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Postprandial Glycaemic response of kodo millet (*Paspalum scrobiculatum*) *upma* in comparison to wheat *upma* in Normoglycaemic subjects

Roopa B Patil, Vijayalaxmi KG and Vijayalakshmi D

Abstract
Glycemic index (GI) is an important tool used in treating people with diabetes and millets including kodo contains a high proportion of complex carbohydrate, dietary fiber and possess low to medium GI which helps in lowering blood glucose response among diabetic patients. Hence the present study was undertaken to develop kodo millet *upma* and to assess the postprandial glycaemic response of kodo millet *upma* in comparison to a wheat *upma* in normal healthy volunteers. Kodo millet *upma* was standardized by incorporating kodo millet grits with wheat semolina at 50% (KUT1), 75% (KUT2), and 100% (KUT3) and control *upma* was prepared from 100% wheat semolina (control upma). Among the variations highest scores for appearance, colour, flavour, texture, taste and overall acceptability were recorded for 50 per cent kodo millet grits incorporated *upma* and hence was selected for the development of kodo millet *upma* mix evaluated for post prandial glycaemic response. The mean peak value of test *upma* (kodo millet *upma*) was 107.2 mg/dL which was significantly lower ($p< 0.05$) than the reference white bread (126.3mg/dL) and control *upma* (110.9 mg/dL). Test food was effective in reducing the mean blood glucose levels at 30 and 60 minutes (107.2g/dL and 105mg/dL) compared to standard (126.3 and 118.1mg/dL respectively) and control *upma* (110.9 and 107.1mg/dL respectively). Control and test *upma* had the glycemic index of 61.11 and 59.82 when compared with the standard food white bread (100). Both control and test *upma* can be classified under moderate glycemic index food. Glycemic load of control *upma* (30.55) and test *upma* (29.99) were classified under high glycemic load (>20). However test *upma* classified under high glycemic load, showed slightly lower values compared to control *upma*. Thus study concluded that by incorporating kodo millet in daily diet help diabetes to reduce blood glucose response.

Keywords: Kodo millet upma, Glycemic index, Glycemic load

Introduction
Millets are grasses with small seeds that are hardy and grow well in dry zones as rain-fed crops. The word millet is derived from the French word "mille" which means thousand, implying that a handful of millet contains thousands of grains (Taylor and Emmambux, 2008) [2]. The edible component of millet kernel is the rich source of phytochemicals, like dietary fiber and polyphenols (0.2-0.3%). Millets also contribute to antioxidant activity with phytates, polyphenols and tannins present in it having important role in aging and metabolic diseases and hence are termed as “nutri-cereals” (Bravo, 1998) [3].
The kodo millet (*Paspalum scrobiculatum*) is one among the minor millets also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass. The local names of kodo varies from region to region and it is called as Harka in Kannada. Kodo millet is rich source of fiber (9%), as compared to rice (0.2%) and wheat (1.2%). Kodo millet contains carbohydrates 66.6g and energy 353 Kcal per 100g, when compared to other millets. Kodo millet can help diabetics and even the obese due to it’s low carbohydrate content and slow digestibility (Deshpande *et al*., 2015) [4]. A fast paced urban lifestyle, increasing dominance of nuclear family structure, rising disposable income, convenience of use have made RTE foods popular. Provision of such RTE foods based on nutritious grains such as millets would be more meaningful in the modern times in the management of life style disorders (Takhellamban and Chimmad, 2015) [6]. Rapid urbanization, industrialization and consequent changes in eating habits of people have led to development of instant dry mixes and ready-to-eat convenience foods. *Upma*, a popular breakfast of south Indian origin, is traditionally made from wheat semolina. Usually it requires 15-25 min to prepare a fresh each time depending on quantity to be cooked at household level.

Convenience mixes reduce the time for preparation by eliminating several steps of cooking. Premavalli *et al.* (1987) developed an instant wheat semolina based *upma* mix, which could be reconstituted within 4–6 min in boiling water and well accepted by the consumers. Glycemic index is an important tool used in treating people with diabetes (Brand-Miller, 2003) [7], cardiovascular disease management, and weight regulation programs (Pawlak *et al*., 2002) [8]. Millets including kodo contain water soluble fiber and this property may be utilized for maintaining or lowering blood glucose response among diabetic and CVD patients. Glycemic load (GL) representing both quality and quantity of carbohydrate in a food and allows comparison of the likely glycemic effect of realistic portion of the different foods. In this context RTC/RTE millet mixes are gaining importance. Hence the present study was undertaken to develop RTC kodo millet *upma* and to assess the postprandial glycaemic response of kodo millet *upma* in comparison to a wheat *upma* in normal healthy volunteers.

Materials and Methods

Procurement of raw materials

Kodo millet was procured from the local farmers of Gopalanahalli of Chikkanayakanahalli taluk of Tumkur district of Karnataka, India. The grains were cleaned and dehulled in Millet Processing unit of Farmers Grower's Association, Gopalanahalli of Tumkur district. The de-hulled kodo millet was converted into grits (semolina) using a flour mill by adjusting clearance between the rotating discs and the obtained semolina was passed through flour sieve to get flour free semolina of uniform size

Formulation of Kodo millet upma

Kodo millet *upma* was standardized by incorporating kodo millet grits with wheat semolina at 50% (KUT1), 75% (KUT2), and 100% (KUT3) and control *upma* was prepared from 100% wheat semolina (KUC). Sensory evaluation of the control and all the variations was done with the help of nine point hedonic scale by a panel of twenty one semi trained judges.

Ready to cook (RTC) Kodo millet millet *upma* mix

The kodo millet grits (50g) and wheat semolina (50g), total of 100 g mixed semolina were roasted in stainless steel on flame with constant stirring till the roast attained 150 ± 3 °C and started to give characteristics aroma and colour of a cooked product. Oil (15 mL) was heated (180 ± 5 °C) in a pan and bengal gram dhal (5 g), black gram dhal (5 g), mustard seeds (2 g), cumin seeds (2 g), dehydrated vegetables (cleaned, washed, peeled blanched for 3-5 minutes and dried in tray drier at 60ºC for 12 to 14 hours) green chillies (1.25 g), curry leaves (0.5g), onion (7.5g), carrot (5 g), Beans (5g), peas (5g), coriander (1.25g) were shallow fried (Yadav and Sharma, 2008). Roasted kodo millet grits and wheat semolina was added in the pan and mixed properly with oil. Salt (3 g) was added to the contents of the pan. For control upma mix KUC 100% wheat semolina were used.

Method of preparation of RTC *upma* mix

Dry mixes of kodo millet based *upm*a were prepared by reconstituting one measure of kodo millet *upma* mix with three measured amount of water and stirred on low flame until the desired constituency was attained (started to leave the pan)

Nutrient composition of upma mixes

All analysis were done by following the AOAC (1980) official protocols. Moisture was determined from sample weight loss after drying at 110° C for 4 h. Protein (g) content was determined by Kjeldahl method. The Soxhlet method was used for total fat (g) determination. Crude fiber was estimated by treatment of sample first with acid and subsequently with alkali. The loss in weight was the crude fibre content. Carbohydrate and energy by difference method. Ash by muffle furnace, micronutrients (mg) iron, zinc and copper by using Atomic Absorption Spectrophotometer and calcium and magnesium by titration method. All samples were analyzed in triplicates.

Glycemic index study

The glycemic index is defined as the incremental area under the blood glucose response curve of a 50g carbohydrate portion of test food expressed as a per cent of the response to the same amount of carbohydrate from a standard food taken by the same subjects (FAO/WHO, 2003) [9].

Study subjects: Ten healthy volunteers who were clinically normal and normoglycemic, aged between 21 to 35 years were selected from Krishi Vigyana Kendra, Konehalli, Tumkur, district. Informed consent was taken from all study subjects after explaining about methods of study.

Anthropometric measurements: All the anthropometric measurements were taken following the standard techniques (WHO, 2004). Height and weight were measured to the nearest 0.1 cm and 0.5 kg, respectively, using an anthropometric rod, and standard weight scale, respectively. Minimum waist (WC) and maximum hip (HC) circumferences were measured to the nearest 0.1 cm using a tape measure.

Standard food: After fasting for 10-12 h, subjects arrived to the laboratory at 8 am in the morning and blood samples were obtained. Fasting blood sugar was estimated and postprandial blood sugar was taken at 30, 60,90 and120 min interval after consumption of measured quantity of white bread (50 g of carbohydrate).

Test foods: Controll *upma* was standardized in lab using 100 per cent wheat semolina and kodo *upma* was developed by incorporating kodo millet grits at 50 per cent level. Fifty g of available carbohydrate for each test foods was calculated from the results of proximate analysis and the measured portion of food was served to the subjects.

Analysis of blood glucose in the subjects: All subjects for investigation fasted overnight (10-12 h). Capillary blood glucose levels were taken at the fasting level and subjects were immediately presented with the white bread or control *upma*, kodo millet *upma* were required to consume the foods within 10 minutes. Their blood sample was collected through finger prick using a hypodermic needle or lancets. Each blood sample was inserted into a calibrated glucometer (ACCU CHEK-Active/ one touch) which gave direct reading after 45 seconds based on glucose oxidase assay method. The determination of blood glucose was taken at different intervals *i.e.* 0 (fasting) min, 15, 30, 45, 60, 90 and 120 min during the 2 hour study visit after feeding the reference food and test foods to the subjects. To assess the glycemic index of all samples ensuring a wash out period of one week between the samples.

Computation of Glycemic Index (GI): Blood glucose response curves will be plotted for both glucose and test food. Blood glucose area under curve (IAUC) was calculated using the trapezoidal rule.
Glycemic index was calculated by using the following formula:

$$GI = \frac{\text{IUAC of the test food}}{\text{IAUC for reference food}} \times 100$$

Glycemic load
Glycemic load (GL) was estimated indirectly by multiplying the amount of carbohydrate contained in a serving size with GI value of specific food divided by 100 (Salmeron *et al.*, 1997) [10].

$$GL = \frac{\text{GI x carbohydrate net content per portion in g}}{100}$$

Ethical Matters
Informed consent was taken from all study subjects after explaining about methods of study

Results and Discussion
Development of product kodo millet *upma* and sensory evaluation: *Upma* is an indigenous traditional breakfast food in mostly southern Indian cuisine, which is boiled semolina made from wheat/rice/millets with added pulses, condiments and spices. Kodo millet *upma* was standardized by incorporating kodo millet grits with wheat semolina at 50% (KUT1), 75% (KUT2), and 100% (KUT3) and control *upma* was prepared from 100% wheat semolina. The mean sensory scores of kodo millet *upma* is presented in Table 1.
Control *upma* had the highest scores for all the sensory parameters. Among the variations highest scores for appearance, colour, flavour, texture, taste and overall acceptability (7.38, 7.26, 7.71,7.57, 7.90 and 8.05 respectively) were recorded for 50 per cent kodo millet grits incorporated *upma* KUT1. However, the difference in scores for all the sensory parameters among the variations was found to be statistically significant ($p < 0.05$). Same is depicted in Fig. 1. Balasubramanian *et al.* (2014) formulated pearl millet based *upma* dry mix who noted the sensory score of upma mix for taste varied from 6.5 to 8.1, mouth feel 6.7–8.0, overall acceptability 6.7–8.1. Dhumketi *et al.* (2018) revealed that sensory parameters of *upma* formulation (UM3) prepared from 65% foxtail millet, 30% semolina and 5% soy had the highest in terms of colour and appearance (8.55), taste (8.40), flavour (8.40), texture (8.50), after taste (8.30) and overall acceptability (8.43).

Table 1: Mean sensory scores of kodo millet *upma*

Products	Sensory attributes					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
KUC (control)	8.38	8.33	8.24	8.19	8.38	8.45
KUT1 (50%)	7.38	7.26	7.71	7.57	7.90	8.05
KUT2 (75%)	7.14	7.14	7.64	7.42	7.60	7.26
KUT3 (100%)	6.91	6.86	7.05	7.14	6.88	6.93
F-value	*	*	*	*	*	*
S.Em±	0.155	0.14	0.16	0.13	0.16	0.13
CD at 5%	0.437	0.40	0.46	0.37	0.44	0.38

*Significant at 5%
KUC – *upma* control, KUT1-Kodo millet *upma* (50%),
KUT2-Kodo millet *upma* (75%), KUT3-Kodo millet *upma* (100%)

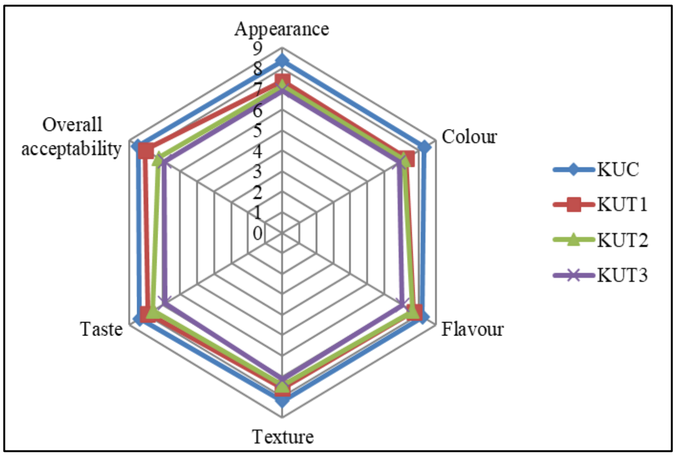


Fig 1: Mean Sensory scores of kodo millet *upma*

Nutritional composition of RTC *upma* mixes
Table 2 shows nutrient composition of control and kodo millet *upma* mix per 100g. It was found that the moisture and fat content were 6.27 per cent ± 0.10 and 7.22 g ±0.09 in control *upma* mix and 7.92 per cent ± 0.06 and 7.90g ±0.10 in kodo millet *upma* mix respectively. Protein, Ash and crude fibre content of kodo millet based *upma* mix were found to be higher (15.13 g ± 0.70, 1.59g ± 0.10 and 15.42g±0.46 respectively) than the control *upma* mix (13.82g ± 0.05, 1.55g±0.12 and 10.61g±0.43respectively). Control *upma* mix had relatively higher carbohydrate content (60.59g±0.69) compared to kodo millet *upma mix* (52.03g±1.01). Calcium, magnesium and iron content were also found to be higher in control *upma* mix (63.66mg±0.57, 157.00mg±1.00and 4.29mg±0.21respectively) compared to kodo millet *upma* mix (46.66mg±1.52, 109.66mg±0.57 and 3.54mg±0.09 respectively). However zinc, copper and manganese content were 1.87mg ±0.11, 0.44mg±0.08 and 0.52mg±0.04 respectively in control *upma* mix and 1.93mg±0.03, 0.42mg±0.03 and 0.57mg±0.06 respectively in kodo millet *upma* ix.
The findings of the study are in accordance with the results obtained by Rodge *et al.* (2018) [13] who reported that the proximate composition of instant upma mix prepared from foxtail millet and garden cress had moisture content varied from 6.15 to 7.62%, protein content 11.30 to 13.84%, fat 7.30 to 16.80%, fiber 3.90 to 4.31% ash 2.89 to 4.43%, carbohydrate content 55.16 to 64.07% and energy value 371.06 to 427.50 kcal/100g.

Table 2: Nutrient composition of the best accepted RTCkodo millet *upma* mix

Nutrients	*Upma* mix per 100 g	
	Control *upma* mix (KUC)	Kodo *upma* mix (KUT)
Moisture (g)	6.27±0.10	7.92±0.06
Fat (g)	7.22±0.09	7.90±0.10
Protein (g)	13.82±0.05	15.13±0.70
Ash (g)	1.55±0.12	1.59±0.10
Crude fibre (g)	10.61±0.43	15.42±0.46
*Carbohydrate (g)	60.59±0.69	52.03±1.01
*Energy (Kcal)	362.67±1.9	339.78±1.74
Calcium (mg)	63.66±0.57	46.66±1.52
Magnesium (mg)	157.00±1.00	109.66±0.57
Iron (mg)	4.29±±0.21	3.54±0.09
Zinc (mg)	1.87±±0.11	1.93±0.03
Copper (mg)	0.44±0.08	0.42±0.03
Manganese (mg)	0.52±±0.04	0.57±0.06

Values are mean of triplicates ± SD, *Carbohydrate-difference method *Energy-computation

Glycemic index of kodo millet *upma* mix

In the present study total of ten healthy volunteers (7 male and 3 famale) in the age group of 23-34 years, with a normal BMI and WHR (Table 3) were selected based on inclusion and exclusion criteria explained in the methodology. Food habits and fitness of the participants is depicted in the Table 4. Eighty per cent of the participants were non vegetarian followed by vegetarian (10%) and ova vegetarian (10%). Cent percent participants have the meal pattern of 3 meals/day. With regard to fitness habits, most of the participants excersise daily (50%) followed by walking (40%) and playing (20%) & jogging (20%).

Table 3: Anthropometric measurements of volunteers participating in the study

Parameters	Participants		Normal range
	Male	Female	
Age 23-34 years	7	3	
Weight (kg)	70.14±6.54	56.93±5.01	
Height (cm)	170±4.39	153.66±5.50	
BMI (kg/m^2)	24.47±2.50	24,14±1.84	<25
Waist circumference (cm)	84.14±8.27	75±4.35	
Hip circumference (cm)	95.41±4.25	95±5	
WHR	0.85±0.05	0.78±0.03	<0.95 Male <0.80 Female

Values are mean of triplicates ± SD

Table 4: Food habits and fitness pattern of the participants

Parameters	Participants	Total	Percentage
Food habits			
Vegetarian	1	1	10
Ovo vegetarian	1	1	10
Non vegetarian	8	8	80
Meal pattern			
2 meals/day	0	0	0
3meals/day	10	0	100
4 meals/day	0	0	0
Fitness deatails *			
Walking	4	4	40
Playing	2	2	20
Jogging	2	2	20
Excersise	5	5	50
Yoga	1	1	10

***Multiple responses**

Glycemic index study was carried out for the foods standard, control and kodo millet *pulav*, *upma* and *roti* among the ten healthy volunteers. A 50g of available carbohydrate from standard, control and test foods was given to participants at the interval of one week. The test foods were consumed in random order between the reference food sessions, with at least one week gap between measurements. Seven GI were calculated as mentioned in WHO (1998).

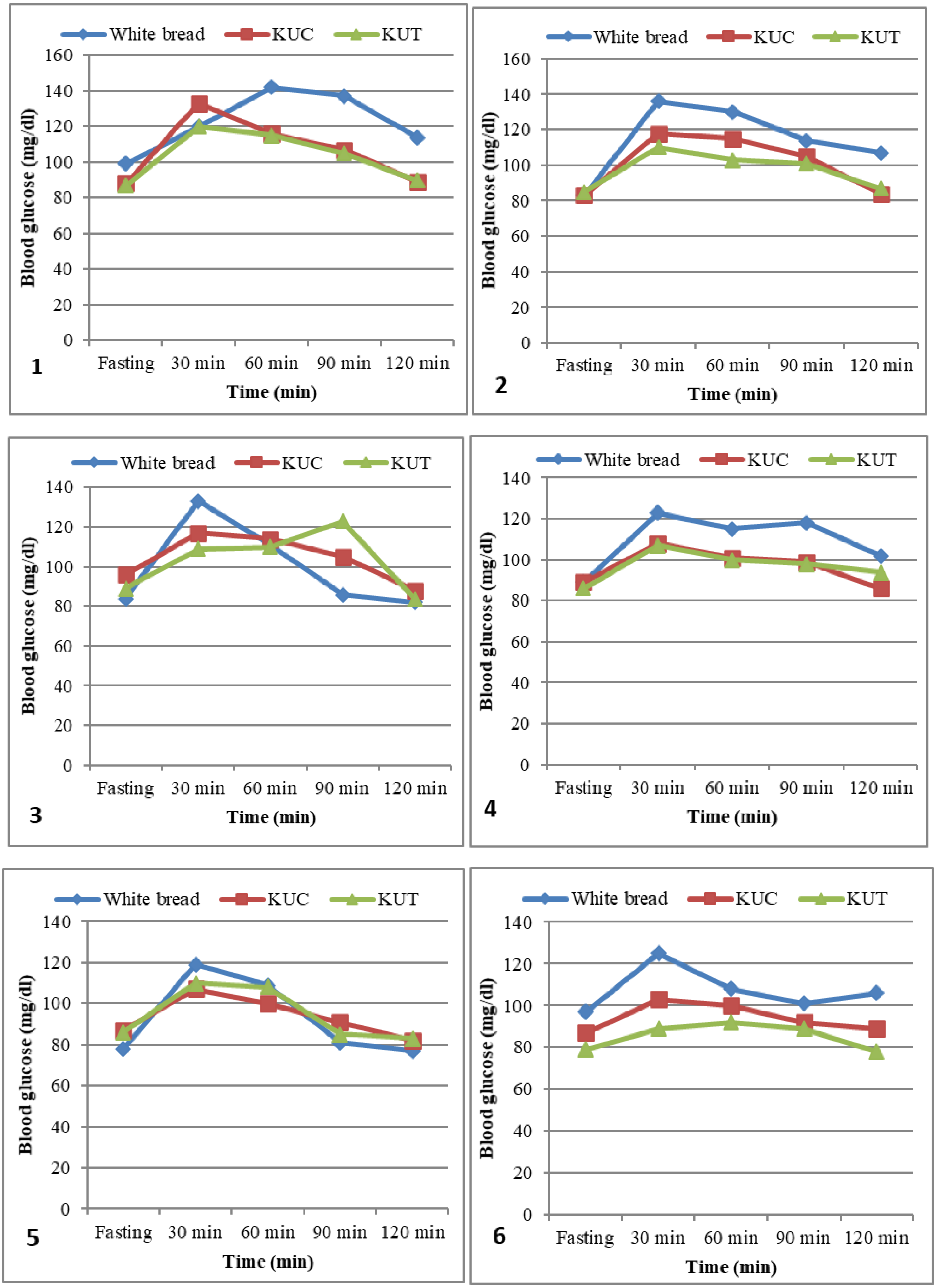
The mean blood glucose levels for the test foods (control and test *upma*) in comparison with standard (white bread) food among 10 normal volunteers is depicted in Table 5 and Fig. 3 and also individual blood glucose response after consuming standard and test foods are shown in Fig. 2. The fasting blood glucose levels ranged from 84.7 to 86.4 mg/dL and no significant difference was observed in fasting blood glucose level among the standard, control and test food groups. A steady increase in mean blood glucose was observed after consuming white bread, control and test *upma* and the peak was reached at 30 min. The mean peak value of test *upma* was 107.2 mg/dL which was significantly lower ($p< 0.05$) than the reference white bread (126.3mg/dL)) and control *upma* (110.9 mg/dL). Test food (kodo millet *upma*) was effective in reducing the mean blood glucose levels at 30 and 60 minutes (107.2g/dL and 105mg/dL) compared to standard (126.3 and 118.1mg/dL respectively) and control *upma* (110.9 and 107.1mg/dL respectively). Significant differences were observed at 30 min and 60 minutes between standard and control *upma* and also between standard and test *upma* and no significant difference was observed between control and test *upma*. The difference in the mean blood glucose levels of standard and control *upma* was non significant at all time intervals (Fasting to 120 minutes) and also no significant difference was observed among standard, control and test *upmas* at fasting, 90 minutes and 120 minutes time interval

Table 5: Blood glucose (mg/dL) levels after ingestion of standard, control and test foods (u*pma*)

Foods	Carbohydrate source	Blood glucose levels (Mean ± SD)					F test	S.Em±	CD at 5%
		Fasting	30 min	60 min	90 min	120 min			
Standard	White bread	86.3^a	126.3^a	118.1^a	103.9^a	92.4^a	*	4.04	11.54
Test	Control *upma*	86.4^a	110.9^b	107.1^b	98.3^a	85.2^a	*	2.39	6.84
	Kodo millet *upma*	84.7^a	107.2^b	105^b	97.1^a	84.9^a	*	2.50	7.15
F test		NS	*	*	NS	NS			
S.Em±		1.74	2.79	3.08	4.33	2.86			
CD at 5%		-	8.13	8.98	-	-			

*Significant, NS- Non significant

Note: Means in the same column followed by the same lowercase superscript letters are not significant and bearing different superscripts are significantly different.


White bread
KUC
KUT
Blood glucose (mg/dl)
Time (min)
Fasting
30 min
60 min
90 min
120 min
1
2
3
4
5
6

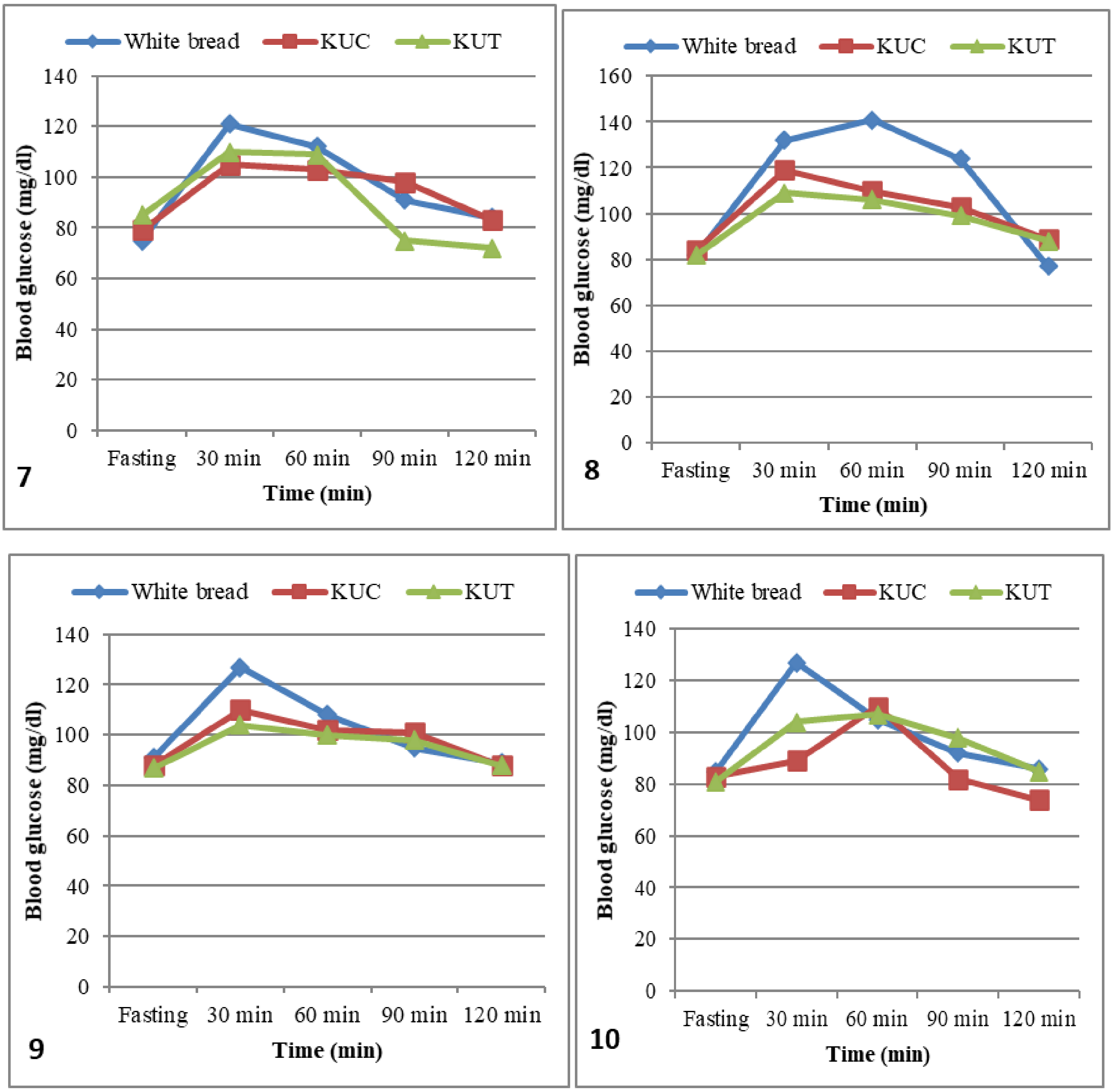


Fig 2: Blood glucose response after consuming white bread, control *upma* and kodo millet *upma* in subjects (1-10)

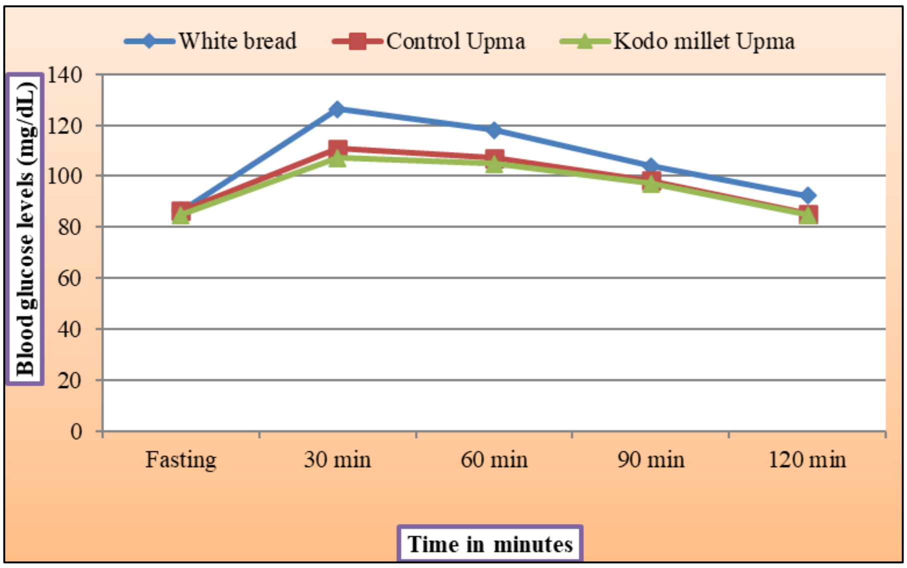


Fig 3: Mean blood glucose (mg/dL) levels after ingestion of standard and test foods (*upma*)

Glycemic index (GI) and glycemic load (GL) of the test foods in comparison with standard food is shown in Table 6. Control and test *upma* had the glycemic index of 61.11 and 59.82 when compared with the standard food white bread (100). Thus both control and test *upma* can be classified under moderate glycemic index food. Glycemic load of control *upma* (30.55) and test *upma* (29.99) were classified under high glycemic load (>20). However test *upma* classified under high glycemic load, showed slightly lower values compared to control *upma*. Pathak and Srivastava (1998) [14] developed foxtail millet mixes in combination with fenugreek seeds and legumes for different food products such as *dhokla*, *upma* and *laddu* revealed that the glycemic index of the three products in the normal subjects as 35 for *dhokla*, 17.6 for *upma* and 23.5 for *laddu*.

Table 6: Glycemic index (GI) and glycemic load (GL) of the standard and test foods (*upma*)

Aspects	Standard	Test food (*upma*)	
		Control	Test
Glycemic index (GI)	White bread=100	61.11	59.82
Glycemic load (GL)	50	30.55	29.91
Glycemic index classification	High (>70)	Moderate (55-70)	Low (<55)
Glycemic load classification	High (>20)	High (>20)	High (>20)

*Significant, NS- Non significant

Conclusion

Minor millets play important role in achieving food and nutrional security and also address life style disorders. The RTC kodo millet mix was developed from the best accepted variation (50%). Except carbohydrate and energy content of all macro and micro nutrients were higher in kodo millet based *pulav*, *upma* and *roti* mixes compared to control *pulav*, *upma* and *roti* mixes. Kodo millet *upma* significantly ($p<$ 0.05) reduced blood glucose level at 30 and 60 minutes (107.2g/dl and 105mg/dl) effectively and had the moderate GI (59.82) and glycemic load (29.91) values were lower compared to the standard white bread (50) and control *upma* (30.55).

Acknowledgement

I would like to extend my thanks to co-workers and also the study subjects who participated in the GI study because withought their co-operation it had not been possible and I also render my sincere gratitude for the institute ICAR Krishi Vigyan Kendra, Konehalli, Tiptur, Karnataka.

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