Review
ARTIFICIAL SWEETENERS: BOON OR BANE?

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ABSTRACT

Artificial sweeteners have an important role to play in planning diets for people with diabetes and obesity. When a nutritive sweetener is used an appropriate adjustment of calories can be made in exchange of certain foods, mainly carbohydrates. On the other hand when a non-nutritive sweetener is used, no adjustment is required. Hence the latter is important in weight reduction regimes. Artificial sweeteners are ubiquitously present in a variety of foods, beverages and hygiene products. A search for a more versatile and better tasting sweetener is ongoing to yield improved products. This would find improved palatability and acceptability by the consumer.

KEY WORDS: Nutritive sweetener, Non-nutritive sweeteners, Aspartame, Sucralose, Diabetes; Obesity, Saccharin, Steviosid.

The sensory properties of food highly influence the selection and consumption of food in man (1). Taste, smell, texture and appearance of the food plays a crucial role in the regulation of human appetite and nutrient intake. When a wide variety of food is offered, food intake increases, thus adding to an increase in energy intake. The perception of taste is extremely important in determining appetite regulation. There are four primary taste sensations. They are sour, salty, bitter and sweet. Physiologically, the tip of the tongue is highly sensitive to sweet and salty substances. It has been also studied that the T1r3 gene is linked with sweet tasting ability (2). Thus the ability for sweet taste varies genetically. As a result, there are varying levels at which the perception of sweet taste occurs in different individuals and in certain diseases.

A person with diabetes would not like to miss this sweet taste and cut out twenty-five percent of his eating pleasure. The main problem that a person with diabetes faces is an increase in the threshold level of sweetness compared to non-diabetics. Therefore a person with diabetes needs sweeter food than a person without diabetes to appreciate the same taste. This is supported by certain studies done in the past decade. One such study showed that the perception of sweet taste is significantly impaired in patients with type 2 diabetes but not in those with type 1 diabetes (3). This evidence is corroborated by the fact that there is a raised threshold level for blood glucose sensing in the beta cells of the pancreas.

The villain of the piece is sucrose. Sucrose or 'cane sugar' is the direct table sugar that one uses daily. It is a disaccharide made up of glucose and fructose and it provides four calories per gram. Hence, sweeteners are very important as they provide fewer calories than sugar. A sweetener is a food additive which duplicates the effect of sugar on taste. Therefore they are also called 'sugar substitutes'. There are two types of sweeteners, nutritive and non-nutritive.

NUTRITIVE SWEETENERS

The nutritive sweeteners provide same or fewer calories than sugar. Examples are fructose; maltose; lactose; honey; polyols like sorbitol, xylitol, lactitol, mannitol, erythritol, isomalt, maltodextrin, polydextrose, hydrogenated starch hydrolysate.

Fructose

It is a monosaccharide component of sucrose present in fruits as fruit sugar (laevulose). It is used in beverages, fruit juices, pulps. It provides similar amount of energy as sucrose. Fructose is termed a 'slow sugar' as it is metabolized slower than sucrose. In a well-controlled diabetic, the fructose metabolic pathway demonstrates a positive flux towards formation of glycogen from fructose i.e. glycogenesis. Further the breakdown of glycogen to glucose i.e. glycogenolysis occurs as and when required in a slow and steady pace. On the other hand, in an uncontrolled diabetic glycogenesis occurs at the same pace, but glycogenolysis occurs rapidly. This causes a brisk rise in the blood glucose levels in these patients. In either case the metabolism of fructose is slower than that of sucrose. The utilization of fructose follows an insulin independent pathway (4). Fructose is

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metabolized even in the absence of insulin which is important in a diabetic. Hence, it causes an overall slower rise in blood glucose levels than glucose. An increased intake of fructose may cause hypertriglyceridemia, especially in patients with uncontrolled diabetes. Consumption of fructose up to 50 – 60 gm per day is seen to have no adverse effect on bloodglucose, glycosylated hemoglobin and serum lipids (5). The recommendation of 2 to 3 servings of fruit per day holds good in a well-controlled diabetic.

Polyols

These are alcohol derivatives of sugar and provide fewer calories than sucrose. It is synthesized from dextrose on a commercial scale. Polyols are stable up to 160°C. They are absorbed by passive diffusion and metabolized slowly. They produce a low glycemic response. Intake of large amounts of polyols exerts a laxative effect causing abdominal cramps and diarrhea. Erythritol has the best tolerance level among all Polyols. Polyols also prevent dental caries when used a substitute for sugar in different products. It is popularly used a bulking agent in the food industry to improve the taste, mouth-feel and texture of the food (6).

Glycyrrhizin

It is the root extract of an Asian and European shrub, commonly known as licorice (7). It is a triterpene glycoside by nature. It is mainly used as coating for candies and chewing tobacco. Ingestion of large amounts of these foods may cause headache, lethargy, sodium and water retention, excessive excretion of potassium, high blood pressure and sometimes heart failure. Hence it behaves like a mineralocorticoid.

NON-NUTRITIVE SWEETENERS

These provide negligible calories. They are also known as high-intensity sweeteners as they are required in minute quantities to provide the same sweetness as sugar. Examples are saccharin, aspartame, sucralose, acesulfame-K, stevioside, cyclamate.

Saccharin

It is one the oldest non-nutritive sweeteners. It is over 125 years old and has had a history with great vicissitudes. It was banned in 1977 as it was incriminated in the causation of bladder cancer in rats. This ban was revoked in 1991 after much review and scrutiny (8). Till late, a warning label was required for products containing saccharin. It has been recently removed from the carcinogen list. It is a sulfonamide produced from a compound found in coal tar. It has a bitter, metallic aftertaste and is unstable at high temperatures. It may cause urticaria and eczema in some people. Intake of saccharin is restricted in pregnant women as it is avidly concentrated in the placenta. In India, it is widely used in the cosmetic, pharmaceutical, food and beverage industry.

Aspartame

Aspartame is one sweetener that many people love to hate. It has been one of the most controversial sweeteners till date. Aspartame is extensively used all over the globe and is slowly replacing saccharin in India too. It is a high intensity sweetener dipeptide in nature. It is made up of two amino acids, aspartic acid and methyl ester of phenylalanine. It is unstable at high temperatures and is added in the end-cycle of cooking. The specific byproducts of aspartame i.e. methanol, formaldehyde and phenylalanine have been studied individually. They are said to cause an array of side-effects, including allergic reactions in some people. It has also been linked to neuropsychiatric disorders like migrainous headaches in sensitive individuals, panic attacks, mood changes, epileptic seizures (9). People who are sensitive to monosodium glutamate may also experience side effects with aspartame. All this data is a lot of hype and jargon from deterrents of aspartame and do not hold much ground. It is a known fact that amino acids and methyl esters are found naturally in foods like milk, meat, fruits and vegetables. When digested the body handles the amino acids in aspartame in the same manner as those in our daily food. eg an 8 oz glass of milk has six times more phenylalanine and thirteen times more aspartic acid than an equivalent amount of soda sweetened with aspartame sweetener. An 8 oz glass of tomato juice or fruit juice contains 3 to 5 times more methanol than an equivalent amount of soda sweetened by aspartame sweetener. This dispels this misconception. Hence, aspartame is relatively safe to use.

Acesulfame-K

It is a high intensity sweetener which is a potassium salt of dimethyl-oxathiozine dioxide in nature. It is not metabolized and excreted unchanged

in the body. It can withstand high temperature cooking and baking. Acesulfame-K has a grittier texture than direct sugar but it has a slight bitter aftertaste. This sweetener needs long-term study from the carcinogenicity and genotoxicity angle to confirm its safety (10). Caution is required in individuals on potassium restricted diet or having sulfa antibiotic based allergy. Abroad, it is being used increasingly along with aspartame in many foods and beverages and is second in popularity to aspartame.

Sucralose

Sucralose is an extremely versatile and interesting high intensity sweetener. It is simply a modification of the sucrose molecule ie. a chlorinated version known as trichlorogalactosucrose. It is not absorbed and gets excreted unchanged in the body. Sucralose retains its sweetness over wide range of temperatures. It does not cause any rise in blood glucose levels. It goes by the brand name Splenda abroad. It has recently been marketed in India under the brand name Zero and Sugarite. There have been some reports on the side-effects and adverse reactions of sucralose, e.g. it causes shrinkage of the thymus gland, enlargement of the liver and kidney. A theoretical possibility always exists, but for all practical purposes these side effects are inconsequential (11).

Cyclamate

Cyclamate was also implicated along with saccharin in the causation of bladder cancer. It was reviewed and exonerated in 1982 but it is still a banned compound in India.

NEWER ARTIFICIAL SWEETENERS

Alitame and Neotame

These non-nutritive sweeteners are awaiting approval from the FDA. They are structurally similar to aspartame. Alitame is 2,000 times sweeter than sucrose whereas neotame is 8,000 times sweeter than sucrose. Both are already in use in beverages and soy-based, nutritionally fortified products, respectively. Their carcinogenicity and reproductive toxicity reports are yet to be scrutinized.

Fructofibres

Fructofibres are essentially fructanes or fructo-oligosaccharides. They contain inulin and oligo-fructose both of which are inert polysaccharides. It goes through unabsorbed in the body. Fructofibres provide added benefit as it gives the bulk to the diet and help prevent constipation. It lowers blood glucose levels and serum lipids. These effects exerted by fructofibres may be insignificant as they are used in very small quantities in sweeteners.

Steviosid

Stevia rebaudiana is a naturally, sweet herbal plant native to South America, mainly Paraguay and Brazil. The leaf extract has the main constituents comprising of glycosides, namely, stevioside and rebaudiside (12). These glycosides are not metabolized and pass out unabsorbed from the body. It is heat stable up to 200° c. It can be used in cooking, baking and frying. It has shown no teratogenic, carcinogenic activity in rats. It is approved as a 'dietary supplement by the FDA. It is used widely in the South Americas and the Orient. It is popular in Japan, China and Korea and has been used there for more than three decades. It is marketed in India by the brand name 'Stugar'.

OTHER PROPERTIES OF ARTIFICIAL SWEETENERS

It is also important to look into the other properties of artificial sweeteners as a group. A comparison of the degree of sweetness is crucial to know in order to use them more efficiently. The nutritive sweeteners are only marginally sweeter than sucrose. Whereas the non-nutritive sweeteners are more than hundred folds sweeter than sucrose. Hence, they are called high intensity sweeteners as very minute quantities are required to manifest the same level of sweetness.

The commercial availability of sweeteners is of practical importance. In India, aspartame and saccharin are widely used. Aspartame is available in tablet as well as powder form in sachets. The tablet provides 18 mg of aspartame and is equivalent to one teaspoon of sugar. The sachet contains 35 mg of aspartame and is equivalent to two teaspoons of sugar. Saccharin is available in tablet form and contains 12 mg per sachet. It is equivalent to two teaspoons of sugar.

The artificial sweeteners have to be classified according to the concept of safety levels. Generally, they are designated as food additives which are expressed as accepted daily intake (ADI) (13). This reflects an amount hundred times less than the maximum level at which observed adverse effects occur in animal or human studies. Accepted daily

intake is usually expressed as mg per kg body weight per day.

High intensity sweeteners e.g. saccharin, aspartame, acesulfame-K, sucralose are usually promoted as food additives .Other nutritive sweeteners are usually classified as generally recognized as safe substances (GRAS) substances. Stevioside is approved by FDA as a 'dietary supplement'.

The side-effects and contraindications of the artificial sweeteners have to be looked into to determine their use. Large amounts of fructose when ingested may cause hyperglycemia and have a laxative effect (70 to 100 gm /day) (14). Large amounts of sorbitol (30 to 50 gm/day) may also result in diarrhea. Consumption of more than 15 to 30 gms/ day of honey may cause hyperglycemia due to its glucose content. Apsartame has been implicated in causing migrainous headaches. It is not recommended for growing children, phenylketonuric children and pregnant women with hyperphenylalaninemia. The blood–brain barrier in children is not fully developed and both the amino acids contained in aspartame are easily absorbed across this border. Thus elevated levels of these substances which seemingly act as a neurotransmitter alters the behavior pattern in children. Phenylketonuria is a genetically transmitted disease. In this condition, an enzyme called phenylalanine hydroxylase is dysfunctional thus resulting in accumulation of phenylalanine. A high level of this amino acid is neurotoxic to the individual. Hence, in pregnant women with hyperphenylalaninemia, aspartame is restricted as the mother may not be able to metabolize phenylalanine which is toxic to the fetus. The warning of restriction of aspartame in pregnancy was present earlier, but has now been revoked. Therefore, use of aspartame in pregnancy is allowed (about 20 mg/kg body weight /day). This should still be used with caution. Saccharin is restricted in pregnancy as it is avidly concentrated by the placenta. Sucralose does not seem to show any specific side effects and is considered relatively safe in all conditions and across all age groups.

COMMERCIAL USE OF ARTIFICIAL SWEETENERS

Artificial sweeteners are used widely in various industries. They are used as tabletop sweeteners, in the food industry in baked goods, confections, convenience foods, diet foods. They are used extensively in the beverage industry in both hot and cold beverages. Other than these, artificial sweeteners have created their own niche in other consumer products such as the cosmetic industry, pharmaceutical industry. Presently, the trend is to blend high intensity sweeteners so as to increase their potency.

Fructose and other non-nutritive sweeteners like saccharin, aspartame, sucralose, acesulfame-K, stevioside are used as tabletop sweeteners. Sorbitol, sucralose, acesulfame-K are used in baked products as they can withstand high temperature cooking. Confections, candy, lozenges and chewing gum mainly contain polyols like sorbitol, xylitol, lactitol and erythritol. They may also use sucralose as a sweetening agent. Saccharin and aspartame are mainly used in cold beverages, as they cannot withstand high temperatures. Whereas other sweeteners like sucralose, fructose, polyols and stevioside are used in a variety of beverages, both hot and cold.

Diabetic foods mainly contain sorbitol, sucralose and saccharin. Polyols and fructofibres essentially are used a bulking agents or diluents with many sweeteners.

The cosmetic industry uses saccharin in various flavored cosmetic products. The pharmaceutical industry uses mainly saccharin, sorbitol and sucralose in a variety of medicines e.g. inadvertently a patient maybe prescribed a cough syrup which contains sorbitol in large amounts which may act as a laxative. Many hygiene products such as toothpaste, mouthwashes contain polyols and sucralose as sweeteners.

USE OF ARTIFICIAL SWEETENERS IN VARIOUS CONDITIONS

Dental Health

It has been established that the between-meal consumption of high-sugar foods promotes dental caries (15). Foods containing polyols especially sorbitol, mannitol, xylitol and other non-nutritive sweeteners are non-cariogenic, thus help prevent tooth decay and cavities.

Behavioral Disorders

There exists a paradox of sorts. It is inferred that

excessive consumption of sugar in growing children causes extreme hyperactivity, restlessness and leads to attention deficit disorder (ADD). On the other hand, carbohydrate – rich foods are recommended to alleviate negative moods and a depressive state of mind. Unfortunately, there is no clear evidence and carbohydrate-rich foods are loosely linked to both these conditions. Hence, artificial sweeteners would be of tremendous help in preventing these situations. Aspartame has been indicated to cause mood alteration and headaches in sensitive individuals and has to be used with caution in these conditions (16).

Children

Children show the highest intake of sweeteners because of high food and beverage consumption. Sweetened drinks, fruit drinks have high fructose and sorbitol content and may cause non-specific diarrhea in children. Aspartame is restricted in children as this compound diffuses easily across the blood-brain barrier and high levels of this neurotransmitter causes alteration in brain activity. We should consider the consumption of diet drinks by youngsters by a practical example. A youngster, weighing 60 kg decides to lose weight and replaces regular colas with diet colas. He may raise the daily consumption to 10 to 12 cans per day. Each 12 ounce can of cola contains 54 mgs of aspartame. Hence, the total consumption may be to the tune of 540 to 600 mg of aspartame daily. Yet, this falls well below the ADI of 40 to 50 mg/kg body weight/ day i.e. 2000 mg/day. However, this does not mean that one encourages the consumption of these beverages. Sucralose, apparently has no adverse effect and is considered safe.

Pregnancy

Generally recognized (GRAS) as safe sweeteners are accepted in pregnancy. Saccharin is restricted in pregnancy as the placenta actively concentrates it (17). Aspartame was found to have no adverse effect on fetal exposure but it is restricted in pregnant women with hyperphenylalaninemia. Sucralose is found in low levels in the placenta. It is safe in pregnancy. Acesulfame-K and stevioside need more studies to ascertain their safety in pregnancy.

Diabetes Mellitus

Nutritive sweeteners like sucrose, lactose, maltose, fructose, sorbitol are used extensively in diabetes. Monosaccharides and disaccharides have to be avoided if they cause hyperglycemia in diabetics. As an alternative, use polysaccharides. In type 2 obese diabetics, non-nutritive sweeteners are recommended. Use of these would increase adherence to the diet regime.

Obesity

The role of sugar in the etiology of obesity is not very well established and no direct correlation is seen (19). On the whole, non-nutritive sweeteners play a crucial role in weight management strategies. It is a Herculean task cutting down 500 calories in a weight reduction diet. A reduction of direct sugar i.e. about 100 calories from the diet by replacing it with an artificial sweetener is one-fourth the battle won. If this is done daily for about 2 months, one has lost approximately 1 kg in weight. It further helps in improving the adherence to the diet program. Hence, the artificial sweeteners play a very important role in obesity as well as diabetes.

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