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LOW GI DIETS: NUTRITIONAL PERSPECTIVES AND HEALTH OUTCOMES

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Abstract

Carbohydrates (CHO) are widely consumed food ingredients and hold a great importance in the diet of people all over the world. Glycemic index (GI) is the ability of CHOs to release glucose after consumption of particular amount of food and Glycemic load (GL) is another term to express the glucose response. In this review, relation of GI is explained with starch digestibility, total starch and resistance starch contents. There are different factors such as particle size, fiber, beta glucon, amylose content along with various cooking methods microwave, baking, roasting, frying etc which influence the GI, GL and starch digestibility of food products. Role of GI has also been highlighted in different health ailments like diabetes, cardiovascular (CVD), cancer and hyperlipidemia.

Keywords: Carbohydrates, Glycemic index, Glycemic load, Starch digestibility, Cooking methods.

Introduction

Carbohydrates serve as an energy source (starch and glycogen), they are the components of co-enzymes and also a part of nucleic acids (Safina, 2012). Moreover, like other nutrients such as proteins and fats in a diet, CHOs have direct or indirect effect in maintaining the different metabolic functions of the body. CHOs are the direct source of energy and their requirement in body is much more than the other nutrients as they provide 60-70% of the total energy. Now-a-days people are aware of the alterations in blood glucose levels or GI after consuming carbohydrate-rich diet. To assess the quality of CHO in food products the concept of "GI" (Glycemic index) was developed by Jenkins *et al.* (1981). GI is a quantitative assessment of foods based on the postprandial glucose, blood glucose levels and to observe the variations in as blood glucose levels (Jenkins *et al.,* 1981). On the other hand, in order to account for the differences in glycemic response to the amount consumed the term glycemic load (GL) was introduced. Some foods with high GI may have a low GL. The blood glucose may also be affected by other physiological and nutritional factors (Singh *et al.,* 2010 and Kaur *et al.,* 2007). A wide range of food processing methods and cooking methods is being used for different food materials. These methods influence the food structure and nutritional properties of food including starch digestibility, resistance starch, glycemic load and GI (Roopa and Premavali, 2008, Chung and Liu, 2011).

Carbohydrate metabolism and regulation

CHO metabolic rate depends to the higher degree on the body's energy needs at a time. There are number of energies generating cyclic pathways which are related to CHO metabolism (Gropper and Smith, 2012). During the process of glycolysis which is found approximately in all organisms, small amount energy is required as a glucose molecule that is translated into two pyruvate molecules. Glycogenesis is the synthesis of storage of glucose such as glycogen in vertebrates while glucose levels are elevated and breakdown of glycogen by the process glycogenolysis when glucose supply is short. Furthermore, if glucose is produced from non-CHO sources this process is called as gluconeogenesis. The pentose phosphate pathway is responsible for the conversion of glucose 6 phosphates, derived from glucose to ribose 6 phosphate and other kinds of monosaccharides (Wamelink *et al.,* 2008). Ribose-6-phosphate is the sugar which is utilized for the synthesis of nucleotides and nucleic acids. NADPH (nicotinamide adenine dinucleotide phosphate) is a cellular reducing mediator which is also synthesized. Depending upon the metabolic requirements of cells glucose may be used to produce other monosaccharides, fatty acids and amino acids. Figure 1 is showing the summary of the major CHO metabolism pathways in organisms. Moreover, there are four different ways by which the dietary sources of carbohydrates influence the systematic metabolism in human body. These are the, nature of absorption of monosaccharide, the quantity of absorbed carbohydrate, the degree of CHO absorption and the fermentation in colon (Wolever, 2003).

Glycemic index

GI is defined as the response of blood glucose measured by an individual under standard conditions in response to consume a fixed meal of test food expressed as a percentage of the area under curve following consumption of a standard food consumed by the same person on a different day (Wolever, 2013). Both standard food (glucose or white bread) and test food (50g) must be consumed by the same person and have same amount of carbohydrates. For the measurement of GI, it is necessary to standardized GI testing procedures and conditions which are expressed in details in report of FAO/WHO 1998 (Venn *et al.,* 2007). Various food samples have been tested and based upon these test, food is classified into high GI foods >70, intermediate GI 56-69 and low GI foods < 55. Complex CHO require longer digestion time and delay gastric emptying which lowered the glycemic response. Foods containing simple CHOs like glucose and maltose include a more rapid rise in glucose concentration (Riccardi *et al.*, 2008). GI depends upon the fact that in one serving of a food contains what amount of CHO and it may be outlined by direct or indirect methods. In direct method for each subject area of curve for glucose is determined for a range of doses of the reference food measured on different days. A standard curve is designed for each subject on x axis with increasing amount of reference food comparable to AUC (area under curve) for blood glucose on y axis (Venn *et al.,* 2006). In indirect method, GI of a particular food is multiplied by the amount of CHO present in the portion of the food which is consumed by the same person (Venn *et al.,* 2007). Table 1 is explaining the amount of GI of commonly

used Indian foods according to the classification. GI may be a helpful reference for individuals with suffering from type 2 diabetes mellitus to use dietary guidelines and helpful for clinical practice in diabetes. Low GI foods have shown beneficial effects on glycemic control in both long term and short term (Augustin *et al.,* 2002).

Glycemic load

It is measured by the product of the GI and the amount of CHO in a serving (Ray and Singhania 2011). Glycemic load classification of different foods is like Low GL <10, intermediate GL 11-19 and High GL >20.

Table 1: Classification of Indian foods according to Glycemic index.

No.	Name of the food	Glycemic index (%)
1	White bread	75
2	Whole wheat bread	74
3	Wheat roti	62
4	Chapatti	52
5	White boiled rice	73
6	Brown boiled rice	68
7	Barley	28
8	Instant oat porridge	79
9	Rice porridge	78
10	Millet porridge	67
11	Sweet corn	52
12	Cornflakes	81
13	Apple (raw)	36
14	Orange	43
15	Banana	51
16	Pineapple	59
17	Mango (raw)	51
18	Watermelon (raw)	76
19	Potato (raw)	78
20	French fries	63
21	Carrots (boiled)	39
22	Milk (full fat)	39
23	Milk (skim)	37
24	Ice cream	51
25	Chick peas	28
26	Soya beans	16
27	Lentils	32
28	Chocolate	40
29	Popcorn	65
30	Soft drinks	59
31	Honey	61
32	Glucose	103

Kinetics of Starch digestibility

The starch is digested by undergoing hydrolysis in the presence of several enzymes and is converted to glucose. The enzyme salivary α amylase with ph 7.0 plays a minor role in digestion as it is degraded at early stage (acidic surroundings). α amylase acts exclusively on α1,4 glycosidic bond of amylose and amylopectin (Singh *et al*., 2010). On the other hand, the pancreatic amylase which is released by pancreatic duct in small intestine has major role in digestion of stch. Maltose, maltotriose and maltotetraose are the end products of hydrolysis of starch. Maltohexose and maltoheptose are produced from hydrolysis of starch by α amylase present in some microbial sources (Yook and Robyt, 2002). The kinetics of starch hydrolysis is determined by the first order equation during hydrolysis and described in AUC (area under curve) (Goni *et al*., 1997).

Classification of starch according to the enzymatic action

Different methods are used for the starch digestibility of starch rich foods in vivo and in vitro to estimate the glucose response. The enzymatic method for determination of starch is published by Schweizer *et al.,* (1988) to measure the digestive rate of starch in vitro and in vivo. In addition to this, mostly used method to examine the kinetics of starch digestion was published by Goni *et al* (1997) and Englyst *et al.*, (1992). In Figure 2 starch fractions are classified according to the performance in rapidly digestible starch (RDS), slowly digestible starch (SDS) and Resistance starch (RS), when incubated with different enzymes.

Classification of starch according to nutritional properties

Digestible starches

These starches are digested by the body enzymes such as rapidly digestible starch RDS and slowly digestible starch SDS.

Resistance starch

It is not digestible by body enzymes and there are number of factors contributing to starch resistance leading to uneasy digestion. Figure 3 shows that the resistance starch is divided into four categories which have almost same type of resistance properties.

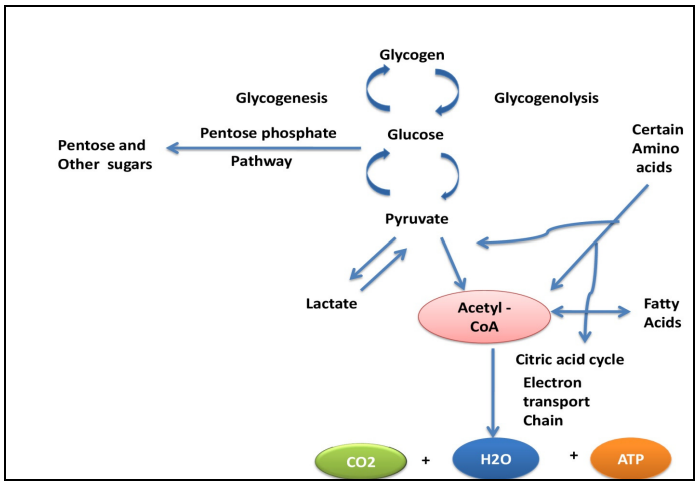

Fig. 1: Major carbohydrate metabolic pathways.

Effect of different factors on starch digestibility, GI and GL

Particles size

The morphological properties of CHO are varied due to the size and shape of starch molecules (Singh *et al.,* 2006). The starch digestibility of sorghum is affected by particle size and found that cryomill conditions has effect on the particle size of the samples such as higher the impactor speed, grinding time or cycles of sample the lower was the size of particles (Mahasukhonthachat *et al.*, 2009). This study found that the size distribution parameters like 5-50µm, 50-500 and 500- 2000µm size and suggested that fine samples contained particles less than 50 µm and coarse samples had size variation between 500- 2000 µm. The result of this investigation is shown that the lower the size of particles more will be the digestibility. Moreover, particle size had effect on the hydrolysis of cellulose. The size of cotton cellulose was reduced by media mill to submicron scale and hydrolyzed by cellulase. As the concentration of substrate was increased the hydrolysis rate of cellobiose to glucose was also raised (Yeh *et al.,* 2010).

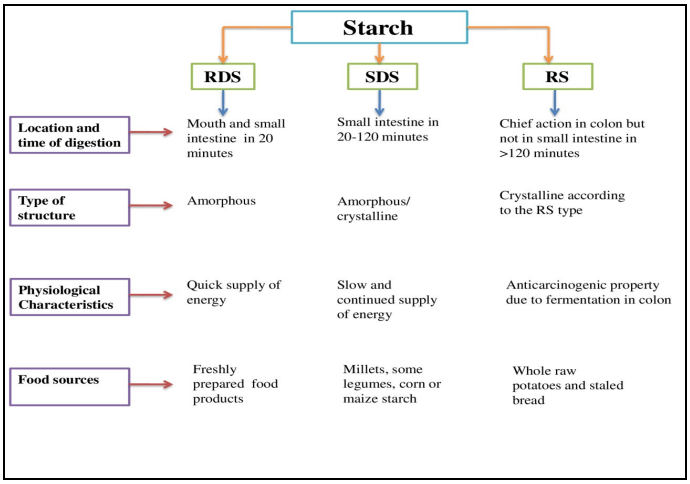

Fig. 2: Classification of starch according to enzymatic action.

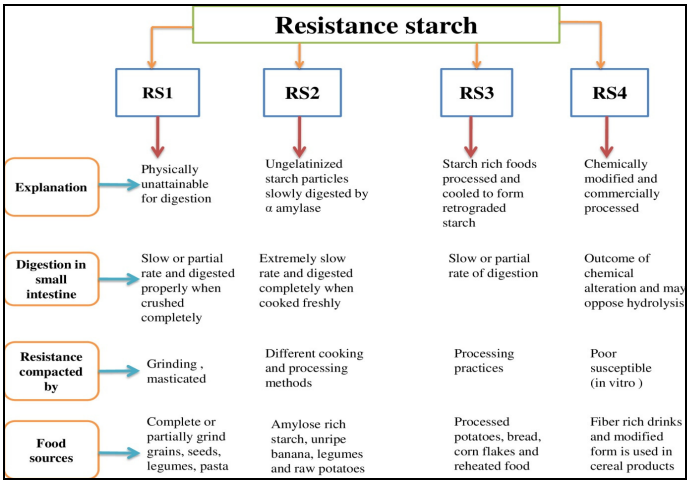

Fig. 3: Classification of starch according to nutritional properties.

Fiber

Fiber is of two types soluble and insoluble and fruits, legumes are the sources of soluble fiber which has beneficial effect to improve the satiety as it provides bulk to the stool and increase the transition time in stomach. These properties of dietary fiber lowered down the postprandial glucose rate, blood glucose and insulin responses among people and decrease the threat of developing diabetes and other chronic ailments (Vuksan *et al.,* 2010). The addition of fiber PGX (polyglycoplex) with different quantity and there was a difference in AUC for fullness and with the increased dose of PGX, the AUC for fullness was also increased. It provided satiety to the consumers for long time and also reduced the plasma glucose AUC by 50%. Moreover, psyllium mixed meal reduced the plasma glucose and insulin responses the level of glucose and serum insulin are lowered and also decreased the plasma ghrelin, GLP-1(Glucagon like peptide 1) and PYY (peptide) responses (Karhunen *et al.,* 2010). In addition to this, incorporation of commercially available dietary fiber into pasta was responsible to reduce the GI and increase starch digestibility (Brennan and Tudorica, 2008).

β-glucan

β-glucan is a soluble fiber derived from oat and barley fiber and has physiological effect on upper gastrointestinal tract (Dikeman and Fahey, 2006). There are several studies which are related to β glucan and its association to reduce postprandial sugar, blood glucose and insulin levels. Jenkins *et al.* (2002) suggested that with the addition of β glucan into oats, the level of GI was reduced in volunteers. Regand *et al.* (2011) also reported that presence of beta glucan in oats have ability to reduce the postprandial blood sugar and insulin responses and to increased the starch digestibility and starch resistance. As the amount of oats was more in meal there was reduction in GI and increased level of RS.

Amylose content

The amylose and amylopectin ratio have effect on the functional characteristics of starch. Elevated amylose ratio has been related with decreased inclination of enzymes to hydrolysis of freshly cooked rice (Lu *et al.,* 2009). Moreover, the presence of amylose in different legumes has effect on the GI and starch digestibility (Sandhu and Lim, 2008). This study reported that black gram has high amylose content as compare to pigeon pea and black gram have RS lower than pigeon pea whereas digested starch is also lower than pigeon pea. Hydrolysis index of black gram is higher than pigeon pea and GI was also higher. Furthermore, amylose content of rice starches has effect on starch digestibility and long grain had high amylose content (27.2%), Calrose (15.4%), Arborio (188.8%) and waxy have low amylose content (4.2%). On the other hand, the value of rapidly digested starch was low and slowly digested starch and resistance starch value was high in long grain as compared to other varieties as it contains high amylose content (Chung *et al.,* 2011).

Cooking methods

A broad variety of methods are used by various production industries to process the different foods sources. These processing techniques affect the structural and nutritional characteristics of food samples comprising starch digestibility as well GI and glycemic load (Singh *et al.,* 2010). Allen *et al.* (2012) estimated that different cooking methods affected the GI of potatoes and found difference on both flesh and skin of the potatoes. This study reported about the effect of raw cooking, steamed, baking, microwave cooking and dehydration and result was found that GI for flesh was 32, 63, 64, 66 and 41and for skin part it was 19, 30, 34 respectively. Capriles *et al.*, (2008) observed the effect of different cooking methods like popping, flaking, boiling and extrusion on starch digestibility of amaranth seeds and result came out to be 112%, 96%, 120%, 93% respectively and also found out the variation in total starch, resistance starch, and GI of amaranth seeds. Eyaru *et al.* (2009) found the effect of different processing methods such as soaking, boiling and cooking on the starch digestibility of green peas and yellow peas. This study expressed the result that the cooking methods affected the starch digestibility of peas in term of rapidly digested starch, slow digested starch and resistance starch. Roopa and Permavali, (2008) found that the effect of cooking method on starch digestibility of ragi and reported about the processing methods like cooking, pressure cooking, autoclaving, puffing, roasting, baking, frying, and toasting and have effect on the starch digestibility i.e. 34, 42, 39.7, 33.4, 37.2, 7.2, 11.2, 31.8 (expressed in %) respectively.

Role of low GI diets with diseases

GI and GL in Diabetes

Diabetes is the chronic metabolic disease which is identified by hyperglycemia and resulted from disturbed insulin secretion due to defected CHO, protein and fat metabolism in the body (Prabhakar *et al.,* 2019 and Garg *et al.,* 2019). Among the millions of people around the world,

the most prevalent metabolic disorder is diabetes mellitus (Bashary *et al.,* 2020). Diabetes mellitus 2 is non insulin dependent type of disorder which acts as the root cause for critical conditions and complications in 285 million people across the globe which is directly affected by the GI of food. Low GI diet reduces the glucose and insulin release and also reduces postprandial sugar levels. Famakin *et al*., (2016) estimated the plantain-based dough meals with soybean has significant role in lowering the GI and glycemic load of food and hence the ability to lower down the level of blood glucose release. Ugare *et al*., (2011) also reported that barnyard millet was found to be having significant role in lowering the GI in type 2 diabetic patients and investigated the level of triglycerides and total cholesterol. PPARγ is also emerging as an important therapeutic target for varied disease states other than type 2 diabetes like neurodegenerative disorders, cancer, spinal cord injury, asthma, and cardiovascular problems (Shafi *et al.,* 2019). Therefore, with the control on BMI (body mass index), dietary habits and other factors, there was considerable inverse link among vigorous work out and gestational diabetes in women (Zhang *et al.,*2006), Hopping *et al.*, (2009) reported 8587 cases of diabetes in 14 years follow up cohort study. Beside this, intake of CHO rich food such as rice has direct relation with development of diabetes among Chinese people in 4.5 years of follow up study.

GI and GL in Hyperlipidemia

Lipids profile contains different type of cholesterol test like triglycerides, HDL (high density lipoprotein), LDL (low density lipoprotein), and VLDL (very low-density lipoproteins). These lipids have significant role in maintaining the health of a person but if their levels get elevated can lead to different health issues. Low GI diet has role in controlling the lipid level in patients which have elevated levels. Jarvi *et al.* (1999) investigated the lipid profiles in volunteers with high GI diet and low GI diet for 3 weeks and found that all the lipid profile is lowered with low GI diet within 3 weeks. Rizkalla *et al.* (2004) also estimated that the intake of low GI foods for five weeks improved the lipid profiles in diabetic and obese patients. Large body of scientific research have illustrated that hyperlipidemia is coupled with oxidative/nitrosative stress (Bhardwaj *et al*., 2013a and Bhardwaj *et al*., 2013b)

GI and GL in CVD risk

Cardiovascular diseases are more prevalent now days due to intake of faulty food habits and more intakes of sugary products and high fatty foods. Diet rich in fiber and low in GI has significant role in lowering down the risk of cardiovascular diseases which is described in Table 2. Cardiovascular and metabolic diseases (CVMD) are the leading causes of death worldwide, underscoring the urgent necessity to develop new pharmacotherapies (Feng *et al.,* 2019). High glucose level and insulin level in patient suffering from diabetes have more risk of development of cardiovascular disorders (Dong *et al*., 2012). The effect of low GI and protein diet has potential to decrease the risk of cardiovascular disease and low GI diet has effect on lowering the low-density lipoproteins and triglycerides and low level of hsCRP (C reactive protein) in different groups of people. Moreover, the high level of C reactive protein also identified as a mark of cardiovascular disorders and low-grade inflammation. Therefore, study was designed for 26 weeks in 932 overweight adults with high protein and low GI diet and following results were found out to be 1.41, -0.87, -1.29 and -1.23 respectively (Gogebakan *et al.,* 2011). Another study explained the significant role of low level of postprandial sugar with low GI diet to reduce the level of C reactive protein and there was 29% lower value in persons having low GI diet than having high GI diet. The high GI diet increased the level of C reactive protein by 40% and levels were lowered down by 15-20% within 3-12 months with low GI diet (Wolever *et al.*, 2008). Moreover, during two cohort studies of male and female population with the high GI food samples resulted that the risk of cardiovascular diseases was common in women with high CHO diet and less common in men and GI is inversely proportional to heart problems in men (Sieri *et al.,* 2010) and (Grau *et al.*, 2011). Ischemia-reperfusion injury is one of the major causes of cardiovascular mortality and may lead to myocardial infarction, cardiac arrhythmias, and contractile dysfunction (Rajinder *et al.,* 2015)

GI and GL in Cancer

Cancer, also known as malignant neoplasm is a group of diseases that, according to the WHO, affects approximately 2 million new patients annually in the USA, of whom, one-third are expected to die as a result of their disease (Jain *et al.,* 2018). Cancer is an abnormal cell division and cell reproduction and it can spread throughout the body with blood and lymph (Sardana *et al.,* 2018). According to the WHO report 6.5 million people died due to cancer in the 2000 and American cancer society reported that 7.6 million of people died in 2007 due to cancer. In India each year more than one million people are diagnosed with cancer. Cancer is one of the most widespread diseases in the world which causes high rate of mortality and morbidity (Chaurasia *et al.,* 2018). Precision medicine (PM) is an advanced high-model approach under which standard therapy for the right patient at an accurate time is provided, which is necessary for cancer therapy (Mishra *et al.,* 2018). The cancer cells need to overcome anoikis (apoptosis due to loss of attachment to ECM) for metastasis event as this is a crucial barrier preventing tumor cell migration to secondary sites (Jena and Janjanam, 2018). The future burden of cancer will probably be even larger because people are adopting poor lifestyles with poor diet, frequently smoking and less physical activity (Tandon *et al.,* 2019). Understanding the mechanism by which the fore mentioned risk factors because cancer can help in better developing cancer prevention strategies (Akhtar and Bansal, 2017).

Conclusions

The concept of glycemic index plays a vital role in the digestion and metabolism of carbohydrate. There are number of significant starch factors like amylose: amylopectin ratio, starch structure, fiber, β glucan, size of starch particles and mainly processing methods which attribute to starch characteristics and hydrolysis. In this review, various epidemiological studies have been discussed which prove that consumption of low GI products helps in maintaining human health and can lower the risk of various metabolic disorders. Whereas, replacement of high GI diet with low GI diet helps to maintain postprandial blood glucose along with insulin responses and thus reduce the long-term complications.

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