

Carbohydrates: Good Carbs, Bad Carbs or No Carbs?

Carbohydrates have been discussed in relation with nutrition and diet for a long time. They have been recognised as essential nutrients providing energy to tissues along with many other important physiological roles. However, they were implicated in obesity and various diets appeared restricting their intake such as low-carb or no-carb diets. Again in the last few years they have been recognised as essential in our diets but the nature of these were being recommended such as complex carbohydrates were preferable compared to simple carbohydrates. More recently, concepts of glycemic index and glycemic load have been developed to group the foods containing different types of carbohydrates that would help selecting the diets.

Introduction

Carbohydrates are the most abundant of the major classes of biomolecules. They carry out many important functions in living beings including serving as energy stores e.g. starch and glycogen with readily available energy utilising glucose. They are important structural components in plants (cellulose) and in animals (cartilage and chitin). Carbohydrates and their derivatives perform important roles in immune systems, fertilisation, pathogenesis, blood clotting and development processes.

Carbohydrates are found in many foods like bread, beans, milk, cereal grains, potatoes, cookies, soft drinks, cakes etc. The most commonly they are found as sugars, dietary fibres and starches. Carbohydrates are grouped in two categories: simple carbohydrates such as sugars like fructose, glucose, common sugar (sucrose) etc. and complex carbohydrates such as oligosaccharides, starch, dextrins etc.

Chemically the building blocks of the carbohydrates are monosaccharides such as glucose, fructose, and galactose which combine with two or more of the same or different monosaccharides to form other carbohydrates. Disaccharides contain two monosaccharides so maltose contains two glucose units; sucrose contains one each of glucose and fructose while lactose (sugar in milk) contains one each of glucose and galactose. Similarly trisaccharides contain three monosaccharide units and so on. In fact, those containing between two and ten units of monosaccharides are also called oligosaccharides.

Besides disaccharides, important oligosaccharides are raffinose (trisaccharide of galactose, fructose & glucose, present in beans, cabbage, broccoli etc.) and stachyose (tetrasaccharide of 2 galactose, 1 glucose and 1 fructose present in soya and other beans). One oligosaccharide is being used recently is fructooligosaccharide (FOS) contains mostly fructose units and may be prepared from inulin (natural fructose polymer present in Jerusalem artichoke and chicory) by chemical or enzymatic degradation.

Larger carbohydrates are called polysaccharides, examples being starch and cellulose. Although both are glucose polymer, starch contains alpha 1-4 linkages of glucose units whereas cellulose contains beta 1-4 linkages of glucose units. Hence, while starch can be digested by humans, cellulose is not since human enzymes cannot hydrolyse beta linkages of cellulose. Ruminants like cow and goat have microbes in their rumen capable of hydrolysing cellulose so these animals can eat cellulosic materials like grass and leaves. Starch is present in large quantities in cereals and pulses as well as many unripe fruits and most vegetables.

There are many polysaccharides used in food industry that are derived from beans, vegetables, trees, microbes etc. Some examples are gum Arabic (acacia), guar gum, gum karaya, locust bean gum, pectin, hemicellulose, xanthan, and dextran. These are large polymers and are indigestible by humans. They have applications in food products as thickeners, stabilisers and texture modifiers. Some of them like pectin may also form gels. There are some like chicle gum and modified or synthetic gums that are used in chewing and bubble gums. Since these are not digestible, they form part of dietary fibre along with cellulose. They help push food in gastro-intestinal tract, thus preventing constipation and also prevent colon cancer.

Carbohydrate Metabolism

Only monosaccharides like glucose, fructose and galactose can be absorbed in small intestine so larger carbohydrates including disaccharides need to be digested or hydrolysed to monosaccharides before being absorbed. Food is consumed in the form of fruits and vegetables (either raw or cooked) that may contain some starch and sugars, grain products like bread or chapatti may contain mostly starch, certain foods may contain added sugar and dairy products may have lactose.

All these products when eaten are first acted upon by salivary amylase and then with pancreatic amylase that break down bigger starch molecules to maltose, maltotriose and some glucose. These are then acted upon by enzymes at intestinal brush border converting them to glucose. There are enzymes in small intestine that digest disaccharides like sucrose and lactose to respective monosaccharides. All these monosaccharides are then absorbed in small intestine. Cellulose and other non-digestible carbohydrates including raffinose, stachyose, FOS, various gum polysaccharides, limit dextrins left after hydrolysis of amylopectin fraction of starch etc. may pass through the intestine undigested but in large intestine some partial breakdown may occur due to bacteria.

Of the monosaccharides absorbed, glucose is delivered to various tissues/cells which use it for their energy needs. Fructose and galactose are converted to glucose in liver although they can also be used for energy. Glucose may also be converted to other necessary carbohydrates like ribose, deoxyribose, glucosamine, etc. and also for synthesis of nonessential amino acids. Excess is converted to glycogen or fatty acids and stored in the body. The blood glucose level is affected when glucose is absorbed from the intestine as well as when glucose is consumed by various cells or tissues for energy purpose and also when glucose is converted to various metabolites and glycogen or fatty acids. All these conversions either increase or reduce the blood glucose level.

Fasting level of blood glucose is between 70 and 100 mg/100ml and this may either be replenished by glucose absorbed after a meal and/or be depleted by energy demands or conversions to other substances. Glycogen in liver and muscle also plays important role in supply of glucose when needed. Some energy needs of various tissues are also met by fat although brain can utilise only glucose for its energy needs. There are various

hormones that regulate reactions involved in glucose metabolism and ensure that glucose level in blood is maintained at somewhat constant level. Among these are insulin, glucagon, epinephrine, glucocorticoids and growth hormone. When the glucose level falls below 70 mg/100ml hypoglycemia occurs and a person may experience a variety of symptoms but most problems occur due to lack of glucose supply to brain causing its impairment leading to seizures or coma.

Insulin helps metabolism of glucose to energy or to other substances. When carbohydrates are consumed blood glucose rises but insulin tries to keep constant level by metabolising it so it does not rise too high. However, when insulin is not adequately produced by body or carbohydrate consumption and its digestion is too rapid for the control mechanism, the level of blood glucose goes high. If it remains high for long, the condition is called diabetes. In type I diabetics, insulin production is low and in type II, body develops resistance to insulin. Type II diabetes is preventable and is caused mainly due to obesity and lack of physical activity, a problem of today's lifestyle.

Glycemic Index

Different carbohydrates in foods are digested and absorbed at different rates. One means of comparing the speed at which they are taken up is Glycemic Index (GI). Taking the GI of glucose as 100, foods containing carbohydrates are compared and given numbers, higher numbers indicating faster utilisation and lower indicating slower uptake. Foods containing fixed amounts of carbohydrates (about 10 to 50 g) are fed to healthy individuals after overnight fasting and their blood sugar is measured over next 2 hours. The rise and fall of blood glucose is then measured and compared with reference and GI is calculated.

GI however does not give any idea about amount of digestible carbohydrate the food contains. Although watermelon has very high GI it has very small amount of carbohydrate per serving so the effect on blood sugar is quite small. Hence the concept of glycemic load (GL) has been developed by multiplying GI by the amount of carbohydrate (in %) the food contains. In general GL of 20 or more is high, 11 to 19 medium and 10 or less is low.

Glycemic load (GL) is another useful system of measuring carbohydrate content and its utilisation from a mixed meal. It depends on the portion size of each carbohydrate containing food. High GI food consumed in small quantity would give same effect as larger quantities of low GI food on blood sugar. When lesser quantities of high GI foods are consumed, rise in blood glucose is less and this is important in meal planning for diabetics. GL is obtained by multiplying carbohydrate content of a food by GI and gives an idea about how much effect that portion of food has on blood sugar level.

GI & GL of some foods

Food	Glycemic index (GI)	Carbohydrate content (by wt)	Glycemic Load (GL)
Baguette (French bread)	95	50%	48
Banana	52	20%	10
Carrots	47	7.5%	3.5
Corn tortilla	52	48%	25
Potato	50	19%	9.3
Rice (boiled white)	64	24%	15.4
Watermelon	72	5%	3.6

Carbohydrate contents & GI of some common foods

High GI Foods	Portion size	GI	Carbohydrate per portion	Calories (kCal)
Corn flakes	1 small bowl (30g)	84	26	108
White rice	6 tbsp (180g)	87	56	248
White bread	1 large slice (38g)	70	18	85
Pizza	1 large slice (115g)	60	38	288
Baked potato	1 medium (180g)	85	22	94
Chips	Average (165g)	75	59	450
Raisins	1 tbsp (30g)	64	21	82
Watermelon	1 slice (200g)	72	14	62
Ice cream	1 scoop (60g)	61	14	62
Tortilla	1 bag (50g)	72	30	230
Glucose	1 tsp (5g)	100	5	19
Sucrose	1 tsp (5g)	65	5	19
Moderate GI Foods				
Muesli	1 small bowl (50g)	56	34	183
Basmati Rice	4 tbsp (60g)	58	48	215
Noodles	4 tbsp (230g cooked)	46	30	143
Rye Bread	1 slice (25g)	41	11	55

Muffin	1 (68g)	44	34	192
Sponge cake	1 slice (60g)	46	39	181
Carrots	2 tbsp (60g)	49	3	14
Boiled potato	2 medium (175g)	56	30	126
Peas	2 tbsp (70g)	48	7	48
Baked beans	1 small tin (205g)	48	31	166
Apricots	1 (40g)	57	3	12
Banana	1 (100g)	55	23	95
Mango	Half (75g)	55	11	43
Milk chocolate	1 bar (54g)	49	31	281
Low GI Foods				
Chick peas	4 tbsp (140g)	33	24	168
Red kidney beans	4 tbsp (120g)	27	20	124
Red lentils	4 tbsp (160g)	26	28	160
Soya beans	4 tbsp (120g)	18	6	169
Apples	1 (100g)	38	12	47
Full cream milk	300 ml	27	14	198
Skimmed milk	300 ml	32	15	99
Yoghurt (low fat)	150g	33	27	135
Peanuts	50g	14	4	301
Fructose	5g	23	5	19

Many factors affect the glycemic index. Grains that are milled and are refined after removing bran and germ and also those that have been finely ground have higher glycemic index than whole grains. Starch has different configuration, some of which are easier to digest to sugar molecules. Starch in potato is digested and sugars absorbed into blood relatively quickly. Fibre in foods delays the digestion of carbohydrates and absorption of sugars so they reduce the GI. As fruits and vegetables ripen there is more sugar than in unripe ones so their GI increases. Fat and acid content of the foods also slow down the digestion and absorption of carbohydrates.

Diets rich in high GI foods, which cause quick and strong increases in blood sugar levels, have been linked to an increased risk for diabetes, heart disease, and overweight. There is preliminary evidence that high GI diets are related to age-related macular degeneration, ovulatory infertility and colorectal cancer. Foods with low GI have been shown to help control type 2 diabetes and improve weight loss. There are some studies that show no effect of GI on weight or health. In sports and physical activity or work, energy may be needed quickly for continuation in sports and recovery after exhaustion. High GI may be useful in such instances.

Diabetes:

When one eats foods containing carbohydrates, the digestive system breaks down the digestible ones in to sugar, which then enters blood. As blood sugar rises, pancreas makes insulin which helps metabolise glucose for energy or storage and sugar level in blood falls. When it falls lower than normal, pancreas starts making glucagon that makes liver release stored sugar. Thus insulin and glucagons ensure that all cells in body and especially brain, gets enough of glucose. People with type 1 diabetes don't make enough insulin so their cells can't metabolise glucose rapidly. Those with type 2 diabetes generally don't respond well to insulin signal. It is known as insulin resistance and causes blood sugar and insulin levels to remain high long after eating. Over time insulin production slows or stops. It is estimated that 90% of type 2 diabetes cases could be prevented by a combination of healthy diet and a physically active lifestyle. Genes, sedentary lifestyle, obesity, and diet rich in high GI foods can promote insulin resistance. Eating whole grains can improve insulin sensitivity and also controlling type 2 diabetes, atherosclerosis, heart disease, colon cancer, etc.

Applications in Food Industry

Since carbohydrates serve as most easily accessible energy source for muscles and organs most energy drinks and energy bars contain these. Sugars are easily digested and so are many starches. Most sports drinks contain carbohydrates as these sustain the energy required in various physical activities including very vigorous energy intensive ones as well as long distance marathons. Addition of low GI carbohydrates sustains the energy needs for a longer period. Carbohydrates also have a role in recovery after an exhaustive workout or an intensive sports activity. There are many formulations of sports drinks or bars meant for specific sports with different combinations of carbohydrates for better effectiveness.

Sugars have special place in foods because of their sweetness. Most people like sweet taste and some crave for it. Sweets such as candies, sweet biscuits (cookies), fruit based products like jams, jellies, preserves, squashes, syrups, etc., cakes and other similar sweet bakery products, chocolates, ice creams, Indian traditional sweets like pedha, burfi, jalebi, shrikhand, gulab jamun, roso golla, mysore pak, and a long list of sweets are very popular among people of all ages. Sugar in many of these products has a dual role of preservation besides sweetness. In products like jelly and ice creams, they also markedly affect the texture.

In many formulated foods, besides the other nutrients and ingredients that give flavour, colour etc. as well as some other active ingredients, there is a need for filler material that gives bulk to the food. This is commonly provided by carbohydrates. Starch and maltodextrins have been used for such purposes but in case caloric restriction is essential then cellulose and gum based substances are used to some extent. Many carbohydrates especially maltodextrins from potato and rice starch have bland flavour profiles so they could be added to any food without affecting the original flavour of the food. There are many artificially sweetened foods that use intense sweeteners instead of sugar. Since sugar in sweets is a major

ingredient bulking agents are very essential in these products to fill the gap left by leaving out sugar. Such bulking agents are mostly carbohydrates.

Carbohydrates have been used for giving desired texture to food products. They have great affinity of water and hold large amount of it, so when one needs body in a beverage, carbohydrates are used that will thicken them. Different carbohydrates have different ability of tie up water and increase the viscosity. Among gums, acacia gum does not change viscosity much unless good amounts are used, but guar gum immediately elevates viscosity even with small amounts. Gums are commonly used at 0.25% to 0.5% level. Some may be partially hydrolysed to give desired properties at the process and storage temperatures and pH.

Starches and hydrocolloids interfere with ice crystal formation in ice cream or thicken pastry filling preventing weeping into surrounding crust. They can also substitute fat to some extent helping reduce fat without affecting mouthfeel.

Dietary fibre, mostly composed of non-digestible carbohydrates, has become very important because of its healthful effects. It prevents constipation and colonic cancer that is on the rise because of present diets with low dietary fibre intake. Also it helps diabetics to control blood glucose when carbohydrates are consumed as it slows the uptake of sugars. It also helps satiety after a meal so overeating may be curtailed. Many food products have come in market which use ingredients like whole grains or fibre derived from rich sources to be added to foods. Prime examples are bakery products like bread and biscuits that earlier used refined flour with low fibre content, are now being prepared from whole wheat and other grains. Alternatively fibre is added in formulations. Process needs modification when such changes are made as gluten formation and leavening are affected adversely when fibre is increased. Fibre also has effects on taste.

Browning is another effect of carbohydrates alone or with amino groups mostly from proteins. When bread is baked, coffee is roasted, potatoes are fried, and sugar is heated, brown colour is formed along with an appealing aroma. This is because of reactions involving sugars with or without amino compounds.

Many soft products like cakes, become hard and less palatable if they lose moisture. Carbohydrates along with emulsifiers are also useful in binding and holding moisture in foods for a longer period. Commonly polyols are like sorbitol, mannitol are used as humectants. These are sugar alcohols prepared from carbohydrates by fermentation but there are polyols that are naturally present. They also have sweetness.

Gazing Into Future

There has been a lot of negative perception in the minds of people about carbohydrates. As long as people love snacks there will always be carbohydrates from grains like wheat, corn and rice used for making them. Although sweets will be increasingly made from artificial sweeteners but sugars will have their prime place. Texture is becoming quite important as more novel ingredients are used to make foods and carbohydrates in many forms and their derivatives will be used. The market for sports nutrition is expanding and drinks and bars use more varieties of carbohydrates with different GI. As greater emphasis is being given on health from fibre, more products are being made from fibre from a variety of sources. There are even natural foods like corn and rice with more resistant starch being used for healthy reasons.

Most people think of refined flours and sugars when they think of carbohydrates and equate them with undesirable food components. But this perception is changing rapidly and many carbohydrates, some quite novel, are being used for newer applications as the consumer needs are changing.
