Effect of cinnamon on postprandial blood glucose, gastric emptying, and satiety in healthy subjects[1–3]

Joanna Hlebowicz, Gassan Darwiche, Ola Björgell, and Lars-Olof Almér

ABSTRACT

Background: Previous studies of patients with type 2 diabetes showed that cinnamon lowers fasting serum glucose, triacylglycerol, and LDL- and total cholesterol concentrations.

Objective: We aimed to study the effect of cinnamon on the rate of gastric emptying, the postprandial blood glucose response, and satiety in healthy subjects.

Design: The gastric emptying rate (GER) was measured by using standardized real-time ultrasonography. Fourteen healthy subjects were assessed by using a crossover trial. The subjects were examined after an 8-h fast if they had normal fasting blood glucose concentrations. GER was calculated as the percentage change in the antral cross-sectional area 15–90 min after ingestion of 300 g rice pudding (GER1) or 300 g rice pudding and 6 g cinnamon (GER2).

Results: The median value of GER1 was 37%, and that of GER2 was 34.5%. The addition of cinnamon to the rice pudding significantly delayed gastric emptying and lowered the postprandial glucose response ($P < 0.05$ for both). The reduction in the postprandial blood glucose concentration was much more noticeable and pronounced than was the lowering of the GER. The effect of cinnamon on satiety was not significant.

Conclusions: The intake of 6 g cinnamon with rice pudding reduces postprandial blood glucose and delays gastric emptying without affecting satiety. Inclusion of cinnamon in the diet lowers the postprandial glucose response, a change that is at least partially explained by a delayed GER. *Am J Clin Nutr* 2007;85:1552–6.

KEY WORDS Gastric emptying, blood glucose, healthy subjects, cinnamon, diabetes, satiety

INTRODUCTION

Around the world, the incidence of type 2 diabetes mellitus is increasing rapidly. Changing the diet helps to prevent development of type 2 diabetes and to control blood glucose concentrations. Traditional herbs and spices also can be used to control blood glucose concentrations. Allspice, cinnamon, bay leaf, cloves, nutmeg, witch hazel, oregano, and black and green tea have been shown to have an insulin-like biological activity (1). Of these substances, cinnamon has been shown to have the highest bioactivity (1). A water-soluble polyphenol typ-A polymer from cinnamon has been isolated and shown in vitro to have insulin-like activity as well as an antioxidant effect (2). Cinnamon has been shown to reduce fasting serum glucose, triacylglycerol, and total and LDL-cholesterol concentrations in patients with type 2 diabetes when it is added to the diet for 40 d in doses of 1, 3, or 6 g (3). The same study showed that, after the consumption of cinnamon for 40 d, the serum concentrations of glucose and triacylglycerol remained lower, even after a 20-d washout period (3), which indicated that it is not necessary to consume cinnamon every day (3).

The effect of cinnamon on gastric emptying has not previously been studied. Gastric emptying, along with other factors, regulates the postprandial blood glucose response, and a delay in the gastric emptying rate (GER) leads to a lower postprandial blood glucose concentration. Therefore, this study was designed to determine whether there is a delay in gastric emptying that affects postprandial blood glucose concentrations and satiety in healthy subjects after cinnamon consumption.

SUBJECTS AND METHODS

Fourteen healthy subjects [8 M, 6 F; $\bar{x} \pm$ SD age: 25.6 ± 4.8 y (range: 20–38 y); body mass index (BMI; in kg/m^2): 22.6 ± 2.2 (range: 18.4–26.0)] without symptoms or a history of gastrointestinal disease, abdominal surgery, or diabetes mellitus were included in the crossover study. The subjects had no connective tissue disease or cerebrovascular or endocrine disease, and only the 4 women who took birth control medication were receiving any drugs. Two subjects were smokers and 2 were snuff users. All subjects were recruited from the population in southern Sweden.

The subjects were examined between 0730 and 1000 after an 8-h fast. Smoking and snuff-taking were prohibited for 8 h before and during the test. Each subject was checked for a normal fasting blood glucose concentration on the day of the examination. If the subjects reported symptoms from the gastrointestinal tract (diarrhea or constipation) on the study day, the examination was postponed. The test meal consisted of 300 g rice pudding (Axa Goda Gröten Risgrynsgröt; Lantmännen AXA, Järna, Sweden) mixed with 6 g cinnamon (Santa Maria AB, Mölndal, Sweden). The total caloric value was 330 kcal: 10% of energy from protein (3 g), 58% of energy from carbohydrate (16 g), and 32% of energy from fat (4 g). The reference meal consisted of 300 g rice

[1] From the Departments of Medicine (JH, GD, and L-OA) and Radiology (OB), Malmö University Hospital, University of Lund, Lund, Sweden.

[2] Supported by grants from the Malmö Diabetes Association.

[3] Address reprint requests to J Hlebowicz, Department of Medicine, Malmö University Hospital, Ingång 35, 205 02 Malmö, Sweden. E-mail: joanna.hlebowicz@skane.se.

Received July 12, 2006.

Accepted for publication January 24, 2007.

pudding (Axa Goda Gröten Risgrynsgröt). The meals were served in a random order and ingested within 5 min.

GER was estimated by using a previously described, standardized ultrasound method (4) The sonographic examination was performed with a 3.5-MHz abdominal transducer and an imaging system (Acuson 128 XP 10; Siemens Medical Solutions, Mountain View, CA). The measurements of the gastric antrum were performed by the same radiologist, who was blinded with respect to the meals. At each observation of the gastric antrum, the abdominal aorta and the left lobe of the liver were used as internal landmarks. The subjects were examined in a supine position, but, between examinations, they were seated. The measurements were taken 15 and 90 min after the end of meal consumption. Gastric emptying was expressed as the percentage change of the antral cross-sectional area from 15 to 90 min. At each examination, 3 measurements of the longitudinal (d1) and anteroposterior (d2) diameters were taken, and mean values were used to calculate the cross-sectional area of the gastric antrum by using the following equation:

$$\text{Antral area} = \pi \times r^2 = \pi \times d1/2 \times d2/2 = (\pi \times d1 \times d2)/4 \quad (1)$$

The GER was calculated by using the following equation:

$$\text{GER} = [1 - (\text{antral area at 90 min}/\text{antral area at 15 min})] \times 100 \quad (2)$$

Finger-prick capillary blood samples were taken 15, 30, 45, 60, 90, and 120 min after the start of the meal to measure glucose. Blood glucose concentrations were measured with the HemoCue Glucose system (HemoCue AB, Ángelholm, Sweden). A validated satiety score scale was used according to the method of Hauber et al (5) on the basis of a scoring system with grades from −10 (extreme hunger) to 10 (extreme satiety). Satiety scores were estimated before the meal (0 min) and 15, 30, 45, 60, 90, and 120 min after the start of the meal by using scoring that was graded from 0 for extreme hunger to 20 for extreme satiety.

All subjects provided written informed consent. The study was approved by the Ethics Committee at Lund University and performed according to the Helsinki Declaration.

Median values and quartiles (q1 and q3) are presented for the antral cross-sectional areas and the GER. The areas under the curves (AUCs) of each subject were measured for blood glucose and satiety by using GRAPH PAD PRISM software (version 4; GraphPad, San Diego, CA). The AUC was calculated above zero. The AUC values are presented as means ± SEMs. All statistical calculations were performed with SPSS for WINDOWS software (version 14.0; SPSS Institute, Chicago, IL). Significant differences in GER, gastric antral cross-sectional areas, and AUCs were evaluated with the use of Wilcoxon's *t* test. $P < 0.05$ was considered significant.

RESULTS

Postprandial blood glucose response

Ingestion of rice pudding with cinnamon resulted in a significantly ($P < 0.05$) lower blood glucose response in the postprandial phase (15, 30, and 45 min) than did the reference meal

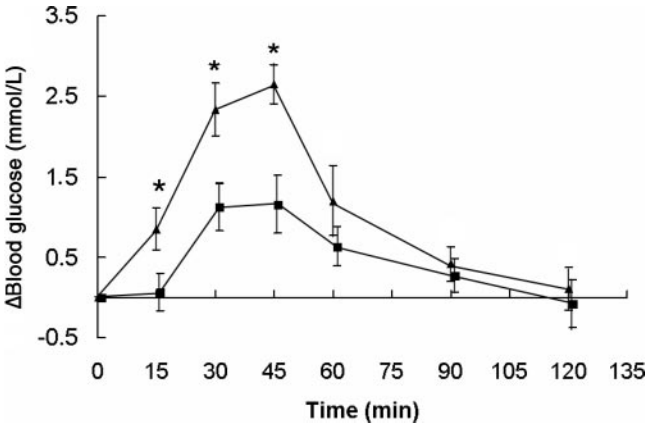

FIGURE 1. Mean (± SEM) incremental blood glucose concentrations in 14 healthy subjects after ingestion of meals consisting of rice pudding with (■) and without (▲) cinnamon. Δ, change. *Significantly different from the response to rice pudding with cinnamon, $P < 0.05$.

(**Figure 1**). The blood glucose AUCs at 0–30, 0–45, 0–60, 0–90, and 0–120 min were significantly ($P < 0.05$) lower after ingestion of rice pudding with cinnamon than after ingestion of the reference meal (**Table 1**). However, the AUCs at 0–15 min did not differ significantly between the test and reference meals (Table 1).

Gastric emptying rate

The median values of the antral cross-sectional area after the ingestion of the cinnamon meal were 595 ± 234 mm^2 (range: 283–1181 mm^2; q1 = 458 mm^2, q3 = 809 mm^2) and 372 ± 366 mm^2 (range: 83–1525 mm^2; q1 = 282 mm^2, q3 = 593 mm^2) 15 and 90 min, respectively, after the end of the study meal. In the same subjects, the median values of the antral cross-sectional area after the ingestion of the reference meal were 531 ± 386 mm^2 (range: 262–1626 mm^2; q1 = 319 mm^2, q3 = 891 mm^2) and 317 ± 338 mm^2 (range: 50–1389 mm^2; q1 = 195 mm^2, q3 = 546 mm^2) 15 and 90 min, respectively, after the end of the meal. The median gastric antral cross-sectional areas were significantly ($P < 0.05$) larger 90 min after ingestion of rice pudding with added cinnamon than 90 min after ingestion of rice pudding. There were no significant differences between gastric antral cross-sectional areas at 15 min. The median value of GER after

TABLE 1
Postprandial blood glucose areas under the curve (AUCs) in healthy subjects after ingestion of meals consisting of rice pudding with or without added cinnamon[1]

AUC	Rice pudding without cinnamon	Rice pudding with cinnamon
	mmol · min/L	
0–15 min	6.8 ± 1.8	3.6 ± 1.0
0–30 min	30.7 ± 5.1	13.7 ± 3.4[2]
0–45 min	68.1 ± 8.2	32.4 ± 6.6[2]
0–60 min	97.2 ± 11.0	47.3 ± 9.2[2]
0–90 min	125.0 ± 16.8	63.3 ± 11.7[2]
0–120 min	139.1 ± 19.6	75.0 ± 13.7[2]

[1] All values are $\bar{x}$ ± SEM; $n = 14$. Significant differences in postprandial blood glucose AUCs were evaluated with Wilcoxon's *t* test.
[2] Significantly different from rice pudding without cinnamon, $P < 0.05$.

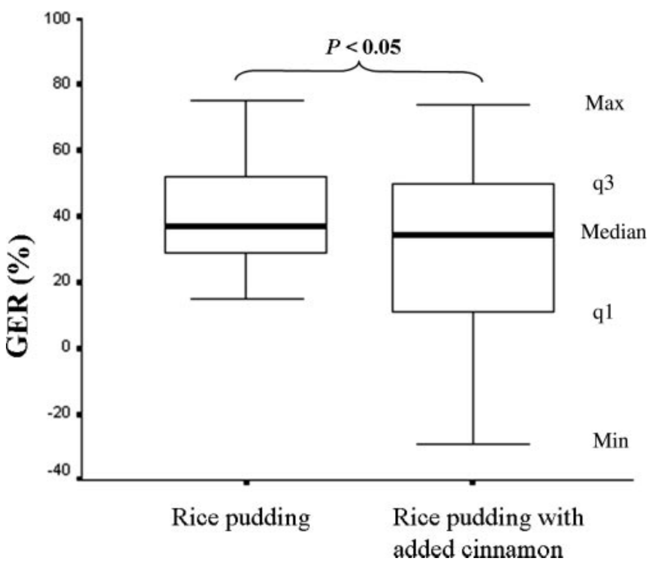

FIGURE 2. Gastric emptying of rice pudding with and without cinnamon, estimated as the gastric emptying rate (GER), in 14 healthy subjects. The median, minimum (Min), and maximum (Max) values and the values of the first (q1) and third (q3) quartiles are shown. Values of $P < 0.05$ (Wilcoxon's *t* test) were considered significant.

the cinnamon meal was estimated at 34.5% (range: −29% to 74%; q1 = 7%, q3 = 52%) (**Figure 2**), whereas that after the reference meal was estimated at 37.0% (range: 15–87%; q1 = 28.8%, q3 = 54%) (Figure 2). The ingestion of cinnamon resulted in significantly ($P < 0.05$) lower GERs.

Satiety

Ingestion of rice pudding with cinnamon did not result in significantly longer satiety (15, 30, 45, 60, 90, and 120 min) than that seen with the reference meal of rice pudding (**Figure 3**). The AUCs at 0–15, 0–30, 0–45, 0–60, 0–90, and 0–120 min for satiety were not significantly longer after ingestion of rice pudding with cinnamon than after ingestion of rice pudding only (**Table 2**).

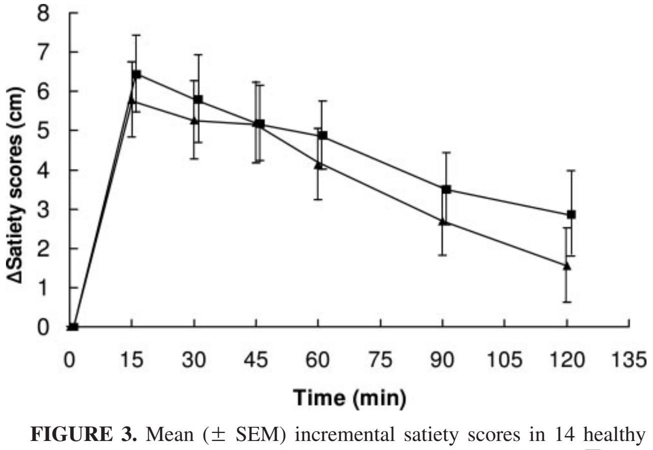

FIGURE 3. Mean (± SEM) incremental satiety scores in 14 healthy subjects after ingestion of meals consisting of rice pudding with (■) and without (▲) cinnamon. Δ, change. There were no significant differences between the mean incremental satiety scores.

TABLE 2
Satiety score areas under the curve (AUCs) in healthy subjects after ingestion of meals consisting of rice pudding with or without cinnamon[1]

AUC	Rice pudding without cinnamon	Rice pudding with cinnamon
	cm · min	
0–15 min	43.4 ± 7.2	48.3 ± 7.3
0–30 min	126.9 ± 21.5	140.8 ± 22.2
0–45 min	207.0 ± 35.3	225.9 ± 35.6
0–60 min	282.6 ± 47.4	302.7 ± 47.2
0–90 min	390.0 ± 68.7	430.7 ± 70.2
0–120 min	466.4 ± 89.8	538.7 ± 92.9

[1] All values are $\bar{x}$ ± SEM; $n = 14$. Significant differences in satiety score AUCs were evaluated with Wilcoxon's *t* test. No significant differences were found between the satiety score AUCs.

DISCUSSION

This study shows that ingestion of 6 g cinnamon reduces postprandial blood glucose concentrations and GER in healthy subjects. This finding could indicate that the reduction in the postprandial blood glucose response seen after the ingestion of cinnamon could be partly explained by an accompanying reduction in gastric emptying, because the rate of gastric emptying acts as a major factor in blood glucose homeostasis in normal subjects by controlling the delivery of carbohydrate to the small intestine (6, 7). However, the reduction in the blood glucose concentrations, unexpectedly, was much more noticeable and pronounced in the present study than was the lowering of the GER. Therefore, it should be assumed that the change in GER itself could not be the only reason for the lower blood glucose response after the addition of cinnamon to the meal. In fact, cinnamon has been shown to improve insulin receptor function by activating insulin receptor PI 3-kinase and inhibiting tyrosine phosphates (8). Cinnamon has also been shown to stimulate the insulin receptor activity by increasing the concentrations of the phosphorylated intracellular protein IRS-1 and increasing the binding to PI 3-kinase, which leads to enhanced cellular glucose uptake (9). It has been shown that cinnamon prevents the development of insulin resistance in rats fed a high-fructose diet by enhancing the insulin signaling, possibly via the nitric oxide pathway in skeletal muscle (10). Essential oils composed of pumpkinseed oil, extra virgin olive oil, oregano, cinnamon, fenugreek, cumin, fennel, myrtle, allspice, and ginger lowered blood glucose concentrations and increased insulin sensitivity in rats (11). There was no significant difference in the concentrations of circulating insulin after the intake of the different essential oils (11). A new study shows that rats given cinnamon and then administered a glucose tolerance test had decreased blood glucose concentrations (12). The same study shows that cinnamon has a direct antidiabetic effect by increasing insulin concentrations in plasma (12).

After meal ingestion, the food initially remains in the proximal part of the stomach (fundus) (13) and is then delivered in portions to the distal stomach (eg, antrum) (14, 15). If there is a substantial inhibition of gastric emptying, one could expect a 90-min antral area wider than a 15-min antral area and thereby a negative GER, which was the case in 3 of the participants.

Prolonged postmeal satiety is in accordance with a reduced GER, because distension of the stomach is one factor that promotes a feeling of satiety. The data suggest slightly greater satiety at each timepoint after ingestion of cinnamon, but there were no significant differences in satiety, probably because of the low number of study subjects. Consequently, it is not clear why cinnamon ingestion did not result in a prolongation of postmeal satiety in the present study. An elevation of blood glucose concentrations, even including concentrations within the physiologic range, reduces the GER in healthy subjects (16), and hypoglycemia increases the GER (17, 18). It has also been shown that insulin-induced hypoglycemia increases botht he gastric emptying and the drinking capacity of meat soup in healthy volunteers (19). Accordingly, because the reduction in postprandial blood glucose concentrations was prominent, it may well have influenced the results of the GER, giving a less pronounced reduction in gastric emptying and less postmeal satiety than would otherwise be expected.

To prevent development of diabetes mellitus, the American Diabetes Association recommends a reduction in calories and consumption of dietary fiber and foods containing whole grains (20). Low-glycemic-index food that reduces postprandial hyperglycemia is recommended, but it is not clear whether it prevents diabetes mellitus (21–27). Glycemic index, glycemic load, and carbohydrate consumption are probably not associated with insulin sensitivity, insulin secretion, or adiposity (28). A low-glycemic-index diet can be recommended to control glycemia (29, 30). Patients with diabetes mellitus (type 2 or type 1) are recommended to have 60–70% of energy intake provided by carbohydrates and monosaturated fat (20). There are no recommendations for the intake of herbs, but they may be an important unexplored source of glycemia control in patients with diabetes mellitus type 2. In the present study, the rice pudding with added cinnamon was well tolerated, and none of the subjects reported any discomfort or postprandial nausea. The question of whether cinnamon could be a cause of contact stomatitis was discussed previously (31). However, only a few cases were reported during past years, and this possibility should be evaluated in the future. Whether a continuous daily intake of cinnamon can be recommended also should be further evaluated. The present study was designed to determine the mechanism of cinnamon's effect on postprandial blood glucose concentrations and on gastric emptying.

The present study shows that the presence of cinnamon in a semisolid meal reduces postprandial glucose responses in healthy subjects and that the cause of this reduction could at least partly be a delayed GER. Further investigation of the effect of cinnamon on the insulin resistance in patients with type 2 diabetes mellitus is needed.

The authors' responsibilities were as follows—JH: the design of the study, recruitment of subjects, performance of statistical calculations and creation of the graphs, and drafting of the manuscript; GD: the design of the study, performance of the statistical calculations and creation of the graphs, securing study funding, and drafting of the manuscript; OB: the design of the study and performance of the ultrasound examinations; and LOA: the design of the study and drafting of the manuscript. All authors read and approved the final manuscript. None of the authors had any personal or financial conflict of interest.

REFERENCES

1. Broadhurst CL, Polansky MM, Anderson RA. Insulin-like biological activity of culinary and medical plant aqueous extracts in vitro. J Agric Food Chem 2000;48:849–52.
2. Anderson RA, Broadhurst CL, Polansky MM, et al. Isolation and characterization of polyphenol type-A polymers from cinnamon with insulin-like biological activity. J Agric Food Chem 2004;52:65–70.
3. Khan A, Safdar M, Khan MMA, Khattak KN, Anderson RA. Cinnamon improves glucose and lipids of people with type 2 diabetes. Diabetes Care 2003;26:3215–8.
4. Darwiche G, Almér L, Björgell O, Cederholm C, Nilsson P. Measurement of gastric emptying by standardized real-time ultrasonography in healthy subjects and diabetic patients. J Ultrasound Med 1999;18:673–82.
5. Haber GB, Heaton KW, Murphy D, Burroughs LF. Depletion and disruption of dietary fibre. Effects on satiety, plasma-glucose, and serum-insulin. Lancet 1997;2:679–82.
6. Horowitz M, Edelbroek MA, Wishart JM, Straathof JW. Relationship between oral glucose tolerance and gastric emptying in normal healthy subjects. Diabetologia 1993;36:857–62.
7. Blair EH, Wing RR, Wald A. The effect of laboratory stressors on glycemic control and gastrointestinal transit time. Psychosom Med 1991;53:133–43.
8. Imparl-Radosevich J, Deas S, Polansky MM, et al. Regulation of PTP-1 and insulin receptor kinase by fractions from cinnamon: implications for cinnamon regulation of insulin signalling. Horm Res 1998;50:177–82.
9. Qin B, Nagasaki M, Ren M, Bajotto G, Oshida Y, Sato S. Cinnamon extract (traditional herb) potentiates in vivo insulin-regulated glucose utilazation via insulin-regulated glucose utilazation via enhancing insulin signalin in rats. Diabetes Res Clin Pract 2003;62:3:139–48.
10. Qin B, Nagasaki M, Ren M, Bajotto G, Oshida Y, Sato S. Cinnamon extract prevents the insulin resistance induced by a high-fructose diet. Horm Metab Res 2004;36:119–25.
11. Talpur N, Echard B, Ingram C, Bagchi D, Preuss H. Effect of a novel formula of essential oils on glucose-insulin metabolism in diabetic and hypertension rats: a pilot study. Diabetes Obes Metab 2005;7:193–9.
12. Verspohl EJ, Bauer K, Neddermann E. Antidiabetic effect of *Cinnamomum cassia* and *Cinnamomum zelanicum* in vivo and in vitro. Phytother Res 2005;19:203–6 (abstr).
13. Collins PJ, Houghton LA, Read NW, et al. Role of the proximal and distal stomach in mixed solid and liquid meal emptying. Gut 1991;32:615–9.
14. Meyer JH, Ohashi H, Jehn D, Thomson BJ. Size of liver particles emptied from the human stomach. Gastroenterology 1981;80:1489–96.
15. Camilleri M, Malagelada JR, Brown ML, Becker G, Zinsmeister AR. Relation between antral motility and gastric emptying of solids and liquids in humans. Am J Physiol 1985;249:580–5.
16. Schvarcz E, Palmer M, Aman J, Horowitz M, Stridsberg M, Berne C. Physiological hyperglycemia slows gastric emptying in normal subjects and patients with insulin-dependent diabetes mellitus. Gastroenterology 1997;113:60–6.
17. Schvarz E, Palmer M, Aman J, Berner C. Hypoglycemia increases the gastric emptying in healthy subjects. Diabetes Care 1995;18:674–6.
18. Kong MF, Horowitz M. Gastric emptying in diabetes mellitus: relationship to blood-glucose control. Clin Geriatr Med 1999;15:321–38.
19. Hjelland IE, Overland NP, Leversen K, Berstad A, Hausken T. Insulin-induced hypoglycemia stimulates gastric vagal activity and motor function without increasing cardiac vagal activity. Digestion 2005;72:43–8.
20. Bantle JP, Wylie-Rosette J, Albright AL, et al. Nutrition recommendations and intervention for Diabetes–2006: a position statement of the American Diabetes Association. Diabetes Care 2006;29:2140–57.
21. Janket JS, Manson JAE, Sesso H, Burning JE, Liu S. A prospective study of sugar intake and risk of type 2 diabetes in women. Diabetes Care 2003;26:1008–15.
22. Meyer KA, Kushi LH, Jacobs DR, Slavin J, Seller TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Am J Clin Nutr 2000;71:921–30.
23. Salmeron J, Ascherio A, Rimm EB, et al. Dietary fiber, glycemic load, and risk of NIDDM in men. Diabetes Care 1997;20:545–50.
24. Colditz GA, Manson JE, Stampfer MJ, Rosner B, Willettt WC, Speizer FE. Diet and risk of clinical diabetes in women. Am J Clin Nutr 1992;55:1018–23.
25. Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of non-insulin-dependent diabetes mellitus in women. JAMA 1997;277:472–7.
26. Lundgren H, Bengtsson C, Blohme G. Dietary habits and incidence of noninsulin-dependent diabetes mellitus in a population study of women in Gothenburg, Sweden. Am J Clin Nutr 1989;49:708–12.

27. Sherad NF, Clark NG, Brand-Miller JC, et al. Dietary carbohydrate (amount and type) in the prevention and management of diabetes. Diabetes Care 2004;27:2266–71.
28. Liese AD, Schultz M, Fang F, et al. Dietary glycemic index and fiber intake, and measures of insulin sensitivity, secretion, and adiposity in the insulin resistance atherosclerosis study. Diabetes Care 2006;28:2832–8.
29. Brand-Miller J, Hayne S, Petocz P, Colagiuri S. Low glycemic index diet in the management of diabetes: a meta-analysis of randomized controlled trials. Diabetes Care 2003;26:2261–7.
30. Buyken AE, Toeller M, Heitkamp G, et al. Glycemic index in the diet of European outpatients with type 1 diabetes: relations to glycated hemoglobin and serum lipids. Am J Clin Nutr 2001;73:574–81.
31. Endo H, Rees TD. Clinical features of cinnamon-induced contact stomatitis. Compend Contin Educ Dent 2006;27:2140–57.