The Pharmaceutical and Chemical Journal, **2016, 3(1):21-29**

Available online www.tpcj.org

Review Article

ISSN: 2349-7092
CODEN(USA): PCJHBA

A critical review on natural and artificial sweeteners

Puneet Sudan, Ravneet Kaur, Shaveta Sharma, Upendra K Jain

Chandigarh College of Pharmacy, Landran-Punjab

Abstract The purpose of this review article is to gain knowledge about the different kinds of existing sweeteners and their composition. By this, we will get to know to understand, how artificial sweeteners are metabolized within the human body and their effects on human health. A proper understanding of the health effects of artificial sweeteners and natural sweeteners will help readers to construct a healthy diet plan and make wise decisions while choosing products containing sweeteners.

Introduction

Sweeteners are food additives that are mainly used to improve or enhance the taste of everyday foods. Natural sweeteners are sweet-tasting compounds with natural origin and have great nutritional value; the major ingredient of natural sweeteners is either mono- or disaccharides. Artificial sweeteners, on the other hand, are compounds that have no or little nutritional value. This is possible because artificial sweeteners are synthesized compounds that have high-intensities of sweetness, meaning less of the compound is necessary to achieve the same amount of sweetness. Artificial sweeteners are generally added in pharmaceutical preparations or other products to limit caloric intake or to prevent dental cavities. Sugar alcohols are natural compounds with varying degrees of sweetness which are often added to boost or fine tune flavors of products while increasing their sweetness. They are often used in conjuncture with natural or artificial sweeteners in order to achieve a desired degree of sweetness, taste or texture. Sugar alcohols typically provide some amount of nutrition but have other benefits such as not affecting insulin response or promoting tooth decay which makes them a popular sweetening choice [1-6].

Natural Sweeteners

Natural sweeteners are sweeteners that are mainly extracted from natural products or herbal drugs without any chemical modifications during the production or extraction procedure. Some of these natural sweeteners have played a vital role and have been in use for decades. Natural sweeteners are well known and their production process has been perfected over time making their cost low and leaving their demand high. Some of the commonly used natural sweeteners are listed below:

- Honey
- Maple Syrup
- Molasses
- Stevia
- Liquorice
- Sucrose

Honey

Honey is a sweet food made by *Apis mellifica* using nectar from flowers. The variety produced by honey bees (*Apis mellifica*) is the one most commonly used type of honey collected and consumed by humans. Honey produced by other bees and insects has distinctly different properties. Honey bees form nectar into honey by a process of regurgitation and store it as a food source in wax honeycombs inside the beehive. Beekeeping, which is a common practice these days, encourages overproduction of honey so that the excess can be taken without endangering the species and their colony. Honey gets its sweetness from the monosaccharides fructose and glucose and has approximately the same relative sweetness as that of granulated sugar. Micro-organisms do not show growth in honey because of its low water activity of 0.6. The main uses of honey are in cooking, baking, as a spread on breads, and as an additive to various beverages such as tea and as a sweetener in some commercial beverages. Honey is also used as an adjunct in beer. Its glycemic index ranges from 31 to 78, depending on the variety. Honey is a mixture of sugars and other compounds. With respect to carbohydrates, honey mainly contains fructose (about 38%) and glucose (about 31%). The remaining carbohydrates present in honey are maltose, sucrose, and other complex carbohydrates. Honey contains traces of many types of vitamins and minerals. Honey also contains many other compounds, showing actions like antioxidants, including chrysin, pinobanksin, pinocembrin, and vitamin C. The specific composition of particular batch of honey depends on the variety of flowers available to the bees. A typical honey analysis goes as follows: Fructose: 38.2%, Glucose: 31.0%, Sucrose: 1.5%, Maltose: 7.2%, Water: 17.1%, Higher sugars: 1.5%, Ash: 0.2%, Other/undetermined: 3.2%. Honey has a density of about 1.36 kg/L (36% denser than water). The pH of honey is commonly between 3.2 and 4.5. This relatively acidic pH level prevents the growth of many bacteria. 12 Many varieties of processing exist for honey. Crystallized honey is honey in which some of the glucose content has spontaneously crystallized from solution as the monohydrate .Also called "granulated honey." Pasteurized honey is honey that has been heated in a pasteurization process. Pasteurization in honey reduces the moisture level, destroys yeast cells, and liquefies crystals in the honey. While this process sterilizes the honey and improves shelf-life, it has some disadvantages. Excessive heat-exposure affects appearance, taste, and fragrance. Heat processing can also darken the natural honey color (browning). Raw honey is honey as it exists in the beehive or as obtained by extraction, settling or straining without adding heat (although some honey that has been "minimally processed" is often labeled as raw honey). Raw honey contains some pollen and may contain small particles of wax. Ultra filtered honey is honey processed by very fine filtration under high pressure to remove all extraneous solids and pollen grains. The process typically heats honey to 65-77 °C to more easily pass through the fine filter. Ultra filtered honey is very clear and has a longer shelf life, because it crystallizes more slowly because of the high temperatures breaking down any sugar seed crystals, making it preferred by the supermarket trade. The heating process degrades certain qualities of the honey similar to the aforementioned pasteurization process [7].

Maple Syrup

Maple syrup is a sweetener which is mainly obtained from the cell sap of maple trees. In cold climatic conditions, these trees store sugar in their roots before the winter and the sap which rises in the spring can be tapped and concentrated. This sap has only 3% to 5% total solids, consisting mainly of sucrose. Maple Syrup has about the same 50 cal/tbsp as white cane sugar. However, it also contains significant amounts of potassium, calcium, small amounts of iron and phosphorus, and trace amounts of B-vitamins. Its sodium content is very low. The sugar content of sap averages 2.5% and the sugar content of syrup averages 66.5. Canada is the major producer of maple syrup and contributes about 80 % of the world's requirement. The vast majority of this comes from Quebec: the province is by far the world's largest producer, with about 75 % of the world production. Traditionally, maple syrup was usually harvested by tapping bark and trunk of maple tree, then letting the sap run into a bucket, which required daily collection. Harvesting is mainly done in the month of February, March, and April, depending on local weather conditions. Freezing nights and warm days are the most suitable conditions to induce sap flows. The change in temperature from above to below freezing causes water uptake from the soil, and temperatures above freezing cause a stem pressure to develop, which, along with gravity, causes sap to flow out of tap holes or other wounds in the stem or branches. To collect the sap, holes are bored into the maple trees and tubes are inserted. Sap flows through the spouts into buckets or into plastic tubing. Modern use of plastic tubing with a partial vacuum has enabled increased production. It takes approximately 40 L of sap to be boiled down to 1 L of syrup. A mature sugar maple produces about 40 L of sap during the 4 to 6 week sugaring season.[8-9]

Molasses

Molasses are the highly viscous by products of the processing of sugar cane or sugar beets into sugar. The quality of molasses mainly depends on the maturity of the sugar cane or sugar beet, the amount of sugar extracted, and the method of extraction which is followed. Molasses has the molecular formula $C_6H_{12}NNaO_3S$, a molecular weight of 201.22 g/mol, and a density of 1.41 g/cm^3. A typical composition of molasses contains the following substances: sucrose 35.9 %, fructose 5.6 %, 16 nitrogen 1.01 %, reducing substances 11.5 %, glucose 2.6 %, and sulfur 0.78 %. Sulphur molasses is mainly obtained from young sugar cane. Sulphur dioxide, which mainly acts as a preservative, is added during the sugar extraction process. Unsulphured molasses is made from mature sugar cane, which is devoid of sulphur treatment. There are three grades of molasses: mild, dark, and blackstrap. These grades may be sulphur containing or not. To make molasses, the sugar cane plant is harvested .Its juice is usually extracted from the canes, mainly by crushing under pressure. The juice is boiled to concentrate, which promotes the crystallization of the sugar. The result of this first boiling and removal of the sugar crystals is mild molasses, which has the highest sugar content extracted from the source. Dark molasses is obtained at second boiling and sugar extraction stage, and has a slightly bitter taste. The third and final stage of boiling of syrup makes blackstrap molasses. The majority of sucrose from the original juice has been crystallized, but blackstrap molasses is still mostly sugar by calories. However, unlike refined sugars, it contains significant amounts of vitamins and minerals. Blackstrap molasses is a main source of calcium, magnesium, potassium, and iron; 15 mL provides up to 20% of the daily value of each of those nutrients. Blackstrap, often sold as a health supplement, is also used in the manufacturing of cattle feed and for other industrial uses. Molasses that comes from the sugar beet is different from cane molasses. Only the syrup left from the final crystallization stage is called molasses; intermediate syrups are referred to as high green and low green, and these are recycled within the crystallization plant to maximize extraction. Beet molasses is about 50% sugar by dry weight, predominantly sucrose, but also contains significant amounts of glucose and fructose. Beet molasses is limited in biotin (Vitamin H or Vitamin B_7) for cell growth; hence, it may need to be supplemented with a biotin source. The non-sugar content includes many salts, such as calcium, potassium, oxalate, and chloride. These are either as a result of concentration from the original plant material or as a result of chemicals used in the processing. As such, it is unpalatable, and is mainly used as an additive to animal feed. It is possible to extract additional sugar from beet molasses through a process known as molasses desugarisation. This technique exploits industrial-scale chromatography to separate sucrose from nonsugar components. The technique is economically viable in trade-protected areas, where the price of sugar is supported above the world market price. As such, it is practiced in the U.S. and parts of Europe [10-12].

Stevia

Stevia is one of the newest and readily prevailing sweeteners available in the market. It has been known of since 1899 for its sweet taste and has been cultivated in Japan since 1970. Stevia can also be known under its trade name as TruVia and PureVia which were patented by Coca Cola and Pepsi. Many different forms of Stevia as a sweeteners exist such as: Reb A, Reb B, Reb C, Reb D, Rebiana, Stevioside, SunCrystals and Enliten. Each has a small variation in the manufacturing process or how it is used. SunCrystals, TruVia and PureVia for example combine Stevia with an emulsifier to make a white, crystalline powder used as a tabletop sweetener, while Rebiana typically does not contain an emulsifier and is in a white powder form similar to the consistency of powdered sugar. Liquid forms of Stevia exist but are typically mixed with other sugar alcohols for a particular desired effect. Stevia is an all natural sweetener because it is extracted from the Stevia plant and undergoes no chemical changes in the manufacturing process. This makes it very desirable to many consumers looking for healthy alternatives to sucrose sugar. Currently the FDA approves Stevia for general use with the exclusion of meat and poultry use due to a lack of research material. An important distinction needs to me made about the FDA approval in that the Stevia plant in-ofitself cannot be used as a food additive where the extracts from the plant can be. Certain individuals have noted a "black liquorice" aftertaste which seems to be more relevant at high sweetener concentrations but it does not seem to be very present during everyday use. Stevia has quite high heat resistance and can be used in most cooking applications. It is relatively stable under a fairly wide range of pH and can be stored for a relatively long period of time. Stevia is a general term referring to a plant, Stevia rebaudiana (Bertoni), native to Paraguay. The plant contains a number of diterpene glycosides that taste sweet; the main ones are Stevioside and rebaudioside A. These glycosides are 200 and 300 times' sweeter then sucrose respectively [13-14].

Sucrose

Sucrose is a disaccharide, formed from the monosaccharides glucose and fructose. It has the molecular formula $C_{12}H_{22}O_{11}$ and a molecular weight of 342.30 g/mol. Its soluble in water. It consists of two monosaccharides, α-glucose and fructose, joined by a glycosidic bond between carbon atom 1 of the glucose unit and carbon atom 2 of the fructose unit. What is notable about sucrose is that unlike most disaccharides, the glycosidic bond is formed between the reducing ends of both glucose and fructose, and not between the reducing end of one and the non-reducing end of the other. This linkage inhibits further bonding to other saccharide units. Sucrose melts and decomposes at 186 °C to form caramel. Like other carbohydrates, it combusts to carbon dioxide and water. Sugar cane is grown in over 110 countries with an estimated total production of 1,591 million metric tons in 2007, more than six times the output of sugar beet. In 2005, the world's largest producer of sugar cane was Brazil, followed by India. Sugar consumption varies by country depending on the cultural traditions. Brazil has the highest per capita production and India has the highest per-country consumption. The European Union, the United States, and Russia are the world's three largest sugar beet producers, although only the European Union and Ukraine are significant exporters of sugar from beets. The U.S. harvested 4,065 km2 of sugar beets in 2008 alone. Beet sugar accounts for 30% of the world's sugar production. Sugarcane processing is practiced in many variations, but the essential process consists of the following steps: extraction of the cane juice by milling or diffusion, clarification of the juice, concentration of the juice to syrup by evaporation, crystallization of sugar from the syrup, and separation and drying of the crystals [15-18].

Metabolism of Sweeteners

The metabolism of sweeteners can be divided into two main categories—the metabolism of natural sweeteners and the metabolism of artificial sweeteners. The major difference that separates these two categories comes from the fact that natural sweeteners contain some form of carbohydrate (sugar) while artificial sweeteners do not. For this reason, natural sweeteners such as table sugar (sucrose), honey, and fruit sugar (fructose) induce pathways that result in the production of ATP. On the other hand, artificial sweeteners have little or no nutritional value to the human body. Research shows that for most artificial sweeteners, more than 90% of the initial compound can be found in feces and urine unprocessed. Glycolysis is an anaerobic process in which glucose ($C_6H_{12}O_6$) is converted into two molecules of pyruvate to form two net molecules of ATP(47) . The overall reaction of glycolysis is $C_6H_{12}O_6 + 2NAD^+ + 2ADP + 2P \rightarrow 2\ pyruvate + 2ATP + 2NADH + 2H^+$. The 2 pyruvate molecules that are produced during glycolysis enter the mitochondrion to produce energy via oxidative respiration. Maintenance of blood glucose levels within the bloodstream is accomplished by insulin and glucagon. Both are secreted from the pancreas; glucagon is released during low blood glucose levels to induce the liver to release glucose into the bloodstream; insulin is released during high blood glucose levels to induce fat cells to absorb glucose from the bloodstream [19].

Artificial Sweeteners

Artificial sweeteners are sweeteners that are derived from a chemical synthesis of organic compounds which may or may not be found in nature. Artificial sweeteners are relatively new and their uses are being researched and extended every day. Much controversy surrounds artificial sweeteners and their health effects as artificial sweeteners may break down into harmful chemical sub-compounds. New artificial sweeteners are always being researched and due to their low cost and ease of production, they will likely become the primary sweetening compounds in the future. Some of the commonly used artificial sweeteners are listed below:

- Ace k
- Aspartame
- Cyclamate
- HFCS
- Neotame
- Sacchrin
- Sucralose

Ace k

Acesulfame potassium (Ace-K) is a white crystalline powder with molecular formula $C_4H_4KNO_4S$, molecular weight of 201.24 g/mol, and a density of 1.81 g/cm^3. It is stable under heated conditions and has a structural likeness to that of saccharin. Acesulfame potassium is a calorie-free artificial sweetener commonly known as Sunett and Sweet One. It was discovered by a German chemist, Karl Clauss, in 1967. It has a white crystalline structure and is about 180-200 times sweeter than sucrose. At high concentrations, it tends to have a very bitter aftertaste but less so as lower concentrations. Kraft Foods patented the use of sodium ferulate to mask this bitter aftertaste. The US FDA approved the use of Ace-K along with the Kraft Food patented version in 2003. Much controversy revolves around Ace-K and its possibility of being carcinogenic but the FDA has dismissed all such claims to date. Ace-K, unlike its popular rival sweetener aspartame, is stable in high-heat situations and is therefore often used in baked products. Currently it can be found in many tabletop sweeteners, desserts, puddings, baked goods, soft drinks, candies (including breath mints, cough drops and lozenges), dairy products, canned foods and alcoholic beverages. Ace-K has an extraordinarily long shelf life and because of this is ideal for use in candies, canned foods and alcoholic beverages. Another important aspect of Ace-K is its ability to remain stable and retain its sweetness under pasteurizing conditions which often exposes dairy products to a wide variety of temperatures and pH values. Ace-K does not promote tooth decay making it an ideal candidate for 'sugar free' candies and diet drinks. Considering Ace-K's bitter aftertaste, it is frequently used along with another sweetener in most products. Typically aspartame or sucralose are used in order to balance the aftertaste. Common products which contain solely Ace-K or a combination of Ace-K and another sweetener are: Diet Rite Cola, Pepsi One/Pepsi Max, Coca-Cola Zero, Diet Coke with Splenda, Trident gum, and sugar-free Jell-O [20-21].

Aspartame

Aspartame is composed of 57.1% carbon, 6.2% hydrogen, 9.5% nitrogen, and 27.2% oxygen. It has the chemical formula $C_{14}H_{18}N_2O$, a molar mass of 294.3 g/mol, and a density of 1.3 g/cm^3. Aspartames three components are aspartic acid, phenylalanine, and methanol .Aspartame was discovered accidentally by chemist James M. Schlatter in 1965 when he licked his finger which happened to have gotten contaminated by a chemical he synthesized while trying to develop an anti-ulcer drug .Aspartame was not immediately approved by the US FDA when a large study showed a direct connection between aspartame and bladder cancer in rats. In 1980 there were no further conclusive studies correlating aspartame to cancer or brain damage and it was then approved as a general sweetener. In 1983 it was further approved for use in carbonated beverages then further again in 1996 when it was allowed for use in other beverages, baked goods and confections. In 1996, the FDA removed all restrictions from aspartame use. Between its discovery and today, aspartame has become one of the most studies artificial sweeteners in the world. Aspartame has practically no aftertaste allowing it to be used in many products as a sugar alternative. It is a non-nutritive sweetener which makes it very popular among people looking to watch calories, stay in better overall health or simply enjoy many of the low- or reduced-calories products available today. Several aspects of aspartame make it a very desirable sweetener in fruit-flavored products, especially gum, because aspartame has an ability to 'extend' flavors making them seem sweeter and given them a more full-bodied taste. Aspartame can be found in over 6,000 products, including carbonated soft drinks, powdered soft drinks, chewing gum, confections, gelatins, dessert mixes, puddings and fillings, frozen desserts, yogurt, tabletop sweeteners, and some pharmaceuticals such as vitamins and sugar-free cough drops. Aspartame can be made by various synthetic chemical pathways. In general, phenylalanine is modified by a reaction with methanol and then combined with a slightly modified aspartic acid which eventually forms aspartame. The quality of the compounds is checked regularly during the manufacturing process. Of particular importance are frequent checks of the bacterial culture during fermentation. Also, various physical and chemical properties of the finished product are checked, such as pH level, melting point, and moisture content [22-26].

Cyclamate

Cyclamate (Cyclohexylsulfamic acid) is the sodium or calcium salt of cyclamic acid. It is prepared by the sulfonation of cyclohexylamine, this can be accomplished by reacting cyclohexylamine with either sulfamic acid or sulfur trioxide. The sodium salt has the molecular formula $C_6H_{12}NNaO_3S$ and a molecular weight of 201.22 g/mol. Cyclamate, like aspartame, was discovered accidentally. In 1937, Michael Sveda carelessly placed a cigarette into a white power and when he placed the cigarette back into his mouth, he found a sweet and pleasant taste waiting. Cyclamate has a very long shelf life and a wide operating temperature allowing for it to be heated and frozen without any effect on sweetness or stability. It is used as a tabletop sweetener, in diet beverages, and in other low-calorie foods. Also, cyclamate is useful as a flavor enhancer as well as a good flavoring agent for many pharmaceuticals and toiletries. It is often used synergistically with other artificial sweeteners, especially saccharin; the mixture of 10 parts cyclamate to 1 part saccharin is common and masks the off-tastes of both sweeteners. Cyclamate is stable under heating, making it ideal for baking. Cyclamic acid is very sparingly soluble in water, and is slowly hydrolyzed in hot water. Sodium cyclamate and calcium cyclamate are both freely soluble in water [27-30].

HFCS

High fructose Corn Syrup (HFCS 55, Isoglucose) contains both fructose and glucose, commonly in a ratio of 55% fructose to 45% glucose. Fructose and glucose both have the molecular formula $C_6H_{12}O_6$, although the atoms are in different arrangements .High fructose corn syrup is a viscous liquid. Because of the fructose content, high fructose corn syrup does not tend to form crystals, as sucrose syrups do. The level of sweetness depends on the extent to which glucose has been converted to fructose, glucose is less sweet than sucrose (table sugar), and fructose is sweeter. The 55:45 ratio creates a sweetness that is about equal to that of sucrose. High fructose corn syrup is produced from corn starch. Starch is a polymer made of glucose molecules linked into long chains. Corn starch is first treated with the enzymes alpha-amylase and glucoamylase. These break the starch down to glucose. The glucose is then treated with another enzyme, glucose isomerase that can reversibly convert glucose to fructose. At the end of this step, the mixture usually contains about 42% fructose and 58% glucose. A separation step produces a syrup containing about 90% fructose, and this can be blended with the 42% fructose material to make the 55% fructose syrup that is widely used in beverage manufacture [31-32].

Neotame

Neotame (N-[N-(3, 3-dimethylbutyl)-L-alpha-aspartyl]-L-phenylalanine 1-methyl ester) is a more stable sweetener molecule made from aspartame. It has a temperature and heat dependent stability but is still useful in baking applications. Its' chemical formula is $C_{20}H_{24}N_2O_5$ and it has a molar mass of 378.46 g/mol. Neotame is chemically very similar to aspartame but is much more stable and much more potent. Aspartame is about 200 times sweeter than sucrose sugar while Neotame is between 7000 and 13000 times sweeter than sucrose sugar. Neotame is used in foods and beverages, including chewing gum, carbonated soft drinks, ready-to-drink beverages, tabletop sweeteners, frozen desserts and novelties, puddings and fillings, dairy products (such as yogurt), baked goods and candies. It can also be used in both cooking and baking applications because of its good heat resistance. Neotame, along with many other artificial sweeteners, is often used in combination with other sweeteners. It does not have a particularly strong aftertaste and because of its high potency, is often used alone or with sweeteners such as aspartame or Ace-K. Also, because of its potency, it is very desirable by mass manufacturers of food products because large amounts can be produced, cheaply and not very large amounts are needed for sufficient sweetening purposes. Neotame is produced by adding a 6-carbon (neohexyl) group to the amine nitrogen of aspartame. Peptidases, which would typically break the peptide bond between the aspartic acid and phenylalanine moieties, are effectively blocked by the presence of the 3, 3-dimethylbutyl moiety, thus reducing the production of phenylalanine, thereby making its consumption by those who suffer from phenylketonuria safe [33-35].

Saccharin

Saccharin (benzoic sulfimide) is a very stable organic acid with a pKa of 1.6 and chemical formula $C_7H_5NO_3S$. Its' chemical composition is 45.9% carbon, 2.7% hydrogen, 7.7% nitrogen, 26.2% oxygen, and 17.5% sulfur. It has a molar mass of 183.2 g/mol and a density of 0.83 g/cm^3. Saccharin is one of the oldest artificial sweeteners. It was developed by a John Hopkins University graduate student in 1879. It was originally used as a preservative and antiseptic but became a very popular sweetener during the first and second World Wars .In acid form saccharin is not water soluble. Therefore, the form used as an artificial sweetener is its sodium salt. Saccharin can be synthesized using the Remsen-Fahlberg and Maumee or Sherwin-Williams method. In the Remsen Fahlberg method, the process begins by reacting toluene with chlorosulfonic acid to give ortho and para forms of toluene-sulfonic acid. The acid is then converted to sulfonyl chlorides through treatment with phosphorus pentachloride. The ortho form, o-toluene-sulfonyl chloride is then treated with the compound ammonia to produce o-toluene-sulfonamide. This compound is then oxidized with potassium permanganate to produce o-sulfimide-benzoic acid. This is then heated to produce the desired product, saccharin. The Maumee method of synthesis, now called the Sherwin-Williams process, is also used. This process starts with phthalic anhydride and then converts this to anthranilic acid. The acid is reacted with nitrous acid, sulfur dioxide, chlorine, and ammonia, thus producing saccharin [36-38].

Sucralose

Sucralose (1', 4, 6'-Trichloro-galactosucrose) is a chlorinated sugar with chemical formula $C_{12}H_{19}C_{l3}O_8$ and a molar mass of 397.64 g/mol. Sucralose is a stable molecule that maintains its sweetness property when exposed to high temperatures, making it suitable for use in baking. Sucralose is one of the most stable artificial sweeteners available in today's market and can be used in nearly every application sugar is used. Sucralose is derived from sugar and is therefore very similar to it in its chemical structure and reactivity. Sucralose is significantly more stable than aspartame thereby allowing it a significantly longer shelf life without loss of sweetness. Its synthesis is carried out by the selective chlorination of sucrose (table sugar), which converts three of the hydroxyl groups to chlorides. The selective chlorination is achieved by selective protection of the primary alcohol groups followed by acetylation and then deprotection of the primary alcohol groups. In the course of the chlorination, the stereochemistry at position 4 of the glucose ring gets inverted, so it becomes a derivative of galacto-sucrose. Following an induced acetyl migration on one of the hydroxyl groups, the partially acetylated sugar is then chlorinated with a chlorinating agent such as phosphorus oxychloride, followed by removal of the acetyl groups to give sucralose [39-41].

Conclusion

Health effects related to the consumption of artificial sweeteners were analyzed through a review of scientific literature and examination of sweetener manufacturing processes. Survey results and the professional concerns expressed were compared to published scientific literature. This paper concludes that sweetener consumption within FDA approved guidelines appears to be a safe way for individuals to enjoy a diet high in sweetness yet low in calories with reduced risk of detrimental health effects. Based solely on the analysis of the chemical structures and production methods of popular sweeteners, no significant differences between natural and artificial sweeteners were found that would indicate any health concerns. It can be generally concluded that the sweeteners themselves are not composed of any harmful chemicals and are unlikely to pose a major threat to human health. However, the manufacturing and production processes that these sweeteners undergo need to be carefully regulated. In general, artificial sweeteners, when used in moderation are an acceptable substitute to natural sweeteners. They appear to be a healthy and pleasant way to enrich food sweetness, taste, and texture while keeping major health risks low.

References

1. Spillane, W. J. Optimizing sweet taste in foods. Null: CRC, 2006. Print.
2. Wade, L. G. Organic chemistry. Upper Saddle River, N.J: Pearson Prentice Hall, 2006. Print.
3. Sweeteners discovery, molecular design, and chemoreception. Washington, DC: American Chemical Society, 1991. Print.
4. Shallenberger, R. S. Sugar chemistry. Westport, Conn: Avi Pub. Co., 1975. Print.
5. Sugar science and technology. London: Applied Science, 1979. Print.
6. Walters, Eric D. "All About Sweeteners." All About Sweeteners. Web. 23 Sept. 2009.
7. Honey.com - The National Honey Board | Home. Web. 03 Feb. 2010.
8. "Canadian Maple Syrup - Nutritional Information." James Bay Wild Fruit. Web. 03 Feb. 2010. .
9. C.O. Willits and C.H. Hill 1976. Maple Syrup Producers Manual. USDA Agriculture Handbook No.
10. 134 and North American Maple Syrup Producers Manual, 2nd ed, 2006.
11. "Molasses, Beet molasses, 68476-78-8." ChemBlink Database of Chemicals from Around the World. Web. 15 Feb. 2010.
12. "Sugar (chemical compound) :: Cane sugar -- Britannica Online Encyclopedia." Encyclopedia - Britannica Online Encyclopedia. Web. 15 Feb. 2010.
13. "Composition." Suga-Lik. Web. 15 Feb. 2010.
14. Walters, Eric D. "All About Sweeteners." All About Sweeteners. Web. 23 Sept. 2009.
15. "Stevia/Rebaudioside A | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009.
16. Shallenberger, R. S. Sugar chemistry. Westport, Conn: Avi Pub. Co., 1975. Print.
17. J.C.P. Chen and C. Chou, Cane Sugar Handbook, Twelfth Edition, John Wiley and Sons, Inc., NY, 1993.
18. Sugar And Sweetener Yearbook, U. S. Department Of Agriculture, Economic Research Service, Washington, DC, June 1995.
19. "Sugar (chemical compound) :: Cane sugar -- Britannica Online Encyclopedia." Encyclopedia - Britannica Online Encyclopedia. Web. 15 Feb. 2010.
20. 2. Sherwood, Lauralee. Human Physiology From Cells to Systems Seventh Edition. s.l. : Brooks/Cole, 2008.
21. Sweeteners discovery, molecular design, and chemoreception. Washington, DC: American Chemical Society, 1991. Print.
22. "Useful in Diabetic Diets, Acesulfame K no effect on serum glucose | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009. <http://www.caloriecontrol.org/sweeteners-and-lite/sugar-substitutes/acesulfame-k>.
23. Shallenberger, R. S. Sugar chemistry. Westport, Conn: Avi Pub. Co., 1975. Print.
24. Sugar science and technology. London: Applied Science, 1979. Print
25. "Aspartame." How Products are Made. Ed. Stacey L. Blachford. Gale Cengage, 2002. eNotes.com. 2006. 20 Dec, 2009 http://www.enotes.com/how-products-encyclopedia/aspartame.
26. "Aspartame | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009. <http://www.caloriecontrol.org/sweeteners-and-lite/sugar-substitutes/aspartame>. 95
27. "Aspartame: Aspartame." Flavored Waters - Vitamin Enhanced Oxygenated and Structured Waters. Web. 20 Dec. 2009. <http://www.flavored-waters.com/Sweeteners/Aspartame.asp>.
28. Sugar science and technology. London: Applied Science, 1979. Print.

29. Walters, Eric D. "All About Sweeteners." All About Sweeteners. Web. 23 Sept. 2009. <http://www.sweetenerbook.com/>.
30. "Cyclamate | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009. <http://www.caloriecontrol.org/sweeteners-and-lite/sugar-substitutes/cyclamate>.
31. "Cyclamate: Cyclamate." Flavored Waters - Vitamin Enhanced Oxygenated and Structured Waters. Web. 20 Dec. 2009. <http://www.flavored-waters.com/Sweeteners/Cyclamate.asp>.
32. Spillane, W. J. Optimizing sweet taste in foods. Null: CRC, 2006. Print
33. Sugar science and technology. London: Applied Science, 1979. Print.
34. Sweeteners discovery, molecular design, and chemoreception. Washington, DC: American Chemical Society, 1991. Print
35. "Neotame | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009. http://www.caloriecontrol.org/sweeteners-and-lite/sugar-substitutes/neotame
36. "Neotame - NutraSweet: Neotame - NutraSweet." Flavored Waters - Vitamin Enhanced Oxygenated and Structured Waters. Web. 20 Dec. 2009. <http://www.flavored-waters.com/Sweeteners/Neotame_-_NutraSweet.asp>.
37. Shallenberger, R. S. Sugar chemistry. Westport, Conn: Avi Pub. Co., 1975. Print.
38. Walters, Eric D. "All About Sweeteners." All About Sweeteners. Web. 23 Sept. 2009. <http://www.sweetenerbook.com/>.
39. "Saccharin: Saccharin." Flavored Waters - Vitamin Enhanced Oxygenated and Structured Waters. Web. 20 Dec. 2009. <http://www.flavored-waters.com/Sweeteners/Saccharin.asp>.
40. Walters, Eric D. "All About Sweeteners." All About Sweeteners. Web. 23 Sept. 2009. <http://www.sweetenerbook.com/>.
41. "Sucralose | The Calorie Control Council." The Calorie Control Council | Healthy Eating & Exercise for Life. Web. 20 Dec. 2009. <http://www.caloriecontrol.org/sweeteners-and-lite/sugar-substitutes/sucralose>.