjects then drank dextrose solution (250 mL of water containing 75 g of dextrose), after which collection of blood specimens was repeated at 1, 2, and 3 hours. For the second test, the same procedure was repeated except that subjects drank honey solution. The tests were performed in random order.

Experiment 2: Effects of natural honey, artificial honey, or dextrose on lipid profile in normal subjects

Healthy adult subjects, six men and three women, 25–42 years old (mean 34 years), were selected randomly from our medical staff at the Dubai Specialized Medical Center and Medical Research Laboratories. Complete physical examination and laboratory tests were performed. The volunteers were studied three times, with an interval of 1 week between the tests. After 14 hours of fasting, blood specimens were collected for total cholesterol, low-density lipoprotein-cholesterol (LDL-C), HDL-C, and TG level assays. Each subject than drank dextrose solution, after which collection of blood was repeated at 1, 2, and 3 hours for estimation of the same variables. For the second test, the same procedure was repeated except that the subjects drank honey solution. The same experiment was repeated after another week except that the subjects drank artificial honey solution. The tests were performed in random order.

Experiment 3: Effects of daily consumption of honey on blood glucose level, blood lipids, homocysteine, and CRP in healthy subjects

Eight healthy subjects, five men and three women, 25–48 years old, were recruited for the study. After 14 hours of fasting, blood specimens were collected for estimation of PGL, blood cholesterol, LDL-C, HDL-C, TG, CRP, and homocysteine. The subjects then drank honey solution daily for a 15-day period. The subjects continued their normal daily activity, and their diet regimen was not changed. At day 16, the same blood investigations were repeated after 14 hours of fasting.

Experiment 4: Effects of natural or artificial honeys on elevated total cholesterol or TG

Six patients, four men and two women, 35–55 years old, with elevated cholesterol (more than 200 mg/dL) and LDL-C (more than 130 mg/dL) and five patients, three men and two women, 45–60 years old, with elevated TG (more than 200 mg/dL) were studied twice, with an interval of 1 week between the tests. On the first occasion, blood specimens were collected after 14 hours of fasting for estimation of total cholesterol and LDL-C. Each patient then drank honey solution, and total cholesterol and LDL-C were estimated after 1, 2, and 3 hours. After 1 week, the same procedure was repeated except that the patients drank artificial honey solution instead of natural honey solution. In patients with hypertriglyceridemia, blood specimens were collected after 14 hours of fasting for estimation of TG level. Each

patient then drank honey solution, and TG level assay was performed after 1, 2, and 3 hours. For the second test, the patients were subjected to the same procedure except that they drank artificial honey solution. The tests were performed in random order.

Experiment 5: Effect of daily consumption of honey on elevated total cholesterol and CRP

Five patients, three males and two females, 40–60 years old, with elevated total cholesterol, LDL-C, and CRP were enrolled in the study. After 14 hours of fasting, blood specimens were collected for total cholesterol, LDL-C, and CRP assays. Each patient then drank honey solution daily for a maximum of 15 days. No changes in the patients' diet or daily activity were made. The same investigations were repeated at day 16.

Experiment 6: Effects of honey on blood glucose level in type 2 diabetic patients

Seven patients, five males and two females, 40–62 years old, with type 2 diabetes mellitus were studied on two occasions. In the first occasion, each patient drank 250 mL of water containing 70 g of dextrose. Blood specimens were collected before, and at 30, 60, 90, 120, and 180 minutes after drinking dextrose solution for estimation of PGL. For the second occasion, the same procedure was repeated after 1 week except that the patient drank 250 mL of water containing 90 g of natural unprocessed honey. The tests were performed in random order.

Experiment 7: Effects of natural honey or sucrose on blood glucose level in type 2 diabetic patients

Five male patients, 40–62 years old, with a long history of diabetes mellitus were studied on two occasions. For the first occasion, after 14 hours of fasting, blood specimens were collected for PGL and plasma insulin and C-peptide assays. The patients then drank 250 mL of water containing 30 g of sucrose, and blood specimens were collected at 30, 60, 120, and 180 minutes for estimation of PGL and plasma insulin and C-peptide. For the second occasion, the same procedure was repeated after 1 week except that patients drank 250 mL of water containing 30 g of natural honey. The tests were performed in random order.

Statistical analysis

Investigational values are presented as mean ± SD. One-way analysis of variance was used to compare between more than two means, and paired Student's *t* test was used to compare between two means. The *F* value from the analysis of variance table is the measurement of the distance between individual distributions, indicating the probability of a true relationship. A probability value $<.05$ was significant. GraphPad Prism software was used for statistical analysis.

RESULTS

Experiment 1

Table 1 demonstrates changes in PGL, serum insulin, and serum C-peptide after honey or dextrose ingestion. Dextrose when compared with honey appears to cause greater elevation of PGL, plasma insulin, and plasma C-peptide during the 3 hours after ingestion.

Experiment 2

Natural honey caused a slight reduction of cholesterol, LDL-C, and TG levels, and a slight elevation of HDL-C at all time intervals. Dextrose and artificial honey increased TG and caused unremarkable changes in HDL-C (Table 2).

Experiment 3

Natural honey used for 15 days decreased cholesterol by 7%, LDL-C by 1%, TG by 2%, CRP by 7%, homocysteine

Table 1. Effects of Dextrose or Honey on Blood Glucose Level and Plasma Insulin and C-Peptide Levels in Healthy Individuals

	Time (hours)			
Variable, type of treatment	*0*	*1*	*2*	*3*
Blood glucose level (mg/dL)				
Dextrose	97.67 ± 11.2	149 ± 24[a]	101 ± 22	76 ± 11.4
Honey	101 ± 5.6	115 ± 11.8[a]	102 ± 22.5	91 ± 8.02
Plasma insulin (ng/mL)				
Dextrose	21.67 ± 10.4	208.7 ± 80[a]	126.6 ± 114.5[a]	24.78 ± 20.7
Honey	10.36 ± 4.4	51 ± 23.7[a]	29.2 ± 20.49	8.76 ± 3.89
Plasma C-peptide (ng/mL)				
Dextrose	1.5 ± 0.8	8.95 ± 3.18[a]	29.25 ± 20.49[a]	2.99 ± 2.18
Honey	1.16 ± 0.66	3.66 ± 2.2[a]	2.17 ± 1.65	1.06 ± 0.15

[a]$P > .05$ as compared with time 0.

Table 2. Effects of Dextrose (70 g), Artificial Honey (30 g of Glucose + 40 g of Fructose), and Honey (80 g) on Blood Lipids During 3 Hours After Ingestion in Healthy Subjects

	Time (hours)				
Variable, type of treatment	*0*	*1*	*2*	*3*	*F value*
Cholesterol (mg/dL)					
Dextrose	166.3 ± 16.7	162.4 ± 14	156.6 ± 14	168.5 ± 18.7	.8406
Artificial honey	160 ± 11.1	157.3 ± 14.8	155.3 ± 13.7	156.7 ± 13.7	.1509
Honey	174 ± 24.5	170 ± 25.5	168 ± 25.5	170 ± 24.7	.1008
LDL-C (mg/dL)					
Dextrose	102.9 ± 13.3	98.2 ± 8.9	92.8 ± 11.7	102.8 ± 13.1	1.607
Artifical honey	98.3 ± 16	97.43 ± 18.3	93 ± 9.5	91.14 ± 11.3	.4010
Honey	93.3 ± 16.39	90.67 ± 14.5	90 ± 16.4	87.5 ± 15.5	.8925
HDL-C (m/dL)					
Dextrose	43.7 ± 8.74	43.2 ± 8.5	43.6 ± 8.3	43.7 ± 8.4	.007
Artificial honey	42.7 ± 7.7	42.2 ± 9	42.8 ± 8.8	42.13 ± 10.3	.0069
Honey	38.5 ± 6.6	39.2 ± 7	40.6 ± 7.3	40.4 ± 8	.2768
TG (mg/dL)					
Dextrose	93.7 ± 24.1	99 ± 32.4	100 ± 31.5	108 ± 36.9	.3438
Artificial honey	131.6 ± 29	135.7 ± 30	144.1 ± 33.1	155.3 ± 35.4	.7477
Honey	119.7 ± 33.4	116 ± 3	116 ± 32.4	117 ± 32	.0192

[a]$P < .05$ as compared with time 0.

by 8%, and PGL by 6%. It increased HDL-C by 2% in normal individuals (Table 3).

Experiment 4

In patients with elevated cholesterol, LDL-cholesterol, or TG, honey seems to lower TG, cholesterol, and LDL-C, while artificial honey caused elevation of these measurements (Table 4).

Experiment 5

Daily consumption of honey solution for 15 days decreased cholesterol by 8%, LDL-C by 11%, and CRP by 57% in patients with elevated cholesterol, LDL-C, and CRP (Table 5).

Experiment 6

Table 6 shows that PGL estimated after honey drinking was significantly lower than that estimated after dextrose ingestion at all time intervals.

Experiment 7

Honey compared with sucrose caused earlier and higher elevations of PGL, plasma insulin, and plasma C-peptide levels (Table 7). These were followed by a greater reduction of the elevated PGL and plasma C-peptide than those obtained after sucrose. Elevation of insulin was more profound with honey than with sucrose after 30, 60, and 180 minutes in patients with diabetes mellitus.

Table 3. Effects of Natural Honey Solution on Lipid Profile, Blood Glucose, CRP, and Homocysteine in Healthy Subjects

	Time (days)			
Variable	0	16	*Percent change*	P *value*
Total cholesterol (mg/dL)	186.2 ± 9.9	173.5 ± 14.15	7%	.1082
LDL-C (mg/dL)	111.1 ± 4	110.3 ± 7.31	1%	.7704
HDL-C mg/dL)	39.5 ± 8.9	40.3 ± 8.8	2%	.1403
TG (mg/dL)	110 ± 30.4	107 ± 28.1	2%	.7185
CRP <5 mg/dL (mg/dL)	1.6 ± 0.5	1.5 ± 1.4	7%	.977
Homocysteine (mg/dL)	9.3 ± 2.11	8.61 ± 1.87	8%	.1428
Blood glucose (mg/dL)	102.3 ± 6.2	95.4 ± 6	6%	.0931

TABLE 4. EFFECTS OF HONEY SOLUTION OR ARTIFICIAL HONEY ON PATIENTS WITH ELEVATED CHOLESTEROL (>200 MG/DL), LDL-C (>130 MG/DL), OR TG (>200 MG/DL)

Variable, type of treatment	*Number of patients*	*Time (hours)* 0	1	2	3	F *value*
Cholesterol (mg/dL)						
Artificial honey	6	237.6 ± 8.7	240.6 ± 8.7	242.6 ± 8.7	243 ± 13.6	.29.15
Honey	6	223.7 ± 26.4	220 ± 28.4	217 ± 29.1	220 ± 29.9	.0428
LDL-C (mg/dL)						
Artificial honey	6	148.5 ± 7.6	150.2 ± 9.3	150 ± 8.2	146.4 ± 13.1	.016
Honey	6	151.2 ± 23.4	147.2 ± 23.7	143.2 ± 24.5	141 ± 25.6	.2078
TG (mg/dL)						
Artificial honey	5	229.6 ± 11.4	232.4 ± 11.2	245.2 ± 11.6	249.6 ± 21.5	2.198
Honey	5	213.2 ± 50.2	202.6 ± 40	182.2 ± 38.4	173.4 ± 48.6	.832

DISCUSSION

The types of subjects enrolled in this study were healthy individuals, hyperlipidemic individuals, and diabetic patients. Four types of carbohydrate sources were tested: honey, dextrose, artificial honey, and sucrose solutions. These showed different effects on PGL in normal subjects or diabetic patients. In normal subjects, dextrose elevated PGL after 1 and 2 hours, which was reduced after 3 hours, while honey slightly elevated PGL after 1 hour, which was slightly reduced after 3 hours. In addition, daily consumption of honey for 15 days reduced fasting PGL by 6%. In diabetic patients, honey compared with dextrose caused a significant reduction in postprandial glucose level. When compared with sucrose, honey resulted in a lower elevation of PGL (60–180 minutes). Elevated PGL following dextrose ingestion was associated with a significant rise in plasma insulin. Honey elevated PGL slightly, which was associated with a slight elevation in plasma insulin, which, as compared with dextrose, resulted in a lower reduction of PGL at hour 3 (10%). It was found that infusion of small amounts of fructose induced amplification of the counterregulatory response to mild hypoglycemia in normal individuals.[20] Therefore, the mild reduction of PGL obtained by honey might be a result of the honey content of fructose or due to the mild elevation of PGL obtained after honey ingestion. Honey might augment hormonal responses against any hypoglycemia caused by honey ingestion. If this is true, the augmentation of the hormonal response to hypoglycemia by using honey, which contains fructose, might have a place in the prevention of hypoglycemia following therapeutic doses of insulin in patients with type 1 diabetes. This potential role needs further investigations.

Dextrose compared with honey resulted in significant elevation of postprandial plasma insulin and C-peptide in normal subjects. Honey decreased the insulin level after 3 hours. In diabetics, honey compared with sucrose caused lower elevation of PGL, and compared with dextrose or sucrose, honey decreased insulin levels in normal subjects while increasing those in diabetic patients. The mild effect of honey on PGL and plasma insulin and C-peptide in normal subjects might be due to the finding that fructose does not stimulate insulin secretion from pancreatic beta cells, and that the consumption of foods and beverages containing fructose produces smaller postprandial insulin excursions than does consumption of glucose-containing carbohydrates.[21] A recent study has demonstrated that very small amounts of fructose could increase hepatic glucose uptake and glycogen storage, as well as reduce peripheral glycemia and insulin levels; this could be beneficial in diabetic patients.[22] Therefore, as honey contains fructose in excess of glucose, this suggests that honey might be a suitable food for diabetics and nondiabetics. However, fructose consumption does induce insulin resistance, hyperinsulinemia, hypertriglyc-

TABLE 5. EFFECT OF DAILY CONSUMPTION OF HONEY SOLUTION ON PATIENTS WITH ELEVATED CHOLESTEROL (>200 MG/DL), LDL-C (>130 MG/DL), AND CRP (>5 MG/DL)

Variable	*Time (days)* 0	16	*Percent changes*	P *value*
Cholesterol (mg/dL)	212 ± 4.2	195 ± 13.27	8%	.016
LDL-C (mg/dL)	138 ± 7.38	123 ± 9.6		
CRP (mg/dL)	10.56 ± 7.53	4.49 ± 3.01	57%	.034

Table 6. Effects of Oral Ingestion of 90 g of Honey on Blood Sugar in Type 2 Diabetics and Compared with the Glucose Tolerance Test

	Time (minutes)						
Diabetics given 70 g of	*0*	*30*	*60*	*90*	*120*	*180*	F *value*
Dextrose	145.2 ± 39.7	301 ± 64.7[a]	331 ± 62.4[a]	376.8 ± 78.7[a]	342.6 ± 65.8[a]	310.6 ± 59[a]	8.218
Honey	141.3 ± 39.19	200 ± 40.1[b]	244 ± 54[b]	232 ± 85.5[b]	230 ± 91.9[b]	168.9 ± 48.26[b]	2.881

[a]Statistically significant as compared with time 0 in the same group.
[b]Statistically significant as compared with glucose tolerance test values at the same time intervals.

eridemia, and hypertension in animal models.[23] L-Arginine is able to prevent fructose-induced hypertension and hyperinsulinemia.[24] Honey contains NO metabolites, and it increases NO production in various biological fluids.[18,25] Therefore, NO might inhibit fructose-induced hyperinsulinemia after ingestion of honey. This needs to be explored.

Hyperinsulinemia was found to be a single independent determinant for coronary artery disease.[26] Hyperinsulinemia increased homocysteine in healthy normal weight, overweight, and obese premenopausal women.[27] Hyperglycemia acutely increases circulatory cytokine concentrations by an oxidative mechanism, and this effect is more pronounced in subjects with impaired glucose tolerance.[28] Honey compared with dextrose reduced PGL and insulin in normal subjects. Therefore, with use of honey we might avoid development of hyperglycemia and hyperinsulinemia, as encountered with other sources of carbohydrates.

Honey contains fructose in addition to various minerals and antioxidants. Small amounts of fructose could increase hepatic glucose uptake and glycogen storage and reduce glycemia and insulin levels.[22] Zinc appears to lower PGL via improvement of insulin sensitivity.[29] Treatment with copper sulfate significantly decreased PGL.[30] Honey increased serum levels of zinc and copper, which are important for insulin and glucose metabolism.[16] Honey might reduce PG levels and elevate NO.[17,18] Different NO donors stimulated a marked increase in insulin secretion.[31] Therefore, honey might partly affect glucose levels via its effects on PG and NO production. Moreover, the honey content of fructose, zinc, copper, and other constituents might also might play a role in the effect of honey on PGL. Given that honey has a gentler effect on PGL on a per gram basis, and tastes sweeter than sucrose so that fewer grams of honey would by consumed, it would seem prudent to recommend honey over sucrose. Pure natural honeys in low doses might be recommended as sources of carbohydrates and even as sweetening agents in place of sucrose to diabetic patients.

Natural honey decreased total cholesterol and LDL-C in healthy and hyperlipidemic subjects. Increasing dietary fructose from 3% to 20% of calories at the expense of starch

Table 7. Effect of Oral Ingestion of 30 g of Honey and 30 g of Sucrose on Blood Glucose Level and Plasma Insulin and C-Peptide in Diabetics

	Time (minutes)					
Variable, type of treatment	*0*	*30*	*60*	*120*	*180*	F *value*
Blood glucose level (mg/dL)						
Sucrose	128 ± 30.6	200 ± 24.9 (56%)[a]	210 ± 25.5 (64%)[a]	160 ± 18.6 (25%)	130 ± 21.7 (1.7%)	14.28
Honey	127 ± 23.5	205 ± 13.2 (61%)a	185 ± 16.2 (31%)[a]	138 ± 27.11 (8%)	112 ± 11.5 (12%)	24.79
Insulin (ng/dL)						
Sucrose	3.9 ± 2.1	5.8 ± 2.4 (47%)	5.45 ± 3.3 (38%)	3.9 ± 1.44 (1.2%)	5.2 ± 4 (32%)	.588
Honey	6.6 ± 4.6	10.5 ± 8.4 (58%)	8.9 ± 6.5 (35%)	7.7 ± 5.37 (16%)	10.4 ± 10.7 (69%)	.3118
C-Peptide (ng/dL)						
Sucrose	0.97 ± 0.3	1.163 ± 0.2 (19%)	1.79 ± 0.91 (84%)	1.73 ± 0.74 (78%)	1.08 ± 1.01 (10%)	2.894
Honey	0.74 ± 0.42	1 ± 0.43 (35%)	1.04 ± 0.41 (41%)	0.98 ± 0.39 (32%)	0.82 ± 0.36 (11%)	.6024

[a]Statistically significant as compared with time 0 in the same group.

increased total cholesterol by 9% and LDL-C by 11%.[32] Therefore, artificial honey increased lipids because of the presence of fructose. Honey contains fructose, but it decreased blood lipid levels. The difference between the effects of artificial and natural honeys on cholesterol might be due to the presence of certain substances in natural honey able to reduce blood lipids in healthy and hyperlipidemic subjects. Further research is needed to determine what these putative substances may be.

Artificial honey compared with dextrose resulted in higher elevation of TG. This might be due to the presence of fructose in artificial honey since fructose potentiates postprandial lipidemia in both diabetic and nondiabetic subjects.[33] Increased fasting TG is observed with very high intake of sucrose or fructose.[34] Honey decreased the fasting TG level after 15 days of daily consumption. Honey, in spite of its fructose content, has a beneficial effect on the level of TG in normal subjects and subjects with elevated TG level. Therefore, honey may contain certain substances that affect TG other than its contents of carbohydrates. There is risk of elevated TG and cholesterol following consumption of high levels of carbohydrates. Therefore, honey may be considered as a safe alternative to mono- or disaccharide intake in healthy and hyperlipidemic subjects.

CRP may be involved in the pathogenesis of atherothrombosis.[35] CRP also decreased endothelial NO release, and this effect remained unchanged by hyperglycemia. Through decreasing NO synthesis, CRP may facilitate the development of diverse cardiovascular diseases.[36] In the present study, honey reduced CRP, a marker of inflammation. We have reported for the first time that oral honey could reduce plasma and urinary PGE_2, PGF_2-alpha, and thromboxane B_2.[17] Therefore, it appears that honey has anti-inflammatory properties that make it a suitable nutrient to be used in acute or chronic inflammatory conditions. Many reports have demonstrated lowering effects of antioxidants on CRP levels.[9] Honey contains many antioxidants. Therefore, honey might reduce CRP by its antioxidant properties.

Honey decreased the homocysteine level by 8% in normal subjects after 15 days of consumption. Vitamin C protects low-density lipoprotein from homocysteine-mediated oxidation.[37] The ability of honey to decrease homocysteine concentrations might be a result of its content of antioxidants and minerals. Homocysteine could exert its atherogenic action in healthy and diabetic subjects partly by inhibiting platelet NO production, with subsequent increased platelet activation and aggregation.[38] We found that honey increased the NO concentration and antioxidant levels in humans.[16,18,27] This might explain, in part, the hypohomocysteinemic effects of honey.

The main limitation of the study was the small number of subjects and the use of a 15-day test to evaluate blood lipids. This might be the reason for statistically insignificant levels obtained in part of the results. Further studies recruiting larger number of subjects as well as using a longer duration of treatment might demonstrate significant results and substantiate the findings of the present study. These studies are certainly warranted.

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