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Research Article

Diabetes and Glycemic Index: Influence of Various Foods

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Abstract

Diabetes mellitus affects metabolism of several nutrients with varying ill effects. However nutrition therapy along with correct medicines is an integral part for improving glycemic control and reduces the risk of complications. For people with diabetes the challenge however is to maintain good glycemic control while providing nutrients for fulfilling the basic health requirements. Specific strategies to include foods having controlled energy, with reduced saturated fat, trans fat and sodium, moderate protein and high dietary fiber and low glycemic index foods should be planned and implemented for adequate management of diabetes.

Glycemic index (GI) can be used as a guide in selecting foods for meal planning. It classifies carbohydrate containing foods according to their potential to reduce blood sugar levels. But like others it is also influenced by many factors like use of single food items rather than combinations of foods, affect of particular size, different nutrients, how the product is prepared and how much is eaten. This paper is based on a desk review of available literatures to support the use of glycemic index in the management of diabetes.

Keywords: Diabetes Mellitus; Nutrition; Foods; Glycemic Index

Introduction

Diabetes mellitus or 'madhumeham' has been known for centuries as a disease related to sweetness. People with diabetes have too much sugar in blood and urine due to lack of effective insulin. This is because either the pancreas cannot produce enough insulin or what is produced is not effective in controlling the blood sugar. However, there is no need to worry, since diabetes can be kept under control with certain changes in the life style i.e. food intake, exercise and regular intake of prescribed medicines.

Diabetes is also feared because of its complications. It is the mother of illness which affects almost every part of the human body. It is the largest cause of Coronary Artery Disease (CAD) and second largest cause of blindness in India after vitamin A deficiency and lower limb amputations after accident. In any large kidney transplant centre, diabetes end stage renal disease tops amongst the causes of kidney transplants. American Medical Association (ADA) has designated diabetes as a "silent killer" because in uncontrolled condition the vital organs get damaged severely without any warning symptoms (Anon, 1994).

Swidorski (2014) reported that prevalence of type 2 Diabetes Mellitus found in present study was 4.6% with equal prevalence in both the sex. Higher prevalence of diabetes in males was found in the age group of >60 years while in females prevalence occurred a decade earlier i.e. in 51-60 years. Abdominal obesity in females and family history of diabetes were found positively associated with diabetes while there was no significant association found between diabetes and physical activity.

Diabetes Mellitus, particularly type 2 diabetes mellitus is caused by genetic and environmental factors. It is a group of genetically heterogeneous metabolic disorder that causes glucose intolerance, involving impaired insulin secretion and insulin action. The prevalence of Diabetes is increasing rapidly worldwide and the World Health Organization has predicted that by 2030 the number of adults with diabetes would have almost be doubled worldwide, from 177 million in 2000 to 370 million (Nusart., *et al.* 2015).

Diabetes mellitus affects the metabolism of several nutrients with varying ill effects. However with modern regime patients can remain symptom free and maintain good health. Dietary regulation is one of the major components of the diabetes monitoring to avoid further complications. The major objective of dietary treatment in diabetics is to maintain near normo-glycemia with ultimate goal of leading normal span of life in health and comfort. Dietary prescription should be individualized considering the dietary pattern, habitual diet and regional availability of the foods to achieve better meal adherence. Presently the recommended diabetic diet is high carbohydrates, high fibre and low fat because it helps in minimizing the rise in post-prandial hyperglycemia and serum cholesterol. Diabetic diet should provide 60-65 per cent calories from carbohydrates, 15-25 per cent from protein foods and 15-20 per cent from fat to achieve closeness to the normal diet. The total calorie requirement for the diabetic depends on age, gender, weight, height, physical activity and physiological needs of the individual.

People with diabetes have been previously advised to cat some "complex" carbohydrates at each meal and to avoid "simple" carbohydrates except when hypoglycemia occurs. However the traditional classification of starchy foods as "slow" and sugary foods as "quick" to be digested and absorbed is now thought to be inaccurate. The recent research into Glycemic Index has led nutritionists to reconsider the diet of diabetic patients. In general a high carbohydrate, low fat diet with moderately small amounts of sucrose is recommended for all people with diabetes. However, not all the foods high in carbohydrates are suitable and it depends on their value of Glycemic Index. Sugar is not thought to be the "bete noire" of the past and can be included as a part of a mixed meal.

The term Glycemic Index (GI) was conceived in 1981 by David Jenkins. It was originally thought that all simple sugars caused a more rapid rise in blood sugar levels than did complex carbohydrates. But some studies emerged to challenge this conventional wisdom about sugars. Jenkins sought to systematically test the impact of different carbohydrates on blood sugar levels, compared to glucose and ranked the carbohydrates by what became known as the glycemic index.

The glycemic index ranks carbohydrate-containing foods on how quickly they elevate blood sugar levels. It is measured by comparing the increase in blood sugar after eating 50 grams of carbohydrates from a single food with the increase in blood sugar after eating the same quantity of carbohydrate from a reference food, which is either pure glucose or white bread. The average change in blood sugar levels over the next two hours, compared to the change in blood sugar levels after consuming the reference food, is the glycemic index value of that particular food. The blood sugar response of the reference food is given a value of 100 and all other foods are compared to this value. Lower values of GI one beneficial in management of diabetes.

Jenkins, a professor of nutrition at the University of Toronto, Canada, was first to describe the concept of glycemic index to determine which foods are best for people with diabetes. His path breaking study, "Glycemic index of foods: a physiological basis for carbohydrate exchange", appeared in March 1981 issue of American Journal of Clinical Nutrition. In the subsequent 15 years literally hundreds of clinical studies in India, the United Kingdom, France, Italy, Canada and Australia have proved the value of glycemic index. Despite this, many diabetic associations in Western countries in particular the American Diabetes Association (ADA) have adopted carbohydrate counting as the most important meal planning principle.

Jenkins coined the term "Glycemic Index (GI)" to provide numeric classification of carbohydrate foods on the assumption that such data would be useful in situations in which glucose tolerance is impaired. The glycemic index is defined as the indexing of the glycemic response of a fixed amount of carbohydrate from a test food to the same amount of available carbohydrate from a standard food (white bread/ glucose) consumed by the same subject. The blood glucose area after consumption of the test food is expressed as a percentage of the standard.

A related concept Glycemic Load (GL) was proposed as a method to characterize the glycemic effect of diets differing in macro nutrient composition. The GL is defined as the weighted mean of the dietary GI multiplied by the percentage of total energy from carbohydrate (Ludwig and Eckel, 2002).

The glycemic index can be approximated by the carbohydrate content of each meal is determined to approximate the glycemic index of a meal. The proportion of carbohydrate contributed by each food is then multiplied by its glycemic index and the values are totaled to give the glycemic index of the meal. It was also determined that this method of combining the glycemic indices of meal components yields a glycemic index within 2% of the measured value forth aggregate meal [1,2]. This principle has also been applied to generate a corresponding insulin index of foods.

The world wide two large study groups namely Diabetes Controlled Complication Trial of United States of America (DCCT) and United Kingdom Prospective Diabetes Study (UKPDS) confirmed that optimal glycemic control reduced the risk of vascular complications by 60 per cent. With good glycemic control throughout the course of illness, one can to a very significant extent prevent the dreaded complications of diabetes. It has been also remarked that if 100,000 persons with diabetes are offered a good glycemic control one can lead to a gain of 920,000 years of sight, 691,000 years free from end stage renal disease and 611,000 years of life.

The term was explained way back in many studies. In 1983 by Bantle., *et al*. showed that when five iso-caloric breakfast meals containing identical amounts of protein, fat and carbohydrates (glucose, fructose, sucrose, potato d wheat starch) were given to 127 Type I and 10 Type II diabetic subjects greatest glycemic response to glucose and least to fructose and no apparent differences were seen between potato, wheat starch and sucrose thus highlighting the view that dietary sucrose when consumed as a part of meal did not aggravate post prandial hyperglycemia. Low glycemic index meal revealed excellent inhibitory effects upon post prandial glycemic elevation in the elderly diabetics which suggested the clinical usefulness of a low GI meal (beans) for post prandial glycemic regulation in elderly diabetes mellitus.

Inclusion of low GI foods in the diets of diabetic patients favorably influences carbohydrate and fat metabolism. Miller (1994) reported that low GI diets reduced glycosylated haemoglobin by 9%, fructosamine by 8% urinary C peptide by 20% and daylong blood glucose by 16%. Cholesterol was reduced by an average of 6% and triglycerides by 9%. It was concluded that unlike high fibre diet, low G I diets are "user friendly".

Studies have also shown that tight control of blood glucose through glycemic index could reduce risk of diabetes up to 35% while good control of blood glucose can reduce complications of eye (76%), kidneys (50%), nervous system (60%) and cardiovascular diseases (35%) amongst the diabetics [3]. Supplementing subjects' diet with low glycemic index foods would lead to lower depression of antioxidants and consequently fewer micro and macro vascular complications. Low GI diets may also benefit weight control in obese by promoting satiety and by promoting fat oxidation at the expense of carbohydrate oxidation. These two qualities stem from slower rates at which they are digested and absorbed and the corresponding effects on post-prandial glyecmia and hyperinsulinemia (Brand Miller. 2002).

The glycemic index is a physiological assessment of a food's carbohydrate content through its effect on postprandial blood glucose concentrations. Esfanani., *et al*. (2009) showed that low glycemic index diets have also been reported to improve the serum lipid profile, reduce C-reactive protein (CRP) concentration and aid in weight control. In cross sectional studies, low glycemic index or glycemic load diets have been associated with higher levels of high-density lipoprotein cholesterol (HDL-C), with reduced CRP concentrations. In addition, some case-control and cohort studies have found positive associations between dietary glycemic index and risk of various cancers including colon, breast and prostate. The glycemic index may have a role to play in the treatment and prevention of chronic diseases.

Mechanism of action

The hypothesized metabolic effects relate to the rate at which glucose is absorbed from the small intestine. A reduced rate of glucose absorption after the consumption of low glycemic index carbohydrate foods will reduce the postprandial rise in gut hormones (in cretins) and insulin. The prolonged absorption of carbohydrates seen overtime will maintain the suppression of the fatty acids (FA) and the counter regulatory responses, while at the same time will achieve lower blood glucose concentrations. Over time, with the reduction in FA concentrations and the rise in the respiratory quotient with tissue insulinization glucose is withdrawn from the circulation at a faster rate. Consequently, blood glucose concentrations return towards baseline despite continued glucose absorption from the small intestine. The rise in peak post prandial blood glucose in therefore reduced, together with the incremental blood glucose area above baseline (Jenkins., *et al.* 2002).

Main factors affect glycemic index which includes the nature and physical form of food, processing, storage and cooking, type and amount of fibre and in case of fruits their ripeness. In the setting of a mixed meal the amount of protein and fat content also play a role. Apart from food, "human factors" also influence glycemic index (Kapoor., *et al*. 2000).

Diets with high or low protein content and glycemic index for weight-loss maintenance were reported by Leherson., *et al* (2010). A diet with a low glycemic index may have beneficial effects on body weight and body composition and on certain risk factors in overweight persons but the effectiveness of ad- libitum consumption of low-glycemic-index diets for weight control is controversial. Study was designed to assess the efficacy of moderate-fat diets that varying protein content and glycemic index for preventing weight regain and obesity-related risk factors after weight loss.

The studies conducted to assess glycemic index of different foods in relation to their processing methods, amount and type of carbohydrate, fiber percentage of other nutrients and mixed meal, have been reviewed and presented in the following paragraphs of different food groups:

Cereals

Patel (1985) reported that addition of wheat bran (11 g) in the form of biscuits for 30 days in 14 NIDDM diet, lowered fasting and post prandial glucose levels but observed no change in glycosylated hemoglobin and amino acid levels.

A Study was, conducted to look at the effect of processing wheat and rye on blood glucose responses with special reference to bulgar and pumpernickel bread, groups of 9-12 NIDDM and 5-6 IDDM volunteers were fed test meals containing 50g carbohydrate portions of whole wheat and three rye products. Results revealed that traditional processing of cereals, such as parboiling (bulgar) or the use of whole grains in bread (pumpernickel) may result in the low GI value associated with the un-milled cereal. Cereal foods processed in these ways may form a useful part of the diet where a reduction in postprandial glyecmia is required. (Jenkins., *et. al*.,1986).

Chitra and Bhaskaran (1989) demonstrated that food form, dietary fibre and the nature of carbohydrates have a marked influence on post prandial glyecmia. Different glycemic responses were observed when 50g of carbohydrate given in the form of parboiled rice, rice flour (idappaim) broken wheat, {upma). wheat flour (chapathi) and ragi flour (iiinddc) in 3IDDM. 3 NIDDM and 3 non-diabetic subjects. It was interesting to note lower glycemic response to idiappam than cooked rice among IDDM and healthy volunteers and elevated glycemic response to wheat flour and ragi flour as compared to broken wheat in all the three groups.

The post prandial response to maize (Zea mays), bajra (*Pennisetum typhoideum*) and barley (*Hordeum vulgare*) was studied in a pool of 18 healthy volunteers and 14 patients having non insulin dependent mellitus (NIDDM). It was concluded that barley with a low glycemic index (68.7 in healthy and 53.4 in NIDDM subjects) and a high insulinemic index (105.2) in NIDDM becomes a specially suitable cereal for diabetes mellitus (Shukla., *et al*. 1991).

Brand., *et al*. (1992) determined GI of 12 rice products. The high amylose rice exhibited lower GI than the normal GI in range of 64-93. Usually rice varieties contain 20 percent amylose but varieties with high amylose content (>28%) have shown slower rate of digestion producing hypoglycemic effect.

Bijlani evaluated the acute post prandial and long term metabolic response to a traditional mixture of barley (Cicer arietinum) and wheat (Triticum astivim) on eight healthy and six NIDDM subjects. Results showed that post prandial glycemic index was 68.6 and 64.9'and insulinemic index was 88.4 and 66.0 in healthy and NIDDM subjects respectively.

Increase in consumption of whole grain cereals (including millets) due to beneficial physiological effects of fibre and resistant starch, whole grains contain 3-20 percent of starch resistant to digestion, which can be fermented in the colon. The resistant starch hinders absorption of glucose and reduces the pH of colon thereby reducing the effect of carcinogenesis.

Lintas., *et al*. (1995) noticed that test meals given in the form of pasta and cereals (fibre enriched) to 10 NIDDM subjects showed lower glycemic responses than rice and plain pastas, indicating that physiological effects of cereal based meals depend on the interrelationship between chemical and physiological properties of dietary fibre and other fibre components.

Yenagi., *et al*. (2001) proposed that inclusion of dicoccum wheat in daily diet benefits the diabetics as compared to bread wheat. The lowered glycemic, cholesterolemic and triglyceride levels were observed in diabetics after consumption of dicoccum chapathis (200g flour) everyday for the period of 45 days as compared to bread wheat chapathis eating diabetic group.

Legumes

The blood glucose response of the normal volunteers to a variety of carbohydrate (50g) foods such as eight varieties of dried legumes, grams, bread, pasta, tubers and biscuits tested revealed smaller rise in post prandial glucose levels after consumption of legume than the other foods (Jenkins, 1980). Dilwari., *et al*. (1987) obtained a significant lower GI for legumes (Rajmah, 29.59 green gram, 48.14 and Chana 48.89) as compared to cereals (wheat 87.86 and rice 89.67).

Kurup and Krishnamurthy [4] reported that 75g carbohydrates given in the form of pulses such as black gram (Phaseolus mungo Roxb), bengal gram (*Cicer arietinum*), horse gram (*Dolichos biflorus*) and green gram (*Phaseolus aureus* Roxb) with the replacement of wheat during dinner to four groups of non diabetic dinner to four groups of non diabetic volunteers varying from 22 to 41 g in quantity, appeared to be beneficial in reducing lipemic changes and not glycemic levels. Black gram and bengal gram found to be more effective in reducing triglyceride levels by 8% and increasing HDL cholesterol by 20 percent as compared to horse gram and green gram dhal. Hence the inclusion of legumes approximately l/5th of the calorie requirement would prevent coronary complications in diabetes.

The glycemic response to white bean (*Cicer arietinum* Linn) and black bean (P*haseolus Vulgaris* Linn) was significantly lower than the French beans (Phaseolus vulgaris), Pigeon pea (*Cajanus cajan* Linn huth) and moth bean (*Phaseolus aconitifolius*, Jacq.). The blood glucose response to all legumes was significantly lower compared to bread among healthy volunteers. The differences in the glycemic responses among the legumes could be due to amount and kind of dietary fibre, amylose content and the presence of anti nutrients. Therefore inclusion of legumes in diabetic diet found to be beneficial (Panlasigui., *et al*. 1995).

Rema., *et al*. (1998) reported that glycemic index values in non-diabetic and 28.9 in diabetics for green gram (*Phaseolus aureus* Roxb.) and for bengal gram (*Cicer arietinum*) 115.5 and 36.3 respectively. The significant difference between two meals was observed in non-diabetics but not in diabetic subjects. In general pulse exhibit lower glycemic response.

Sai Priya and Mageshwari (1998) reported that supplementation of the therapeutic premix (30g) based on legumes as a drink to 12 NIDDM subjects for a period of one month reduced fasting and past prandial glucose levels. The premix was prepared from sprouted bengal gram (l0 g), dry peas (5g). The mix was dried, roasted and provided than mixed with rice flour in order to increase dietary fibre content without much alteration in their regular diet

Vegetables

Iyer and Mani [5] reported that supplementation of 12g curry leaves powder (2.5g fibre) in 30 NIDDM diets for the period of 30 days lowered the glucose response.

Anuradha and Vidhya [6] reported that four gram supplementation of spirulina (micro algae) for the period of 60 days in 10 NIDDM subjects reduced significantly fasting glucose by 14 percent and post prandial glucose level by 8 percent as compared to control group. Ceruti., *et al*. (1987) reported that inclusion of 66g vegetable in form of dietary fibre in adolescents diabetic diet reduced glycosylated haemoglobin and insulin requirement. The glycemic response of six healthy males to potato, bread, rice and green gram (Phaseolus aureus Roxb) was compared by Sud., *et al*. (1987) with that to meals equivalent to these foods in terms of carbohydrate, protein, fat and fibre content, but made up of maize flour, casein, maize oil and isaphghula husk. Results revealed that natural foods led to a higher post prandial glycemia than their respective equivalents, but the difference was significant only in the case of potato at 0.5 h ($P < 0.05$).

William., *et al*. [7] demonstrated that the blood glucose response of meals containing bitter gourd, curry leaves and drumstick leaves were 72, 60 and 56 respectively as compared to 75g glucose and to the standard meals without these vegetables was 8, 97 and 79 respectively, thus indicating the fact that some vegetables lower post prandial glucose level to greater extent than mixed meal adherence. The presence of inhibitors in the bitter gourd, glycopeptide in curry leaves showed hypoglycemic action in diabetics. Along with this, presence of small amounts of mineral likes calcium, magnesium and phosphorous in vegetables triggered the hypoglycemic effect.

Mushrooms, spinach and isabgol were incorporated in powdered form into a -pulka at different levels. Mushooms at levels of 15g and spinach and isabagol at l0g each effectively controlled blood glucose levels. Rema., *et al.* (1998) reported that addition of 40g of bitter gourd (*Momordica charantia*) for 30 days lowered post prandial glucose level by 37 percent in non-diabetic subjects and 36 percent in diabetic subjects without definite change in fasting glucose and plasma lipid parameters.

Milk and milk products

Milk produced lower GI due to its fat content (8%) as compared to rice (1%) and wheat (1.5%). Fat is known to slow down gastric mobility and emptying, resulting in low GI. Paul and Vijayalakshmi (1992) reported that millet soya mix milk (foxtail and samai) in different proportions such as 1:1 and 2:1 exhibit lower values of net protein utilization (NPU) as compared to skim milk, due to the presence of fibre thereby making them suitable as diabetic health foods. Ostman., *et al*. (2001) characterized the glycemic and insulinemic responses after intake of regular or fermented milk products. It was found that lactic acid in the fermented milk products did not lower the glycemic and insulinemic indexes. Despite low glycemic indexes of 15-30, all of the milk products produced high insulinemic index than that of the reference bread. Addition of fermented milk (yogurt) and pickled cucumber to a breakfast with high glycemic index bread significantly lowered post prandial glycemia and insulinemia compared with the reference meal. In contrast addition of regular milk and fresh cucumber had no favourable effect on the metabolic responses.

Individual foods

About 62 commonly eaten foods and sugars were fed individually to groups of 5-10 healthy volunteers, to test GI of the foods by Jenkins., *et al*. (981 b). The highest value of GI was reported for root vegetables (72 ± 6) followed by vegetables (65 ± 14), breakfast cereals (65 ± 5), cereals and biscuits (60 ± 3), fruit (50 ± 5) dairy products (35 ± 1) and dried legumes (31 ± 5) excluding sugars. Verma., *et al*. (1989) demonstrated the GI of five common foods and four fruits on 21 NIDDM subjects. The GI ranged widely for rice flour (76.2 ± 4.1), dhalia (71.6 ± 3.2), chapathis (66.42), rice (65.4 ± 1.5) and milk (52.3 ± 1.9). GI of papaya, orange, orange juice, apple, apple juice and banana were 55.9 ± 2.8, 61.3 ± 3.3, 73.9 ± 3, 65 ± 3.8, 74.5 ± 0.9 and 77.4 ± 1.9 respectively.

Wolever and Jenkins (1986) tested 11 foods in at least three different centres using groups of diabetics. GI values of the foods tested ranged widely viz., whole meal bread 100 ± 5, potato 98 ± 26 oat meal 89 ± 10, banana 84 ± 14, corn flakes 121 ± 13, white rice, 77 ± 12 white spaghetti, 67 ± 16, orange, 59 ± 14, apple 52 + 5 and kidney beans 38 + 9 in diabetics. Raghuram., *et al*. [8] categorized the Indian foods in different groups on the basis of glycemic index as high GI group ranging from 65 - 75 includes cereals (wheat and rice), millets and root and tuber vegetables (sweet potato, yam, beet root), intermediate group with 45 - 55 GI (fruits) and low GI group (30 - 40) consisting dried beans, peas and legumes.

Borent., *et al*. (1987) demonstrated that different glycemic index was obtained in six isocaloric meals containing different amounts of fibre in 18 NIDDM subjects as compared to six starchy foods taken alone. The least glycemic index was obtained for beans and lentils followed by rice and spaghetti, potato and bread exhibiting different kinds of glycemic response in a mixed meal. Donduran., *et al*. (1999) compared 7 kinds of carbohydrate foods with glucose in 52 type II diabetic patients and 31 normal volunteers. The results showed that the foods ranked from the highest to the lowest GI as follows: white bread, whole bread, macaroni, tarhana soup, white rice, potatoes and noodle soup.

The addition of fenugreek seed significantly reduces the glycemic index of the preparation by 1 0 to 20 percent. It has been advised to consume as 25 g seeds incorporated in different recipes by Raghuram., *et al*. (1993) or in sprouted form (3.0 g) by Chandra and Aruna (1997) for reduction in blood sugar or less excretion of sugar in urine with improvement in glucose tolerance by the diabetics. This hypoglycemic property of fenugreek seeds is attributed to its mucilaginous fibre (20 %) and total dietary fibre (50 %) content. It contains trigonellinean alkaloid, which reduces blood sugar level. The 50 % of soluble dietary fibre content of the fenugreek seeds forms colloidal suspension when hydrated and decreases the rate of gastric emptying and also slows carbohydrate digestion (Ramulu and Rao, 1998).

Glycemic index of six cereal based traditional recipes namely bati with dhal (wheat) dhokla with dhal (maize) and khi&hda-m4 muthia with chutney (pearl millet) was determined by N. Wadhawan and Choudhary M [9]. Recipes were standardized for 50g carbohydrates per serving size and acceptability. All the recipes scored between 7 and 9 on nine points hedonic rating scale revealing that they were liked moderately to extremely by the panel members and the diabetic and non diabetic subjects. Results revealed that glycemic index of pearl millet recipes' namely pearl millet khichda (67.9, 64.5) and pearl millet muthia with chutney (79.2, 77.8) in diabetics as well as non diabetics was low. GI was high for maize dhokla with dhal (116.3) a steamed and wheat bati with dhal (112.6) a baked recipe. The GI of pressure cooked recipes i.e. maize dalia and wheat dalia was 94.1, 75.2 and 84.7, 74.1 respectively in diabetics and non diabetics. The results of the study concluded that glycemic index of the 'recipes varies by the type and amount of cereals, ingredients used and cooking method employed. Pearl millet recipes heaving low glycemic index arc suitable in diabetes management. GI-Studies can be conducted on either diabetic or healthy subjects or both.

In a similar study by G. Purohit and N. Wadhawan [10] Glycemic response of the selected Quality Protein Maize based nutria- rich product was determined. The selected product was an extruded ready to eat snack product which was developed and standardized in the Lab of College of Dairy and Food Science Technology, Udaipur for its processing parameters and acceptability scores. Moisture, protein, fat, carbohydrate, ash and fibre content of the product were 6.05 gram, 11.24 gram, 6.71 gram, 63.81 gram, 6.48 gram, and 5.71 gram per 100 gram respectively. Results revealed that glycemic index calculated from Area Under Curve (AUC) for the test recipe was 48.10 which is low when compared with classification suggested by Monro., *et al*. (2008). Further glycemic load calculated using standard formula was 9.20 which is also low suggesting the positive effect of test recipe in the management of diabetes.

Mixes and mixed meals

Different foods raise the blood sugar to variable extent and exhibit different glycemic responses. However when the individual food is used in mixed meal or in mixture of certain foods, it exhibits glycemic response in different ways. Similarly long term feeding trials with particular food or mixes may also exhibit varied results. Unexpected plasma glucose responses to different mixed meals fed to normal and diabetic volunteers were reported in few studies. Therefore Wolever., *et al*. (1985) examined in normal volunteers, the effect of mixing carbohydrate foods of different glycemic indexes (GI) without the addition of protein and fat. The observed GI of the mixed meal was within 2 per cent of the expected value.

Another study reporting glucose responses to mixed diet containing fat and protein concluded that the results were totally disparate from what would have been expected from published GI values of the foods fed. However this conclusion was based upon an inappropriate assessment of data using absolute rather than incremental blood glucose response areas. This report demonstrates how data may be analysed to make use of the GI values of individual foods to predict the GI of mixed meals ($r = 0.987$; $p<.02$). It was concluded that the GI concept applies well to mixed meals containing fat and protein. Mani., *et al*. [11] reported highest GI value for rice with peas (80) followed by rice (74). The combination of rice-legume (bengal gram and green gram) and rice-dal combinations (green gram dal and red gram dal) elicited GI range between 54-59 emphasizing that combinations of foods especially with legume and dal reduces the glycemic index of foods.

Mukherjee [12] reported that supplementation of 80 g cereal -pulse mix significantly lowered blood glucose, uric acid and amino acid levels in 10 NIDDM subjects during long term study, thus highlighting the fact that cereal pulse mix had beneficial effect on glucose as well as glucosaminoglucan metabolism, causing improvement in carbohydrate metabolism and preventing degenerative complications.

Mani., *et al*. [11] determined the glycemic index of the diabetic mix formulated from a variety of cereals and pulses in 15 NIDDM subjects. The GI of the cereal pulse mix found to be 38.25 ± 1 1.02 after consumption of 90 g mix in the form of khichadi. Bijlani., *et al*. (1993) reported that the substitution of 100 g cereal pulse mix (wheat, barley and bengal gram dal flour in equal proportions) with carbohydrate exchange in 5 healthy and 4 NIDDM patients diet, for a period of four weeks lowered post prandial glycemic and insulinemic response noting GI for mix 68.6 in healthy and 64.9 in NIDDM subjects. The hypoglycemic effect was attributed to the high total dietary fiber content, viscous fibre content. (P - glucans) present in barley and higher protein content (15 %) of the mix.

Potdar., *et al*. [13] reported that mixed diet (defatted soya flour, wheat bran and roasted barley flour) reduced blood glucose level by 19 percent in 27 obese diabetics as compared to 24 diabetics who consumed customary iso - caloric diet (less fibre and without mix) for the period of 10 weeks. Pathak and Srivastava (1998) observed a reduction in blood glucose level in normal and diabetic subjects after consumption of dhokla, upma and laddu prepared from millet mix based on foxtail millet, fenugreek seeds and legume. The glycemic index of different foods was: upma, 17.6; dhokla 35 and laddu 23.5 when tested against 25 g carbohydrate load in normal subjects [14,15].

Conclusion

It is concluded that the concept of GI can be successfully used in ranking the relative glycemic impact of individual foods as well as the mixed meals containing fat and protein. However the exact clinical utility of controlling post prandial glycemia still remains to be established but the apparent success of diets containing low glycemic index foods suggests that in near future low glycemic index foods may prove worthwhile, as diabetics are increasing day by day.

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Volume 3 Issue 5 May 2019