Sugar, Sweeteners, and Metabolism



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# Introduction

Metabolism is an essential chemical-cellular process. The metabolic process is responsible for the breaking down and building up of energy, fueling the body at every level. Understandably, then, food science frequently concerns itself with understanding how our bodies break down different consumables. In this paper we will explore how the body metabolizes sugar and artificial sweeteners. The body’s metabolization of sugar is fairly simple and straightforward, and the metabolic risks associated with sugar are more associated with sugar in excess than with ordinary intake. Artificial sweeteners, on the other hand, pose more significant metabolic risks even considered in moderation. Despite the fact that sugars and artificial sweeteners both “taste sweet,” the similarities between the two end in their flavor. Our bodies metabolize them in markedly different ways.

# The Basic Need for Sugar

 While it is common to speak of (natural) sugar as though it were a monolithic substance, there are really a variety of different sugars. Glucose is arguably the most common, sometimes referred to as “blood” sugar; the body breaks down fat, protein, and especially carbohydrates to create and circulate glucose throughout the body. This is our main source of energy and is indispensable. Fructose is similar to glucose but is associated with more traditionally sweet foods, especially fruit, but unlike glucose which can be broken down throughout the body, fructose is only broken down in the liver where it is turned into glucose.[[1]](#footnote-1) And then there is sucrose, which is a combination of glucose and fructose. Sucrose is associated with sweet plants like sugar cane, and it composes table sugar. Sucrose is broken down into its component parts, glucose and fructose. And of course, whether glucose, fructose, or sucrose, the actual source of these sugars ranges considerably and is more or less ubiquitous—carbohydrates (rice, potatoes, bread, etc.) are all sources of glucose, fruit and many vegetables are sources of fructose, and table sugar/cane sugar (along with anything it is added to) are sources of sucrose. It would be tremendously difficult to develop and maintain a diet with none of these sugars at all.

 And it would be unwise to. Sugars represent the most basic and fundamental source of energy for our bodies, especially the brain and nervous tissues, glucose in particular. As a monosaccharide (i.e., “simple” sugar or “simple carbohydrate), glucose is a turnkey energy source for our bodies. Fructose is converted to it, and disaccharide sugars (i.e., “complex” sugars made of multiple sugar molecules) like sucrose are broken down into it[[2]](#footnote-2). So the question over the healthiness of sugar is not a binary one but a dynamic one. Since we *need* sugars, the question is one of quantity and of quality.

# Sugar Metabolized

 The metabolic process behind sugars is fairly straightforward. A food is consumed containing one of or some combination of natural sugar. The process begins with salivation which helps break down starch into shorter polysaccharides, which is then passed through the stomach and pancreas into the small intestine, where they are continually broken down into disaccharides and monosaccharides; at the level of a monosaccharide they are sent to the liver where any further conversion to glucose occurs as necessary, with excesses either being stored in the liver or passed to the large intestine undigested.[[3]](#footnote-3) Supposing that a person is healthy, there is nothing complicated nor dangerous about this process. The food sources is simply broken down into smaller and smaller components until it is usable by the body, at which point it is sent to the bloodstream and whatever is left over is stored.

 The challenge arises when the amount of sugars consumed becomes excessive. Exactly what constitutes excessive is a matter of some debate, but most advisory bodies tend to concur around an acceptable sugar intake of 25-38 grams, with the lower end of the range indicating the high end suggestion for women and the higher end indicating the high end suggestion for men.[[4]](#footnote-4) But regulating sugar intake is rendered more difficult in a world with added sugars.

 Added sugars are distinct from artificial sweeteners, because they are natural, albeit fortified sources of sugar. But they are also distinct from natural sugars because they rely on mechanical intervention to manipulate the degree of “natural” sweetness. Arguably the most common of these is high-fructose corn syrup, which is exactly what it sounds like: a corn syrup (an existing sugar) with fructose added to it. It is a tremendously popular added sugar for food and beverage manufacturers because it provides an opportunity for cost-savings. Its increased sweetness makes it a more efficient way to produce sweet items: cookies, candies, sodas, etc. However, given its more concentrated and intense fructose levels, the ubiquity of added sugars like high fructose corn syrup makes it incredibly difficult to regulate a healthy sugar intake. In fructose alone, American adults consume an average of fifty-five grams per day, with adolescents averaging almost seventy-five grams per day.[[5]](#footnote-5) The results of this overconsumption can cause some notable metabolic challenges.

 As mentioned previously, fructose must be broken down in the liver. The metabolic processes that break down fructose in the liver produce triglyceride, which is a type of fat. This can build up in the liver and cause liver damage, and what triglycerides that are released into the blood stream can result in fat-filled plaque inside the walls of the arteries.[[6]](#footnote-6) The problems don’t end there, as fructose also breaks down into ulric acid and form free radicals, each of which can result in artery wall weakening, insulin resistance, and enzyme damage.[[7]](#footnote-7) Although the evidence is not yet conclusive, what this means in the long term is that high fructose intake could very well be associated with diabetes, fatty liver disease, and obesity.

 However, the challenges posed to the metabolic processes by added sugars like high fructose corn syrup should be considered in their proper context. These negative effects are not so much associated with fructose as such, but with the sort of excessive and relentless fructose intake that has become common-place. In other words, it is more a matter of “too much of a good thing” than it is a matter of fructose (or even high fructose corn syrup) being properly, in and of itself, unhealthy.

# Summary of Sugar

 In sum, the metabolic processes that our bodies employ to break down sugars are fairly straightforward. Glucose is essentially the end goal of all consumed sugars, although non-glucose sugars must be further broken down. These sugars are necessary for our bodies to sustain energy and function. When consumed temperately they pose no metabolic risk in a healthy person. There are nevertheless fairly serious concerns about sugar overconsumption, especially with added sugars like high-fructose corn syrup. These more intense and concentrated sugars are more difficult for the metabolic mechanisms to keep up with, and as a result are suspected to contribute to serious health problems over time.

# Artificial Sweeteners Background

 Artificial sweeteners, on the other hand, are quite distinguishable from both sugars and added sugars. Artificial sweeteners became *en vogue* in the seventies when aspartame was discovered—a synthetic chemical which promised a sweetness about two hundred times that of natural sugars. For the same reason that corn syrup became a popular way to sweeten foods, artificial sweeteners like aspartame became incredibly popular in food and beverage industries due to their efficiency.

 In the seventies, artificial sweeteners were viewed chimerically. Artificial sweeteners, having no (or virtually no) caloric quality, were billed as a way to maintain the desired flavor or sweetness level in a food without the risk of fat associated with calories.[[8]](#footnote-8) So while they did not provide any energy fuel to the body, this was viewed as their saving grace—without caloric value, they could or would not contribute to weight gain. To date, these sweeteners are often viewed (at least popularly) as a legitimate way to lose weight or prevent weight gain. Since they have no nutritive value, it has long been assumed by the popular mind that they cannot pose any nutritive risks. But artificial sweeteners can indeed pose nutritive both nutritive and metabolic risks.

# Aspartame Metabolized

 Since Aspartame (often labelled as “Equal” or “NutraSweet”) is the most ubiquitous of artificial sweeteners, we will begin with it. When aspartame is metabolized it is broken down into three different amino acids: phenylalanine, aspartic acid, and methanol.[[9]](#footnote-9) While each of these is not harmful in itself and are found across a variety of ordinary, foods and drinks. But some studies have indicated that the amounts contained in aspartame could pose diverse risks[[10]](#footnote-10). Methanol, which often provides an initial shock effect due to its nature as a carcinogen and its inclusion in highly toxic products like jet fuel, is not actually voluminous enough in aspartame to cause any detrimental effects to the central nervous system. But phenylalanine levels in aspartame are notably excessive, and result in a variety of problems.

Individuals who are pregnant, or who suffer from high blood pressure, anxiety or phenylketonuria (a genetic defect denoted by excessive phenylalanine) are all recommended to avoid any supplements that would increase their phenylalanine[[11]](#footnote-11). However, the high levels of phenylalanine in aspartame do not only endanger these small subsets of populations, but may cause problems for the population in general. For instance, Rycerz and Jaworska-Adamu found these levels to interfere with the transport of amino acids to the brain, resulting in reduced levels of dopamine and serotonin[[12]](#footnote-12). Dopamine and serotonin are crucial neurotransmitters which play important roles in regulating reward behaviors as well as mood, social behavior, appetite, sleep, memory, etc.

In addition to the broad-ranging risks the metabolized phenylalanine poses, aspartic acid also gives cause for concern. Aspartate metabolite from aspartame was found to be neurotoxic, leading to “hyperexcitability of cells, free radicals release, oxidative stress, and neuronal degeneration.”[[13]](#footnote-13) Aspartate is also a substrate for glutamate (a fundamental and ubiquitous neurotransmitter for excitability processes) which can result in overproduction, and excess glutamate activates together with astrocytes, further exacerbating neurodegeneration.

Studies have also found that aspartame intake is associated with glucose intolerance, at least especially in individuals who are already obese.[[14]](#footnote-14) In Kuk and Brown’s research, participants were given natural sugars (sucrose, fructose) and also aspartame in a control group. The research indicated that those who used aspartame only showed a significantly higher positive association between body mass index and glucose intolerance. The reasons for this association are still somewhat ambiguous, but it has been speculated across the scholarly realm that sweet tastes trigger an insulin response by the pancreas, but since there are no actual carbohydrates present (given that artificial sweeteners are non-nutritive), insulin lowers glucose levels.[[15]](#footnote-15) Another possible explanation could be related to some evidence for aspartame contributing to metabolic syndrome, which refers to a collection of symptoms associated with type 2 diabetes and cardiovascular disease. This metabolic mechanism results from the high levels of phenylalanine which may prevent the communications of enzymes which prevent metabolic syndrome.[[16]](#footnote-16) With that prevention removed, weight gain and other indicators of diabetes like insulin resistance can result.

 Whether these different proposals adequately describe the association between aspartame and glucose tolerance or not, it has also been suggested that over time aspartame (and other artificial sweeteners) lead our bodies to no longer associate sweetness with caloric intake, and as a result, we crave more sweets—a sort of faux addition.[[17]](#footnote-17) As sweets begin to compose a normative or even substantial portion of our diet (in place of healthier foods), weight gain ensues. And of course weight gain is significantly correlative with a plethora of different conditions from diabetes to cardiovascular disease. So however one looks at it, there are risks broadly associated with diabetes and similar complications correlated with the use of aspartame.

# Acesulfame Potassium

 Acesulfame Potassium is somewhat newer than aspartame, and goes by a variety of shorthand names, such as “Ace-K” or even just “K.” It is not quite as potent as aspartame, but it nevertheless is widely used. Like aspartame, there are a variety of serious question marks regarding how we metabolize Ace K.

 Like Aspartame, clinical trials have been conducted on Ace-K and concluded that at minimum, it does not help control weight gain or promote weight loss.[[18]](#footnote-18) With Ace-K, a variety of studies have gone to show that the substance very probably behaves the way that aspartame is suspected to viz. sweetness stimulation. The body detects the sweet flavor and readies insulin out of an expectation for carbohydrates, but not receiving any from Ace-K, the reward responses (which associate sweetness with actual sugar, and therefore glucose energy) become muted and dulled.[[19]](#footnote-19) As a result, the body continually craves sweetness, but so long as it is delivered via Ace-K the fundamentally desired reward (energy via carbohydrates and glucose) remains absent, and the appetite is stimulated even beyond need.

# Summary of Artificial Sweeteners

 As can be seen, artificial sweetener’s effect the body in a very different way than sugar. As non-caloric and non-nutritive substances they provide no energy value. While this was initially regarded as a positive quality (since they were believed to not factor into weight gain), further research has revealed that there are a variety of different problems with artificial sweeteners and how our body metabolizes them. Phenylalanine excess in particular has been linked not only to metabolic syndrome which contributes to diabetes and cardiovascular disease, but has also been shown to contribute to neurodegredation, as has aspartic acid. Aspartame is the most widely used artificial sweetener and produces these metabolites in excess. But it is not the only artificial sweetener with a negative outlook; Ace-K has also been shown to play a role in interfering with the body’s reward sensors, by “tricking” the body into thinking that carbohydrates are going to be delivered when artificial sweeteners are ingested. Aspartame is also suspected to produce this effect.

**Stevia**

 Stevia is a *natural* non-caloric sweetener, and as such it eludes categorization, given that unlike natural sugars it is non-nutritive, but unlike artificial sweeteners it is not synthetic nor artificial. Stevia has gain popularity in the west in recent years, and it does seem to avoid the metabolic pitfalls associated with Ace-K, aspartame, and other non-caloric artificial sweeteners. As a newer inclusion in the western market it has not been studied as extensively as other, longer-enduring sweeteners, but the studies to date suggest that it poses no serious metabolic risks or side-effects[[20]](#footnote-20) [[21]](#footnote-21).

# Discussion & Conclusion

 While artificial sweeteners and sugar may be viewed popularly as being “the same thing”, at least for all intents and purposes—since they’re both used to sweeten what we consume—our bodies handle them in wildly different ways. Natural sugars are broken down into glucose and glucose is a crucial component of both storing and maintaining energy throughout the body. Like many other naturally occurring substances found in our foods, sugar intake is not a problem in itself, supposing the intake is moderate. When in excess, as it very often is (especially due to added sugars like high fructose corn syrup), sugar can pose greater challenges to the metabolic system and processes, contributive to liver damage, weight gain, and so on. Sugar is not a problem, but too much sugar certainly is.

 On the other hand, artificial sweeteners are broken down completely differently. Aspartame in particular raises serious questions, given that it is metabolized into excesses of phenylaline and aspartic acid. This relates to a variety of both neurological and physiological problems, many of which—paradoxically—aspartame is commonly regarded as guarding *against*. Weight gain and the broad effects of obesity (diabetes, cardiovascular disease, etc.) are serious problems for both the American and global health systems, yet aspartame is sometimes considered as a *solution* to these problems. And while the evidence to date does not conclusive establish a direct, causal connection between artificial sweeteners and these negative outcomes (at least, not in the way that say, cigarette smoking has finally been *conclusively* shown to cause respiratory illnesses and diseases), the suspicions of researchers and the medical community are quite high due to the significant correlation between these substances and those health problems.

 It would be a mistake to conflate sugar and artificial sweeteners. They are *quite* different substances, and the way that our bodies metabolize them is the greatest proof of this. The similarities between sugar and artificial sweeteners end beyond them both “being sweet.” By raising awareness of the importance of *moderate* sugar intake as a way to maintain healthy functions and energy levels (rather than as a way to satiate cravings), a greater appreciation for how sugar helps us might be had, and temperate use of natural sugars might become the norm again. And if it is understood that sugar plays a much greater role in our diets than merely satisfying cravings, artificial sweeteners, as a consequence, will be more exposed as illegitimate substitutes for the effects of sugar.

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