Sugar

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Sugar in many forms and permutations is ubiquitous, naturally occurring, and required for most life forms on Planet Earth. Conversely, chemically refined and highly purified sugar in all of its myriad forms (sucrose, high-fructose corn syrup [HFCS], and approximately 59 other names) is also ubiquitous in our modern world, but is not something that occurs in the natural world except in rare cases, such as honey production by bees. In the timeline of human evolution, purified sugar is a very recent addition to our diets. Sugar is ever present in the modern world and is estimated to be found in 75% of packaged foods (1). This short monograph focuses on refined/processed sucrose and HFCS and will refer to them collectively as "sugar," with the understanding that this term, in reality, can be applied to many other carbohydrates.

Indications

Sugar is used as a preservative, a viscosity-enhancing agent, a sweetening agent, and for other reasons in foods and beverages. The U.S. Food and Drug Administration (FDA) designates sugar as "generally recognized as safe" (GRAS) (2,3). Although the Center for Science in the Public Interest has petitioned the FDA to remove GRAS status from products containing extreme amounts of added sugar, this effort has not been successful (4). Additionally, sucrose and glucose have been shown to be effective analgesics in newborns undergoing heel lancing, venipuncture, or intramuscular injection, and its use has been suggested to be the standard of care for these procedures in this population (5).

Dose

Actual dose. The actual dose of sugar varies widely depending on the individual. Currently, it is estimated that the average American consumes ~66 lb of added sugar annually, which translates to 82 g or 19.5 teaspoons daily (1). However, this estimate is based on an assumption regarding how much purchased sugar is actually consumed versus how much is delivered (114 lb per person). By contrast, it has been estimated that, in 1790, an average of 8 lb of sugar was consumed annually per person (6). There has been an exponential increase in the consumption of sugar during the past several hundred years. The dose of sugar in one standard 16-oz soda is 64 g or 16 teaspoons.

Recommended dose. The American Heart Association recommends that adult females consume ≤6 teaspoons (~25 g) and that adult males consume ≤9 teaspoons (~38 g) of added sugar daily (1).

The disparity between the actual and recommended doses of sugar is significant. It is estimated that, on average, Americans consume three to six times the recommended amount of sugar (1).

Pharmacokinetics and Metabolism

Sucrose and HFCS are rapidly absorbed and highly bioavailable. Sucrose is

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enzymatically cleaved into the monosaccharides glucose and fructose via sucrase or isomaltase glycoside hydrolases. HFCS is composed of fructose and glucose in varying ratios. Although these monosaccharides are typically found in a 55:45 ratio of fructose to glucose, the fraction is variable depending on the particular product in which the HFCS is used.

Fructose is transported almost exclusively to the liver, where it is used to produce glycogen, lactate, glucose, and triglycerides. Fructose does not stimulate the release of insulin. Glucose stimulates the release of insulin and is distributed throughout the body, where it is utilized as an energy source via the production of adenosine triphosphate or stored in the form of glycogen.

Mechanisms of Action

In addition to serving as an energy source or as a precursor for the production of glycogen, lactate, and triglycerides, sugar also has several other actions or functions. First, its glucose component is a potent stimulator of insulin secretion and of the incretin pathway, which is also a potent stimulus for insulin secretion. Additionally, sugar stimulates specialized taste cells on the dorsal surface of the tongue and the soft palate. Activation of these cells results in release of neurotransmitters in afferent cranial nerves, which in turn transmit information to the brain. This taste information, along with textural, olfactory, and thermal stimuli, is interpreted by the brain, which produces a complex and multifaceted neural, endocrine, and even motor response (ingest or not).

One aspect of this central nervous system response is the stimulation of the reward pathway. Sugar stimulates the release of dopamine in the nucleus accumbens. This dopamine release is perceived as highly rewarding and further stimulates pathways to the frontal cortex and the hippocampus, which reinforce neural pathways regarding the salience of the ingestion and the memory of the event. A recent review of this phenomenon concluded that "hyperpalatable foods, notably those high in added sugar, can induce reward and craving that are at least comparable to addictive drugs" (8).

Potential Advantages

There are none. Carbohydrates found in their natural state in combination with other nutrients and fiber are far superior to high-dose refined sugar products in terms of overall nutritive effects and glycemic impact.

Potential Disadvantages

Chronic ingestion of high-dose sugar has been linked to obesity, metabolic syndrome, type 2 diabetes, cardiovascular disease, some cancers, Alzheimer's disease, and cellular aging (1). Additionally, the incidence of nonalcoholic fatty liver disease (NAFLD) and nonalcoholic steatohepatitis (NASH) has doubled since 1980, with the rise in consumption of refined sugar (1). It is estimated that 13% of children now suffer from NAFLD. A recent study reported that 37.6% of children and adolescents with NAFLD also demonstrated evidence of NASH (9). This study also confirmed an association between NASH and fructose consumption.

Cost

The cost of sugar is nominal. For example, the retail cost of a 25-lb bag of sucrose from a common vendor in the United States is $15.64 (62.6 cents/lb). HFCS is less expensive than sucrose, which in part explains the frequency of its use as a hidden sugar in processed food products.

Commentary

There has been much discussion regarding the relative contribution of various dietary factors to the development of coronary heart disease (CHD). Since the 1960s, much of the focus has been on dietary and metabolic fats. However, it is worth remembering that in the 1960s, medicine came to a figurative fork in the road and has since traveled almost exclusively in one direction. One branch of the road was defined by John Yudkin's hypothesis that added sugar was the primary causative agent of CHD; the other was defined by Ancel Keys' hypothesis that dietary fat was the primary causative agent. Keys, of course, was the first author of the famous Seven Countries Study. Medicine embraced fat as the primary causative agent and discounted or essentially ignored the possibility that refined sugar might be a salient contributor to this problem.

A recent analysis of historical documents from the Sugar Research Foundation, a pro-sugar trade organization, found that industry-sponsored research in the 1960s and '70s was successful in casting doubt on the possibility that refined sugar was partially responsible for the observed increase in CHD, while promoting dietary fat as the offender (10). This in and of itself proves nothing, but because of this analysis and other studies suggesting that refined sugar may not be benign after all, there has been a renewed interest in the notion of refined sugar as a contributor to chronic disease.

Bottom Line for Diabetes

Clearly, much remains to be clarified regarding the health impacts secondary to the chronic ingestion of high-dose sugar. However, if we look at the data regarding increases in consumption of refined sugar during the past 400 years, and if we simply observe the habitus and chronic disease patterns of our population, it is impossible to avoid a strong suspicion of association between the two.

Is occasional consumption of reasonable amounts of refined sugar problematic? Almost certainly it is not. Is chronic consumption of 66 lb of sugar per year problematic? Very likely it is. For people with diabetes, refined sugar may be even more toxic. In the words of the famous physician and father of toxicology Paracelcus, "Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy."

Duality of Interest

No potential conflicts of interest relevant to this article were reported.

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