Mal J Nutr 19(2): 215 - 222, 2013

Efficacy of Millets in the Development of Low Glycemic Index Sweets for Diabetics

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ABSTRACT

Introduction: Three types of *burfi* (a sweet confection), namely, foxtail millet *burfi* (FMb), barnyard millet *burfi* (BMb) and control Bengal gram flour *burfi* (CBGFb) were developed for the consumption of diabetics. **Methods**: The flour blends for FMb and BMb contained 43% of foxtail millet and barnyard millet flour, respectively and 57% of bengal gram flour. The CBGFb was prepared by using 100% Bengal gram flour and served as control. The *burfis* were analysed for sensory quality, acceptability, storage stability, nutritional quality, glycemic index (GI) and glycemic load (GL). **Results**: All the three *burfis* were acceptable to diabetic as well as non-diabetic subjects and could be stored easily for 15 days under ambient conditions. The millet *burfis* possessed fibre and starch contents which contributed to a low GI value of 37.5 for FMb compared to the control. The GL values were 14.7, 17 and 17.9 for FMb, BMb and CBGFb, respectively. **Conclusion**: The millet, especially foxtail millet which had a low GI value has the potential of being served to diabetics in the form of sweets.

Keywords : Foxtail millet, barnyard millet, glycemic index, glycemic load, sweets

INTRODUCTION

In the past, some people, even endocrinologists believed sugar to be the major cause of diabetes. But this fact has been denied by many researchers. A number of clinical and preclinical studies (Manders *et al.,* 2009; Montonen *et al.,* 2007; Black *et al.,* 2006; Lau *et al.*, 2005) conducted in the last decade have clearly indicated that sucrose intake by diabetics in a controlled manner is not associated with insulin resistance, lipemia and diabetes risk. Nutritional recommendation for diabetics (Choudhary, 2004; ADA, 2008) have elucidated the fact that addition of sucrose as part of ordinary meal may not impair blood glucose in diabetic subjects, if consumed in controlled amounts or substituted by other carbohydrates .

Also, many diabetics appear unwilling to do without sweets and claim that the pleasure of eating is reduced by 25% (Modi & Borges, 2005). Exclusion of sucrose may result in increased intake of fat and high glycemic index (GI) starch (Wolever & Miller, 1995).

Though scarce, evidence is now available to advocate a prominent role for millets in the management of diabetes. However, as of today, there is little public awareness on the use of millets for preparing low GI sweet products for diabetics and availability of millet based sweet food

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products for diabetic subjects is almost negligible in the market. Thus, development of sweet products with hypoglycemic effect may prove to be a partial solution to prevent craving of diabetic subjects for sweets; perhaps such a development will help reduce their psychological burden.

METHODS

The foxtail millet (*Setaria italica*) and barnyard millet (*Echinochloa frumentacea*) grains were purchased from local farmers of Almora district, Uttarakhand, India. The millet grains were cleaned free of dust and foreign particles and ground to obtain flours, which were stored in dried airtight plastic containers during the course of the study. The rest of the ingredients were purchased from the local market.

Preparation of sweet - burfi

Three types of *burfi* namely, foxtail millet *burfi* (FMb), barnyard millet *burfi* (BMb) and control bengal gram flour *burfi* (CBGFb) were prepared. The flour blends for FMb and BMb contained 43% of foxtail millet and barnyard millet flour, respectively and 57% of bengal gram flour. The CBGFb was prepared by using 100% bengal gram flour and served as control. The rest of the ingredients – sugar (27 %), hydrogenated fat (9 %), powdered cardamom (1 / 4th tsp) were similar in all the three kind of *burfis*.

Millet flour and bengal gram flour were mixed thoroughly. The above mix was roasted in hydrogenated fat for 5 minutes in low flame and powdered cardamom was added. Sugar syrup at soft ball stage was prepared and added to the flour mixture and mixed properly. The mixture was then quickly poured into a greased tray and allowed to set. Finally it was cut into square shaped *burfi* and decorated with silver foil.

Sensory quality of burfi

All the three types of *burfi* were served to a semi-trained panel of ten judges. The appearance, texture, flavour, aroma, and overall eating quality were evaluated on a 9-point hedonic scale, with 0 being the minimum and 9 the maximum score for the *burfis.*

Since the *burfi* were developed for diabetics, all the three *burfis* were evaluated for acceptability by diabetic subjects at field level. A total of 25 subjects consisting of adult males and female diabetic subjects were included in the sensory panel of the field trial. The subjects were asked to taste the different *burfi* and rank it on a 9-point hedonic scale. The subjects were also interviewed for their willingness to purchase the sweets if available in the market.

Storage stability of burfi

An amount equal to 75g of all the three types of *burfi* viz. FMb, BMb and CBGFb, in duplicate were kept in thermally sealed polyethylene bags for exactly 15 days at room temperature ranging from 28to 32^{0}C and relative humidity of 75-95%. The sensory quality was evaluated by the trained panel as mentioned above at intervals of 7 days.

Nutritional quality of burfi

The nutritional composition of raw ingredients viz. foxtail millet flour and barnyard millet flour were taken from our earlier published work (Bisht & Srivastava, 2010). Bengal gram flour was analysed for proximate composition (AOAC, 1984), total starch (Cerning & Guilbot, 1973; Clegg, 1956), total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) (Asp & Johansson, 1981).

The nutritional value for other ingredients used was taken from the food composition table for Indian foods (Gopalan, Ramashastri & Balasubramanium, 2004) for estimating nutritional content of all the three *burfis.* The minerals viz. chromium, zinc, magnesium, manganese, copper, phosphorus and potassium and vitamins viz. thiamine, riboflavin and niacin were calculated for all the three types of *burfi* from the food composition table for Indian foods.

Glycemic Index (GI) and Glycemic Load (GL) of burfi

Ten females aged 22-27 years with a BMI ranging from 16.5 to 26.3 kg / m^2 with normal blood pressure were randomly selected from the University's female hostel. The purpose of study was explained to each subject and signed consent forms to participate voluntarily in the study were obtained. The subjects were given general instructions to avoid any physical exertion, medication, fasts and feasts during the experimental period.

The glucose tolerance test (GTT) was carried out on overnight fasted subjects with a glucose load of 50g. Blood glucose was measured at 0, 15, 30, 60, 90 and 150 min. Thereafter, all the three *burfis* were adjusted to provide 50g carbohydrate and served to the subjects on separate occasions (15 days apart). The subjects were asked to finish eating within 10-15 min of serving. The blood glucose was again measured at specified intervals by finger prick method using glucometer (Glucotrend 2, Roche Diagnostics Gmbh, Germany). The subjects were interviewed for after effects of *burfi* consumption.

The incremental area under the blood glucose response (iAUBGR) for *burfis* and glucose were calculated using the formula given by Wolever *et al.* (1991). The GI value for each subject was calculated as iAUBGR curve after burfi / iAUBGR curve for glucose X 100. Finally the GI for each *burf*i was recorded as average value of 10 replicates. The GL for each *burf*i was calculated as available carbohydrate (g) X GI / 100.

Statistical analysis

All the data are presented as mean + SD (Standard Deviation) of three replicates. The 'student *t*-test' was used to measure the difference on sensory quality and acceptability of *burfis.* The 'paired *t*-test' was used to assess the significant difference on storage quality of *burfis*. ANOVA test was applied to determine significant differences in nutritional values, iAUBGR and GI ($p \leq 0.05$).

RESULTS AND DISCUSSION

The first step after developing *burfi* was the evaluation of sensory qualities and acceptability of all three types of *burfi* as surveys indicate that taste is the primary factor in food purchase choices. Today consumers are demanding 'no compromise' foods that offer hedonistic appeal along with perceived health benefits (Sorensen *et al.,* 2003). The data obtained on sensory quality and acceptability of the *burfis* showed a non significant difference amongst the three which indicated that millet *burfi* was equally liked by subjects as the control burfi (Table 1). Also, 92% of diabetic subjects indicated willingness to purchase the *burfi*, if available in the market. The remaining 8 % were not willing probably due to financial reasons or lack of purchasing power.

A non significant difference was observed between stored and fresh sample for all the three types of *burfis* (Table 1), which shows that *burfis* could be stored without any change in sensory quality at room temperature and in simple packaging material for a period of 15 days. Literature on shelf life and packaging requirements of various types of *burfi* is very scarce. According to Manay & Shadaksharaswamy (2000), the shelf life of Indian sweets is only from to 2-5 days due to high moisture content. The short shelf life at room temperature is because of high water activity (Kaur & Ahmed, 2000). Cold storage temperature condition and appropriate packaging may further improve the shelf life of *burfis.* Thus, the millet *burfis* can be successfully stored for a longer period, if required.

The nutrient composition of the flours (Table 2) clearly shows that millet flour,

Table 1. Scores for sensory quality by semi-trained panelists[a]; acceptability by diabetics[b] and storage stability[c] of *burfis*.

Burfis	*FMb*	*BMb*	*CBGFb*	*SEM1±*	*CD1 at 5%*
Score [a]*	8.2±0.63	8.2±0.63	8.2±1.03	0.249	0.72
Score [b]*	8.11±0.65	8.23±0.51	8.23±0.58	0.11	0.32
0 day score [c]*	8.2±0.63	8.2±0.63	8.2±1.03		
7th day score [c]*	8.3±0.82	7.6±0.69	8.4±0.69		
15th day score [c]*	8.0±1.24	7.6±0.69	8.4±0.69		
SEM2±	0.29	0.21	0.21		
CD2 at 5%	0.85	0.62	0.75		

* Mean±SD; FMb: foxtail millet burfi; BMb: barnyard millet burfi; CBGFb: control Bengal gram flour burfi; CD: Critical difference; SEM: Standard Error of mean SEM1± and CD1 values are between FMb, BMb and CBGFb for scores a and b, respectively whereas SEM2± and CD2 values are between 0, 7th and 15th day for FMb, BMb and CBGFb, respectively.

Table 2. Nutrient composition of the flours

*Nutrients**	*FMF*	*BMF*	*CBGF*
Crude Protein (%)	9.9±0.53	11.0±0.66	18.0±0.20
Crude Fat (%)	4.7±0.15	4.4±0.11	3.1±0.08
Crude Fiber (%)	8.0±0.89	8.1±1.34	1.3±0.03
Total Ash (%)	2.9±0.03	3.8±0.11	2.8±0.02
Carbohydrate (%)	65.9±0.72	63.7±2.2	64.7±0.71
Physiological energy (kcal/100g)	346±4.35	339±6.50	359±3.46
Starch (%)	64.1±1.94	52.1±0.64	50.2±0.64
TDF (%)	26.9±0.12	31.7±0.38	18.3±0.39
SDF (%)	11.0±0.13	9.7±0.13	6.3±0.09
IDF (%)	15.9±0.02	22.0±0.51	12.0±0.31

*Mean ± SD, FMF: foxtail millet flour; BMF: barnyard millet flour; CBGF: Control bengal gram flour; TDF: Total Dietary Fibre; SDF: Soluble Dietary Fibre; IDF: Insoluble Dietary Fibre

especially foxtail millet, is a good source of dietary fibre and starch whereas bengal gram flour is almost twice richer in protein content. The other nutrients are almost similar for the flours

The nutrient composition of *burfis* is shown in Table 3. The results indicate that on replacing bengal gram flour with 43% millet flour, there was a three-fold increase in crude fibre content in FMb and BMb than in CBGFb. The millet *burfis* were a good source of minerals and vitamins. Chromium and zinc levels were higher in FMb and BMb as compared to CBGFb. The remaining minerals and vitamins were almost similar in all the three *burfis.* Diabetics are known to suffer a deficiency of these minerals and vitamins. These minerals and vitamins play a key role in glucose homeostasis and fat metabolism (Martini, Catania & Ferreira, 2010; Gunasekara *et al.,* 2011).

Amongst the three *burfis,* the mean iAUBGR curve (mmol/L) was lowest for FMb, intermediate for BMb and highest for CBGFb. The FMb elicited 34.2% and 37.0% lower glucose response than BMb and CBGFb, respectively (Table 4). The results for GI showed that FMb had the lowest GI of 37.5 compared to 43 for CBGFb and 45 for BMb (Table 4). Since, the macronutrient components of all the three types of *burfi* were almost similar, the difference in GI could be attributed to good starch and SDF content of FMb as compared to BMb and CBGFb. All

Table 3. Nutrient composition of *burfis*

	FMb	*BMb*	*CBGFb*
Crude Protein (%)	7.9	8.3	10.6
Crude Fat (%)	10.7	10.6	10.1
Crude Fiber (%)	3.1	3.1	0.8
Total Ash (%)	1.7	2.0	1.7
Carbohydrate (%)	63.9	63.2	63.4
Physiological energy (kcal / 100g)	383	381	388
Starch (%)	34.3	30.3	29.6
TDF (%)	13.7	15.3	10.8
SDF (%)	5.3 (38.7)	4.9 (31.8)	3.7 (34.2)
IDF (%)	8.4 (61.3)	10.4 (68.2)	7.1 (65.8)
Chromium (%)	0.0181	0.0306	0.0055
Zinc (%)	1.2386	1.4408	1.0019
Magnesium (%)	60.16	60.5	76.68
Manganese (%)	0.4676	0.5889	0.6193
Copper (%)	0.8106	0.5409	0.7903
Potassium (%)	266.26	-	424.67
Phosphorus (%)	181.41	178.04	195.23
Thiamine (%)	0.3201	0.2324	0.2830
Riboflavin (%)	0.0825	0.0792	0.1061
Niacin (%)	1.6852	2.0222	1.4155

Figure in parenthesis show percent contribution. FMb: foxtail millet burfi; BMb: barnyard millet burfi; CBGFb; control bengal gram flour burfi; ; TDF: Total Dietary Fibre; SDF: Soluble Dietary Fibre; IDF: Insoluble Dietary Fibre

Table 4. Incremental area under Blood Glucose Response (iAUBGR) curve and GI of the *burfis*

Product	*iAUBGR curve* for burfis (mmol/L)*	*iAUBGR curve* for glucose (mmol/L)*	*GI*	*GL*
FMb	88.44^{a}±17.41	298.02^{b}±175.9	37.5±18.5	14.7
BMb	118.71^{a}±50.56	298.02^{b}±175.9	45.0±14.5	17
CBGFb	121.17^{a}±11.00	298.02^{b}±175.9	43.0±14.9	17.9
SEM±	16.83			
CD at 5%	48.85		14.7	

* Mean ± SD ($p \leq 0.05$)
FMb: foxtail millet burfi; BMb: barnyard millet burfi; CBGFb: control bengal gram flour burfi; CD: Critical Difference; SEM: Standard Error of Mean
Figures with different superscripts show significant difference

the three *burfis* fell in the low GI category (less than 55).

Several empirical investigations have reported that dietary fibre, especially soluble dietary fibre, has a lowering effect on blood glucose levels. The good dietary fibre content of *burfis* may have protected starch from enzymatic degradation and both fibre and starch may have trapped the products of digestion (Vessby, 1994; Wong & Jenkins, 2007). Also, high cereal fibre may have attenuated insulin sensitivity (Weickert *et al.,* 2011) and improved glucose tolerance through colonic fermentation and generation of short chain fatty acids (Nilsson *et al.,* 2010). Besides, the process of *burfi* roasting may have led to an increase in starch crystallinity (Bjorck, Liljeberg & Ostman,

2000) and TDF content by formation of resistant starch, leading to physical inaccessibility of starch enclosed within the intact cells (Kavitha, Parvathi & Mageshwari, 2001). Madhuri, Pratima & Rao (1996) reported that roasting decreased the digestibility of cereals and legumes.

The BMb and CBGFb had 12% and 14.4% lower starch content, respectively as compared to FMb. The SDF content in terms of percent contribution to TDF of FMb was higher (38.7%) compared to CBGFb (34.2%) and BMb (31.8%).

The addition of bengal gram flour to millet flour helped to improve the protein content of millet *burfis.* Legumes like bengal gram exemplify a class of food that is high in protein with soluble and insoluble fibres and antinutrients which are found to be effective in decreasing postprandial glucose (Messina, 1999). Protein stimulates insulin secretion by direct effect on β cells and decreases the blood glucose response and is inversely correlated to GI (Gannon *et al.*, 2003). Therefore, incorporation of bengal gram flour to millet flour has the effect of enhancing the protein content which may have further improved glucose tolerance and alleviated the GI.

In relation to GL, the findings showed that FMb had a GL of 14.7, BMb 17 and CBGFb 17.9. All the three *burfis* were in medium GL category (11-19 = medium GL). Determining GL is important as it represents carbohydrate quantity and diets high in GL are associated with increased risk of diabetes (Sluijs *et al.,* 2010). A high GL diet leads to pancreatic β cell exhaustion, insulin resistance and glucose intolerance. A high fibre, high magnesium and low GL diet protects against diabetes (Hopping *et al.,* 2010) which is true of FMb as it had high fibre and magnesium and low GL.

Thus, it can be concluded that millets, especially foxtail millet along with bengal gram flour can be effectively used to develop a low GI sweet for diabetics owing to its good soluble fibre and starch content. Such sweets comply with the human desire for sweet taste, thus reducing the sense of deprivation and the psychological burden of diabetic subjects.

ACKNOWLEDGEMENT

The funds provided by the NATP (ICAR) project are acknowledged. The authors thank Dr KC Lohani, Chief Medical Officer and Dr Manoj Joshi for their support in conducting the study.

CONFLICT OF INTEREST

None

REFERENCES

ADA (2008). Nutrition recommendations and interventions for diabetes. A position statement of American Diabetic Association. *Diabetes Care* 31: S61-S78.

AOAC (1984). Official Methods of Analysis of the Association of Analytical Chemists. AOAC, Washington DC.

Asp NG & Johansson CG (1981). The techniques for measuring dietary fibre: principal aims of methods and comparison of results obtained by different techniques. In: *The Analysis of Dietary Fibre in Food*. James WPT & Theander O (eds). Market Dekker, Inc.

Bisht AT & Srivastava S (2010). Suitability of foxtail millet (*Setaria italica*) and barnyard millet (*Echinochloa frumentacea*) for development of low glycemic index biscuits. *Mal J Nutr* 16: 361- 368.

Bjorck I, Liljeberg H & Ostman E (2000). Low glycaemic index foods. *Br J Nutr* 83: 5149-5155.

Black RNA, Spence M, McMohan RO, Cuskelly GJ, Ennis CN, McCance DR, Young IS, Bell PM & Hunter SJ (2006). Effect of eucaloric high- and low-sucrose diets with identical macronutrient profile on insulin resistance and vascuxlar risk. A randomised controlled trial. *Diabetes* 55: 3566- 3572.

Cerning J & Guilbot J (1973). Changes in carbohydrate composition during maturation of wheat and barley kernel. *Cereal Chem* 50: 220- 232.

Choudhary P (2004). Review of dietary recommendations for diabetes mellitus. *Diabetes Res Clin Pract* 65: S9- S19.

Clegg KM (1956). The application of anthrone reagent in the estimation of starch in cereals. *J Sci Food Agric* 7: 40- 44.

Gannon MC, Nuttall FQ, Saeed A, Jordan K & Hoover H (2003). An increase in dietary protein improves blood glucose response in persons with type 2 diabetes. *Am J Clin Nutr* 78: 734-741.

Gopalan C, Ramashastri BV & Balasubramanium SC (eds). (2004). Nutritive Nalue of Indian Foods. ICMR, Delhi.

Gunasekara P, Hettiarachchi M, Liyanage C & Lekamwasam S (2011). Blood sugar lowering effect of zinc and multivitamin / mineral supplementation is dependent on initial fasting blood glucose. *J Diabetology* 1:2. From *http://www.journalofdiabetology.org* [Retrieved on Oct 28 2012].

Hopping BN, Erber E, Grandenetti A, verheus M, Kolonel LN & Maskarinee G (2010). Dietary fibre, magnesium and glycemic load alter risk of type 2 diabetes in multiethnic cohort in Hawaii. *J Nutr* 140: 68-74.

Kaur S & Ahmed J (2000). Development of ready to eat halwa. *J Food Sci Technol* 32: 304- 306.

Kavitha P, Parvathi EP & Mageshwari SU (2001). Effect of different methods of cooking in dietary fiber content of wheat and wheat products and their hypoglycemic effect on NIDDM patients. *Ind J Nutr Dietet* 38: 173-181.

Lau C, Faerch K, Glumer C, Tetens I, Pedersen O, Carstensen B, Jorgensen T & Borch-Johnsen K (2005). Dietary glycemic index, glycemic load, fibre, simple sugars and insulin resistance. The Inter 99 Study. *Diab Care* 28: 1397- 1403.

Madhuri K, Pratima S & Rao B (1996). Effect of processing on in vitro carbohydrate digestibility of cereals and legumes. *J Food Sci Technol* 33: 493- 497.

Manay NS & Shadaksharaswamy M (2000). Foods- Facts and Principles. New Age International, New Delhi.

Manders R, Pennings B, Beckers C, Aipassa T & Loon L (2009). Prevalence of daily hyperglycemia in obese type 2 diabetic men compared with that in lean and obese normoglycemic men: effect of consumption of a sucrose-containing beverage. *Am J Clin Nutr* 90: 511-518.

Martini LA, Catania AS & Ferreira SR (2010). Role of vitamins and minerals in prevention and management of type 2 diabetes mellitus. *Nutr Rev* 68: 341- 354.

Messina MJ (1999). Legumes and soya beans: overview of their nutritional profiles and health effects. *Am J Clin Nutr* 70: 439S- 450S.

Modi SV & Borges VJ (2005). Artificial sweeteners: Boon or bane? *Int J Diab Dev Countries* 25: 1- 5.

Montonen J, Jarvinen R, Knekt P, Helliovaara M & Reunanen A (2007). Consumption of sweetened beverages and intakes of fructose and glucose predict type 2 diabetes occurrence. *J Nutr* 137: 1447- 1454.

Nilsson AC, Ostman EM, Knudsen KEB, Holst JJ & Bjorck IME (2010). A cereal based evening meal rich in indigestible carbohydrates increases plasma butyrate the next morning. *J Nutr* 140: 1932- 1936.

Sluijs I, Van der Schouw YT, Van der-A DL, Spijkerman AM, Hu FB, Grobbee DE & Beulens JW (2010). Carbohydrate quantity and quality and risk of type 2 diabetes in the European Prospective Investigation into Cancer and Nutrition–Netherlands (EPIC-NL) study. *Am J Clin Nutr* 92: 905-911.

Sorensen LB, Mella P, Flint A, Martens M & Raben A (2003). Effect of sensory perception of food in appetite and food intake. A review of studies on humans. *Int J Obesity* 27: 1152- 1166.

Vessby B (1994). Dietary carbohydrates in diabetes. *Am J Clin Nutr* 59: 742S-746S.

Weickert MO, Roden M, Isken F, Hoffman D, Nowotny P, Osterhoff M, Blaut M, Alpert C, Gogebakan O, Bumke-Vogt C, Mueller F, Machann J, Barber TM, Petzke KJ, Hierholzer J, Hornemann S, Kruse M, Illner A-K, Kohl A, Loeffelholz CV, Arafat AM, Mohling M & Pfeiffer AFH (2011). Effects of supplemented isoenergetic diets differing in cereal fibre and protein content on insulin sensitivity in overweight humans. *Am J Clin Nutr* 94: 459- 471.

Wolever TMS & Miller JB (1995). Sugars and blood glucose control. *Am J Clin Nutr* 62: 212S- 221S.

Wolever TMS, Jenkins DJA, Jenkins AL & Josse RG (1991). The Glycemic Index: methodology and clinical implications. *Am J Clin Nutr* 54: 846- 854.

Wong VMW & Jenkins DJA (2007). Carbohydrate digestibility and metabolic effects. *J Nutr* 137: 2539S- 2546S.