PHYTOTHERAPY RESEARCH
Phytother. Res. **23**: 1543–1548 (2009)
Published online 7 April 2009 in Wiley InterScience
(www.interscience.wiley.com) **DOI**: 10.1002/ptr.2795

Effect of Fenugreek Fiber on Satiety, Blood Glucose and Insulin Response and Energy Intake in Obese Subjects

Jocelyn R. Mathern[1], Susan K. Raatz[3], William Thomas[2] and Joanne L. Slavin[1]

[1]Department of Food Science and Nutrition, University of Minnesota, St Paul, MN USA 55108
[2]Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis, MN USA 55455
[3]Department of Medicine, University of Minnesota, Minneapolis, MN USA 55455

Eighteen healthy obese subjects participated in a single blind, randomized, crossover study of three test breakfasts, containing 0 g (control), 4 g or 8 g of isolated fenugreek fiber. Subjects recorded ratings of hunger, satiety, fullness and prospective food consumption using visual analog scales (VAS) every 30 min for 3.5 h. Postprandial blood glucose and insulin responses were measured. Energy intake from an *ad libitum* lunch buffet and for the remainder of the day was assessed. The 8 g dose of fenugreek fiber significantly increased mean ratings of satiety and fullness, and reduced ratings of hunger and prospective food consumption ($P <$ 0.05). Palatability was significantly reduced with increasing doses of fenugreek fiber ($P < 0.05$). No differences were observed for area under the curve (AUC) for blood glucose among treatments. An increase in insulin AUC was found with 8 g fenugreek fiber. Energy intake at an *ad libitum* lunch buffet was significantly lower for 8 g than 4 g fenugreek fiber, but not significantly different from control, although there was a trend towards a lower intake ($p = 0.11$). No differences were observed for energy intake for the remainder of the day. Fenugreek fiber (8 g) significantly increased satiety and reduced energy intake at lunch, suggesting it may have short-term beneficial effects in obese subjects. Satiety results were not related to postprandial blood glucose.

Keywords: fiber; fenugreek; satiety; glucose; insulin; obesity.

INTRODUCTION

Several review papers have concluded that fiber may aid in weight regulation by promoting satiety and reducing energy intake (Howarth *et al.*, 2001; Slavin, 2005). Many mechanisms by which dietary fiber can affect satiety are reported in the literature. Fiber is hypothesized to affect satiety through both pre- and post-absorptive effects after consumption, such as reducing energy density and palatability of diets; slowed gastric emptying; altering postprandial glycemic response and the production and secretion of satiety hormones (Slavin and Green, 2007). Fiber also may influence fat oxidation and storage.

There is a large gap to fill between current intake of dietary fiber and recommended intakes. Increasing fiber intake through diet requires substantial lifestyle change. Common fiber sources include fruit, vegetables, whole grains and legumes. Additionally, fiber intake is directly related to total food intake, which means consumers on low-calorie weight-loss diets are particularly susceptible to low fiber intakes (Davis *et al.*, 2006). Fiber levels of popular weight-loss diets such as high-protein, low-carbohydrate diets are less than 10 g per day (Slavin, 2005). Therefore, some individuals may choose to rely on commercially available fiber supplements to increase their intake.

Isolated fiber from fenugreek is commercially available. Fenugreek (Trigonella foenum-graecum L.), is a legume native to the Middle East, and is cultivated in parts of Europe, India, China, Northern Africa and Canada for its seeds. Fenugreek seeds have a pungent maple aroma and flavor, and are often used as a spice in curries or a flavoring agent in imitation maple syrup, baked goods and chutneys. Fenugreek also has a long history of use as an herbal folk medicine as an appetite stimulant, to treat digestive disorders and to increase milk production in lactating women (Grover *et al.*, 2002). Fenugreek has also been used in the treatment of hyperlipidemia and diabetes in many parts of the world (Al-Habori and Raman, 1998).

Fenugreek seeds are rich in protein and dietary fiber (Madar *et al.*, 1988). Most of the fiber in fenugreek is water-soluble galactomannan. Guar gum and locust bean gum are also sources of galactomannan. The galactomannan structure in fenugreek is composed of a linear $(1 \rightarrow 4)$ β linked D-mannan backbone, to which D galactosyl residues are attached as singled unit side chains by $(1 \rightarrow 6)$ α linkages. The mannose: galactose ratio is fenugreek is approximately 1.1:1. The mannose: galactose ratio in guar gum galactomannan is 1.6:1 and locust bean gum is 3.4:1. Fenugreek seeds also contain lipids, steroidal saponins and other phytochemicals.

* Correspondence to: Joanne Slavin, Department of Food Science and Nutrition, 1334 Eckles Avenue, St. Paul, MN 55108, USA.
E-mail: jslavin@umn.edu
Funding for this study was supported by M01-RR00400, General Clinical Research Center Program, National Center for Research Resources, National Institutes of Health. Additional research funding was provided by Frutarom USA, North Bergen, NJ.

Received 7 August 2008
Accepted 7 January 2009

Ground, whole fenugreek seeds and extracts have been shown to lower postprandial and fasting blood sugar (Sharma *et al.*, 1990), mainly in diabetic subjects (both Type 1 and Type 2). Much of the hypoglycemic effect of fenugreek in clinical studies has been attributed to its galactomannan fraction (Hannan *et al.*, 2007), which inhibits glucose absorption and slows gastric emptying (French and Read, 1994). Data on the effects of fenugreek fiber on satiety are non-existent. However, fenugreek galactomannan resembles guar gum, which has been shown to affect satiety (Chow *et al.*, 2007). Studies using fenugreek seeds have also found reductions in postprandial blood glucose concentrations (Sharma, 1986).

The primary aim of our study was to examine the effects of an isolated fiber from fenugreek on postprandial satiety. Secondary aims were to determine if fiber from fenugreek would reduce glycemic and insulin response to a mixed meal and decrease *ad libitum* energy intake at the next meal.

MATERIALS AND METHODS

Subjects. Non-smoking, obese, but otherwise healthy men and women between the ages of 18 and 65 were recruited through flyers distributed throughout the University of Minnesota and surrounding communities. Anyone interested in participating in the study completed a telephone interview. Subjects demonstrated spoken and written English literacy and displayed obesity, characterized by a body mass index (BMI) equal to or greater than 30. Subjects also had to regularly eat breakfast. Exclusions included the following criteria: BMI < 30 upon study admission, currently pregnant or lactating, fasting blood glucose >6.99 mmol/L (126 mg/dL), elevated serum total cholesterol, cancer in previous five years, recent bacterial infection (<2 weeks), active weight loss >5 kg in prior 3 months (intended or unintended), history of binge-eating disorder, history of drug or alcohol abuse in prior 6 months, renal or hepatic disease, use of weight loss, lipid-lowering, antihypertensive or anti-inflammatory steroid medication, concurrent use of fiber supplements, concurrent or recent intervention study participation (within 30 days). If subjects met eligibility criteria through the phone screen, they were asked to participate in the study. Subject's BMI was verified at the first study visit and they were also screened by finger-prick blood glucose. If subjects' BMI was 30 or greater and blood glucose was <6.99 mmol/L (126 mg/dL), they were eligible to continue with study visits. Eighteen subjects (10 women and 8 men) were recruited for this study based on sample size estimates for statistical power (Flint *et al.*, 2000).

The University of Minnesota Institutional Review Board Human Subjects Committee approved the study. All subjects gave written, informed consent after reviewing the study protocol and procedures. The study was conducted at the General Clinical Research Center (GCRC) at the University of Minnesota. The study was a randomized crossover design of three single meal treatments, consisting of a test breakfast plus 0 g (control), 4 g or 8 g of fenugreek extract added to a beverage. Subjects completed all three treatments in a randomized order. Each of the three test breakfasts were consumed on different mornings, at least 48 h apart after an overnight fast of at least 10 h. Subjects were blinded to which test breakfast they were receiving. To avoid any effects of high-fiber consumption the day before, subjects were asked to adhere to a low-fiber diet the day before the study. An example low-fiber meal plan was provided. No food or drink except water was permitted 10 h before study visits. Study protocol required subjects to maintain their usual exercise habits throughout the course of the trial. Subjects did not use fiber or weight-loss supplements during the study and were asked not to lose weight during participation in the study.

On each test day, subjects arrived in a fasted state (at least 10 h) as verified by self-reported time of last meal. Subjects' vital signs were taken and body weight and height were measured. Subjects were instructed on how to record satiety, hunger, fullness and prospective food consumption using visual analog scales (VAS). Subjects were also instructed how to record a 24-h food diary by a registered dietitian (RD) at the GCRC. An indwelling catheter was placed by nurses at the GCRC, into a vein in the cubetal fossa through which a 5 ml fasting blood sample was collected. Subjects were served a test beverage containing 0 (control), 4 or 8 g of fenugreek extract and were required to consume the beverage within 5 min. Subjects were then served a standard breakfast, which they were required to consume within 30 min. Subjects were asked to complete VAS to rate their satiety, hunger, fullness and prospective food consumption before consuming the test beverage and every 30 min thereafter for 3.5 h. The sensory characteristics of the test beverages were also assessed using VAS.

Blood was collected through the indwelling catheter for serum glucose and insulin analysis at 15, 30, 45, 60, 90, 120, 150 and 180 min from the start of the test meal. Water was offered *ad libitum* throughout the study visit. After 3.5 h from the start of the test beverage, subjects were offered food from a buffet containing a set range of foods and allowed to consume food *ad libitum*. Subjects were given a food diary to complete for the remainder of the day.

The fenugreek extract investigated in this trial (FenuLife® Frutarom Inc, North Bergen, NJ, USA) was a purified fenugreek fiber product, containing high concentrations (>75%) of soluble fiber in the form of galactomannan, with gelling properties. The product was produced from a single batch of fenugreek seeds through milling and ethanol extraction. Percentage of total fiber and soluble fiber content in the fenugreek extract was assessed using AACC Method 32-05 by POS Pilot Plant Corporation, Saskatchewan, Canada. Total fiber content was 90% by weight. Soluble fiber content was 78.9% by weight. Therefore, 4 g of fenugreek extract provided 3.6 g of total fiber and 8 g of fenugreek extract provided 7.2 g total fiber, respectively.

The fenugreek fiber powder was mixed with a commercially available, low-calorie beverage (Minute Maid® Light, Atlanta, GA, USA). Eight ounces of the chilled beverage, plus 4 ounces of crushed ice was added to the fiber and mixed on high speed in a blender for 1 min. The beverage was served to study participants immediately after blending. Subjects were given 5 min to consume the test beverage.

DOI: 10.1002/ptr

After consumption of the test beverage, subjects were served a low-fiber (<1 gram) breakfast of cereal (Rice Krispies®), toasted white bread, butter and jelly. Subjects were required to consume the entire breakfast within 30 min. All the breakfasts were equal except for the amount of fiber. The composition of the test breakfasts was calculated using First DataBank Nutritionist Pro™.

Ratings of satiety, hunger, fullness and prospective food consumption were assessed using visual analog scales (VAS) as described by Flint *et al.* (2000). Subjects completed VAS questionnaires at 0 min (before breakfast) and at 30-mine intervals from the start from breakfast or 3.5 h. The scales were 100 mm in length and anchored with descriptors. To assess satiety, subjects were asked how satisfied they felt (not at all satisfied – I cannot eat another bite). For hunger and fullness, subjects were asked how hungry or full they felt (not at all – extremely). To assess prospective food consumption, subjects were asked how much they thought they could eat (nothing – a lot). Subjects were asked to mark an 'X' anywhere along the scales that matched their perception of satiety, hunger, fullness and prospective food consumption. Participants' ratings were converted to a numerical score (0 to 100) from the far left anchor of the scale. Peak scores (mm) as well as area under curve (AUC, mm*h) were calculated. The cut-off for AUC was 3.5 h.

Sensory characteristics of the test beverages were also assessed using VAS. Subjects were asked to rate on 100 mm scales the visual appeal, smell, taste, aftertaste and palatability of the test beverages immediately after consumption (good – bad). Participants' ratings were converted to a numerical score (0 to 100) from the far left anchor of the scale.

Blood was collected into tubes containing lithium heparin for glucose and serum separator gel for insulin analysis. Samples were centrifuged immediately, aliquoted into vials and frozen at –20 degrees Celsius for transport to Quest Diagnostics (Wood Dale, IL, USA) for analysis.

After subjects completed an *ad libitum* lunch buffet, leftover food was weighed and recorded by a metabolic cook at the GCRC. Energy intake was analyzed by a GCRC RD using First DataBank Nutritionist Pro™. Subjects received verbal instruction on how to accurately record all of the food and drink they consumed for the remainder of the day using food records. Energy intake for the remainder of the day was analyzed from subjects' completed food records using NCC Food and Nutrient Database version 2006 (University of Minnesota).

Statistical methods. Baseline demographic characteristics were reported by gender as means and standard errors. Area under the curve (AUC) was calculated using the trapezoidal rule. All endpoints were compared between intervention groups using a mixed-effects linear model with random subject intercepts and terms to model possible carryover and treatment-period interaction. There was no evidence for either carryover or treatment-period interaction in any endpoint, so the estimated means and standard errors are reported from a mixed-effects linear model with terms for period and treatment and random subject intercepts. Analysis was done using SAS Proc Mixed (version 9.1, SAS Institute, 2006, Cary, NC, USA).

RESULTS

All eighteen subjects completed the study (10 women and 8 men). Their mean age ± SEM was 32 ± 11 and their mean BMI was 36 ± 5.

Results of subjective appetite ratings for satiety, hunger, fullness and prospective food consumption are listed in Table 1.

Satiety. For satiety, ratings of 0 on the scales = I am completely empty. Ratings of 100 = I cannot eat another bite. No significant difference was found for satiety AUC between control (162 ± 12 mm*h) and 4 g (168 ± 12 mm*h) fenugreek fiber powder. However, 8 g resulted in significantly higher AUC (200 ± 12 mm*h) as compared to both 0 g ($p = 0.002$) and 4 g ($p = 0.008$). Peak satiety was significantly higher after 8 g as compared to 0 g ($p = 0.0004$) and 4 g ($p = <0.0001$). No differences were found between control and 4 g for peak satiety (peak mean ± SEM; 0 g, 70 ± 3 mm; 4 g, 69 ± 3 mm; 8 g, 81 ± 3 mm).

Hunger. For hunger, ratings of 0 = I am not hungry at all. Ratings of 100 = I have never been more hungry. The AUC for hunger was significantly lower with 8 g fenugreek fiber powder as compared with control

Table 1. Ratings of satiety, hunger, fullness and prospective food consumption[1,2,3]

	Treatments			F-test
Measurement	0 grams	4 grams	8 grams	p value
Satiety AUC (mm*hr)	162 ± 12[a]	168 ± 12[a]	200 ± 12[b]	0.004
Satiety peak* (mm)	70 ± 3[a]	69 ± 3[a]	81 ± 3[b]	0.0001
Hunger AUC (mm*hr)	150 ± 13[a]	155 ± 13[a]	124 ± 13[b]	0.02
Hunger peak* (mm)	73 ± 4[ab]	78 ± 4[a]	69 ± 4[b]	0.01
Fullness AUC (mm*hr)	170 ± 13[a]	161 ± 13[a]	194 ± 13[b]	0.01
Fullness peak* (mm)	74 ± 4[a]	67 ± 4[b]	82 ± 4[c]	<0.001
Prospective food consumption (mm*hr)	185 ± 15[a]	184 ± 15[a]	152 ± 15[b]	0.002
Prospective food consumption peak* (mm)	81 ± 4[a]	80 ± 4[a]	75 ± 4[b]	0.01

[1] Mean ± SEM.
[2] Treatments were compared within rows, and the p-value is from the overall F-test.
[3] Means that do not share a letter were significantly different ($p < 0.05$).
* Subjective rating on a scale from 0 to 100.

DOI: 10.1002/ptr

Table 2. Sensory ratings of test beverages[1,2,3]

	Treatments			F-test
Measurement	0 grams	4 grams	8 grams	p value
Visual appeal	19 ± 4[ab]	16 ± 4[a]	27 ± 4[b]	0.05
Smell	24 ± 4[a]	23 ± 4[a]	39 ± 4[b]	0.0001
Taste	26 ± 5[a]	38 ± 5[b]	48 ± 5[c]	0.0006
Aftertaste	75 ± 6[a]	66 ± 6[ab]	60 ± 6[b]	0.04
Palatability	24 ± 4[a]	34 ± 4[b]	44 ± 4[c]	0.0003

[1] Mean ± SEM.
[2] Treatments were compared within rows, and the p-value is from the overall F-test.
[3] Means that do not share a letter were significantly different ($p < 0.05$).

($p = 0.031$) and 4 g ($p = 0.010$) (AUC mean ± SEM; 0 g, 150 ± 13 mm*h; 4 g, 155 ± 13 mm*h; 8 g, 124 ± 13 mm*h). Peak hunger was also significantly reduced with 8 g fenugreek fiber powder (69 ± 4 mm) as compared with 4 g (78 ± 4 mm) ($p = 0.0035$). Peak hunger was not significantly different between 8 g and 0 g (73 ± 4 mm) ($p = 0.175$).

Fullness. For fullness, ratings of 0 on the scales = I am not at all full. Ratings of 100 = I am totally full. The AUC for fullness was significantly greater with 8 g fenugreek fiber powder as compared to control ($p = 0.041$) and 4 g ($p = 0.005$) (AUC means ± SEM; 8 control, 170 ± 13 mm*h; 4 g, 161 ± 13 mm*h; 8 g 194 ± 13 mm*h). Peak fullness ratings were also significantly higher after consuming 8 g fenugreek fiber powder (82 ± 4 mm) compared to control (74 ± 4 mm) ($p = 0.006$) and 4 g (67 ± 4 mm) ($p < 0.001$). There was no difference in peak fullness ratings between control and 4 g fenugreek fiber powder.

Prospective food consumption. For prospective food consumption, ratings of 0 on the scales = I can eat nothing at all. Ratings of 100 = I can eat a lot. Consistent with results for satiety, hunger and fullness, consumption of 8 g fenugreek fiber powder resulted in significantly lower AUC for prospective food consumption compared to both control ($p = 0.009$) and 4 g ($p = 0.019$) (Mean ± SEM; control, 185 ± 15 mm*h; 4 g, 184 ± 15 mm*h; 8 g 152 ± 15 mm*h). Peak ratings of prospective food consumption were also lower with 8 g fenugreek fiber powder (75 ± 4 mm) compared to both 0 g (81 ± 4 mm) ($p = 0.009$) and 4 g (80 ± 4 mm) ($p = 0.019$).

Palatability. Results of the sensory evaluation of the test beverages are presented in Table 2. Lower scores meant better palatability than higher scores, since on the scale 0 = good and 100 = bad. Subjects rated the beverage with 8 g fenugreek extract less visually appealing than the beverage containing 4 g ($p = 0.021$) or 0 g ($p = 0.0687$) although the latter was not significantly different. The smell of the beverage containing 8 g fenugreek extract was rated significantly worse than control ($p = 0.0002$) or 4 g ($p = 0.0001$). Regarding taste of the beverages, ratings were significantly worse for the beverage containing 4 g fenugreek extract compared to control ($p = 0.037$). Addition of 8 g was rated significantly worse tasting than both control ($p = 0.0001$) and 4 g ($p = 0.038$). Aftertaste of the beverage was worse with 8 g compared to control ($p = 0.01$), but there was no difference between either 4 g and placebo or 8 g and 4 g. The overall palatability ratings were inversely related to the dose of fenugreek extract. The addition of 4 g fenugreek extract decreased palatability significantly compared to control ($p = 0.022$). Addition of 8 g was rated significantly less palatable than either 0 g ($p < 0.0001$) or 4 g ($p = 0.035$).

Energy intake. After consuming 8 g fenugreek fiber powder with breakfast, subjects ate significantly less than after 4 g ($p = 0.01$) and tended to eat less (~100 kcal) than compared to 0 g fenugreek fiber powder, although results were not significantly different ($p = 0.11$) (Table 3). There was no difference between 0 g and 4 g on energy intake at lunch. There was no difference between treatments for energy intake the remainder of the day ($p = 0.48$).

Blood parameters. No differences were seen in postprandial AUC (cut off at 3 h) for blood glucose ($p = 0.22$) or for peak glucose ($p = 0.83$) among treatments (Table 4). Postprandial insulin AUC was not different between 0 g and 4 g fenugreek fiber ($p = 0.50$) (Table 4). Insulin AUC was significantly increased after 8 g compared to 0 g ($p = 0.07$). Peak insulin was also greater after 8 g compared to control 0 g ($p = 0.01$). Peak insulin was reduced with 4 g fenugreek fiber powder compared to 8 g ($p = < 0.01$), and showed a trend toward reduction with 0 g, although not significantly different ($p = 0.09$). There was no difference between peak insulin for 0 g and 4 g ($p = 0.13$).

DISCUSSION

Consumption of 8 g of fenugreek fiber powder in addition to a standard breakfast enhanced subjective reports of satiety and fullness and reduced hunger and reported prospective food consumption compared to either a placebo breakfast or 4 g of fenugreek fiber

Table 3. Energy intake in response to different treatments[1,2,3]

	Treatments			F-test
Measurement	0 grams	4 grams	8 grams	p value
Calories eat at *ad libitum* lunch (Kcal)	1285 ± 98[ab]	1352 ± 98[a]	1157 ± 98[b]	0.05
Calories eaten rest of study day (Kcal)	1057 ± 150	1266 ± 142	1171 ± 142	0.48

[1] Mean ± SEM.
[2] Treatments were compared within rows, and the p-value is from the overall F-test.
[3] Means that do not share a letter were significantly different ($p < 0.05$).

Table 4. Serum glucose and insulin response to different treatments[1,2,3]

Measurement	Treatments			F-test
	0 grams	4 grams	8 grams	p value
Serum glucose AUC (mmol/L * hr)	17.67 ± 0.7	18.2 ± 0.7	18.2 ± 0.7	0.22
Glucose peak (mmol/L)	7.67 ± 0.4	7.61 ± 0.4	7.78 ± 0.4	0.83
Serum Insulin AUC (mIU/L * hr)	141 ± 18[a]	136 ± 18[a]	153 ± 18[b]	0.04
Insulin peak	93 ± 11[ab]	81 ± 11[a]	104 ± 11[b]	0.01

[1] Mean ± SEM.
[2] Treatments were compared within rows, and the p-value is from the overall F-test.
[3] Means that do not share a letter were significantly different ($p < 0.05$).

powder. A trend towards a reduction in energy intake was seen at an *ad libitum* lunch meal for 8 g fenugreek fiber powder, although it was not significant compared to control ($p = 0.11$). Fenugreek fiber, given at a breakfast meal, did not influence energy intake for the remainder of the day, suggesting effects on satiety are short term.

The presence of the viscous fiber from fenugreek may have played a role in promoting satiety by slowing the rates of gastric emptying. Fenugreek galactomannan has been shown to slow gastric emptying in animal models (Hannan *et al.*, 2007). In a study utilizing pectin as a viscous fiber source a dose of 15 g pectin added to a breakfast meal slowed gastric emptying and increased obese subjects reported satiety (DiLorenzo *et al.*, 1988). Fiber is also suggested to affect palatability, which may decrease energy intake. The test beverages containing fenugreek were rated less palatable than control in our study.

The increase in satiety in our study was not related to reduced absorption of glucose as our study did not find any effects of fenugreek fiber on postprandial blood glucose concentrations. A previous study by Madar *et al.* (1988) found significant reductions in postprandial blood glucose in response to a mixed meal supplemented with 15 g fenugreek seeds. However, the subjects were Type 2 diabetics with altered glucose metabolism. A study by Sharma and Raghuram (1990) found that 5 g of fenugreek gum significantly reduced postprandial blood glucose in normal subjects, when given with a large dose (100 g) of glucose. The amount and type of carbohydrates consumed are largely responsible for postprandial blood glucose and insulin responses to meals and large amounts of fat or protein (>50 g) are needed to significantly impact the glucose and insulin response to a meal (Wolever and Bolognesi, 1996). All three test meals provided the same amount of protein and fat, so we should have been able to detect differences from the addition of fiber.

Alternatively, we may not have fed enough total kilocalories or carbohydrate to see an effect of fiber on blood glucose in this study. Galgani *et al.* (2006) found that meal size affected blood glucose response to a low-glycemic-index meal. Therefore, it would be interesting to investigate whether fenugreek fiber powder would have significant effects on postprandial blood glucose response to a larger meal. Taken together, the data suggest that fenugreek fiber powder may alter blood sugar in response to a large glucose load, but not with a mixed meal either with the amount of food provided or at the dosages we studied (4 or 8 g).

The postprandial insulin AUC was increased with the addition of 8 g of fenugreek fiber powder, which is contrary to other studies, which have found decreased insulin response with fiber (Ellis *et al.*, 1991), and a previous study showing that fenugreek gum can lower postprandial insulin response (Sharma, 1986). However, a study utilizing chickpea flour added to white bread found increased postprandial insulin response (Johnson *et al.*, 2005). In addition, fenugreek is known to contain 4-hydroxyisoleucine, a free amino acid that has been shown to increase insulin secretion in animal models (Broca *et al.*, 1999). However, the protein content of the fenugreek fiber used in this study was minor, so this does not fully explain the increased insulin response.

In conclusion, an 8-g dose of viscous fiber powder from fenugreek added to a breakfast meal increases reported satiety in obese subjects. There was also a trend for decreased energy intake with 8 g of fenugreek fiber powder, although it was not statistically significant. This study did not provide evidence that addition of fenugreek fiber to a mixed meal altered carbohydrate metabolism, as no effects were seen on postprandial glycemia. Insulin response was significantly increased with 8 g fenugreek fiber powder and requires further study. The effects on appetite suppression and food intake suggest that fenugreek fiber may have a role in the control of food intake in obese individuals.

REFERENCES

Al-Habori M, Raman A. 1998. Antidiabetic and Hypocholesterolaemic Effects of Fenugreek. *Phytother Res* **12**: 233–242.

Broca C, Gross R, Petit P, Sauvaire Y, Manteghetti M, Tournier M, Masiello P, Gomis R, Ribes G. 1999. 4-Hydroxyisoleucine: experimental evidence of its insulinotropic and antidiabetic properties. *Am J Physiol* **277**: E617–E623.

Chow J, Choe YS, Noss MJ, Robinson KJ, Dugle JE, Acosta SH, Garleb KA. 2007. Effect of a viscous fiber-containing nutrition bar on satiety of patients with type 2 diabetes. *Diab Res Clin Prac* **76**: 335–340.

Davis JN, Hodges VA, Gillham MB. 2006. Normal-weight adults consume more fiber and fruit than their age- and height-matched overweight/obese counterparts. *J Am Diet Assoc* **106**: 833–840.

DiLorenzo C, Williams CM, Hajnal F, Valenzuela JE. 1988. Pectin delays gastric emptying and increases satiety in obese subjects. *Gastroenterology* **95**: 1211–1215.

Ellis PR, Dawoud FM, Morris ER. 1991. Blood glucose, plasma insulin and sensory responses to guar-containing wheat breads: effects of molecular weight and particle size of guar gum. *Br J Nutr* **66**: 363–379.

Flint A, Raben A, Blundell JE, Astrup A. 2000. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *Int J Obes* **24**: 38–48.

French SJ, Read NW. 1994. Effect of guar gum on hunger and satiety after meals of differing fat content: relationship with gastric emptying. *Am J Clin Nutr* **59**: 87–91.

Galgani J, Aguirre C, Diaz E. 2006. Acute effect of meal glycemic index and glycemic load on blood glucose and insulin responses in humans. *Nutr J* **5**: 22–28.

Grover JK, Yadav S, Vats V. 2002. Medicinal plants of India with diabetic potential. *Journal Ethnopharmacology* **81**: 81–100.

Hannan JMA, Ali L, Rokeya B, Khaleque J, Akhter M, Flatt PR, Abdel-Wahab YHA. 2007. Soluble dietary fibre fraction of Trigonella foenum-graecum (fenugreek) seed improves glucose homeostasis in animal models of type 1 and type 2 diabetes by delaying carbohydrate digestion and absorption, and enhancing insulin action. *Br J Nutr* **97**: 514–521.

Howarth NC, Saltzman E, Roberts S. 2001. Dietary fiber and weight regulation. *Nutr Rev* **59**: 129–129.

Johnson SK, Thomas SJ, Hall RS. 2005. Palatability and glucose, insulin and satiety responses of chickpea flour and extruded chickpea flour bread eaten as part of a breakfast. *Eur J Clin Nutr* **59**: 156–176.

Madar Z, Abel R, Samish S, Arad J. 1988. Glucose-lowering effect of fenugreek in non-insulin dependent diabetics. *Eur J Clin Nutr* **42**: 51–54.

Sharma RD, Raghuram TC. 1990. Hypoglycaemic effect of fenugreek seeds in non-insulin dependent diabetic subjects. *Nutrition Res* **10**: 731–739.

Sharma RD, Raghuram TC, Sudhakar R. 1990. Effect of fenugreek seeds on blood glucose and serum lipids in Type I diabetics. *Eur J Clin Nutr* **30**: 301–306.

Sharma RD. 1986. Effect of fenugreek seeds and leaves on blood glucose and serum insulin responses in human subjects. *Nutrition Res* **6**: 1353–1364.

Slavin JL. 2005. Dietary fiber and body weight. *Nutrition* **21**: 411–418.

Slavin J, Green H. 2007. Dietary fibre and satiety. *Nutr Bulletin* **32**(Suppl 1): 32–42.

Wolever TM, Bolognesi C. 1996. Source and amount of carbohydrate affect postprandial glucose and insulin in normal subjects. *J Nutr* **126**: 2798–2806.