Innovative Approaches to Modify Traditional Indian Foods for Glycemic Control in Type 2 Diabetes- A Systematic Review

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Abstract—**India has experienced a significant rise in the prevalence of Type 2 diabetes mellitus (T2DM) in recent decades, with rates increasing from 5.0% in 1980 to 7.3% in 2000, and further to 8.8% by 2014. The International Diabetes Federation (IDF) estimates that the number of individuals with diabetes in India reached 77 million in 2019 and is projected to rise to 134 million by 2045. This review explores the potential of modifying the traditional Indian diet to incorporate low glycemic index (GI) foods for the prevention and management of T2DM in India, drawing on both evidence-based studies and practical experience. Low-GI foods, which contain slowly absorbed carbohydrates, have been shown to improve glucose control, reduce hyperinsulinemia, enhance insulin sensitivity, and benefit blood lipid profiles and satiety. The article revisits historical studies from India and discusses optimal macronutrient distribution for individuals with T2DM, including carbohydrate intake (60–70%), protein (~20%), and fats (10%). It also examines the impact of low-GI foods on carbohydrate and fat metabolism in T2DM patients. This review synthesizes current research on adapting traditional Indian food practices to support better glycemic control in people with T2DM.**

Index Terms—**Traditional Indian Food, Indian vegetarian Snacks, Indian Vegetarian Mixed Meals, Low GI Food, Glycemic Response**

I. INTRODUCTION

Foods with a high glycemic index (GI), such as white bread, are rapidly absorbed into the bloodstream, leading to quick increases in blood glucose levels [1]. In contrast, low-GI foods, including legumes, lentils, and oats, contain carbohydrates that break down more slowly, resulting in a gradual rise in blood glucose and a more controlled insulin response [2,3]. GI is measured by comparing the blood glucose response to a test food against a standard, typically glucose or white bread [4]. Low-GI diets have been shown to improve glycemic control in patients with Type 2 diabetes, contributing to better insulin sensitivity, reduced blood glucose fluctuations, and decreased insulin requirements [5].

Dietary management in Type 2 diabetes often focuses on weight loss and improved glycemic control, with low-GI foods providing a beneficial alternative to standard low-fat diets. These foods support better metabolic outcomes by promoting insulin sensitivity and stabilizing glucose levels [6].

Traditional Indian Diets

The diverse food cultures of India, shaped by centuries of tradition and geography, offer a rich array of dietary practices. The traditional Indian meal, commonly composed of roti (bread), rice, mixed vegetable curries, yogurt, dal (lentils), and salad, provides a balanced mix of carbohydrates, proteins, and fiber. This dietary pattern varies regionally but remains a crucial source of energy and nutrition. Spices are widely used across India, not only for flavours but also for their nutritional and medicinal properties [7, 8].

· South Indian Diet: Predominantly rice-based, with lentils commonly accompanying meals. Spices and minimal oil use characterize the diet.

· North Indian Diet: Includes whole wheat flour (e.g., chapati), pulses like rajma and chana, and dairy products, often cooked with local spices and ground in traditional mills.

· West Indian Diet: Known for its vegetarian options, especially in Gujarat, where pulses and dairy dominate, alongside wheat and rice as staples. As in most of the other states of India wheat and rice, are

the staple foods of Maharashtra and also include use of variety of coarse cereals, pulses & blends (e.g. thalipeeth, ghavan, bajri, bhakri, jowari flours, handwa mix etc). The diet also includes a variety of coarse cereals and grains.

· Assamese Diet: Focuses on seasonal, locally grown leafy vegetables, fish, and minimal spices, with the regular consumption of fermented rice (pointabhat).

· Jain Diet: Exclusively vegetarian, excluding meat, eggs, and fish, with an emphasis on fresh, non-stored foods.

Each regional variation offers a unique dietary approach, contributing to the broader understanding of how traditional Indian diets can be tailored to help manage and prevent Type 2 diabetes.

Methodology:

A comprehensive literature review was conducted utilizing several academic databases, including PubMed, Scopus, and Google Scholar, to gather relevant research on the relationship between traditional foods, Type 2 diabetes, and the glycemic index (GI). The search terms employed included "Traditional food," "Type 2 Diabetes," "Indian Diet," "Mixed meals," "Snacks," and "Glycemic Index." After screening for relevance and quality, a total of 15 research papers were selected for review. These studies were critically analyzed to assess the impact of modified traditional Indian foods with low GI on the management of Type 2 diabetes, particularly focusing on their effects on glycemic control and insulin sensitivity.

Indian Studies on Glycemic Index of food and glycemic and insulinemic response in Type 2 diabetes

Pande A and et.al in 2011 has successfully confirmed that redesigned Indian vegetarian snacks like Poha (flattened rice flacks), Sprouted Lentils and Buttermilk, Broken Wheat Upma (Lapsi Rava) and chutney, Raddish Paratha and Curd, Thalipeeth and chutney, Brown Idli and Sambar, Dhokla and chutney, to have a low GI and also demonstrated the similar and comparable glycemic and insulinemic effect in both normal and type 2 diabetic [9].

M.Batra and et.al in 1994 in his study on the glycemic index of fermented and nonfermented legume based snack food, concluded that Lentils with husk contribute to fiber which has been shown not only to increase transit time but also shown to suppress postprandial glycemic response[10]

Traditional Upma prepared with roasted Semolina (Rava) has a high GI (GI=76%). Although the carbohydrate content of Semolina and Broken Wheat Upma do not vary much, inclusion of split green gram (rich in protein and fiber content) and vegetables (Cabbage, Carrot) decreased the GI of this modified preparation. It has also enhanced the protein content and hence the nutritive value of this snack. This snack also has a better nutritive value than semolina [11].

In 1992 Mani UV & et al studied the glycemic response of Semolina in NIDDM patients and showed that roasted semolina has high GI (GI= 76%) as compared to steamed semolina (GI=
55%) and semolina in combination with black gram dhal (Udid dal) (GI= 46%) or green gram dhal (GI=62%).This study however did not include insulinemic response, glycemic load, and the details of the snack preparation [11].

In 2000 Pathak P, Srivastava S, Grover S has demonstrated in five normal females and five diabetic male subjects the beneficial hypoglycemic effect of marketed snacks prepared from millets, fenugreek seeds and legumes in type 2 diabetic subject. They showed that maintaining the equicarbohydrate proportion of 50g in all the food products ,Upma(230g) made of foxtail and barnyard millet (Bajra) ,legumes and fenugreek seeds had a lowest GI (17.60) as compared to Dhokla (250g)made of foxtail and barnyard Millets, fenugreek seeds and legumes had a highest GI (34.96) and Laddu (80g)made of amaranath ,foxtail millet and legumes in powder form had a GI (23.52) in normal subjects. In diabetic subjects the GI of Dhokla was (31.11), Uppma(19.35) and Laddu (28.68) [12] .

In 2007, Shanmugam Shobana et al studied Glycemic response of rice, wheat and finger millet based diabetic food formulations in normoglycemic subjects. Food formulations suitable as dietary supplements to diabetic subjects based on wheat, decorticated finger millet, (aralu)(Pressed rice) and expanded (puri) rice(Puffed rice) each blended separately with legumes, non-fat dry milk, vegetable oils, spices and a few hypoglycemic ingredients were formulated. The Glycemic Index (GI) values were 55.4±9, 93.4±7, 105±6 and 109±8 for wheat-based, millet-based, aralu-based and puri-based formulations. The study revealed the suitability of wheat-based formulation as a food supplement or as

meal replacer in diabetic subjects but the unsuitability of rice-based formulations [13].

In a comparative study of snacks, by Shukla K. and et.al. in 1991 studied individual glycemic response of three millets i.e. maize (Jowari), Bajri and Barley. They observed that barley has a lower glycemic index as compared to Jowari and Barley in both normal healthy and type 2 diabetic subjects and also helps to mobilize insulin in type 2 diabetic subjects [14].

Paratha is a traditional snack of Punjab. But Alu paratha is popularly found to be consumed by every Indian in almost every part of India. The flour used in making alu-pararha is normally either refined flour or Whole wheat flour which makes it a high GI food. This snack is also converted into a high TG dish by addition of generous amounts of desi ghee.

Pande A and et.al in 2011 in their study modified the snack by using Raddish instead of Potato and flour used was whole wheat flour, Mothbean flour, and Bengal gram dhal flour (Besan) in the proportion of 1:1/2:1/2. Moth bean flour used because it increases the protein and fiber content of the preparation and Bengal gram dhal is known to lower the glycemic response. One serving of three parathas i.e. 180g of serving amount has 50g of carbohydrate with GL= 20.72g thus had a GI=41.44% which elicited a similar and comparable glycemic response in both normal and type 2 diabetic subjects [9].

Thalipeeth is the traditional snack of Maharashtra. This is prepared by using flours of, Jowari, Whole wheat, Bengal gram dal, and Moong da [11].

In 1997 Mani et al in his study on five south Indian snacks had shown that Idli with chutney (GI= 101.5±7.5) & Dosai with Podi & chutney (GI=91.3± 2.5) have a higher GI than Bisibelle bhat (GI= 58.0±5.5) or Pongal with sambar (GI= 53.6±2.4) and Adai with chutney (GI= 69.6± 8.1) [5].

In 2000 Urooj and Puttaraj S. studied glycemic responses to six cereal based foods traditionally consumed snacks in south India were evaluated in 57 NIDDM & 59 healthy subjects. The GI values for six foods were chapatti(81%) , dosai(77%),idli (77%), Pongal(90%), poori(82%)& Uppitu(67%) in NIDDM & in healthy subjects chapatti(44%) , dosai(55%),idli (60%), Pongal(45%), poori(57%)& Uppitu(69%) with no significant differences within the group & significant relationships were observed between peak responses & area under the curve for foods in patients with NIDDM & in vitro rate of starch hydrolysis [15].

In both these study traditional idli had a high GI which is not suitable as a diabetic snack and in Puttaraj et.al study they used oil in the range of 5g-10g and smashed potato also was included which made the snacks highly lipemic and glycemic again not suitable for diabetics.

But Parboiled rice along with black gram (split & intact husk) used for preparation of the Snack- Brown Idli not only has lower GI (GI=47%) than the conventional preparation (White Idli -GI = 77%).

Traditionally Dhokla is prepared by using plain rice and Bengal gram dhal and allowed to ferment by adding soda bicarbonate and buttermilk or curd. Pande A and et.al have shown that by using Parboiled rice, Bengal gram dhal, and Green gram dhal in at appropriate proportion of 2:1:1/2 and allowed to ferment overnight by adding only buttermilk without soda bicarbonate. One serving of five pieces of Dhoklas i.e. 150g of serving amount has 50g of carbohydrate with GL= 18.50g thus had a GI= 37.01% which elicited a similar and comparable glycemic response in both normal and type 2 diabetic subjects [9].

Idli and Dhokla were the two fermented snacks. The former had comparatively higher GI (GI=47%) than the later (GI=36%). Decreased proportion of starch in the later along with the combination of lentils could be contributing to lower GI. Batra & Sharma have shown that unfermented green gram pancake (Cheela) showed a higher reduction in blood glucose response as compared to the pancake from fermented green gram mixture. Fermentation is said to increase GI due to breakdown of complex carbohydrates into simpler form of mono and disaccharides though it is said to improve the bioavailability of nutrients [10].

The modified Dhokla, shows the combined effect of Green gram dhal and Bengal gram dhal which are rich in protein source as well as in fiber content further decreased the GI of Dhokla as compared to Brown Idli in which only black gram dhal was used [11].

Indian studies on vegetarian mixed meals has also carried out and has shown that postprandial glycemic control in normal subjects which ranged from 86mg%-102.4mg% and a good postprandial glycemic control in type 2 diabetics which ranged from

132.8mg%-148.4mg% [16]. The PP 2 hour fall in blood glucose values was similar and comparable in both the groups and hence may be considered as appropriate for routine consumption by diabetics.

In 2010 Mohan V and et.al studied GI of Indian flatbread (rotis) prepared by using Whole wheat flour and atta-mix added Whole wheat flour and concluded that the GI of atta-mix roti was (27.3%) which is lower than the Whole wheat flour roti (45.1%) [17].

In 2012 Pande and et.al prepared Indian flatbread (Phulkas) and for making Phulka added soybean flour in combination with whole wheat flour and had got a lower GI which was 36% and GL was 18g.The addition of Soyabean flour to whole wheat flour in preparation increased the protein: carbohydrate ratio. Thus this meal containing Phulka along with whole green moong lentil and fibrous green vegetables like Cabbage rendered the GI of this meal to 33.64% [16].

In 1981 Dilawari JB & et al in their study on, reduction of postprandial plasma glucose by Bengal gram dal and Rajmah, showed that the mean peak rise in plasma glucose was decreased by 82.1% with Bengal gram dal, 67% with rajmah, while wheat & rice showed reduction only by 25% & 16%, respectively [18].

Pulses and legumes are known to have a rich source of fibre in the form of galactomannas which are not hydrolyzed by the digestive enzymes of man and hence called unabsorbable carbohydrate. Moreover, galactomannans present in pulses are more viscous than fibre present in wheat and rice. The viscosity of the dietary fibre has been shown to correlate positively with the reduction in pp plasma glucose levels. Studies have shown that lentils, legumes and pulses have high protein content which may lower the glycemic response by

promoting insulin secretion. It may form a complex with starch thus rendering it less susceptible to amylolytic digestion [18,19].

Although, Jowari and Ragi flour have high carbohydrate content, the protein content of soyabean flour and the proportion of each flour along with Bengal gram and cow pea dal contributed in lowering the GI of this redesigned meal [19].

In 1999 Geeta Torangatti and Rama Naik studied glycemic and insulinemic response of two composite meals based on rice and four composite meals based on millets (Bajra) in normal and type 2 diabetic subjects. They observed that GI of Jowari Roti in combination with whole green gram vegetable was 58.83 as compared to Bajra in combination with Brijal curry vegetable(GI= 55.84) [19].

In 1990 UV Main & et al studied ghycemic response of six indian conventional foods, including white rice, a combination of rice-legume (Bengal gram, peas & green gram) & a combination of rice-dal (green gram dal & red gram dal-dal is dehusked & split legume). They found a higher GI was obtained for rice & for rice with peas, all other combinations yielded lower glycemic indices [20].

The Indian study by Kabir et al on inclusion of moderate amounts of food rich in Beta glucan along with chronic use of low GI breakfast have shown a lipid lowering effect in NIDDM individuals23. Sources of Beta glucan in the Indian diet include vegetables (Gunwar gum) and whole grains, thus having the potential to amplify the hypoglycemic effect along with hyolipemic effect [21].

White rice, which is not destarched after cooking, has a higher GI (72%) than parboiled rice GI (57%) [22] . A high amylose content of any rice variety is said to lower the GI of that variety. The amylose: amylopectin ratio is responsible for variations in GI of rice. A higher proportion of amylose has been shown to have slower rate of digestion and produce lower Glycemic & insulinemic response [22]. However the consumer does not have any information on the amylose content of the rice sold in market.

Pande and et.al included destarched rice which had a GI of 19% with a GL of 9.5. White rice which is not destarched after cooking shown to have a higher GI of 57%.10 Diabetics have an option of choosing either white rice which is destarched or parboiled rice in order to maintain glycemic control [16].

In another study of U V Mani & et al (1990) studied the glycemic & lipemic response to various regional meals. Among regional meals which showed the highest GI, the lipemic response was lowest showing a fall in triglyceride levels with the south Indian whole meal whereas it was highest with Gujarati meal in which the fat content of the recipes were similar. The glycemic load of each meal has not been stated in this study. South Indian meal is rice based hence high GI is expected although it may be less lipemic. In the last 4-5 decade since the invention of Pressure cooker, starch is not being removed from cooked rice and this result in high GI of rice [20].

II. INTERPRETATION AND ANALYSIS

The literature on glycemic index (GI) and its impact on glycemic and insulinemic responses, particularly in individuals with Type 2 diabetes, has been extensively studied in India, with numerous studies highlighting the influence of traditional Indian foods and their modifications on glycemic control. The studies demonstrate that certain Indian foods, particularly vegetarian snacks, can be modified to lower their GI, making them suitable for diabetic individuals.

1. Traditional Indian Snacks and Their Modified Versions: Studies by Pande et al. (2011) and others show that several traditional Indian snacks, when modified, can

exhibit lower glycemic responses. For instance, snacks like Poha (flattened rice), Sprouted Lentils with Buttermilk, and Broken Wheat Upma (Lapsi Rava) demonstrated a low GI and similar glycemic and insulinemic effects in both normal and diabetic subjects. The inclusion of vegetables, legumes, and different flours (e.g., whole wheat flour, Mothbean flour, and Bengal gram dhal flour) in traditional snacks has been shown to reduce their GI, enhancing their suitability for diabetics. For example, the substitution of potatoes with radish in Paratha and the addition of fibre-rich legumes like Bengal gram dhal has significantly lowered the GI of these snacks, from what would traditionally be high GI foods.

2. Impact of Legumes and Pulses: Many studies underscore the role of legumes and pulses in modifying glycemic responses. Batra et al. (1994) and Mani et al. (1997) highlighted that lentils and other legumes, due to their fibre content, significantly reduce postprandial glycemic responses. The fibre, especially in the form of galactomannans found in pulses, slows down the digestion of starch, resulting in a lower glycemic response. For example, incorporating legumes like black gram dhal and green gram dhal in foods like Dhokla and Idli has shown to improve their glycemic profile. This effect is particularly evident when comparing fermented and non-fermented forms of snacks, where fermentation tends to increase the GI due to the breakdown of complex carbohydrates.

3. Effect of Millets and Other Whole Grains: Millets like Bajra (pearl millet) and Ragi (finger millet) are highlighted in several studies (Pathak et al., 2000; Shanmugam et al., 2007) as having a lower GI compared to rice and wheat-based products. For example, the study by Pathak et al. (2000) found that millet-based snacks such as Upma made from foxtail and barnyard millet had a significantly lower GI compared to Dhokla or Laddu made from similar ingredients. These findings suggest that millets, when incorporated into snacks, are beneficial for glycemic control in diabetic individuals. Furthermore, the combination of millets with legumes and fenugreek seeds has shown a hypoglycemic effect, reinforcing their potential as diabetic-friendly foods.

4. Fermented vs. Non-Fermented Foods: Fermentation plays a key role in the GI of foods. Studies by Pande et al. and Mani et al. (1997) have shown that traditional fermented foods like Idli and Dhokla have varying GI levels, with Dhokla exhibiting a lower GI compared to Idli. This could be attributed to the different ingredient combinations and preparation methods, such as the use of Bengal gram dhal and green gram dhal in Dhokla, which contribute to its lower glycemic response. While fermentation is known to improve nutrient bioavailability, it can also increase the GI due to the breakdown of starches into simpler sugars. This highlights the importance of selecting ingredients that can help balance the effects of fermentation.

5. Glycemic Load and Meal Composition: The glycemic load (GL) of meals, which takes into account both the carbohydrate content and the GI of a food, is crucial in understanding the long-term impact on blood glucose levels. The studies show that meals with a combination of high fibre, protein, and low GI foods can significantly improve postprandial glucose control in diabetics. For instance, the addition of soybean flour in Phulka (flatbread) not only reduced the GI but also improved the protein:carbohydrate ratio, making it a suitable choice for diabetics. Similarly, the modification of snacks like Paratha by adding legumes and reducing the use of high GI ingredients like potatoes further lowers the glycemic response.

6. Regional Variations and Traditional Foods: The studies also highlight the regional variations in Indian foods and their glycemic responses. For example, in a comparative study of regional snacks, the GI of Idli and Dosa was higher compared to other South Indian dishes like Pongal and Bisibelle Bhath. This variability is attributed to the types of rice and

legumes used, as well as the cooking methods. For instance, the use of white rice in traditional snacks results in a higher GI, while modifications such as using parboiled rice or destarched rice have been shown to lower the GI significantly.

Overall, Indian studies provide a strong foundation for the understanding of how modifying traditional foods can improve their suitability for diabetic individuals. The use of legumes, millets, and low-GI grains, along with the inclusion of vegetables and appropriate cooking methods, can significantly lower the glycemic and insulinemic responses. These modifications make traditional Indian snacks more accessible to people with Type 2 diabetes, offering them healthier alternatives without compromising on taste or cultural preferences. Furthermore, incorporating these modifications into vegetarian mixed meals can help maintain postprandial glycemic control, benefiting both normal and diabetic individuals alike.

III. CONCLUSION

All these traditional Indian vegetarian snacks had low GI i.e < 55%. One of the factors could be the use of lentils with husk which contributes to fibre and has been shown not only to increase transit time but also shown to suppress postprandial glycemic response. Another factor which influenced the glycemic response was the quantity (GL) of each snack served. The amount of carbohydrate in each serving has a significant role in maintaining glycemic response. Several helpings/servings of a low GI snack or food can lead to a high carbohydrate load, thus resulting in hyperglycemic effect.

Studies reporting GI on millet-based snacks are commercial products which may not be affordable by a lower income diabetic on a routine daily basis.

A striking feature of these traditional Indian food (snacks) and mixed meals prepared was the return of the PP 2hr blood glucose level to near fasting levels in both the normal and diabetics. This correlates well with the insulin response which was similar and comparable in both normal and diabetics. The serum levels of insulin at PP - 2 hr continued to be higher than fasting state. This explains the significant fall in the blood glucose level at PP- 2hr for the normal and diabetics. Although the mean insulin levels at Fasting, postprandial- 1hr & 2hr was higher in normal volunteers than the diabetics, the pattern of rise and fall was similar and comparable for both the groups. There appears to be some stimulatory role of the test snacks on the release of insulin.

The reviewed literature underscores the potential of traditional Indian foods, particularly those based on legumes, whole grains, and millets, in managing the glycemic response of Type 2 diabetic patients. Research consistently demonstrates that incorporating low-GI foods into the diet can help improve glycemic control, reduce insulin resistance, and provide a healthier dietary alternative to processed foods. The studies reviewed suggest that with minor modifications to traditional recipes, it is possible to significantly reduce the glycemic impact of Indian meals, offering a promising dietary strategy for diabetes management. These studies reinforce the importance of modifying traditional foods and incorporating low-GI alternatives to better manage Type 2 diabetes. Through adjustments in dietary staples such as rice, wheat, and traditional snacks, individuals with diabetes can potentially experience improved blood sugar control and a reduction in associated complications.

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