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A Synthetic Sweet Tooth:

How High Fructose Corn Syrup Changed the Way We Eat

Extensive government subsidies of corn for the last half century have created a huge surplus of corn in the U.S. High fructose corn syrup (HFCS) is the most profitable use for that corn. Ever since the invention of HFCS in the late 1960's by Dr. Y. Takasaki, it has rapidly gained popularity with food companies such as Coca-Cola and Cargill as a substitute for table sugar that is sold at an artificially high price. Many food companies use HFCS in foods like Twinkies and Power Bars. Rising consumption of both HFCS and traditional table sugar has contributed to rising obesity and Type II diabetes in America. HFCS has not been deemed harmful by the Food and Drug Administration; however, regardless of whether or not it is eventually declared detrimental to human health, the wide use of HFCS present in today's food is causing significant health concerns.

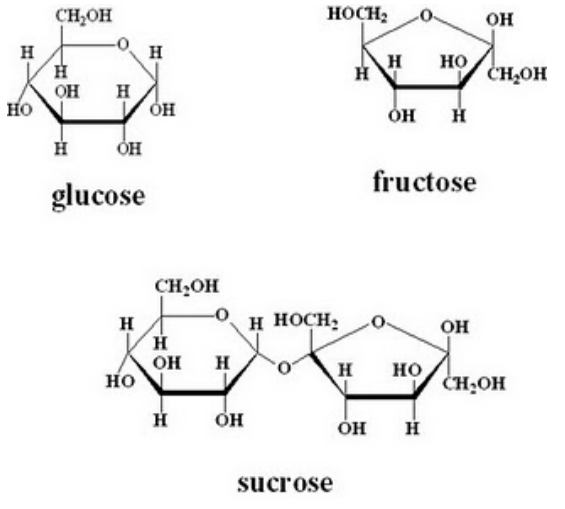

Figure 1. Structures of glucose, fructose, and sucrose

What are the differences between the structures of table sugar and HFCS? As shown in Figure 1, table sugar is primarily composed of sucrose, a complex sugar or oligosaccharide, while HFCS is composed of a mixture of glucose and fructose, two simple sugars called monosaccharides. Sucrose, consists of glucose and fructose molecules

linked together by a polar C-O-C bond that is broken in digestion by the enzyme sucrase. Therefore, after digestion, there are no major structural differences between the two molecules, although many conclusive studies have pointed to discrepancies between their effects on health. One study on differences between HFCS and sucrose by Ferder, Ferder and Inserra in 2010 was presented in, "The Role of High-Fructose Corn Syrup in Metabolic Syndrome and Hypertension." This study showed that fructose is not sufficiently responsive to insulin; therefore, there is no insulin suppression of appetite after a meal (Ferder, Ferder, & Inserra, 2010). If the appetite is not satiated, a consumer of fructose may keep eating more than he or she should, leading to storage of excess calories.

Another study linking HFCS with adverse health effects was conducted in 2007 by Chi-Tang Ho, who showed a link between HFCS and diabetes. In this study, Ho showed that both glucose and fructose have unstable carbonyls that are stabilized in the complex sugar structure of sucrose: "Reactive carbonyls also are elevated in the blood of individuals with diabetes and linked to the complications of that disease." Ho estimates that a single can of soda contains a concentration of reactive carbonyls five times the concentration found in the blood of an adult person with diabetes. (Ho, 2007)Ho's work presents some of the most conclusive findings of HFCS's negative health effects.

A more recent study that also focused on the negative effects of the increased fructose concentration in HFCS was published in July 2011 by Dr. MyPhuong Le and Dr. Julie Johnson. This study tested blood pressure, heart rate, and numerous other biomarkers on a sample population that consumed either 24 ounces of sucrose-sweetened beverages or HFCS-sweetened beverages. The results of the paper showed that HFCS promotes increased entry of fructose into the bloodstream since sucrase,

an enzyme which converts sucrose into fructose and glucose and also limits the amount of fructose metabolized, was no longer needed. It also showed that glucose uptake was increased with HFCS consumption, stating: "We found treatment differences in fructose, glucose, SUA, and SBP. The following metabolic parameters were higher from the HFCS-sweetened beverages than from the sucrose-sweetened beverages: fructose AUC and Cmax, dose-normalized glucose AUC and Cmax, relative bioavailability of glucose, changes in postprandial concentrations of SUA, and observed maximum SBP… This finding suggests that glucose is more efficiently absorbed into the body from HFCS than from sucrose." (MyPhuong &Johnson, 2011)

HFCS is a lucrative product for industry's constant effort to find new markets for corn. The corn surplus problem began in 1973 when increased demand reached an all-time high and food became scarce for less affluent consumers. Earl Butz, head of the Department of Agriculture at the time, countered this food crisis by implementing policies that would lower the price of corn to raise output. With the1973 Farm Bill, Butz took a revolutionary step: loans to farmers were replaced by direct subsidies based on the amount of corn sold (Philpott, 2008). Michael Pollan discussed this on page 51 of *The Omnivore's Dilemma*: "Instead of keeping corn out of a falling market, as the old loan programs and federal granary had done, the new subsidies encouraged farmers to sell their corn at any price, since the government would make up the difference." (Pollan, 2006) The price of corn suddenly had no floor. Soon it had dropped to such a low level that farmers had to produce a higher yield each year to break even, despite extensive government subsidies; payments to farmers each year total $19 billion (Service, 2005).Corn production consumes not only money and energy, but also large quantities of nonrenewable resources to operate corn milling machinery and to transport the corn to the market. As Pollan writes on page 45 of *The*

Omnivore's Dilemma, "When you add together the natural gas needed for fertilizer to the fossil fuels to make the pesticides, drive the tractors, and harvest, dry, and transport the corn, you find that every bushel of corn requires the equivalent of between a quarter and a third of a gallon of oil to grow it." (Pollan, 2006) However, although the level of corn produced was steadily increasing, consumer demand remained fixed; population growth could not keep up with the supply increase. An effective way to cut some of the losses from this huge surplus of corn was to convert part of the corn crop to HFCS.

HFCS was synthesized in 1957 by Richard O. Marshall and Earl R. Kooi. It was only in 1965-1970 that a Japanese scientist, Dr. Y. Takasaki, was able to make HFCS available for mass production (Pakzad, 2006). HFCS is produced from corn by the wet milling process. In this process, corn is milled to produce corn starch from the endosperm of the corn seed. The corn starch is converted to corn syrup (glucose) by adding dilute hydrochloric acid. Then, upon adding alpha amylase, the corn syrup is changed into shorter chains of sugar called oligosaccharides. Then glucoamylase breaks these oligosaccharides to glucose. Last, xylose isomerase converts glucose to a mixture of about 55% fructose and 45% glucose; this mixture is optimal to replicate the taste of sucrose (Food and Agricultural Industry, 2002). The wet milling process is also energy intensive. As Michael Pollan states on page 88 of *The Omnivore's Dilemma*, "…for every calorie of processed food [wet milling] produces, another ten calories of fossil fuel are burned." (Pollan, 2006) Nevertheless, as HFCS has become more prominent in the American food economy, HFCS is the most profitable endpoint of the corn surplus.

The decision by large food companies to use HFCS was shaped, in part, by pressure from the national economy to use the corn surplus economically and, in part, by a reaction to high sugar prices. Raj Patel explains this second motivation on page 114 of *Stuffed and Starved*; "The average wholesale price for sugar in the US in 2005 was over 29 cents per pound. The world price was just over 13 cents per pound. The protection enjoyed by the sugar industry, which accrue to its processors, block sugar imports above a specific quota." (Patel, 2007) With sugar prices high, firms would naturally look to increase profits by incorporating an ingredient into sugar that was inexpensive. Substitution of table sugar for HFCS would lead to no gain in the total amount of sugar consumed; however, the last 30 years have shown that this is not the case. As Michael Pollan writes on page 104 of *The Omnivore's Dilemma*, "Since 1985, our consumption of all added sugars- cane, beet, HFCS, glucose, honey, maple syrup- has climbed from 128 pounds to 158 pounds per person." (Pollan, 2006) Pollan's statement is supported by Figure 2 taken from the USDA ERS Food Availability Data:

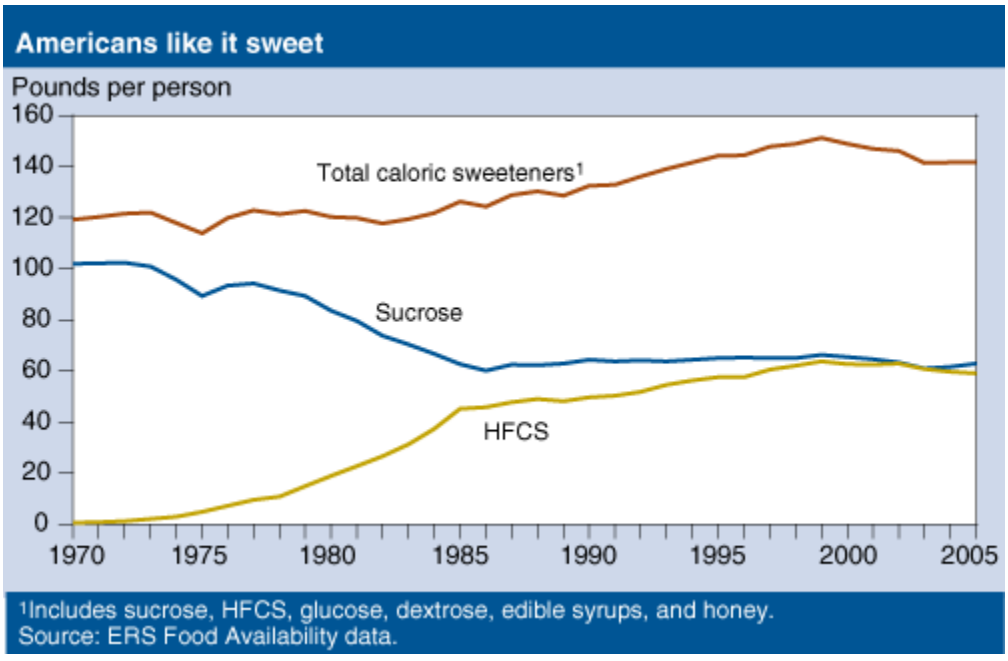

Figure 2. Annual consumption of total caloric sweeteners in the US from 1970-2005

How did companies like Coca-Cola and Pepsi-Cola manage to make a profit upon switching from table sugar to HFCS? To increase soda consumption, the companies could drop soda prices due to cheaper ingredients. However, because soda consumption was already saturated, lower soda prices would reduce, not raise, revenue. A new idea, spearheaded by David Wallerstein, to circumvent the consumer's desire not to be seen as gluttonous, sold supersized soft drinks for just a few cents more. He studied consumer behavior and noted that whereas consumers were reluctant to buy a second serving of drink or food, they would not feel guilty about paying just a little more for one large container of soda or other sweet food. In pioneering the idea of supersizing, he reengineered the U.S. food culture (Critser, 2003). Companies were able to increase their profit not only by buying cheaper ingredients but also by selling more of their products. Therefore, sugar consumption in the U.S. increased remarkably.

Successful expansion of production has taken its toll on consumer health, leading to problems like obesity, heart disease, and diabetes. In addition, many opponents of HFCS claim that beyond supersaturating the market with sugars, it is the chemical differences between sucrose and HFCS that are responsible for adverse health effects.Because HFCS has gained prominence as a sucrose substitute, much public attention has been directed toward its negative health effects. The FDA has not yet ruled that HFCS is a harmful substance, although prominent health experts have concluded that the detrimental properties of HFCS are insignificant compared to the fact that Americans are eating too much of it (Pollan, 2006). As Marion Nestle explained in "Food Politics", "The public now puts HFCS in the same category as trans fats: poison. Biochemically, HFCS is about the same as table sugar, but HFCS is in many foods and Americans eat a lot of it -- nearly 60 pounds per capita in 2006, just a

bit less than pounds of table sugar. HFCS is not a poison, but eating less of any kind of sugar is a good idea these days." (Nestle, 2008) Because food companies want to extract maximum profit from their products, HFCS is ubiquitous. It is the sheer abundance of HFCS rather than its properties that have damaging effects on human health.

HFCS is not a new molecule; it is a mixture of several molecules already present in our food. However, the introduction of this mixture to our diet has impacted our physical health and our farming economies. Research has not yet conclusively shown HFCS to be detrimental to the human diet. It is likely that this cheap replacement for sucrose will become an increasing hazard to our health.

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