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## DIABETOLOGY

## Type 2 Diabetes Mellitus





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# Diet-based Management and Treatment of Diabetes

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## ABSTRACT

A diet rich in refined carbohydrates is believed to be a major factor contributing to the rising incidence of type 2 diabetes mellitus in Indians. Understanding the role of refined carbohydrates on blood glucose excursions is necessary for the proper selection and formulation of foods. This review presents simple and practical ways in which Indian dietaries may be modified not only to lower blood glucose response, but also to enable consumers to enjoy the diverse variety of Indian foods. Practical recommendations are provided that will enable diabetics to consume nutritious and highly palatable foods. The time has come for both consumers and food manufacturers to appreciate the importance of consuming low glycemic foods in order to abate the escalating incidence of type 2 diabetes.

## INTRODUCTION

Asia is emerging as the epicenter of the diabetes epidemic with China and India leading the world with the greatest number of people with diabetes. An estimated 61.3 million individuals are affected by diabetes in India, and this number is expected to increase to a staggering 101.2 million by the year 2030.[1] Population studies have shown that diabetes affects both rural and urban populations in India with the numbers increasing at an alarming rate.[2,3] This has been attributed to changes in diet and lifestyle patterns with the latter having a profound role in the etiology of diabetes. With the increasing prevalence of diabetes and related chronic diseases, greater research attention is necessary to curb its further escalation. Dietary interventions have, therefore, gained considerable interest in diabetes

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management and treatment. Their primary aim is to maintain a modest and stable postprandial blood glucose concentration when consuming a carbohydrate-rich diet.[4] Whilst pharmacological intervention has been the bedrock of diabetes management for several decades, there is increased support for the use of diet in the management and treatment of diabetes.

## ETIOLOGY OF TYPE 2 DIABETES IN INDIANS

Indians are more prone to insulin resistance, developing metabolic syndrome and have an increased risk for developing type 2 diabetes compared to other ethnic groups.[5] Higher insulin levels to a given glucose load was observed in Asian Indians compared to Europeans with hyperinsulinemia.[6] Euglycemic clamp studies demonstrated that insulin resistance was greater among Asian Indians compared to Europeans who were similar in age, sex, and body mass.[7-10]

The Indian diet is generally characterized as one that is high in carbohydrate content. In India where the two most common staples are rice and wheat-based chapati, their consumption is associated with a rapid rise in blood glucose. Refined grains such as white rice have been linked with the risk of type 2 diabetes and metabolic syndrome among urban South Asian Indians.[11,12] The degree of blood glucose excursion after a carbohydrate diet can be described by the glycemic index (GI).

The GI is a very useful methodology in assessing the quality of carbohydrate in the diet. An understanding of the GI concept can be of particular benefit in subjects with diabetes and impaired glucose tolerance. Dietary management of diabetes involves a reduction in postprandial hyperglycemia and adequate glycemic control. This may be achieved through the consumption of low GI foods as part of the Indian diet.

## ROLE OF GLYCEMIC INDEX IN TYPE 2 DIABETES

Jenkins et al. were the first to develop the GI concept, where it was shown to be an important and innovative discovery in nutritional science.[13] The GI is defined as a measure of the blood glucose raising ability of the available carbohydrate in foods. It is expressed as a percentage of the incremental area under the glycemic response curve (AUC) elicited by a portion of food containing 50 g available carbohydrate in comparison with the AUC elicited by 50 g glucose in the same subject. The principle is that the slower the rate of carbohydrate absorption, the lower the rise of blood glucose level and the lower the GI value.[14] A GI value of greater than or equal to 70 is considered high, a GI value 56–69 inclusive is medium and a GI value less than or equal to 55 is low, where glucose is equal to 100.[15] The glycemic load (GL) is a product of the GI and available carbohydrate content per serving

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of the food. Both high GI and GL have shown to increase the risk of type 2 diabetes in both Western and Asian populations[16-19] although some studies have reported no association with diabetes risk.[20-22] The large amount of refined grain consumption (mostly high GI) in the Indian diet, therefore, leads to a higher dietary GL.

An important body of evidence exists to support the preventive and therapeutic potential of low GI diets in diabetes.[14,23] Low GI foods may reduce insulin demand and lipid concentrations, improve blood glucose control and reduce body weight, thus preventing diabetes-related cardiovascular events.[17,18,24,25] A meta-analysis by Brand-Miller et al. demonstrated that choosing low GI foods in place of conventional or high GI foods exhibited a small but clinically important effect on medium-term glycemic control in patients with diabetes. This diet-based intervention was similar to the effects seen using pharmacological agents.[15] There have been numerous studies providing useful information on the GI of various Indian foods and their effect on blood glucose and lipid levels[26-31] although a bulk of GI research has been conducted on Western foods.

One of the main impediments in the use of GI tables worldwide has been the uncertainty of the applicability and consistency of international tables to different ethnic groups. One study examined the role of ethnicity on GI when subjects were resident of their own countries.[32] The glycemic response to common foods (sweet biscuits and breakfast cereals) was higher in Asian Indian subjects compared to United Kingdom (UK) Caucasian subjects, but no significant differences in GI values for the test foods between the two group of subjects was observed.[32] This suggests the potential of the applicability of Western GI tables with the Indian population.

## GLYCEMIC INDEX OF COMMONLY CONSUMED INDIAN STAPLES

A typical Indian diet is high in carbohydrates with cereal-based foods, such as rice and wheat providing the bulk of the energy. Whole grains, such as millet, sorghum, amaranth and barley were commonly used in ancient Indian cooking prior to the "Green Revolution" in 1951, after which refined rice and wheat became popular.[33] Per capita consumption of refined grains tripled in India and the country became the world's foremost exporter of rice and wheat.[33] Traditional cereal-based Indian diets were not only rich in dietary fiber, but also in other micro- and phytonutrients.[34] With modernization, mechanical milling led to an increased total rice yield but produced a highly refined rice grain with starchy endosperm.[11] Polished rice and other highly refined cereals, such as white flour, finger millet and semolina are mostly high GI (Table 1).

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**Table 1: Glycemic Index (GI) of Common Staples (Cereals and Legumes) in the Indian Diet[35]**

| Food | Glycemic index (GI) |
|---|---|
| **Cereals** | |
| White rice (*Oryza sativa*), boiled (India) | 69 |
| Parboiled rice, eaten as part of a traditional Indian meal (India) | 99 |
| *Sona Masuri* (India) | 72 |
| *Ponni rice* (India) | 70 |
| *Surti Kolam* (India) | 77 |
| Basmati, white, boiled (Mahatma brand, Sydney, Australia) | 58 |
| Brown basmati rice | 75 |
| White and brown basmati rice (60% white basmati, 40% brown basmati) | 59 |
| Basmati with wild rice (83% easy-to-cook basmati) and 17% North American wild rice | 63 |
| Easy-to-cook basmati rice | 80 |
| *Chapati* (unleavened bread made from refined wheat flour and water) | 64 |
| Whole wheat flour chapati/roti | 45 |
| *Naan* (leavened bread made from white flour, water and yeast) | 80 |
| Finger millet/ragi | 84 |
| Pearl millet/bajra | 55 |
| Sorghum/jowar (roasted bread made from sorghum flour) | 77 |
| Semolina, steamed, and gelatinized (India) | 84 |
| *Idiyappam or string hoppers* (steamed fresh vermicelli made from red or white rice flour) | 103 (red) |
| **Legumes** | |
| Bengal gram/chickpeas | 33 |
| Kidney beans | 28 |
| Black beans | 20 |
| Green lentils | 30 |
| Red lentils | 26 |
| Moong beans | 42 |
| Peas | 22 |
| Split peas, yellow, boiled | 32 |

Majority of the Indian diet consists of these cereal-based staples. Understanding the GI of these staples is necessary for proper selection and modifications of foods that may be of particular benefit to Indians who are more insulin-resistant and/or have diabetes.[6,8] Almost half of the daily caloric intake of South Indians is derived from refined grains, particularly white rice and rice products[12] whilst

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wheat consumption is higher in Northern India.[36] From an epidemiological study, a typical South Indian meal was found to have more rice and less of other foods, such as legumes, fruits, vegetables, and dairy products.[12] The greater quantity of rice eaten and its associated GL is regarded as a major contributing factor to a higher prevalence of diabetes and associated complications. Therefore, Southern regions of India were found to have a higher prevalence of diabetes than Northern regions.[3,11]

The GI of foods is influenced by several factors, such as the nature of starches, macronutrients, fiber, the cooking/preparation method, cooking time, particle size as well as processing conditions. An analysis of these factors will be useful in making food choices and modifications necessary to develop diabetic foods for Indians.

## Glycemic Response of Rice

Rice variety significantly influences GI. This varietal effect on GI appears to be mainly mediated by its amylose content. Basmati rice is a popular rice in the Indian diet. White basmati rice with intermediate amylose content (20–25%) has been shown to have a GI of 58[37] and 50.[38] Some studies show that parboiling reduces the GI of rice.[38,39] A reduced glycemic response was observed in healthy subjects who consumed parboiled Sri Lankan rice compared to the unparboiled version.[40]

Other factors may also influence the digestibility and GI of rice. Indian rice varieties Sona Masuri (medium grain rice), Ponni (medium grain rice), and Surti Kolam (polished short grain rice) have shown to be high GI (72, 70, and 77, respectively) when they were cooked under similar conditions.[41] These three types of rice were fully polished rice, void of fiber and high in starch, resulting in a higher rate of digestion, therefore, leading to poor glycemic control. Other studies have shown that brown rice has a lower GI than white rice[42] while some have shown it to be high GI. It seems that the GI of brown rice types is affected by the bran constituents (perhaps micronutrients) and not just the bran alone. It is therefore not possible to assume that brown rice has low GI. White rice as opposed to brown rice is more often consumed by Indians due to its taste, consistency and shorter cooking time. Therefore, white rice has been more desirable in Indian dishes. Basmati rice and parboiled rice may be good options for an Indian rice-based meal.

## Glycemic Response of Flatbreads

Flatbreads made using wheat flour (chapati) contribute a major portion of energy notably in North Indian diets. Compared to rice, less work has been done on the effects of different flatbreads on blood glucose responses. North Indian meals

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traditionally have a form of flatbread, either unleavened or leavened. Most GI studies have examined the glycemic responses of bread consumed in the Western diet but few studied the breads in Asian diets. A study by Radhika et al. showed that whole wheat flour used to make chapati has a low GI.[43] Whole wheat flour chapati with the wheat bran and germ present is typically low-to-medium GI but if refined wheat flour (i.e. white flour) is used, the GI is higher due to the removal of bran (Table 1). Furthermore, α-amylase inhibitors present in wheat can withstand cooking temperature and were found to be effective in reducing blood glucose response.[44] More recently, a study evaluated the glycemic and insulin responses of different South Asian flatbreads. Flatbread, such as naan and refined chapati were reported to be high GI.[45] Other flatbreads, such as chickpea flour chapati was of medium GI and whole wheat chapati was of low GI.[45]

## Glycemic Response of Other Cereals

Other popular grains include millet or ragi which can be processed to make porridges, idli (Indian fermented steamed cake), dosa (Indian fermented fried pancake), and roti (unleavened bread). A recent detailed review by Shobana et al. highlighted that finger millet was a cereal grain that possesses components that were likely to lower GI.[46] A study comparing the glycemic response of pearl millet (bajra), barley and maize in healthy and type 2 diabetic individuals showed that the glycemic response to pearl millet and barley, but not maize, was significantly lower than the glycemic response to white bread, particularly in individuals who were healthy.[47]

## Glycemic Response of Legumes

Besides cereals, legumes also form a major source of protein and carbohydrates intake in the Indian diet. It is usually consumed as an accompaniment (dal) to a cereal staple or processed to make snacks. Generally most legumes are low GI (Table 1). Their low GI has been attributed to the high-fiber and polyphenol content, and the slow-digesting starch characteristics. In an early study, Jenkins et al. have showed that dietary fiber in legumes and dals (dehusked and split legumes) are more viscous than the fiber content of cereals and millets.[48] A number of researchers investigated the blood glucose responses of leguminous seeds in the Indian diet. Indian snacks are traditionally made using dehusked legumes. The glycemic response of cheela, an Indian snack was studied by Batra et al.[49] Whole legumes (green gram and Bengal gram) showed a GI lowering effect. In addition, green gram produced a lower GI than Bengal gram, because of the higher protein and crude fiber content in the former.[49] The presence of protein and viscous fiber helps to lower glycemic response. A systematic review and meta-analysis showed

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that pulses were able to reduce blood glucose and insulin in both normal and diabetic subjects.[50] The use of pulses with low GI diets was reported to reduce the amount of glycosylated hemoglobin and fructosamine that are markers of long-term maintenance of blood glucose.[50]

Overall, wholegrain foods and legumes showed a lowering of blood glucose response. However, the GI of most Indian wholegrain foods and legumes have not been tested using standardized methodology.[32,43]

### Processing Techniques Affecting Glycemic Index

Processing techniques, such as puffing, instantiation and fermentation have shown to affect GI and increase starch digestibility. Instant (easy-to-cook) basmati rice, which is pregelatinized rice, results in a significantly higher GI than raw basmati rice. Puffing of finger millet is commonly used to make Indian snacks. An *in vitro* study showed puffed finger millet had an increase in rapidly digestible starch content and lower slowly digestible starch content, with a decrease in resistant starch content of finger millet.[51] The fermentation process of finger millet in making dosa was found to increase the starch digestibility.[52] Idiyappam (string hoppers), which are steamed fresh rice vermicelli, have high GI.[53] Certain processes disrupt the structure of rice, promote gelatinization and therefore increase the GI.

### Cooking Method and Cooking Time Affecting Glycemic Index

Cooking method also affects GI. Carbohydrate foods that had been roasted or baked showed significantly higher blood glucose responses, and therefore a higher GI than the same foods that had been boiled or fried (Bahado-Singh et al. 2006). Cooking time has also shown to influence starch gelatinization and therefore GI. Basmati rice cooked for longer times elicited greater glycemic responses.[38] White basmati rice cooked for 10 min had a GI of 50 (low), but basmati and wild rice, brown and white basmati rice cooked for 25 min had high GI.[38]

## MANIPULATING THE GLYCEMIC INDEX OF INDIAN FOODS

The consumption of large carbohydrate rich meals is common in the Indian diets. The addition of ingredients to staples and supplementing these staples with accompaniments could lower the GI and overall GL of a traditional Indian meal.

### The Potential of Adding Ingredients to Reduce Glycemic Response

Barley β-glucan is a natural soluble dietary fiber that has shown to lower glycemic response when incorporated into carbohydrate foods. High molecular weight

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barley β-glucan was able to reduce the GI of chapati when tested in healthy subjects.[54] The GI values for chapati (Indian flatbreads) with 4 g and 8 g β-glucan were 43–47% less than the control chapatis made of whole wheat flour. The functional properties of β-glucans have always been attributed to their ability to delay carbohydrate digestion and absorption from the gut by increasing the viscosity of the stomach and intestinal contents and forming a protective layer incorporating readily digestible carbohydrates.[55] Another study also found that moderate amounts of β-glucan (~3 g) along with a low GI breakfast have lipid-lowering effects in type 2 diabetics.[56]

The GI of rotis (unleavened flatbread) made of whole wheat flour was reduced with a newly developed "atta mix" containing Bengal gram, psyllium husk, and debittered fenugreek flour in healthy nondiabetic subjects.[43] The therapeutic effects of Bengal gram (legume), psyllium/ispaghula husk, and debittered fenugreek powder on lowering postprandial glucose levels are likely to be due to high viscous soluble fiber, the galactomannans (polysaccharides) that are not hydrolyzed by the digestive enzymes. Soluble fiber results in high viscous intestinal contents with gelling properties that could delay gastric emptying and also intestinal absorption.[43]

Mani et al. investigated the glycemic response in type 2 diabetics subjects who were given 50 g portions of five different conventional meals containing semolina cooked by two different methods, or combinations of semolina and pulse (black gram dal, green gram dal or Bengal gram dal)[28] (Table 2). There were no significant differences in GI among the meals except for roasted semolina and semolina-black gram dal meals. But meals based on steam-cooked semolina and semolina-Bengal gram dal elicited a significantly lower blood glucose response at 1 hour postprandially and semolina-black gram dal at 2 hours postprandially. The cooking method had an influence on the GI by affecting starch digestion and therefore postprandial blood glucose response.[57,58]

**Table 2: Glycemic Index (GI) of Semolina Meals[28]**

| Ingredients | Glycemic index (GI) |
|---|---|
| Semolina-steamed with gelatinization | 55 |
| Semolina + black gram dal | 46 |
| Semolina + green gram dal | 62 |
| Semolina + Bengal gram dal | 54 |
| Semolina-roasted at 105° with resultant gelatinization when water is added | 76 |

All dals were soaked for 4 hours, ground to paste and fermented. Meals were cooked 20 min, 400 mL water added during cooking and 5 g groundnut oil. Meals were approximately isocaloric.

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Finger millet (20%) incorporated into idli, dosa, chapati, rice string hoppers and kozhukattai (steamed rice balls), fed to type 2 diabetics (n = 6) for a month, showed a significant decrease in postprandial blood glucose, but the limitation of the study was the small sample size.[59] Finger millet incorporated into noodles also showed a lower GI when compared to refined wheat flour-based noodles.[60]

A study examined the glycemic response of four formulations (popped rice, expanded rice, wheat and finger millet) combined with legumes in normoglycemic subjects showed that the wheat-based formulation had the lowest GI of = 55.[61] The other formulations were high GI. The finger millet-based formulation, which used polished finger millet, had a GI of 93. The rice-based formulation that used popped rice had a GI of 105 and expanded rice had a GI of 109. This showed that processing techniques and low dietary fiber content had a considerable effect on increasing the GI of foods, even if legumes were present.

## Spices and Herbs

Several spices and herbs, such as curry leaf, turmeric, fenugreek and cinnamon are used by Indians to add characteristic flavor and aroma to dishes. Many of these spices and herbs provide beneficial effects on glycemic control by possessing antidiabetic or blood glucose lowering properties based on successful *in vitro* and *in vivo* studies, where mostly has been investigated using animal models.[62] The constituents of spices have insulin-stimulating and hypoglycemic effects.[63] Fenugreek (methi) is known to play a role in glycemic control, delaying gastric emptying and regulating insulin secretion due to the presence of soluble fiber.[64] Incorporating fenugreek in the form of seeds and flour into Indian foods lowered postprandial glucose levels in type 2 diabetics.[65-68] Cinnamon is known for its potential role on insulin action and was found to improve blood glucose profiles in diabetics.[69] Several other researchers reported the effectiveness of cinnamon in controlling blood sugar in type 2 diabetics.[70,71] Turmeric is a widely used spice in Indian cooking where it functions as a coloring and flavoring agent. Curcumin is an active polyphenol present in turmeric. Human clinical trials have shown dietary curcumin to possess anti-hyperglycemic effects in type 2 diabetics[72] and significantly reduce type 2 diabetes development in prediabetics.[73] Due to curcumin's poor absorption in the digestive system,[74] its beneficial effects on type 2 diabetes still remains to be elucidated. Curry leaf (Murraya koenigii) is a popular aromatic herb known to be used in curry and chutney. A selection of studies have shown hypoglycemic properties of curry leaf powder in controlling the fasting and postprandial blood glucose level among type 2 diabetics.[75] Overall, spices and herbs used in Indian foods potentially have strong antidiabetic and glucose lowering effects in diabetics but much remains to be researched using more long-term human intervention trials.

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## Meal Accompaniments

The conventional meal pattern of most Indians is the use of a staple, for example, boiled white rice or refined wheat chapati, accompanied by a constellation of dishes, such as legumes, vegetables and yogurt. Some of these accompaniments play a crucial role in lowering the GI of a carbohydrate staple. Table 3 represents a selection of accompaniments that can be practically adopted to lower the glycemic response of carbohydrate-rich foods.

**Table 3: Glycemic Index (GI) of Indian Staple Foods with/without Accompaniments**[26,29,35,53,76]

| Food | Glycemic index (GI) | With accompaniment | Glycemic index (GI) |
|---|---|---|---|
| **Rice-based** | | | |
| White rice; low-amylose | Medium-to-high | Rice with lentil and cauliflower curry | 60 |
| White rice; high-amylose | Low-to-medium | Rice, boiled served with Lagenaria vulgaris (bottle gourd) and (Lycopersicon esculentum) tomato curry | 69 |
| Brown rice | 50 | Parboiled rice with green leaf curry (Amaranthus) | 58 |
| Basmati rice | 47 | Parboiled rice with gravy (soya meat) | 56 |
| | | Parboiled rice with green leaf curry and gravy | 55 |
| | | Red rice with lentil curry, boiled egg + *Centella asiatica* (gotu kola) salad and coconut gravy (Kiri hodi) | 63 |
| | | Red rice with lentil curry, boiled egg + *Centella asiatica* (gotu kola) salad and coconut gravy (kiri hodi) and Lasia spinosa (kohila) salad | 57 |
| | | Red rice with lentil curry, boiled egg + *Centella asiatica* (gotu kola) salad, coconut gravy and *Trichosanthes cucumerina* (snake gourd) salad | 61 |
| | | Red rice with lentil curry: Red rice (82% starch), Lentils curry (18% starch) | 60 |
| | | Red rice with coconut gravy | 99 |
| Rice roti | 103 | Dosa (parboiled and raw rice, soaked, ground, fermented and fried) with chutney | 77 |
| | | String hopper (wheat flour) with coconut sambol, egg and coconut gravy | 104 |
| | | String hopper (red rice flour) with coconut sambol, egg and coconut gravy | 103 |
| Pongal (rice and roasted green gram dal, pressure cooked) | 90 | Pongal with sambar | 54 |

*Continued*



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*Continued*

**Table 3: Glycemic Index (GI) of Indian Staple Foods with/without Accompaniments**[26,29,35,53,76]

| Food | Glycemic index (GI) | With accompaniment | Glycemic index (GI) |
|---|---|---|---|
| | | Idiyappam (steamed rice flour dough with tender coconut) eaten with Bengal gram curry | 86 |
| | | Idli (parboiled and raw rice + black dal, soaked, ground, fermented and steamed) with chutney | 77 |
| | | Puttu (rice flour, steamed with tender coconut) eaten with Bengal gram curry | 79 |
| | | Appam (thin pancake made from fermented rice flour batter with tender coconut) eaten with Bengal gram curry | 90 |
| **Wheat-based** | | | |
| Chapati | 64 | Chapati, wheat, served with bottle gourd and tomato curry | 66 |
| | | Chapati with green gram dal | 44 |
| Chapati (maize flour) | 59 | Chapati and dal | |
| Naan | 80 | | |
| **Semolina-based** | | | |
| Semolina, steamed and gelatinized | 54 | Uppittu (roasted semolina and onions, cooked in water) | 67 |
| Semolina, roasted then gelatinized with water | 55 | | |
| **Millet products** | | | |
| Millet/ragi | 84 | Upma kedgeree (millet, legumes, fenugreek seeds; roasted and cooked in water) | 18 |
| | | **Other Indian foods** | |
| | | Dhokla (chickpea-based + wheat semolina) | 35 |
| | | Punjabi meal | 68 |
| | | Uttapam with chutney | 63 |
| | | South Indian meal | 63 |
| | | Curd rice with curry leaves chutney | 65 |
| | | Adai with chutney | 70 |
| | | Bengali meal | 70 |
| | | Rasam rice with papad | 78 |
| | | Gujarati meal | 83 |
| | | Sambar rice | 83 |

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Legumes accompanied with a carbohydrate staple have shown a blood glucose lowering effect in several studies. White bread with a GI of 100 when given with lentils moong (Phaseolus mungo) had a GI of 45 and with mash (Phaseolus aureus) a GI of 56.[77] In conventional Indian foods, rice combined with legumes (Bengal gram, peas and green gram) and a combination of rice-dal (green gram dal and red gram dal, both dehusked and split) was studied to determine the GI in type 2 diabetic subjects.[78] Rice and rice plus peas showed a higher GI while all other rice combinations produced lower glycemic indices. Overall, all the foods with leguminous seeds were able to significantly lower blood glucose response postprandially.[78] Bengal gram dal and rajma (kidney beans; Phaseolus vulgaris) in a carbohydrate meal would be most effective in reducing postprandial plasma glucose levels than wheat and rice alone.[31] Green gram and Bengal gram promote insulin secretion due to the protein content and form a complex with starch to decrease susceptibility to amylolytic digestion. A comparison of the glycemic responses of three Sri Lankan bread-lentil meals had no significant differences in GI (white sliced bread = 77, wholemeal bread = 77, ordinary white bread = 80 and wholemeal bread + lentil curry = 61).[53] However, including legumes to bread helped reduce the GI of bread and lower postprandial glucose concentrations. Yogurt, where it is called dahi in Hindi, has been shown to significantly reduced the GI of the rice when consumed together (prior to or after a carbohydrate meal).[79]

## Indian Snacks

Popular traditional Indian snack foods include upma and dhokla. Upma is made from semolina and dhokla from chickpea, both mostly eaten in South India and Gujarat, respectively. The GI of the snacks were low (GIs: upma 18, dhokla 35).[29] The higher GI of dhokla compared to upma was attributed to the fermentation process, which resulted in rapid digestion of carbohydrate and absorption of sugar, compared to upma.[80] The study demonstrated that these two food products had a hypoglycemic effect in diabetic subjects. A study by Krishnamoorthy et al. investigated the GI of seven traditional Indian snacks modified in composition and preparation to determine their glycemic and insulinemic response in type 2 diabetics.[81] The snacks were standardized in terms of weight. Exclusion of starchy ingredients from the original recipe, such as potatoes, refined flour, and inclusion of whole and split lentils (with intact husk) lowered the GI of Indian vegetarian snacks which are commonly medium-to-high GI (Table 4). In addition, vegetables, such as radish, cabbage, carrot, bottle gourd were included for fiber that also contributed to lowering the GI of the snacks by suppressing the postprandial glycemic response.[81] This study provided a new insight into how Indian snacks could be modified to be suitable for diabetics without causing hyperglycemic effects.

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