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Carbohydrate profiling & glycaemic indices of selected traditional Indian foods

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***Background & objectives*: Consumption of high glycaemic index (GI) food is associated with a high risk for diabetes. There is a felt need to understand the GI of common Indian traditional foods using standard GI protocols. The present study was aimed to analyse the carbohydrate profile of common traditional Indian food preparation and to determine their GI using standardized protocols.**

***Methods*: Twelve food preparations made of millets, wheat, maize and pulses were evaluated for nutrient composition including detailed carbohydrate profiling and tested for GI in healthy volunteers using standard methodology. Capillary blood glucose responses for the test foods containing 50 g available carbohydrates were recorded and compared to the reference food (50 g glucose). GI was calculated from the incremental area under the curve (IUAC) for the test and reference foods.**

***Results*: Available carbohydrate content of the food preparations ranged between 13.6 and 49.4 g per cent. Maize *roti* showed the highest total dietary fibre (7.5 g%). White chick pea '*sundal'* showed highest resistant starch content (3.95 g%). Amongst the 12 test foods, five fell in the high GI category (finger millet balls, sorghum, pearl millet and maize *roti*), four in the medium GI category (sorghum *idli*, wheat *dosa*, *methi roti* and *adai*) and three in the low GI category (broken wheat *upma*, white peas *sundal* and white chick peas *sundal*).**

***Interpretation & conclusions*: Merely being a whole grain-based food does not qualify for a lower GI. The method of processing, food structural integrity and preparation could influence the GI. The type and quality of fibre are important than the quantity of fibre alone. Judicious planning of accompaniments using low GI legumes may favourably modify the glycaemic response to high GI foods in a meal.**

Key words Carbohydrates - diabetes - glycaemic index - millets - resistant starch - structural integrity - whole grains

Carbohydrates form the major source of energy in Indian diets. The quantity and quality of dietary carbohydrates are important as carbohydrates with high glycaemic index (GI) and glycaemic load

(GL) have been found to be associated with the risk of non-communicable diseases[1,2]. Indian culinary preparations are diverse region specific with unique carbohydrate profile and glycaemic properties. In addition, carbohydrate constituents in different foods may undergo modification/transformation during processing/food preparation, all of which could synergistically determine post-meal glycaemic response to the food[3].

Physiologically, dietary carbohydrates are broadly classified as available (glycaemic carbohydrates, which are metabolizable and raise the blood glucose upon consumption) and unavailable carbohydrates (which are not digested and may get fermented in the colon). Most of the dietary fibres and resistant starch (RS) are unavailable carbohydrates[4]. The glycaemic property (carbohydrate quality) of a food is assessed by the GI, a relative ranking system, which classifies carbohydrate-containing foods based on their ability to raise blood glucose levels upon ingestion as against reference food (glucose). This GI system has been recommended for making healthier carbohydrate food choices by the Food and Agriculture Organization (FAO)[4,5]. Glycaemic response of foods is dependent on a multitude of factors such as food form, composition (nature and content of carbohydrates, presence of RS, dietary fibre, protein and fat), method of preparation and processing[3], and is unique for each food. RS, presents in some of the foods or formed during processing, is resistant to digestion by digestive enzymes and may help in reducing the glycaemic response and glycaemic load (GL) of diets and also in improving insulin sensitivity[6].

The prevalence rates of diabetes are alarmingly high in Asian Indians. Almost 7.3 per cent of the Indian adult population is affected with diabetes and 10.3 per cent can be classified as having pre-diabetes[7]. This is partly linked to faulty dietary patterns in Asian Indian diets[8], which may mediate type 2 diabetes (T2D) through insulin resistance and beta cell exhaustion. Foods with lower GI are recommended for Asian Indians[9]. It is necessary to understand the carbohydrate profile and GI of commonly consumed foods to make judicious food choices. Although there are some studies on the GI of Indian foods[10], it is difficult to draw conclusions from these owing to the variable methodologies adopted, and many of the studies report GI based on *in vitro* methods, which may not be a precise indicator of the GI determined through *in vivo* methods. In addition, there is no information on the carbohydrate profile of cooked/processed Indian foods in the National Food Composition Table. Thus, this study was conducted to analyse the carbohydrate profile of different commonly consumed traditional Indian food preparations by standard chemical analytic methods and to further determine the GI using internationally validated protocols[4,12,13].

Material & Methods

The foods taken up for the study (Table I) were prepared in the Institutional test kitchen for GI testing and for nutrient evaluation including carbohydrate profiling (available carbohydrate, dietary fibre and RS contents). Available carbohydrates include free sugars and starch, those that are digested and absorbed by the human small intestine and are glucogenic.

The method of preparation is shown in Table I.

Nutrient evaluation including carbohydrate profiling: Freshly cooked foods were homogenized and were taken up for nutrient evaluation (moisture, protein, fat and ash) using standard AOAC methods [moisture (method 925.10, 2008), ash (method 923.03, 2005), protein (method 984.13, 2005) and fat (method 920.39, 2005)]. The dietary fibre content, available carbohydrates and RS contents were estimated by enzymatic methods using K-ACHDF 06/14 Megazyme kit (Ireland) which is based on the AOAC Official Method 991.43 and AACC Method 32-07.01.

Glycaemic index (GI) testing: Selected foods belonging to four different categories were taken for GI determination:

1. Millet-based preparations [finger millet balls, sorghum *roti*, sorghum *idli* and pearl millet (bajra) *roti]*
2. Wheat-based preparations (wheat *dosa*, *methi paratha*, broken wheat *upma* and wheat flakes *chivda*)
3. Maize-based preparation (*roti*)
4. Pulse-based preparations (white peas *sundal*, white chick peas *sundal* and *adai*).

This study was conducted in the Madras Diabetes Research Foundation, Chennai, India, during the years 2010-13 following the internationally recognized GI protocol[4] which is based on the guidelines recommended by the International Dietary Carbohydrate Task Force for GI Methodology[12,13]. The study was approved by the Institutional Ethics

Table I. Nutrient composition (g/100 g), carbohydrate profile of foods studied

Foods	Description	Method of preparation	Moisture (g/100 g)	Fat (g/100 g)	Protein (g/100 g)	Ash (g/100 g)	Available carbohydrates (g/100 g)	TDF (g/100 g)	RS (g/100 g)
Millet-based preparations									
Finger millet stiff porridge (ball)	Stiff porridge rolled into balls	A soft ball prepared by boiling finger millet flour in water	64.27	0.47	3.9	1.51	26.71	5.42	0.7
Sorghum *roti* (Indian bread)	Unleavened bread	Unleavened flat breads made from sorghum flour and salt	43.47	1.05	4.12	1.55	49.35	7.0	0.69
Sorghum *idli*	Fermented steamed cake	Steamed cake made from fermented batter of sorghum grits and decorticated black gram (3:1, sorghum-to-pulse)	62.15	0.75	4.17	1.25	27.62	4.5	1.87
Pearl millet *roti* (Indian bread)	Unleavened bread	Unleavened flat breads made from pearl millet flour and salt	33.59	2.23	6.63	1.64	47.82	7.05	1.0
Wheat-based preparations									
Wheat *dosa*	Crepe	Thin crisp pancake made from wheat flour batter (with mustard, asafoetida and curry leaves seasoning)	52.36	1.31	6.55	1.8	32.46	6.28	1.95
Broken Wheat *upma*	Boiled broken wheat with seasonings	Toasting followed by boiling wheat grits in water seasoned with onion, salt and spices	61.12	4.08	4.27	1.35	26.34	5.28	3.25
Wheat flakes *chivda*	Snack	Snack made wheat flakes, dry fruits, peanuts and spices	19.68	6.84	11.25	1.97	42.83	5.28	2.45
Methi *paratha*	Unleavened bread	Unleavened flat breads made from dough made by mixing wheat flour, fenugreek leaves, curd, salt, cumin, red chilli powder, coriander powder, oil and water	27.19	7.03	10.0	2.96	42.38	10.39	0.49
Maize-based preparations									
Maize *roti* (Indian bread)	Unleavened bread	Unleavened flat breads made from maize flour salt	40.29	1.36	6.02	1.99	44.78	7.51	1.87

Contd....

Foods	Description	Method of preparation	Moisture (g/100 g)	Fat (g/100 g)	Protein (g/100 g)	Ash (g/100 g)	Available carbohydrates (g/100 g)	TDF (g/100 g)	RS (g/100 g)
			Pulse-based preparations						
White peas *sundal*	Boiled legumes with seasonings	Snack made from boiled white peas, green chillies, spices and coconut	71.19	0.42	6.73	1.73	13.55	4.88	1.28
White chickpea *sundal*	Boiled legumes with seasonings	Snack made from boiled white chickpeas, spices and coconut	58.37	2.65	8.66	1.25	22.27	6.47	3.95
Adai	Spicy pan cake	Thick type of pancake made out of a coarsely ground batter of rice, pulses and spices	49.34	2.35	7.48	2.48	32.63	6.47	2.78

TDF, total dietary fibre; RS, resistant starch

Committee. All volunteers gave informed written consent before they enrolled themselves for the study. The trial was also registered in the Clinical Trial Registry of India (CTRI/2018/04/013456). Fifteen healthy volunteers of both genders aged between 20 and 45 yr, overweight and obese with body mass index (BMI) >23 kg/m^2 were recruited for the purpose. Anthropometric measurements including height, weight and waist circumference were measured in the fasting state using standardized techniques (Table II). The participants were excluded with the BMI <22.9 kg/m^2 and had fasting blood glucose >5.6 mmol (>100 mg/dl), or if they were on a special diet, had a family history of diabetes, suffered from any illness or food allergy or were on medications. A practice test was performed on volunteers who were not familiar with blood sampling via finger-pricking so as to acquaint them with the procedure to minimize the effects of anxiety on blood glucose response. All the volunteers underwent three days of testing with the reference food and one day with the test foods in random order with at least two days gap between measurements to minimize carry-over effects.

Information on the previous day's diet (24 h recall) and physical activity was obtained to ensure that they followed the same pre-test diets and refrained from smoking and alcohol during the study period. Fasting blood samples (10-12 h overnight fast) were taken by finger prick using an automatic lancet device at −5 and 0 min before consumption of the food and the average of these two was taken as the baseline value. The volunteers were given 200 ml of water along with the test food and an extra 200 ml water was provided during the subsequent two hours. The time of first bite in the mouth was set as time 0 and capillary blood samples were taken at 15, 30, 45, 60, 90 and 120 min after starting to eat the test foods.

Available carbohydrates, proximate composition and total dietary fibre were estimated, and the test foods containing 50 g available carbohydrates were provided to the volunteers. Fifty five grams of glucose [glucose monohydrate- (Glucon-D) glucose powder, Heinz India (P) Ltd., Mumbai, India] dissolved in 200 ml of water was used as the reference food [1.1 g monohydrated glucose provides 1.0 g glucose. Hence, 55 g of monohydrate glucose (50×1.1=55) was used to get 50 g of anhydrous glucose. It was consumed at the beginning, middle and end of the test foods testing, while three test foods were consumed in random order between reference foods on different

Table II. Anthropometric features of the study participants (n=15)

Description	Mean±SD
Age (yr)	32.3±6.3
Male n (%)	7 (47.9)
Female n (%)	8 (52.1)
Height (cm)	161.3±8.9
Weight (kg)	68.3±11.6
BMI (kg/m^2)	26.2±3.8
Waist circumference (cm)	85.8±9.7
Systolic blood pressure (mmHg)	113.3±15.5
Diastolic blood pressure (mmHg)	73.9±11.5
Fasting blood glucose	91.0±9.8

SD, standard deviation; BMI, body mass index

occasions with a gap of at least two days between the measurements[13].

The GI was calculated as the incremental area under the blood glucose response curve of a 50 g available carbohydrate portion of a test food expressed as a per cent of the response to the same amount of carbohydrate from a reference food (glucose) taken by the same volunteer. The GL of the foods was arithmetically calculated by multiplying the GI (%) of the foods and the available carbohydrate content of the food per serving. Here, per serving of the food was the 50 g of available carbohydrate containing foods tested for GI.

Statistical analysis: Statistical analysis was performed using SPSS software (SPSS Inc., Chicago, IL, USA). Data were shown as mean with standard error unless otherwise stated. Participants with mean GI <2 SD (standard deviation) were considered as outliers. A total of 15 volunteers were enrolled, of whom one participant each from sorghum *roti*, maize *roti*, *adai*, wheat *dosa* and pearl millet *roti*; two participants each from wheat flakes *chivda* snack and broken wheat *upma* and three participants each from finger millet balls, *methi paratha*, white peas *sundal* and white chick peas *sundal* were removed as outliers and not considered for the present analysis. Multivariate linear regression was carried out to assess the effects of covariates – age, sex, BMI, waist circumference and previous day diet total calories on the GI of each of the test foods.

Results

In the current study, 12 different types of traditional foods prepared based on different cereals were evaluated for their nutrient composition, carbohydrate profile and GI values. The nutrient composition and also the GI values of the cooked foods varied widely. With respect to carbohydrate profile, the available carbohydrate content of the cooked foods ranged from 13.6 per cent for white peas *sundal* to 49.4 per cent for sorghum *roti*. *Methi paratha* showed the highest total dietary fibre (TDF) (10.4%), while sorghum *idli* showed the lowest TDF (4.5 g%). RS content of the foods ranged between 0.69 per cent (for sorghum *roti*) and 3.95 per cent in white chick pea *sundal*. The moisture content of the foods varied considerably depending on the preparation and ranged from 71.9 per cent for white peas *sundal* to 19.7 per cent for wheat flakes *chivda*. Wheat flakes *chivda* showed the highest protein content (11.25 g%) and *methi paratha* showed the highest fat content (7.0 g%), while finger millet ball showed the least for both (3.9 and 0.47 g%, respectively) (Table I).The demographic and clinical characteristics of the GI study participants are presented in Table II.

The mean age and BMI of GI study participants were 32.3±6.3 yr and 26.2±3.8 kg/m^2, respectively. The mean change in blood glucose concentration of high, medium and low GI foods is shown in Figure A-C. Among the 12 foods tested for GI (Table III), three fell in the low GI category and the rest in medium and high GI category. Finger millet balls (gruel) (stiff porridge or *mudde*) showed the highest GI value (98.2±5.5, IAUC 4847.6±543.7) followed by sorghum *roti* (84.1±6.7, IAUC 4502.8±701.1), maize *roti* (74.8±5.5, IAUC 3862.8±547.0), wheat flakes *chivda* (72.5±3.4, IAUC 3358.0±396.9) and pearl millet *roti* (GI= 70.1±3.0, IAUC 3801.6±483.0). It may be noted that even though these are whole grain flour-based preparations, their GI values were in higher range. The legume-based *adai* showed medium GI values 66.2±3.5 (3460.9±454.0), as did wheat *dosa* (GI=61.8±5.7, IUAC 2994.8 ± 460.2), sorghum *idli* (GI 61.3±5.1, IAUC 2871.3±315.1), and *methi paratha* (GI=60.2±6.7, IAUC 3002.4±404.7). The two whole grain legume preparations, namely white peas *sundal* and white chick peas *sundal*, showed the lowest GI values [29.8±4.2 (IAUC 1529.8±220.2) and 24.1±2.6 (IAUC 1259.1±230.6)], respectively, while broken wheat *upma* also showed low GI category food choice [51.7±7.7 (IAUC 2357.6±316.4)]. Multivariate linear regression analysis for each test foods (intercept) showed that age, sex, BMI, waist circumference and previous day dietary calories (kcal/day) of the participants did not influence the GI values of foods (Table IV). The GL of the test foods (shown in Table III)

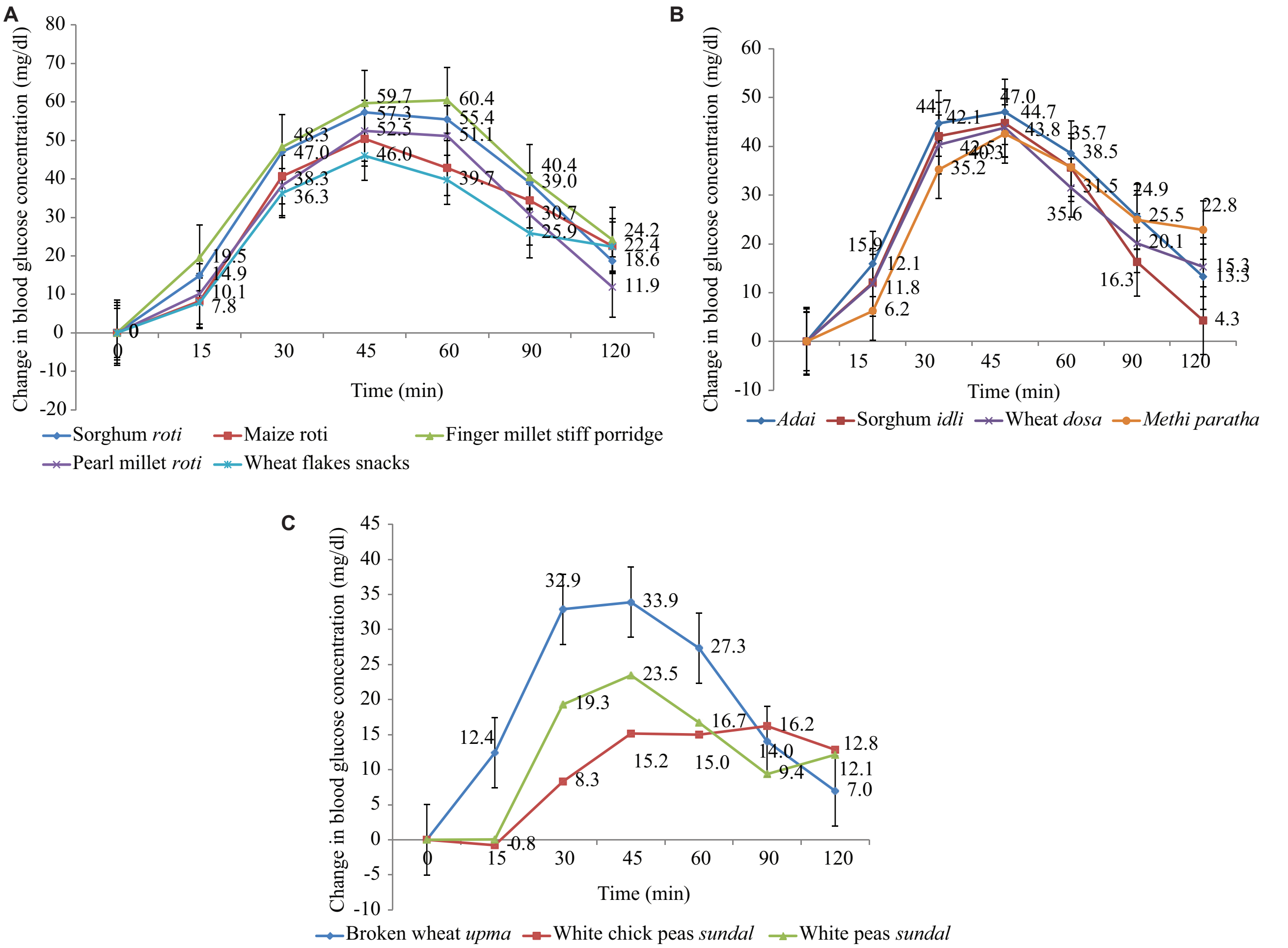

Figure. (**A**) Mean change in blood glucose concentration of high glycaemic index foods. (**B**) Mean change in blood glucose concentration of medium glycaemic index foods. (**C**) Mean change in blood glucose concentration of low glycaemic index foods.

varied between foods and ranged from as low as 12.1 for white chick peas *sundal* to as high as 49.1 for finger millet ball. The *sundal* varieties prepared from legumes showed the lowest GL (12-14), while finger millet stiff porridge and *roti* varieties showed higher GL (35-49) and by design GL correlated with GI of these foods which all had equal amount of carbohydrates (50 g).

Discussion

Our findings show that carbohydrate profile and GI of the foods widely vary and this could be attributed to factors such as inherent nature of the grains, form of food, additional ingredients used and method of preparation. Unleavened flat breads (*rotis*, *paratha*), pancakes (*dosa*, *adai*) and snacks (*chivda*) showed higher available carbohydrate values, probably due to the lower moisture levels (higher solid content) in these foods. In general, the RS content of the foods was low possibly due to the nature of processing undergone and the starch makeup. Most of the foods tested were prepared using wholegrain and contained substantial amounts of dietary fibre (4.5-7.5 g%) though not intact fibre as most of the traditional food preparations were whole meal flour-based.

Observational studies indicate that low GI diets are associated with lower risk of T2D[1,14]. Hence, it is important to understand the GI of commonly consumed foods for efficient meal planning and impart dietary advice with the focus to balance not only carbohydrate quantity but also its quality.

Some of the food processing methods are known to influence RS formation, which could decrease the GI. On the other hand, processes such as grinding are known to alter the food matrix, leading to increase in the bio-accessibility of starch, whereas the food matrix is preserved to a greater extent in the foods where grains are cooked as such[3].

Table III. Mean glycaemic index of the foods tested

Food	n	Cooked weight of the food contributing 50 g available carbohydrate	IUAC		GI		GI classification	GL#
			Mean	SEM	Mean	SEM		
Millet based preparations								
Finger millet stiff porridge (ball)	12	187.3	4847.6	543.7	98.2	5.5	High	49.1
Sorghum *roti*	14	113.9	4502.8	701.1	84.1	6.7	High	42.1
Sorghum *idli*	15	181.8	2871.3	315.1	61.3	5.1	Medium	30.7
Pearl millet *roti*	14	104.6	3801.6	483.0	70.1	3.0	High	35.1
Wheat based preparations								
Wheat *dosa*	14	154.04	2994.8	460.2	61.8	5.7	Medium	30.9
Broken wheat *upma*	13	189.82	2357.6	316.4	51.7	7.7	Low	25.9
Wheat flakes snacks (*chivda*)	13	94.6	3358.0	396.9	72.5	3.4	High	36.3
Methi paratha	12	117.9	3002.4	404.7	60.2	6.7	Medium	30.1
Maize based preparations								
Maize *roti*	14	116.1	3862.8	547.0	74.8	5.5	High	37.4
Pulse based preparations								
White peas *sundal*	12	322.6	1529.8	220.2	29.8	4.2	Low	14.9
White chick peas *sundal*	12	224.5	1259.1	230.6	24.1	2.6	Low	12.1
Adai	14	155.6	3460.9	454.0	66.2	3.5	Medium	33.1

#GL values are provided for the quantity of foods providing 50 g available carbohydrates; SEM, standard error of mean; SD, standard deviation; GI, glycaemic index; IUAC, incremental area under the curve; GL, glycaemic load

Table IV. Multivariate regression model to assess the influence of covariates (age, sex, body mass index, waist circumference and previous days diet-total calories) on glycaemic index of each test food

Foods tested for GI	Intercept (β)	*P*
Finger millet stiff porridge (ball)	183.3	0.12
Sorghum *roti*	−49.8	0.55
Sorghum *idli*	−21.7	0.80
Pearl millet *roti*	−122.6	0.13
Wheat *dosa*	−13.1	0.83
Broken wheat *upma*	62.3	0.47
Wheat flakes snacks	14.6	0.85
Methi paratha	68.8	0.46
Maize *roti*	−20.2	0.81
White peas *sundal*	7.2	0.93
White chick peas *sundal*	19.1	0.35
Adai	70.7	0.26

GI, glycaemic index

Millet-based preparations: Among the millet-based preparations, the wholegrain preparations such as finger millet balls, sorghum *roti* and pearl millet *roti* contained higher levels of dietary fibre. In the case of sorghum *idli*, incorporation of black gram and the presence of RS to the extent preserved in the form of bigger grits of sorghum used for *idli* making might have also added to the RS and DF values, but these were lower for sorghum *idli* than most of the other foods tested owing to its higher moisture content. Vaidya and Sheth[15] reported RS content of 0.9 per cent for pearl millet *roti*, which was comparable to the values observed (1.0 g%) in the current study. The lower RS in finger millet (0.7 g%) in the present study was similar to the values reported by Roopa and Premavalli[16] for finger millet stiff porridge. Similarly, Mangala *et al*[17] had reported very low levels of RS in finger millet products processed by different methods, probably due to lower levels of amylose contents which have higher tendency to form RS during hydrothermal processing. Higher GI for finger millet stiff porridge corroborates with previous reports by Urooj *et al*[18]. Grinding, rolling, pressing or even thoroughly chewing kernel or starch food can disrupt the outer layer of granules and increase the GI. Although finger millet has higher fibre content, but most of its fibre is insoluble in nature. Also, preparation of stiff porridge entails boiling the flour in water with complete loss of grain matrix, leading to increased surface area, finer particle size of the flour and easier exposure of starch granules for swelling and gelatinization during cooking. This increases the accessibility for amylolysis and ultimately higher glycaemic responses. We have earlier reported high GI of finger millet flakes and decorticated finger millet[19]. Many finger millet-based preparations seem to show high GI[20]. *Rotis* (an unleavened flat bread where the flattened dough is toasted on a hot griddle) also showed high GI. However, *methi paratha* showed medium GI, probably due to the characteristic features of ingredients added in the preparation such as curds and oil, which could have influenced lower GI (medium GI) compared to *rotis* (high GI). It is well known that dairy products are low to medium GI choices and the presence of fat delays gastric emptying rate and hence leads to lower GI[3].

Apart from other factors, the nature of starch in the respective grains in the food preparation is also an important determinant of the GI. The high GI observed for sorghum *roti* in the present study corroborated with the reports for sorghum *roti* (GI=77) by Atkinson *et al*[10]. However, Prasad *et al*[21] reported an upper medium GI value of 68±8.6 for sorghum *roti*. In the present study, dough for sorghum *roti* was prepared with hot water and hence could have developed some amount of pre-gelatinized starch. Atkinson *et al*[10] reported low GI value (49) for pearl millet roasted bread and *chapathi*, but Shukla *et al*[22] reported upper medium GI for pearl millet *chapathi* (69.7), which was similar to the values observed in the current study. Medium GI of sorghum *idli* could be due to the nature of starch and the food matrix (prepared from batter with bigger grits of sorghum and finely ground paste of black gram). Jahan and Kamalaja[23] reported a low GI (51.2) for sorghum rava *idli*, the differences in the GI could be attributed to the differences in sorghum to black gram *daal* (pulse) ratio used for the *idli* batter preparation (sorghum:*daal* 3:1 and 2:1 in our study as compared to the study of Jahan and Kamalaja[23]).

Wheat-based preparations: In the case of wheat-based preparations, broken wheat *upma* showed low GI, whereas other foods such as wheat *dosa* and *methi roti* showed medium GI values and wheat flakes *chivda* showed high GI. Higher dietary fibre in wheat *dosa* was possible as whole wheat was used for preparation. Similarly, higher dietary fibre and RS in broken wheat *upma* is expected as these are prepared from whole samba wheat (*Triticum dicoccum*) which is known for higher protein, dietary fibre and also high RS contents. This is hard textured wheat[24] and the broken wheat is prepared by cracking the whole wheat kernels to grits of bigger size which have firmer texture with intact grain matrix, causing slow digestion. In addition, the oil used in the seasoning probably coats the grits, forming a barrier around the grain constituents, reducing its digestibility and the glycaemic response[25]. The bigger and harder wheat grits in *upma* take longer time to hydrate and may lead to incomplete swelling and gelatinization of starch granules and ultimately slower rate of digestion, leading to lower glycaemic response. Vaidya and Sheth[15] reported a RS content of 2.1 g per cent in plain boiled *daliya* (wheat brokens), while in our study, broken wheat *upma* which is made of *daliya* showed a higher RS content 3.5 g%, Wheat flakes *chivda* is prepared from flaked and roasted wheat wherein the grain matrix is disrupted to an extent, probably increasing GI value. The lower GI of broken wheat *upma* could be due to the nature of starch present in the *dicoccum* wheat and the bigger particle size of the grits used for *upma* preparation. There are no reports on the GI of broken wheat *upma* as such, however Bordia[26] reported a higher GI (74.1) for wheat *daliya* which was prepared with vegetables by pressure cooking, while Urooj and Puttaraj[27] have earlier shown a GI of 67 for normal wheat semolina (fibre-depleted starch endosperm) *upma*. The medium GI of *methi roti* as compared to higher GI of other *rotis* could be attributed to higher fat content in the preparation.

Maize-based preparations: In spite of being a wholegrain-based preparation with higher dietary fibre content, maize *roti* showed a high GI. Vaidya and Sheth[15] reported almost similar RS content (2.3 g%) for maize *roti* (as against 1.87 g% in our study). However, Atkinson *et al*[10] reported medium GI (59) for maize *roti*, but Shukla *et al*[22] reported very high GI for maize *chapathi* (84.7). Identification of grain varieties which elicit a lower glycaemic response in the form of *roti* could be beneficial for populations who consume it as staple food.

Pulse-based preparations: Out of the three pulse-based preparations tested, both the *sundal* preparations showed low GI as compared to *adai* (medium GI category), and this is possible as both white peas *sundal* and white chick peas *sundal* are whole grain legumes cooked in the grain form (as a whole legume and not split *daal*) which also contained higher amylose. In addition, cooked legumes tend to retrograde faster to form RS and hence may contain RS3[28], apart from which the protein and fibre contents in the legumes, their effects on gastric emptying and presence of anti-nutritional factors could also contribute to lower glycaemic response. The results of the current study corroborated with the lower GI category reported for boiled chickpea (GI=33) in the international GI tables. Earlier reports also indicate that addition of chickpea flour reduces the GI of pasta and bread[29].

The higher RS (2.78%) for *adai* could be mainly RS1 from the coarsely ground batter of pulses. The medium GI of *adai* is expected as it contains almost 50 per cent legumes. The coarser particle size of the grains in the batter and nature of starch in the legumes indicates that they are slowly digestible as compared to cereal starches. The limitations of our study included the limited number of traditional foods that have been evaluated, as also the fact that only one style of preparation of each of the selected foods was considered for testing. In addition, physical activity during the GI testing period was not assessed.

The carbohydrate profile of traditional Indian foods varied widely. The available carbohydrate contents were higher in foods with lesser moisture content (wheat flakes *chivda*). Merely being a whole grain-based food does not imply a lower GI. The method of processing, food structural integrity (food matrix) and preparation dictate the GI. The GI of the whole grain millet flour-based stiff porridge showed high GI, whereas the GI of whole meal *rotis* varied between medium and high GI. The type and quality of fibre influence the GI rather than quantity of fibre alone. Consumption of intact whole grains cooked along with intact whole grain legumes and vegetables may help to lower GI. There is an urgent need for region-wise databases on GI of commonly consumed foods for developing GI and GI-based food exchange lists in the country for prevention and effective management of chronic diseases such as diabetes.

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***Conflicts of Interest*:** None.

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