The glycaemic index of fermented and non-fermented legume-based snack food

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A study was conducted to estimate the glycaemic index (GI) of four isocaloric and equicarbohydrate variations of the snack food 'cheela' (a savoury pancake) made from powdered whole legumes *Phaseolus aureus* (green gram) and *Cicer arietinum* (Bengal gram) and their respective fermented batters. Fifteen healthy, normal weight females aged 18–23 years comprised the sample. Glucose was used as a reference food. The test meals were given within 4 weeks of reference food administration, with at least 2 days interval between the test meals. The meals and reference food were served at a fixed time in the morning, after a 12-h overnight fast. Blood glucose was estimated at 0, 30, 60 and 120 min after eating using an Ames glucometer II. The GI for the test meals ranged from 36% to 45%. The green gram cheela (unfermented) had the lowest GI (36 ± 0.6%), peak blood sugar value (111.6 ± 1.5 mg%) and AUC (2319 ± 72) as compared to the other three products. There was no significant difference between the fermented and the corresponding unfermented preparations.

Introduction

Approach to dietary modification in the management of diabetes has changed over the years[1,2]. The glycaemic index of food has been proposed as a fundamental parameter for assessment of the physiological bioavailability of glucose from different foods[1]. It is defined as

$$GI = \frac{\text{Area under the curve for food glycaemic response}}{\text{Area under the curve for equicarbohydrate portion of reference food taken by same individual}} \times 100.$$

Using this approach a close correlation has been obtained between GI values derived in diabetic and normal subjects[3,4]. The GIs of a large number of foods and mixed meals have been investigated and implications in diabetic diets assessed[1,5–7]. The various factors affecting GIs have also been studied.

The amount and nature of starch, protein, fibre and other such antinutrients and fat have been reported to affect the glycaemic response. Besides the constituents of food, processes such as grinding and flaking[8,9] cooking[10,11] and canning[12] also influence the GI of a food. Certain food additives such as salt[13] and fat[2] have also been shown to alter the glycaemic response.

Amongst the various foods investigated, legumes show a low glycaemic index, indicating their suitability for diabetic diets. Legumes form a major source of protein in the Indian diet. Apart from being consumed as boiled preparations, these are also processed in the form of snacks. In view of the increasing importance of snacks in the diet with urbanization, the present investigation was undertaken to process legumes in the form of a savoury snack food – 'cheela' – and to study its glycaemic response. Cheela is a snack food prepared by cooking a thin consistency batter of legume or cereal flour, like a pancake.

Methods

The research design comprised two parts –

Part I: selection of specific legumes and formulation of the snack food cheela.

Part II: determination of glycaemic index of the cheelas.

Part I

For selection of the specific legumes, 30 female college students were interviewed to find the frequency of consumption of different whole legumes. *Phaseolus aureus* (green gram) and *Cicer arietinum* (Bengal gram) were selected for formulation of the snack food on the basis of high frequency of consumption (73% and 62% respectively). The legumes required for the study were purchased in bulk from a Government co-operative store to ensure uniformity of sample. The cleaned grains were ground using a 'Milcent' domestic flour mill which was adjusted at a set point '2'. Two variations of each legume-based cheela, using fermented and non-fermented batter respectively, were formulated. The recipe of each was standardized in terms of the amount of flour taken, volume of water added, duration and temperature of fermentation, final volume of batter, thickness and diameter of cheela, amount of fat and cooking time. The standardized recipes for each preparation had 90 g of legume powder, to which 200 ml of water was added. Three cheelas were made from this batter and 5 g of fat was used for each cheela. For the fermented preparation, the respective batter of legumes were fermented for 24 h at 25–30°C. The nutrient composition of the test meals is reported in Table 1. The final products were then subjected to sensory evaluation by 30 apparently healthy students of the Foods and Nutrition Department, Lady Irwin College, Delhi University.

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Table 1: Nutrient composition* of test meals and reference food.

Test meal	Carbohydrate (g)	Protein (g)	Fat (g)	Energy (k cal.)
1 Bengal gram cheela	54.8	15.4	15	369
2 Green gram cheela	51.0	21.6	15	346
3 Fermented Bengal gram cheela	54.8	15.4	15	369
4 Fermented green gram cheela	51	21.6	15	346
Reference food	50	–	–	200

*Nutrient value of Indian Foods, ICMR, NIN, 1989.

Part II

The GI of different variations of the snack food or test meals was determined by comparing their glycaemic response with that of glucose, in 15 selected volunteers, aged 18–23 years with BMI ranging from 19 to 21. The subjects were non-alcoholic, non-smokers and had no family history of diabetes. Their dietary pattern was elicited by a 24-h recall questionnaire on the day prior to each test day. On the first test day, 50 g glucose dissolved in 200 ml of water was given as the reference food. The test meals were given within 4 weeks of reference food administration, with at least 2 days interval between feeding of two test meals. The meals were served at a set time in the morning after a 12-h overnight fast to eliminate the effect of the previous meal. The subjects were instructed not to perform any heavy activity 1 day prior to the test and were made to rest for 30 min before being given the test meal. They were also instructed to finish the meal within 10–15 min with proper chewing. They remained at rest and refrained from eating or drinking during the test period of 2 h.

The blood glucose was estimated at 0, 30, 60 and 120 minutes after the meal. These values for the reference food and test meals were plotted for each subject and the incremental area was calculated geometrically. Any area beneath the fasting level was excluded. An Ames glucometer II was used for glucose estimation. A pretest carried out indicated no difference and a high degree of correlation between this and the traditional O-toluidine method.

A chi-square test was done to find the difference in average scores of the sensory evaluation of the test meals. ANOVA was applied to GI of the test meals and further analysis was done using Tukey's test.

Results and discussion

The mean scores of organoleptic trial based on hedonic five-point scale for appearance, taste and acceptability of the test meals are given in Table 2. The meals ranged in score from satisfactory to good. There was no significant difference in the appearance, taste and acceptability of the meals. This is of relevance as the glycaemic response of a food may be related to its palatability. The dietary recall of the subjects elicited little inter-individual variation for energy (1612 ± 21 kcal/day) and protein intake (49.8 ± 0.9 g/day).

Table 2. Mean scores of sensory evaluation of test meals ($n = 30$).

Test meal	Scores*		
	Appearance	Taste	Acceptability
1 Bengal gram cheela	3.2±0.5	3.6±0.7	3.3±0.1
2 Green gram cheela	3.3±0.5	3.7±0.2	3.4±0.2
3 Fermented Bengal gram cheela	3.1±0.6	3.6±0.3	3.3±0.2
4 Fermented green gram cheela	3.3±0.5	3.5±0.2	3.2±0.2

Results are mean ± S E M.
*Maximum score of 5. 5 = excellent, 4 = good, 3 = satisfactory, 2 = unsatisfactory, 1 = poor.

Table 3. Mean AUC and GI of different test meals and reference food ($n = 15$).

Test meal	AUC	GI (%)
1 Bengal gram cheela	2722±88 (12.27)	42±0.6 (5.5)
2 Green gram cheela	2319±72 (11.94)	36±0.6 (5.9)
3 Fermented Bengal gram cheela	2929±95 (12.29)	45±0.8 (6.6)
4 Fermented green gram cheela	2458±65 (9.96)	38±0.7 (6.2)
Reference food	6423±22 (12.49)	100

Results are mean ± SEM.
The values in the parentheses indicate percentage coefficient of variation.
$F = 2.91, P \leq 0.05$.

All the test meals were well accepted by the subjects. The average figures for AUC and GI of test meals are depicted in Table 3. The GI of all the test meals ranged from 36 to 45%. Various other investigators have also reported similar observations indicating a low GI of legumes[1,4–6]. A comparison of the mean GI of different test meals revealed a significant difference among them. Further analysis using Tukey's test indicated that the GI of green gram cheela (36 ± 0.6%) was significantly lower than that for Bengal gram cheela (42 ± 0.6%) and fermented Bengal gram cheela (45 ± 0.8%).

The glycaemic response of the test meals was also studied at different points of time – fasting, 30, 60 and 120 min after eating, the averages being depicted in Table 4. The lowest

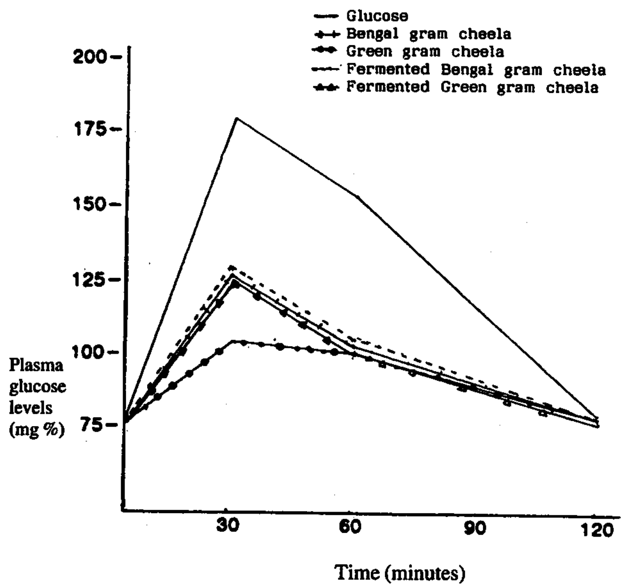

Figure 1. Glycaemic reponse to test meals and glucose.

increment at 30 min was for green gram cheela (111.6 ± 1.5 mg%). As compared to the reference food, there was maximum reduction in mean plasma glucose value at 30 min for green gram cheela (39.77%), followed by fermented green gram cheela (31.94%) and Bengal gram cheela (30.71%). The mean rise in blood glucose value at 30 min for fermented Bengal gram cheela was only 27.67% lower as compared to the reference food. These observations further reiterate the superiority of green gram cheela (unfermented) over the other test meals.

The only experimental variable in the Bengal gram cheela and green gram cheela was the legume used. Therefore, difference in the composition of the two legumes is likely to be a causative factor for the difference observed in GI. The two legumes differ in their fibre and protein content. The higher crude fibre present in green gram (24 g%) as compared to Bengal gram (17.1 g%)[14] might be one of the factors responsible for the observed difference. A hypoglycaemic response has been reported with different levels of crude fibre[17].

The lower GI of green gram cheela may also be attributed to higher protein content (21.6 g) as compared to Bengal gram cheela (15.4 g)[14]. Protein may lower the glycaemic response by promoting insulin secretion. It may form a complex with starch thus rendering it less susceptible to amylolytic digestion[7].

The process of fermentation resulted in increased glycaemic index of green gram cheela and Bengal gram cheela by 2.26% and 2.71%, respectively, which is not significant This increase in GI could be the result of breakdown of complex carbohydrates like starch and other polysaccharides to simpler forms ie disaccharides and monosaccharides. Most of the simpler carbohydrates are known to evoke much greater increase in blood glucose than complex carbohydrates[1,5]. Fermentation is also known to improve bioavailability of nutrients by decreasing the effect of antinutrients like phytates, lectins and tannins. A significant correlation between in-vitro digestibility and GI has been reported in the literature[15,18]. However, Vimla and Easwaran have reported no difference between the GIs of wheat chapati and wheat 'dosai'[19], a fermented preparation.

Traditionally, the majority of Indian snacks like 'Idli', 'Pongal', 'Uppma' and 'cheela', utilize dehusked legumes.

Table 4. Mean plasma Glucose levels of subjects after consumption of test Food ($n = 15$).

Test food	Plasma glucose levels (mg%)			
	Fasting	30min post-prandial	60min post-prandial	120min post-prandial
Reference food	82.06 ± 0.90 (4.2)	185.33 ± 2.60 (5.46)	156.90 ± 3.50 (8.8)	85.74 ± 0.80 (3.4)
Test meal				
1. Bengal gram cheela	80.93 ± 0.30 (1.64)	128.40 ± 1.20 (3.73)	108.50 ± 2.00 (7.07)	83.40 ± 0.40 (1.74)
2. Green gram cheela	80.93 ± 0.30 (1.57)	111.60 ± 1.50 (4.69)	105.06 ± 0.90 (3.51)	83.30 ± 0.40 (1.94)
3. Fermented Bengal gram cheela	81.26 ± 0.30 (1.6)	134.06 ± 0.80 (2.46)	109.70 ± 1.60 (5.65)	82.33 ± 0.40 (1.87)
4. Fermented green gram cheela	80.80 ± 0.30 (1.63)	126.06 ± 1.30 (4.16)	105.20 ± 0.80 (3.19)	82.13 ± 0.30 (1.29)

Results are mean ± SEM.

Values in parentheses indicate percentage coefficient of variation.

These have the disadvantage that most of the fibre portion of the pulse is removed. Clinical trials have, however, reported a favourable use of viscous fibre in the management of diabetes. The present study has shown that whole legumes in the form of cheela have a low GI. The fermentation of the batter also did not cause any significant change in GI. At the same time, fermentation is associated with improved digestibility and nutrient availability. Thus the use of fermented products using whole legume can be recommended for diabetics.

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發酵與未發酵豆類快餐食物的血糖指數 (GI)

摘要

作者研究了 4 種等熱量、等碳水化合物的快餐食物 —— Cheela (一種美味可口的煎餅) 的血糖指數。這些快餐食物是由粉狀的全豆類 Phaseolus aureus (綠色鷹咀豆) 、Cicer arietinum (孟加拉鷹咀豆) 和它們各自的發酵糊狀物製成的。他們選用 15 位 18–23 歲、健康和正常體重的女性爲試驗對象。用葡萄糖爲參考食物。快餐食物在 4 周内試驗完畢。試驗不同的快餐食物最少相隔 2 天。快餐食物與參考食物 (葡萄糖) 是經 12 小時空腹後每天晨早給予。用 Ames II 型葡萄糖計測定餐後 0、30、60 和 120 分鐘的血糖水平。結果發現，快餐食物血糖指數在 35%–45% 之間，與其它三種產品相比較，未發酵的綠色鷹咀豆 Cheela 的 GI 最低、血糖峰值爲 111.6±1.5毫克%、AUC 爲 2319±72。發酵和未發酵製品間沒有明顯差異。