The Immediate Glycemic Response to Four Herbal Teas in Healthy Adults

*Ahmad Mahmoud Faqih** [1] and Faten Yousef Al- Nawaiseh*[2]

Abstract

Objective: To determine the effect of herbal teas prepared from decocted cinnamon bark or fenugreek seeds, or from infused black tea or aniseed on the postprandial glycemic response of white bread.

Methods: Oral glucose tolerance test for 2 hours was applied on seven healthy volunteers, each of whom served as his own control by first ingesting a portion of white bread containing 50 g of carbohydrates together with either 200 mL of plain water (reference) or with 200 mL of at least one of each of the herbal teas. Each herb was used in two concentrations (g per cup of 200 mL): 4 or 8 for cinnamon; 6 or 8 for fenugreek seed; 1.5 or 2.5 for black tea; and 6 or 12 for aniseed.

Results: Assuming the glycemic index (GI) of white bread as a reference is 100, the GI obtained for bread when consumed with the above-mentioned herbal teas in their respective doses and expressed as means ± SEM (in percentages) were: 54 ± 7.3 and 55 ± 7.0 ; 62 ± 4.9 and 39 ± 4.7; 81 ± 5.2 and 72 ± 7.1; and 93 ± 4.0 and 72 ± 4.2 ,respectively.

Conclusion: The present study showed the immediate positive effect of all the above herbal teas in reducing the postprandial glycemic response of bread, and except for cinnamon, the higher dose for the three other herbs resulted in a further significant hypoglycemic effect of bread.

Keywords: glycemic index, cinnamon tea, fenugreek tea, aniseed tea, black tea.

(J Med J 2006; Vol. 40 (4): 266- 275)

Received	Accepted
April 12, 2006	November 16, 2006

Introduction

Increased levels of blood glucose in the postprandial state may be considered as risk factors for the development of diabetes and cardiovascular disease. Conversely, improvement of lipid metabolism and prevention of cardiovascular disease may be caused by lowering the Glycemic Index (GI) of the diet. [1] In addition, weight management may be improved by lowering the GI of the diet. [2]

1. PhD and Professor of Nutrition, University of Jordan, Department of Nutrition and Food Technology.
2. MSc in Nutrition and Food Technology.
*** Correspondence should be addressed to:**
University of Jordan, P.O Box 13103, Amman – Jordan.
Email: faqiham@ju.edu.jo.

The World Health Organization (WHO) and the Food and Agricultural Organization (FAO) recommend consuming foods with low GI as a part of healthy diets for the general population. [3] In Jordan, there is the habit of drinking tea with the meal or after the meal. This habit might extend to drinking herbal teas especially after the meals. Colombani concluded that " the prevention of hyperglycemic situations should be targeted in healthy people ". [4] Such a situation may occur due to drinking certain herbal teas together with or right after a meal. It is important that such herbs should have no or little side effects.

Traditionally, many plant species have been used for their hypoglycemic properties. [5] The use of herbs as a self-care option for maintaining health and for improving the quality of life has received a great deal of public interest. [6, 7] Among such herbs that are commonly used in Jordan are cinnamon bark, fenugreek seeds, black tea and aniseeds.

The extract of cinnamon was reported to potentiate the activity of insulin *in vitro.* [8] This activity was attributed to a water soluble polyphenolic polymer identified as methyl hydroxyl chalcone polymer. [9] The long term effect of cinnamon on blood glucose was studied by Khan et al. [10] in a placebo – controlled study who found that the daily addition of one to six grams of cinnamon capsules to the diet led to a significant decrease in blood glucose triglyceride, total cholesterol, and low density lipoprotein cholesterol.

Fenugreek is a well-known leguminous herb that is grown extensively in India, Egypt and Middle Eastern countries. [11, 12] It has been used as a cooking spice and a flavoring agent for centuries. [12] Fenugreek was used in folk medicine for the treatment of diabetes. The hypoglycemic effect of fenugreek seed was demonstrated in both normal and alloxanized mice [13-15] and in persons with type II diabetes in reducing both glucose and serum insulin levels. [16, 17]

Black tea is the most popularly consumed beverage worldwide. It is obtained from the leaves of a plant named *Camellia sinensis.* [18] Different types of tea including black tea were shown to possess anti-hyperglycemic effect in several animal studies. [19, 20] However, only green and oolong tea were used in human intervention studies. [21, 22]

Anise is a member of Apiaceae/ Umbelliferae family. [23] It was reported by Kreydiyyeh *et al*. [24] that aniseed oil enhances significantly glucose absorption from rat jejunum by increasing the activity of Na^+- K^+, ATpase in a dose-dependent manner. The hypoglycemic effect of this herb has not been studied.

The objective of this study was to determine the immediate glycemic effect of tea made of fenugreek seeds *(Trigonella foennum- graecum*), black tea *(Camellia sinensis)*, cinnamon bark (*Cinnamomum zeylanicum)* and aniseeds (*Pimpinella anisum*) using white bread as a reference in healthy adults. To the best of our knowledge, the immediate effect of these herbs has not been studied especially as tea. The tea of these herbs is commonly consumed in Jordan.

Materials and Methods

Herbs: The aqueous extracts of herbs were prepared by either infusion (hot tea) of aniseed and black tea or by decoction (boiled tea) for fenugreek seed and cinnamon bark.

Each herbal tea was prepared in two different concentrations, the "usual" concentration and about double as much. The grams per cup of herbs used were 6.0 and 10.0 for fenugreek seed, 4.0 and 8.0 for cinnamon bark, 6.0 and 12.0 for aniseed and 1.5 and 2.5 for black tea, since one cup equals 200 mL. All the tested plant materials were cleaned and dried before use and purchased from a local shop in Amman, Jordan. Decoction was achieved by boiling the measured amount of fenugreek seed and ground cinnamon bark with hot water.

The hot decoction was then allowed to cool for 15 min for fenugreek and 5 hours for cinnamon at room temperature before being filtered to be ready for drinking. The infusions were prepared by pouring boiling water onto each tea pot containing the specific amount of the aniseed and black tea, steeping, stirring and strained before drinking. The amount of each herb used in this study was based on the average amount determined in a pilot study from 10 neighboring families and friends of one of the authors (FN).

Subjects: The protocol of the study was approved by the scientific committees of the Nutrition and Food Science Department, the Faculty of Agriculture and the Faculty of Graduate Studies at the University of Jordan.

Seven healthy subjects (3 men and 4 women) with a mean (±SD) age of 22.6 (±4.5) years and normal BMI of 22.0 (±3.6) volunteered to participate in the study (Table 1). Subjects were informed about the experimental protocol and the purpose of the study, *an informed consent was obtained from each subject in accordance with Helsinki Declaration.*

Experimental Design: The procedure of " oral glucose tolerance test" was applied following 10 – 12 hours of overnight fast. Each subject served as his/her own control by first ingesting a portion of white bread containing 50 g of carbohydrate along with 200 mL of either plain water or with 200 mL of at least one of each of the herbal teas in the doses given above. Each subject completed at least three tests on three non-successive days. Subjects were tested at the same time of the day.

All teas were consumed without adding any sweetener. The portion size of white bread (84g) was based on the proximate analysis determined according to AOAC methods. [25] Venous blood samples were taken at the fasting state (0 time) and at 30, 60, 90 and 120 min. after the entire test food was ingested within 10 minutes. Serum glucose was determined in duplicate by standard glucose oxidase method (TECO Diagnostic, Ikview Ave., Anheim, and CA92807). Areas Under The Curve for Glucose (AUCG) were calculated excluding areas below the fasting levels. [26]

Statistical Analysis: Separate analysis for each herb was performed. Results were subjected to One-Way Analysis Of Variance (ANOVA) and repeated measures using the General Linear Models procedure according to SAS. [26] Glucose results were regressed on time to investigate the effect of the type of herb and its level on the curves' behavior. Level of significance is based on $P \leq 0.05$ or as stated otherwise.

Results and Discussion

The mean fasting values for serum glucose in normal fasting subjects, given bread alone or with herbal tea are presented in table (2). All subjects exhibited normal glucose curves as based on the response to ingested bread. Table (2) presents the incremental serum glucose response, the calculated Areas Under The Curve For Serum Glucose (AUCG), and the GI for bread alone and when consumed with the tested herbs. The glucose response curves for bread ingested with plain water or with the herbal teas are shown separately (Figures 1 through 4).

Table (1): Age and anthropometric measurements of the study participants.

Subject	*Sex (M/F)*	*Age (Years)*	*Height (cm)*	*Weight (Kg)*	*BMI (Kg/m^2)*
1	*F*	*25*	*160*	*45*	*17.6*
2	*F*	*18*	*165*	*50*	*18.4*
3	*F*	*18*	*155*	*50*	*20.8*
4	*F*	*30*	*160*	*65*	*25.4*
5	*M*	*19*	*180*	*67*	*20.1*
6	*M*	*24*	*180*	*83*	*25.6*
7	*M*	*24*	*175*	*80*	*26.1*

Effect of Cinnamon Tea: Drinking cinnamon tea reduced significantly the AUCG and GI values of the reference bread to quite similar values of about 55% for either dose of cinnamon (Table 2). This was substantiated by pairwise comparisons using t-test which indicated that the pattern of blood glucose response was similar to both cinnamon dosages but was significantly lower than that elicited by bread ingested with plain water during the two hours intervals (Fig.1).

This finding is consistent with the study of Khan, et al [10] who found that eating 1 to 6 g of cinnamon added to the diet were equally effective in reducing blood glucose. It is also consistent with the general conclusion obtained from *in vitro* studies in which cinnamon extract was found to increase glucose oxidation due to the presence of an insulin- potentiating factor [8] which was characterized as a water–soluble polyphenol and identified to be methyl hydroxychalcone polymer (MHCP). [9, 28]

It was found that MHCP stimulates glucose uptake in 3T3-L1 adipocytes by making fat cells more responsive to insulin through activating the insulin receptor kinase which causes insulin to bind to cells and by further inhibiting insulin receptor- phosphatase which blocks this process, leading to a maximal phosphorylation of the insulin receptor which is associated with increased insulin sensitivity. Due to the immediate hypoglycemic response obtained by drinking cinnamon tea, our data further suggests that the above mechanism for MHCP works in *vivo* and as such suggests the positive hypoglycemic effect for drinking cinnamon tea with a meal or directly after meals as it is not uncommon habit of Jordanians.

Table (2): Incremental serum glucose responses and the glycemic indices of white bread as affected by herbal tea.

Herbal tea	*Serum glucose change(mg/dL)*					*AUC*	*GI (%)*
	Fasting	*30 min*	*60 min*	*90 min*	*120 min*	*(mg.min/dL)*	
Bread	89.6±1.8 [a]	18.4± 5.4 [a]	24.4± 7.0 a	18.2±7.2 [a]	1.0 ± 3.2 [a]	1857± 521 [a]	100 [a]
Bread + cinnamon (4g/cup)	89.8±3.4 [a]	20.6± 5.7 [a]	10.2 ±3.8 [b]	0.6 ± 0.6 [b]	0.0 ± 0.0 [b]	942±270 [b]	54.0±7.3 [b]
Bread + cinnamon (8g/ cup)	88.2±4.9 [a]	14.2± 4.3 [a]	13.4±3.8 [ab]	3.8± 2.1 [b]	0.0±0.0 [b]	942± 221 [b]	55±7.0 [b]
Bread	89.6±2.4 [a]	19.4± 1.7 [a]	21.2± 4.7 [a]	16.4±5.0 [a]	7.4± 5.0 [a]	1823± 235[a]	100 [a]
Bread + fenugreek (6g/cup)	88.4±2.3 [a]	15.4± 2.4 [a]	17.4± 5.7 [ab]	3.6±1.9 [b]	2.4± 1.3 [a]	1123± 212 [b]	62±4.9 [b]
Bread + fenugreek (10g/cup)	82.8±1.5 [a]	12.4±4.0 [b]	10.4±2.5 [b]	0.6± 0.6 [b]	0.0± 0.0 [a]	702± 101[c]	39±4.7 [c]
Bread	89.6±2.4 [a]	19.4± 1.7 [a]	21.2± 4.7 [a]	16.4±5.0 [a]	8.2 ± 5.0 [a]	1823± 235 [a]	100[a]
Bread + black tea (1.5g/cup)	84.8±4.2 [a]	19.2±3.5 [ab]	17.0± 1.5 [a]	9.4± 2.8 [a]	6.2 ±1.6 [a]	1459± 183 [b]	81±5.2 [b]
Bread + black tea (2.5g/cup)	86.4±4.7 [a]	10.0± 2.1 [b]	19.0± 2.8 [a]	11.8± 2.1[a]	3.6 ±1.7 [a]	1278± 150 [b]	72±7.1[c]
Bread	89.0±2.8 [a]	18.3± 1.5 [a]	24.0± 4.4 [a]	20±4.1[a]	7.3± 5.7 [a]	1979±231 [a]	100 [a]
Bread +anise (6g/cup)	82.0±3.6 [a]	28.8± 7.0 [a]	25.2±8.3[a]	6.5±1.7 [a]	0.0±0.0 [a]	1807±135 [a]	93±4.0[b]
Bread +anise (12g/cup)	79.5±2.6 [a]	20.3± 5.2 [a]	14.0±4.6[a]	10.3±5.2[a]	5.8± 1.6 [a]	1421±198 [b]	72±4.2[c]

1. ***Data are means ± SEM (n=5)***
2. ***One way ANOVA adjusted for multiple pairwise comparisons by least significant test***
3. ***Means in the same column for each herb type treatment with different letters are significantly different (P < 0.05)***
4. ***White bread is the reference food ingested with plain water.***
5. ***GI = Glycemic index, AUC= Area under curve, PI= Peak increment.***

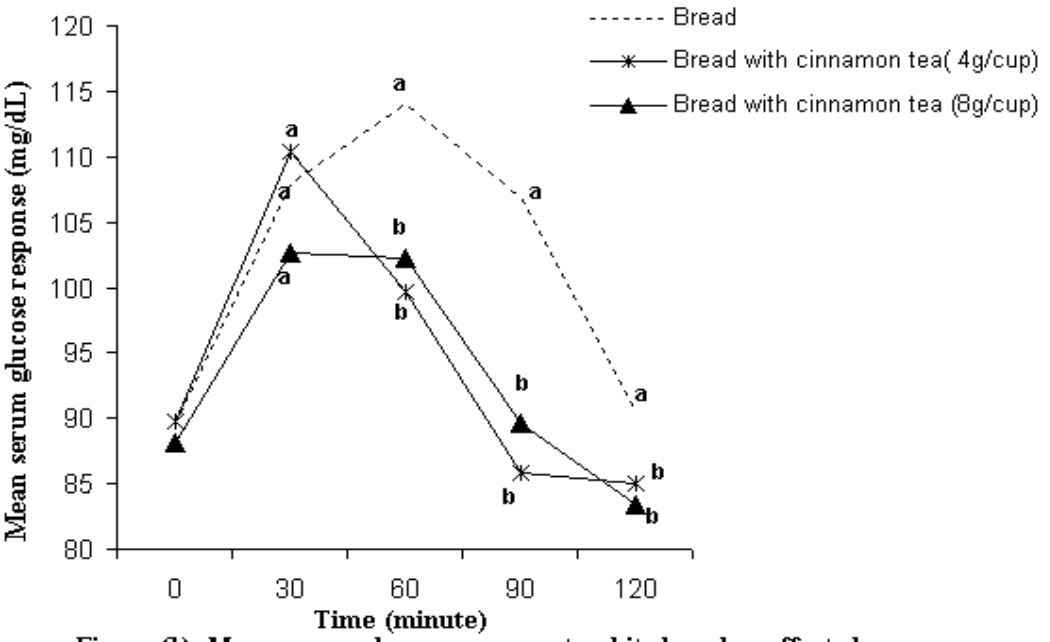

Figure (1): Mean serum glucose response to white bread as affected by cinnamon tea (n=5)

Means at each time point with different letters are significantly different (P< 0.05)

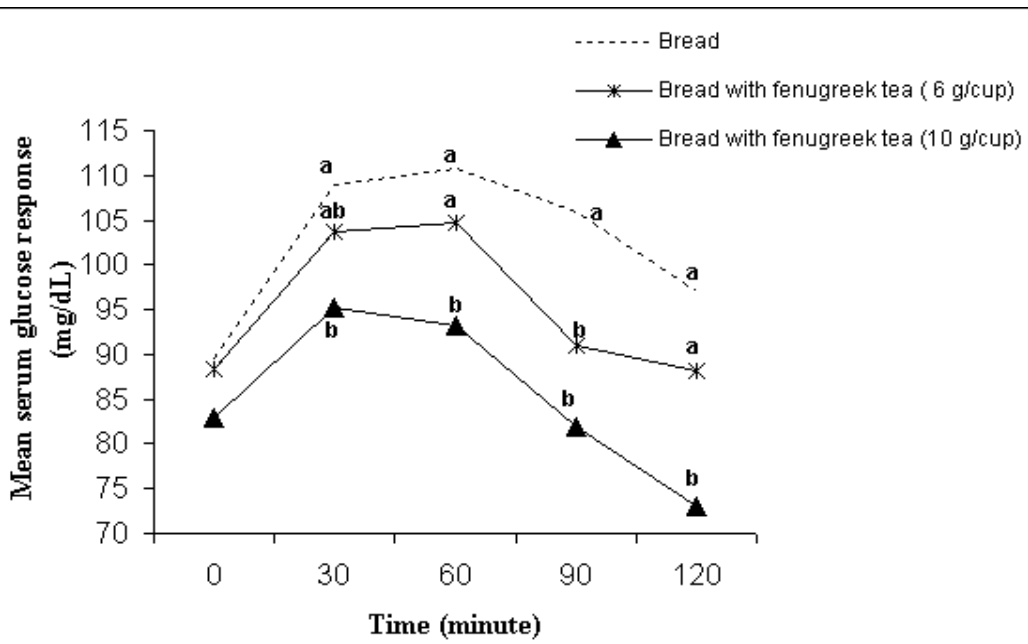

Figure (2) : Mean serum glucose response to white bread as affected by fenugreek seed (n=5)

Means at each time point with different letters are significantly different (P< 0.05)

Effect of Fenugreek Seed Tea: The consumption of 6 or 10 g/cup of fenugreek seed effectively reduced the postprandial glycemic response to bread and consequently the GI of bread from 100% to the respective values of 62 ± 4.9 and 39 ± 4.7.

Pairwise comparison using t-test showed that, compared with the reference bread, the glycemic response of bread was significantly reduced after drinking 10g fenugreek seed/cup at all time intervals but only at 90 min. after drinking the 6g fenugreek seed/cup (Figure 2). The AUCG for bread was significantly reduced by fenugreek tea treatment as expected from their respective glycemic response (1123 ±212 with, 702 ± 101 with 6 and 10g fenugreek seed/cup respectively, Vs 1823± 235 with the reference). This is in agreement with results reported by Ajabnoor and Tilmisany [13] who observed that the oral administration of either water extract or an ethanol extract of fenugreek seed produced a significant dose-dependent fall in blood glucose in normal as well as diabetic rats. This is also consistent with results observed in patients with type II diabetics given a daily dose of 25 g of fenugreek seed powder over 6 months was effective in reducing blood glucose and insulin levels after an oral glucose load test. [16]

The hypoglycemic activity of fenugreek seed was attributed largely to its guar gum- like fiber that is in the form of galagtomannan. Sharma [17] found that degummed fenugreek seed had no effect on blood sugar level, while 5 g of a gum isolate or 25 g of whole or extracted fenugreek seed significantly lowered glucose response at 30 and 60 min. after an oral glucose load. Another hypoglycemic factor is 4-hydroxyisoleucine, an amino acid unique to fenugreek which was shown to stimulate insulin secretion *in vivo* and improve glucose tolerance in normal rats and dogs [29,30] as well as in humans. [31] Compounds like trigonellin and coumarin might have also contributed to the hypoglycemic effect of fenugreek seed. [32]

Effect of Black Tea: The mean GI exhibited by bread ingested with 1.5 and 2.5 g/cup of black tea were 81%±5.2 and 72%±7.1, respectively (Table 2). These values were significantly different from each other and are lower than that of the reference bread (100%), indicating an immediate positive hypoglycemic effect of black tea. The mean blood glucose response to bread was reduced at all time points after it was ingested with black tea in comparison with bread ingested with water, attaining significant levels with 2.5g/cup at 30 and 120 min. and at 60 and 90 min. with 1.5g/cup (Fig.3). This was reflected in a significant reduction in the AUCG of bread after it was given with black tea ,1459 ± 183, 1278 ±159 with 1.5 and 2.5g/cup respectively, Vs1823 ± 235 with the reference. However, no significant difference was observed between the effect of 1.5 and 2.5 g/cup on AUCG (Table 2).

Several studies showed that different types of tea including black tea can effectively reduce blood glucose level and possess anti-diabetic activity in animals [19, 20] as well as in humans. [21, 22] However, only green and oolong tea were used in human intervention studies. To our best knowledge, this is the first trial wherein the immediate effect of black tea is used in man. The results of this study are in agreement with that of Tsuneki and co-workers [22] who found that oral glucose tolerance was improved in healthy volunteers after drinking a suspension of green tea powder (1.5g/150ml of hot water) administered 10 min. after 75 oral glucose load test, compared with hot water administration.

The possible mechanism(s) by which black tea can act on glucose was (were) investigated by *in vitro* techniques and included the inhibitory effect of tea polyphenols exerted on salivary amylase. [33] Epigallocatechin gallate, the main polyphenolic constituent of tea was found to repress hepatic glucose production and promote the phosphorylation of insulin signaling protein. [34]

The acute effect of drinking tea with bread may be also partially explained by the finding that Na-dependent glucose transporter activity is inhibited by tea polyphenols which subsequently suppress intestinal glucose uptake. [35, 36]

Effect of Aniseed Tea: Drinking of aniseed tea (6g/cup) significantly reduced the GI value of the reference bread from 100% to 93%± 4.0 with a further lowering effect to 72% ± 4.2 by drinking the higher dose of 12g/cup (Table 2). The glycemic effect was not reported in literature except in one *in vitro* study in which aniseed oil increased significantly glucose absorption in a dose- dependent manner from rat jejunum cell by increasing the activity of Na^+-K^+, ATPase. [24]

If this mechanism were true in humans, aniseed should have had an acute hyperglycemic effect rather than a hypoglycemic effect as was observed in this study. Thus, further studies are in order to elucidate its glycemic effect.

In conclusion, the present study showed the immediate positive effect of all the above herbal teas in reducing the postprandial glycemic response of bread, and except for cinnamon, the higher dose for the three other herbs resulted in a further significant hypoglycemic effect of bread.

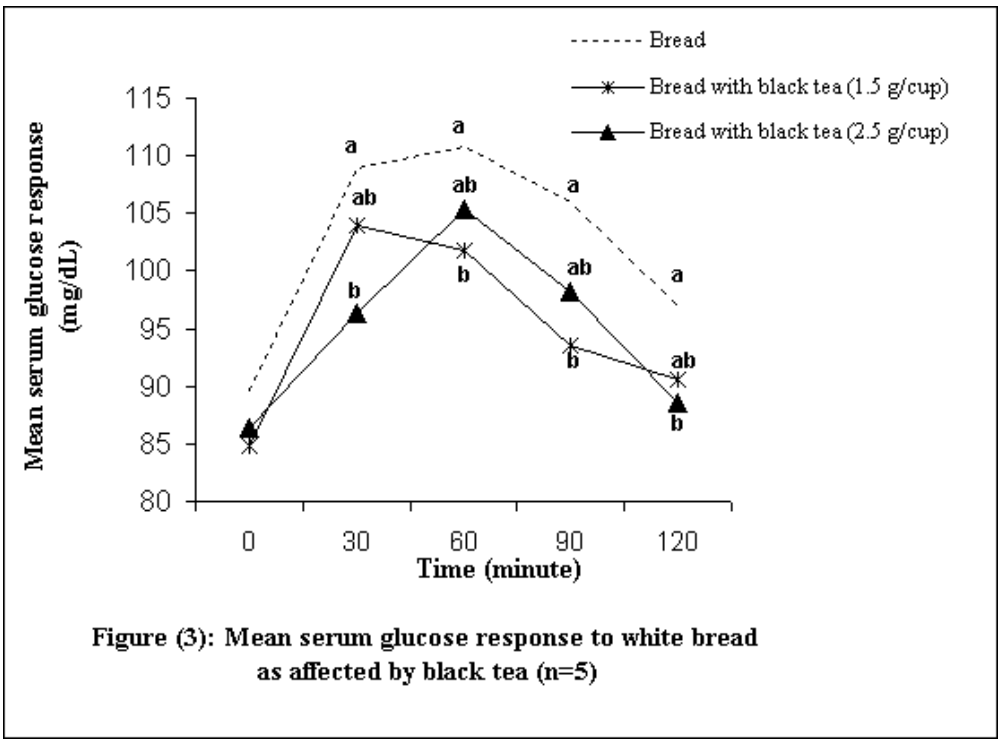

Figure (3): Mean serum glucose response to white bread as affected by black tea (n=5)

Means at each time point with different letters are significantly different (P< 0.05)

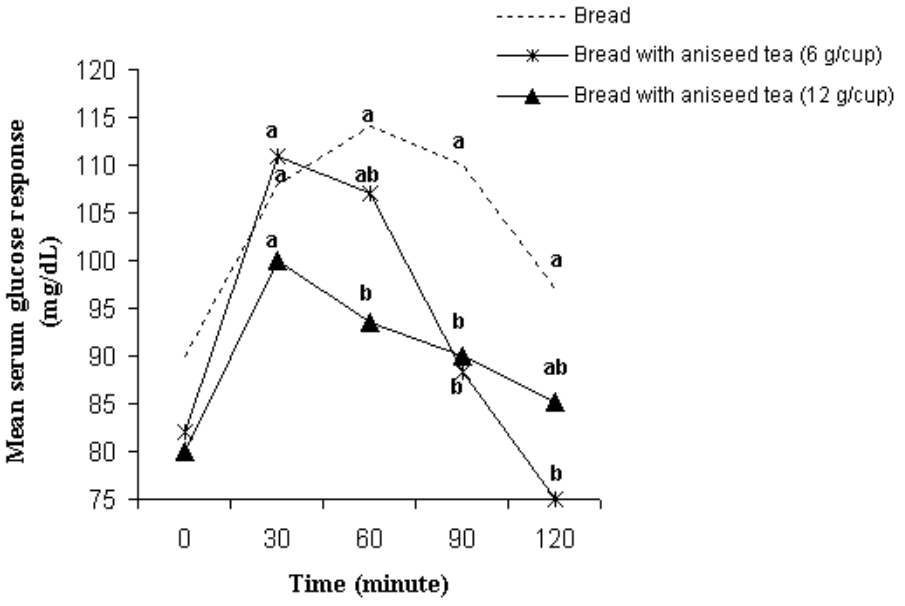

Figure (4): Mean serum glucose response to white bread as affected by aniseed tea (n=5)

Means at each time point with different letters are significantly different (P< 0.05)

References

1. Wolever TMS. Carbohydrate and the regulation of blood glucose and metabolism. Nutrition Reviews 2003; 61: 40S- 48S.
2. Spieth L, Coauthers E. A Low- glycemic index diet in the treatment of pediatric obesity. Archives of Pediatrics and Adolescent Medicine 2000;154: 947-951
3. Food and Agriculture Organization/ World Health Organization. Carbohydrates in human nutrition: Report of a joint FAO/WHO Expert Consultation. FAO Food and Nutrition Paper1998; 66: 1-140.
4. Colombani PC. Glycemic index and load-dynamic dietary guidelines in the context of diseases. Physiology and Behavior 2004; 83: 603-610.
5. Yeh GY, Eisenberg DM, Katchuk TJ and Phillips RS. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care 2003; 26: 1277-1294.
6. Craig WJ. Health promoting properties of common herbs. The American Journal of Clinical Nutrition 1999; 70: 491S - 499S.
7. Tolstoi LG. Herbal remedies: Buyer is ware. Nutrition Today 2001; 36: 223 - 230.
8. Broudhurst CL, Polonsky MM and Anderson RA. Insulin – like biological activity of culinary and medicinal plant aqueous extracts in vitro. Journal of Agriculture and Food Chemistry 2000; 48: 849- 852.
9. Anderson RA, Broudhurst CL, Polonsky MM, Schemidt WF, Khan A, Flanagan VP, Schoene NW and Graves DJ. Isolation and characterization of polyphenolic type- A polymers from cinnamon with insulin- like biological activity. Journal of Agriculture and Food Chemistry 2004; 52: 65- 70.
10. Khan A and Safdar M, Khan MMA, Khattak KN and Anderson RA. Cinnamon improves glucose and lipids of people with type 2 diabetes. Clinical Care 2003; 26: 3215- 3218.

11. Sesikeran, B, Rao, PU., Rao, SP, Naidu, AN, Rao, VV and Ramachandran, EP. Short term nutritional and safety evaluation of fenugreek. Nutrition Research 1996; 16 (9): 1495-1505.
12. Whorter LS. Biological complementary therapies: a focus on botanical products in diabetes. Diabetes Spectrum 2001; 14: 199- 208.
13. Ajabnoor MA and Tilmisany AK. Effect of Trigonella fonenum graceum on blood glucose levels in normal and alloxan-diabetic mice. Journal of Ethnopharmacology 1988; 22: 45- 49.
14. Zia T, Hasnain SN and Hasan SK. Evaluation of the oral hypoglycemic effect of Trigonella foenum- graecum L. (menthe) in normal mice. Journal of Ethnopharmacology 2001; 75:191- 195.
15. Vats V, Grover JK and Rathi SS. Evaluation of anti-hyperglycemic and hypoglycemic effect of Trigonella foenum- graecum Linn, Ocimum sanctum Linn and Pterocarpus marsupium Linn in normal and alloxanized diabetic. Journal of Ethnopharmacology 2002; 79: 95 - 100.
16. Sharma RD, Sarker A, Hazra DK, Mishara B, Singh JB, Sharma SK, Maheshwari BB and Maheshwari PK. Use of fenugreek seed powder in the management of non-insulin dependent diabetes mellitus. Nutrition Research 1996; 16: 1331 - 1339.
17. Sharma RD. Effect of fenugreek seeds and leaves on blood glucose and serum insulin responses in human subjects. Nutrition Research 1986; 6: 1353- 1364.
18. Lukzaj W and Skrzydlewska E. Antioxidative properties of black tea. Preventive Medicine 2004; 40: 910 - 918.
19. Dashti MH and Morshedi A. A comparison between the effect of black tea and kompbucha tea on blood glucose level in diabetic rat. Edocrinology 2000; 13: 83 – 87.
20. Sabu M.C, Smith K and Kuttan R. Anti-diabetic activity of green tea polyphenols and their role in reducing oxidative stress in experimental diabetes. Journal of Ethnopharmacology 2002; 83: 109- 116.
21. Hosoda K, Wang M, Liao M, Chuang CK, Iha M, Clevidence BC and Yamamoto S. Antihyperglycemic effect of oolong tea in type 2 diabetes. Diabetes Care 2003; 26: 1714- 1718.
22. Tsuneki H, Ishizuka M, Terasawa M, Sasaoka T and Kimura I. Effect of green tea on blood glucose levels and serum proteomic patterns in diabetic (db/db) mice and on glucose metabolism in healthy humans. Biomedical Center Pharmacology 2004; 4:18 - 27.
23. Barnes J, Anderson LA and Phillipson JD. Herbal medicines: A guide for health care professionals, 2002; 2nd ed. London - Chicago, Pharmaceutical press.
24. Kreydiyyeh SI, Usta J, Knio K, Markossian S and Dagher S. Aniseed oil increase glucose absorption and reduces urine output in the rat. Life Science 2003; 74: 663 - 673.
25. Association of Official Analytical Chemist (AOAC). Official Methods of Analysis of AOAC International, 1995; 16th ed. Virginia, USA: AOAC.
26. FAO/WHO. Carbohydrates in human nutrition. Report of a Joint FAO/WHO Expert Consultation: Rome, 14-18 April 1997. Food and Nutrition Paper 66.Rome: Food and Nutrition Organization, 1988.
27. Statistical Analysis System (SAS). SAS/STAT User`s Guide, Release 6.03 edition. SAS Institute Inc. Cary, NC, USA, 1988.
28. Jurvill- Tylor KJ, Anderson RA, and Graves DJ. A hydroxychalcone derived from cinnamon functions as a mimetic for insulin in 3T3-L1 adipocytes. Journal of the American College of Nutrition 2001; 20 (4): 327 - 336.
29. Broca C, Manteghetti M, Gross R, Baissac Y, Petit P, Sauvaire Y and Ribes G. 4-Hydroxyisoleucine: effect of synthetic and natural analogues on insulin secretion. European Journal of Pharmacology 2000; 390: 339- 345.
30. Broca C, Gross R, Petit P, Sauvaire Y, Manteghetti M, Tournier M and Masiello P. 4-Hydroxyisoleucine: experimental evidence of its insulinotropic and antidiabetic properties. American Journal of Physiology- Endocrinology and Metabolism 1999; 277: 617 - 623.
31. Sauvaire Y, Petit P, Broca C, Manteghetti M, Baissac Y, Fernandez-Alvarez J, Gross R, Roye M, Leconte A, Gomis R and Ribes G. 4-Hydroxyisoleucine: a novel amino acid potentiator of insulin secretion (abstract). Diabetes1998; 47 (2): 206 - 210.

32. Ali L, Khan AK, Hasan Z, Mosihuzzaman M, Nahar N, Nasreen T, Nur-e-Alam M and Rokeya B. Characterization of the hypoglycemic effects of Trigonella foenum graecum seed. Planta Medica1995; 61: 358 - 360.
33. Zhang J and Kashket S. Inhibition of salivary amylase by black and green teas and their effects on the intra oral and hydrolysis of starch. Caries Research 1998; 32: 233 - 238 (abstract).
34. Waltner ME, Wang XL, Law BK, Hall RK and Nawano M. Epigallocatechin gallate, a constituent of green tea, represses hepatic glucose production. The Journal of Biological Chemistry 2002; 277: 34933 - 34940.
35. Kobayashi Y, Shimizu M, Suzuki M, Satisu H and Miyamoto Y. Green tea polyphenol inhibit the sodium- dependent glucose transporter of intestinal epithet; ial cells by a competitive mechanism. Journal of Agriculture and Food Chemistry, 2000; 48: 5618 - 5623.
36. Shimizu M, Kobayashi Y, Suzuki M, Satisu H and Miyamoto Y. Regulation of intestinal glucose transport by tea catechins. Biofactors 2000; 13: 61- 65.