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ORIGINAL ARTICLE

Glycemic index of millet based food mix and its effect on pre diabetic subjects

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Abstract Diet plays an important role in management of diabetes and foods having low glycemic index are gaining more importance as they delay the release of glucose in the blood. It is essential to develop low glycemic food mix from regionally available ingredients for use in daily dietaries. Hence, the present study was undertaken to assess the glycemic index of the traditional recipes prepared from developed millet based food mix and their effect on pre diabetic subjects. The developed millet based food mix had appreciable amount of protein (19.41 g/100 g) and dietary fibre (21.11 g/100 g). The traditional recipes viz., *roti*, *dosa* and dumpling (*mudde*) prepared from developed mix exhibited higher acceptance with good sensory parameters and are comparable to regional preparations. The glycemic index was found to be 37, 48 and 53 for *dosa*, *mudde* and *roti* respectively with a glycemic load of 11.05, 18.43 and 18.09. However, all the three developed products showed the relatively lower glycemic index (< 55) and moderate glycemic load of < 20. Further, dietary intervention on pre diabetic subjects revealed that there was a significant reduction in FBS (120.50 ± 18.73 to 97.81 ± 20.00) and HbA1c (6.14 ± 0.30 to 5.67 ± 0.40) indicating their preferable option in the management of diabetes mellitus.

Keywords Glycemic index · Millet based food mix · Diabetes · Dietary fiber · Dietary intervention

Introduction

Diabetes mellitus is a metabolic disorder characterized by elevated blood glucose level over a prolonged period. It is caused by inherited and/or acquired deficiency in production of insulin by the pancreas or by ineffectiveness of the insulin. It is a growing public health problem in both developing and developed countries. According to the world health organization (WHO) report, an estimated 1.6 million deaths were directly caused by diabetes in 2015 (WHO 2017). India with rapid urbanization as well as increased socio-economic growth, shares the major part of the global diabetes burden (Ramachandran and Snehalatha 2009). International diabetic federation estimated that in 2017 there are 451 million people aged between 18 and 99 years with diabetes worldwide (Cho et al. 2018). Recent studies revealed the escalating prevalence of diabetes among both urban as well as the rural Indians, with southern India having the sharpest increase in last 2 decades.

Increased intake of refined carbohydrates has been reported to parallel the upward trend in the prevalence of obesity and type-2 diabetes in the United States, suggesting that the type of carbohydrate consumed may impact risk

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through alterations in postprandial blood glucose and insulin concentrations (Augustin et al. 2002). Diet is one of the major factors now linked to a wide range of diseases including diabetes. The amount and type of food consumed is a fundamental determinant of human health. Diet constitutes a crucial aspect of the overall management of diabetes, which may involve diet alone, diet with oral hypoglycemic drugs or diet with insulin (Sofi et al. 2008; Kastorini et al. 2011).

For the effective management of diabetes, besides medication, it is essential to modify the life style and dietary practices. In this context, low glycemic index foods are gaining more importance as they help to keep the euglycemia and normal spectra of lipoprotein level (Connor et al. 2003). Glycemic index represents the blood glucose alteration capacity of the food. Foods with low glycemic index show the slower release of glucose (Jenkins et al. 1992). Due to the established strong and adjacent association of the food habits with the prevalence and management of diabetes, it is imperative to incorporate low glycemic foods for the management of diabetes as a dietary approach. For the effective inculcation and constancy of dietary practices, it is essential to develop the region specific foods with the incorporation of locally available ingredients. Millets being region specific food in Karnataka and rich source of phyto-chemicals as dietary fibre and antioxidants received the spot light in combating the diabetes as a dietary option. Even pulses are known for their low glycemic value due to high protein and dietary fibre content, which aids in slow release of carbohydrates. Functional foods such as fenugreek seeds, curry leaves, flax seeds and bitter gourd are the proven hypoglycemic foods. A meal consisting of the combination of cereals, pulses and functional foods are found to be more effective than only the cereal diet. Many diversified foods are available in market for prevention and management of diabetes which is affordable, available and accessible by the urban population however, there is an immense need to develop cost effective food products using region specific foods which is of practical utility in preventing and management of diabetes among the rural population. Hence, the present study was undertaken to assess the glycemic index of the region specific traditional recipes of Southern Karnataka prepared from developed millet based food mix which may be of daily use for management of diabetes.

Materials and methods

Study site

The present study was carried out at AICRP (All India Co-Ordinated Research Project) on Foods and Nutrition, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru, Karnataka, India.

Development of millet based mix

Millet based food mix was prepared by using the ingredients viz., finger millet (*Eleusine coracana*), little millet (*Panicum sumatrense*), defatted soya (*Glycine max*) flour, whole green gram (*Vigna radiata*), fenugreek seeds (*Trigonella foenum-graecum*), flax seeds (*Linum usitatissium*), curry leaves (*Murraya koenigii*), bitter gourd (*Momoradi cacharantia*) and skimmed milk powder. All the ingredients used for the study were procured from local market of Bengaluru. Fresh bitter gourd and curry leaves were washed thoroughly, blanched for one min and oven dried. Further finger millet, little millet, whole green gram, fenugreek seeds and roasted flax seeds were made into flour. Millet based mix was developed by mixing the flour with skimmed milk powder, defatted soya flour and kept airtight. Region specific traditional recipes were prepared from the developed mix to assess their glycemic index.

Selection of region specific traditional recipes

A preliminary survey was conducted on 50 farm women to select the most commonly consumed breakfast and lunch items in the study area. Based on ex post report, *roti* and *dosa* as two breakfast items, *dumpling* as lunch item were chosen for the study.

Nutrient analysis

Macro nutrients namely moisture, protein, fat, crude fibre and ash as total minerals were analysed in developed food mix using standard protocol (AOAC 1990). Micronutrients viz., iron, zinc, copper and calcium were analysed using atomic absorption spectrometry (AOAC 1990). Dietary fibre was analysed by an enzymatic gravimetric method (Prosky 1990). Further, carbohydrate content was calculated by differential method and available carbohydrate was calculated as the difference, including the subtraction of dietary fibre and other components (FAO 2003). In the energy calculation, energy factor of four for carbohydrate and protein, nine for fat was considered.

Sensory evaluation

The selected three region specific traditional recipes viz., *roti, dosa* and *dumpling* were prepared from developed mix as per the local culinary method. Further, products prepared from finger millet flour were kept as control for comparison purpose. Sensory attributes of the products viz., *roti*, *dosa* and *dumpling* were evaluated by nine-point hedonic scale (Srilakshmi 2007) for their appearance, texture, aroma, taste and overall acceptability by 30 semi trained panel members.

Assessment of glycemic index

Ethical committee approval

Institutional ethical committee clearance certificate was obtained prior to the initiation of the study (Proposal No. AICRP FN 2018001 and approved on 10.02.2018).

Selection of subjects for glycemic index assessment

For the study purpose 10 sedentary, normo glycemic healthy subjects aged between 18 to 30 years were selected randomly for testing of each product. After the clear explanation about the protocol and purpose of the study, written consent was obtained. Selected subjects were requested to maintain their usual daily food intake and activity throughout the study period.

Glycemic index

Glycemic index of the three products prepared from 'millet based mix' was evaluated according to Wolever et al. (2003) method on ten healthy subjects. Developed mix equivalent to 50 g of available carbohydrate was taken for preparation of *roti, dosa* and *dumpling* and used for glycemic index assessment. Capillary blood was drawn through finger prick method and evaluated for glucose content by using the glucometer (Precision I.Q.D.). Further, 50 g of glucone-D in 200 ml of water was given as reference food. Initial fasting blood glucose with overnight fasting of 10–12 h and post prandial blood glucose response at 30, 60, 90 and 120 min interval were assessed. With the gap of one week period *roti, dosa and dumpling* equivalent to 50 g of available carbohydrate were given separately with the wash out period of one week for each product. Fasting and postprandial blood glucose level was assessed for each product. Blood glucose response curves were plotted for both Glucone-D reference food and three test food products. The incremental area under the curve (IAUC) was calculated to reflect the total rise in glucose concentration after the administration of test foods in comparison with reference glucone-D. Glycemic index was calculated by using the formula.

$$\text{Glycemic index} = \frac{\Delta\text{Area under glucose curve for test food}}{\Delta\text{Area under glucose curve for reference food}}$$

Glycemic load

Glycemic load was calculated by multiplying the actual amount of carbohydrates present in one serving of test foods (*roti*, *dosa* and *dumpling*) with glycemic value of respective test food, divided by 100 (Salmeron et al. 1997).

$$\text{Glycemic load} = \frac{\text{Glycemic index} \times \text{Available carbohydrate content per serving of meal (g)}}{100}$$

Dietary intervention on pre diabetic subjects

Food based dietary intervention was carried out to assess the effect of developed low glycemic food mix on selected pre diabetic subjects (Control = 15 and experimental = 15). Written consent was obtained from subject before initiation of the intervention. Clinical parameters viz., fasting blood sugar and HbA1c were assessed as pre evaluation assessment. Subjects with the HbA1c 5.7 to 6.4 were selected for the study. Developed mix to meet 1/3rd Recommended Dietary Allowance (RDA) was given to subjects on daily basis for 120 days. After the completion of intervention period, fasting blood sugar and HbA1c were assessed in both control and experimental subjects as post evaluation assessment.

Statistical analysis

Data are shown as means with their standard deviations unless otherwise stated. The significance of difference between control and test foods for their organoleptic attributes was tested through paired't' test.

Results and discussion

The nutrient composition of millet based mix is presented in Table 1. The developed food mix had 8.77 ± 0.06 g of moisture, 19.41 ± 0.29 g of protein, 5.30 ± 0.11 g of fat, 2.74 ± 0.09 g of minerals per 100 g of mix. Iron, zinc, copper and calcium content were found to be 6.74 ± 0.20, 3.37 ± 0.08, 0.67 ± 0.04 and 309 ± 3.18 mg per 100 g of mix respectively. Mix had 4.49 ± 0.35 g of crude fibre, 63.78 g of carbohydrate and total dietary fibre content was 21.11 ± 0.52 g per 100 g of sample. High dietary fibre is believed to reduce the blood glucose response and thus lower the glycemic index of a food (Pacy et al. 1984). The developed mix had appreciable amount of protein and high dietary fibre content. Staple foods such as wheat and rice are reported to contain much lower levels of dietary fibre and protein has been frequently identified as an important component for dietary strategies for diabetics (Singh et al.

Table 1 Nutrient composition in 100 g of millet based food mix

Nutrients	Mean ± SD
Moisture (g)	8.77 ± 0.06
Protein (g)	19.41 ± 0.29
Fat (g)	5.30 ± 0.11
Carbohydrate (g)*	63.78
Energy (Kcal)*	380.46
Total minerals (g)	2.74 ± 0.09
Iron (mg)	6.74 ± 0.20
Zinc (mg)	3.37 ± 0.08
Copper (mg)	0.67 ± 0.04
Calcium (mg)	309.39 ± 3.18
Crude fibre (g)	4.49 ± 0.35
Total dietary fibre (g)	21.11 ± 0.52

SD standard deviation

*Computed value

Table 2 Mean sensory scores for products prepared from millet based food mix

Parameters	Roti		Dosa		Dumpling (Mudde)	
	C	T	C	T	C	T
Appearance	8.05	7.28*	7.76	6.93*	7.37	7.50*
Aroma	7.78	7.28*	7.42	6.45*	7.40	7.50^{ns}
Texture	7.78	7.20*	7.70	6.77*	7.42	7.53^{ns}
Taste	7.90	7.13*	7.77	6.93*	7.22	7.37^{ns}
Overall acceptability	7.97	7.26*	7.72	6.93*	7.53	7.65^{ns}

ns non significant at $P \leq 0.05$; *C* control food; *T* test food

*Significant at $P \leq 0.05$

2010) as it improves glycemic control and muscle loss prevention (Melnik 2012; Norton et al. 2012). An advantage of having protein in the food matrix is that, it can influence the rate of starch digestion by delaying digestion and control of postprandial hyperglycemia (Beasley and Wylie-Rosett 2013). The protein content of developed millet based mix was comparatively higher than the foxtail diabetic mix developed by Itagi et al. (2012). Developed mix had reasonably good amount of iron, zinc, copper and calcium which is comparable with the mineral composition of kodo millet based hypoglycemic products as reported by Yadav et al. (2013). Many studies have shown the beneficial effect of minerals like zinc, magnesium, manganese and potassium in the control and maintenance of the glucose homeostasis. It is well known that zinc plays important role in insulin homeostasis and its deficiency has been associated with insulin resistance in patients with type 2 diabetes mellitus (Arquilla et al. 1978). The developed mix contain appreciable amount of zinc (3.48 mg) which would meet 1/3rd of the daily requirement. Among the products prepared from millet based mix, *dumpling* scored higher acceptability (7.65) followed by *roti* (7.26) and *dosa* (6.93) as shown in Table 2. The mean sensory scores for products prepared from millet based food mix viz., *roti*, *dosa* showed statistically significant difference at 0.05 per cent for all the sensory parameters between control and test food. However, the overall acceptability scores above seven indicated that test products to be accepted as control. The mean sensory scores between control and test dumpling product was found to be statistically non significant, which implied test product to be accepted as much as control product.

The blood glucose response of products prepared by using millet based food mix viz., *roti*, *dosa* and *dumpling* (test foods) in comparison with reference glucone-D is presented in Fig. 1. The results are expressed as the mean blood glucose concentration after the ingestion of test foods and reference food at different intervals of time along with their fasting blood glucose level. A steady increase in blood glucose level was evident after the ingestion of test foods and glucose at 30 min. After completion of 30 min interval there was slow decline in blood glucose content for test foods in comparison with reference food. The mean glycemic index for all the test foods along with the reference glucose is shown in Fig. 2. The glycemic index was found to be 53, 37 and 48 for *roti*, *dosa* and *dumpling* respectively. All the developed products showed the low glycemic index, it might be due to the inclusion of functional ingredients in millet based food mix. Consumption of finger millet based diets resulted in significantly lower plasma glucose levels, mean peak rise, and area under curve which might have been due to the higher fiber content of finger millet compared to rice and wheat (Lakshmi and Sumathi 2002). As soybeans are common protein substitutes as this is high in lysine, leucine, isoleucine, phenylalanine, calcium, and phosphate, all of which have been shown to aid in increasing glycemic control and insulin sensitivity (Chiu et al. 2018; Pathak 2014). Controlling of postprandial glycemia results in the per cent reduction of glycated haemoglobin (HbA1c) level (Esposito et al. 2004). In the present study the postprandial glycemic response was lower for test foods compared to reference which would be beneficial for diabetics to maintain normal glycated haemoglobin. Among three products *dosa* had lowest glycemic index as compared to that of *roti* and *mudde*. *Dosa* preparation takes lesser time as compared to roti and mudde as the cooking time increases the breakdown of starch increases which might be the reason for low GI value of dosa compared to other two products. The application of heat, moisture and

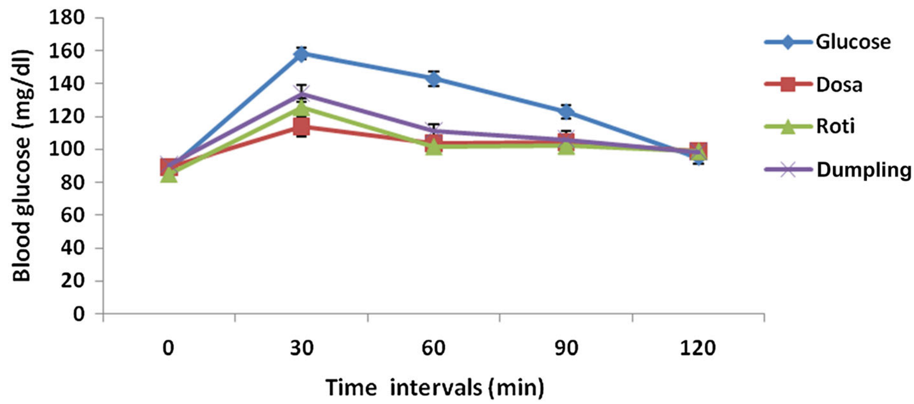

Fig. 1 Mean blood glucose response of millet based food mix products

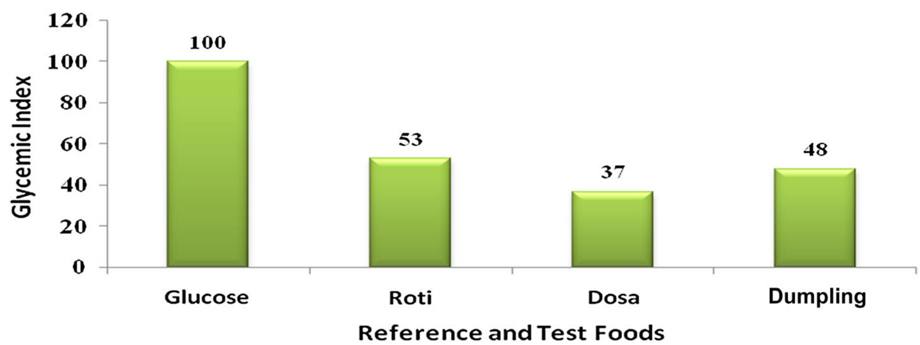

Fig. 2 Glycemic index of millet based food mix products in comparison with reference (glucose)

cooking time affects the starch granules and has significant effect on the GI. It has been demonstrated that heat processing altered the starch content and digestibility of the millet (Ugare 2008). In the present study the *dosa* batter was not fermented instead instantly mixed and prepared, which would also be one of the contributing factors for lowered GI as fermentation leads to breakdown of complex carbohydrates. Similar findings were reported by Narayanan et al. (2016) for millet-based *dosa* which showed the significant reduction in the postprandial blood glucose levels. Vijayakumar and Jemima (2011) also reported the low glycemic value for *dosa* prepared from composite mix prepared by using the millets. All the three test products under the study were found to be of low glycemic index category with GI value < 55 as accordance with the classification of Brand et al. (2009). The developed products in the study with relatively lower glycemic index indicate them as preferable option for the management of diabetes mellitus.

Glycemic load of developed food products for per serving weight is as presented in Table 3 along with the raw and cooked weight. Among the developed products glycemic load of *dosa* (11.05) was comparatively lower than that of *roti* and *dumpling* with the value of 18.09 and 18.43 respectively. The foods with glycemic load < 10 are considered as low, > 10 to < 20 are medium and > 20 are considered as high GL foods (Prasad et al. 2015). The glycemic loads of developed products were comparatively lower than the other traditional products like millet based upma developed by Yadav et al. (2013). Impact of dietary intervention on FBS and HbA1c in selected pre diabetic is presented in Table 4. Results revealed the significant reduction of FBS (120.50 ± 18.73 to 97.81 ± 20.00) and HbA1c (6.14 ± 0.30 to 5.67 ± 0.40) in experimental group and were non-significant among the control group indicating the positive effect of dietary intervention on pre diabetic subjects. Similar finding was also reported by Jali et al. (2012) on diabetic subjects. Salas-Salvado et al. (2011) also reported the lowering risk of plant-based food in diabetes.

Conclusion

Consideration of glycemic index and glycemic load concept in the diet therapy is beneficial in reducing the rising incidence of diabetes in a developing country like India. Millets being region specific food in Karnataka along with locally available low glycemic pulse and vegetables in the mix would be a cost effective dietary option for diabetes. Diabetic food mix being rich source of dietary fibre aids in slow release of glucose and being a rich source of phytochemicals will be beneficial in prevention of cells damage due to the formation of free radicals. Further the mix can be

Table 3 Glycemic load of millet based mix products

Products	One serving weight (raw)	One serving weight (cooked)	Serving size	Glycemic load/serving
Roti	80	140	Medium size (2 no.)	18.09
Dosa	70	137	Medium size (2 no.)	11.05
Mudde	90	265	Medium size (1 no.)	18.43

Table 4 Effect of dietary intervention on FBS and HbA1c

Clinical measures	Experimental group (n = 15)			Control group (n = 15)		
	Pre	Post	'*t*' value	Pre	Post	'*t*' value
FBS(mg/dl)	120.5 ± 18.73	97.81 ± 20.00	6.88**	106.93 ± 8.84	102.81 ± 18.00	-0.80^{ns}
HbA1c	6.14 ± 0.3	5.67 ± 0.4	5.19**	6.46 ± 0.39	6.65 ± 0.4	-2.45^{ns}

**Significant at $P \leq 0.01$

explored for preparation of other traditional recipes for day to day use which would be beneficial for the management of diabetes. The results suggested that developed millet-based food mix had potential role in the lowering the FBS and HbA1c indicating the preferable option of such food mix in diabetics.

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