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The Battle of Natural Sweeteners: A Comprehensive Guide to Monk Fruit and Stevia

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Abstract

In today's world, low-calorie sweeteners are essential due to the growing demand for alternatives to sugar, driven by rising health concerns such as obesity, diabetes, and metabolic disorders. They provide sweetness without the adverse effects of excessive sugar consumption, making them useful in foods, beverages, and dietary products. Natural sweeteners are increasingly favoured over artificial ones because they offer similar sweetness with added health benefits, such as antioxidant properties, without synthetic chemicals. Their natural origins and minimal impact on blood sugar make them a preferred choice for health-conscious consumers. This article explores and compares two popular natural sweeteners, Monk fruit and Stevia, across multiple dimensions. Monk fruit, derived from the fruit of *Siraitia grosvenorii*, has been used for centuries in traditional Chinese medicine. Stevia, obtained from the leaves of the *Stevia rebaudiana* plant, has a similar historical use in South America. The safety concerns, extraction processes, metabolic pathways and interaction with gut microbiota of both the sweeteners have been discussed in detail. The article also highlights, how both these natural sweeteners are processed in the body without contributing to calorie intake, making them suitable for individuals with diabetes and those seeking weight management options. Furthermore, the health effects associated with each sweetener have been explored. This comprehensive comparison aims to guide consumers and food manufacturers in making informed choices about these two natural sweeteners.

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Introduction

The consumption of sugar-sweetened beverages promotes adverse effects on body weight,[1] increases risk for Type 2 diabetes[2] and other medical complications such as cardiovascular disease, kidney disease and cancer. Due to the increased demand for health and nutrition, enhanced palatability and other benefits, a remarkable increase has been seen in recent years in the consumption of low-calorie sweeteners (LCS) in foods and beverages.[3,4] They have become an integral part of modern dietary habits, offering an alternative to traditional sugar. It has been found that consumers using these low-calorie sweeteners (LCS) often have higher healthy eating index (HEI) scores indicating better diet quality. They also tend to be more physically active and smoke less compared to non-consumers, suggesting an association between LCS use and positive health behaviours.[5] These sweeteners can be used primarily to provide the sweet taste that many people crave, without the caloric impact or glycemic response associated with sugar. Aspartame is one of the low-calorie sweeteners in this category, while other sweeteners like stevia, sucralose and monk fruit have no calories at all. They are frequently referred to by many names like low- and no-calorie sweeteners, high-intensity sweeteners, non-nutritive sweeteners or just sugar substitutes. These sweeteners are particularly valuable for individuals' managing diabetes, obesity, or metabolic syndrome, as well as those seeking to reduce their overall sugar intake for health reasons. The commonly used non-nutritive sweeteners can be categorized into artificial sweeteners obtained synthetically and natural sweeteners obtained from the plants.

Artificial sweeteners are low-calorie or calorie free substitutes for sugar, providing sweetness without the calories and thus widely used in diet foods, beverages and as tabletop sweeteners. They have thus become very popular for weight management and for people with diabetes. The commonly used artificial sweeteners are, Aspartame, Sucralose, Saccharin, Xylitol, Acesulfame potassium, Advantame, Neotame. Despite their benefits, artificial sweeteners have potential negative impacts. Some studies suggest that they may alter gut bacteria, potentially leading to metabolic issues like insulin resistance. There are also concerns about long-term health effects, including possible links to certain cancers.[6]

Table 1: Sweetness profile, benefits and health risks of some artificial and natural sweeteners

Sweetener Type	Name	Comparison with Sucrose[9] (Sweeter Than Sucrose)	Health Benefits	Health Risks
Artificial	Aspartame[10]	~170 times	Low-calorie Sweetener	Its consumption may be linked to obesity, glucose intolerance, mood disorders, pre-mature birth, neurode-generative effects.[10]
	Sucralose[11]	~200 times	Low-calorie Sweetener	Its consumption may be linked to metabolic syndrome, type 2 diabetes, hypertension, obesity and potential carcinogenic effect.[11]
	Saccharin[12]	~400 times	Low-calorie Sweetener	Long term consumption may be linked to obesity, diabetes, liver and renal impairment and brain carcinogenesis.[12]
	Acesulfame potassium[13]	~120 times	Low-calorie Sweetener	Long term consumption may lead to increased body weight, metabolic disturbance, and chronic inflammation

				in male rats.[13]
	Neotame[14]	~7000 -13000 times	Low-calorie Sweetener	Long term consumption may lead to metabolic and inflammatory disorders.[14]
	Erythritol[15]	~ 1 times	Low-calorie Sweetener	Long term consumption increases risk of heart attack, stroke and digestive issues.[15]
	Xylitol[16]	~ 1 time	Low-calorie Sweetener	Long term consumption is related to cardiovascular disease and increased risk of blood clot.[16]
Natural	Yacon[17]	0.5 time	Antioxidant, antimic -robial, antidiabetic, anti-cancer, anti-obese and weight management	Long term consumption may lead to digestive issues and abdominal problems.[17]
	Stevia[18]	1. rebaudioside A is 150–320 times 2. stevioside is 100–270 times	Antioxidant, antibacterial, chemotherapeutic, immunomodulating properties, helps in weight manage-ment by reducing appetite	No known side effects but stevia may leave a slightly bitter or metallic aftertaste due to stevioside, while rebaudioside A is reported to lack this aftertaste.[18]
	Monk Fruit [19]	~100 -250 times	Antioxidant, Anti-inflammatory, anti-obese, anti-carcinogenic and anti-diabetic	No known side-effects.[19]

Natural sweeteners on the other hand have garnered significant attention due to their plant-based origins and potential health benefits. These are non-saccharide sweeteners yet intensely sweet, non-toxic with low or no calories. They thus offer healthier alternative to synthetic sweeteners and sugar. These sweeteners are less processed, contain beneficial nutrients, and have a more favourable metabolic impact, avoiding the potential long-term health risks associated with some artificial sweeteners. Stevia, *Glycyrrhiza glabra (liquorice), Acharas sapota, Polypodium glycyrrhiza, Abrus precatorius (leguminosae), Perilla frutescens (Labitae),* Monk Fruit*, Hydrangea macrophylla* (Saxifragaceae) are few plants which are commonly used as a source of natural sweeteners. Among these, Monk Fruit[7] and Stevia[8] stand out as two of the most popular and widely used options. This is because when compared with artificial sweeteners and other natural sweeteners, it has been seen that the use of Monk fruit and Stevia does not have any known or reported side effects and corresponding health risks (Table 1).

Monk Fruit and Stevia sweeteners are derived from the *Siraitia grosvenorii* and *Stevia rebaudiana* plants respectively and hence offer a natural solution to sugar reduction. Both are naturally occurring, zero calorie sweeteners and have been used as a sugar substitute for many years. Consequently, they are of help in achieving diabetes and weight management goals in addition to having other benefits. The choice between natural and artificial sweeteners depends on individual health goals and preferences, balancing the benefits of reduced calorie intake with the desire for a more natural, nutrient-rich option.

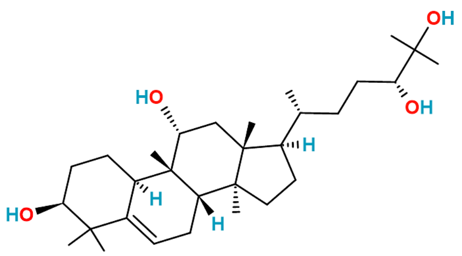
This article aims to provide comprehensive details of Monk Fruit and Stevia, examining their origins, sweetness profiles, health benefits, metabolic pathways, safety and therapeutic uses. By exploring all aspects of these natural sweeteners, we seek to highlight their advantages over synthetic sweeteners, which often carry concerns about long-term health impacts and potential side effects. Here, we emphasize the fact that Monk fruit and Stevia are the safer and more sustainable options, aligning with the growing consumer demand for cleaner and more natural food products.

Origin

Monk fruit or *Siraitia grosvenorii* is a small fruit round in shape, greenish brown in colour originating in the southern part of China. The fruit is named after the Buddhist monks who used to cultivate it hundreds of years ago. The plant commonly known as Swingle fruit or luo han guo in the native language is a herbaceous perennial vine belonging to the *Cucurbitaceae* gourd family. This fruit has effectively been used since a long time in the traditional medicines in China to treat ailments like cold, congestion, asthma and intestinal diseases. Previous studies have indicated that *S. grosvenorii* contains triterpenoids, flavonoids, lignans, vitamins, proteins, saccharides, and volatile oil. The fruits of *S. grosvenorii* are considered a healthy food with many pharmacological activities. The plant is also becoming very popular in the recent times for the juice extracted from its fruit mogroside which is much sweeter than sucrose. It is due to this overtly sweet sensation that the mogroside extract is now being used effectively in drinks as a no-calorie sweetener.[20,21] The Monk fruit sweetener is available under various brand names viz, Monk Fruit In The Raw®, Lakanto®, SPLENDA® Durelife, SweetLeaf®, Nature's besti and Whole Earth® in liquid and granular forms.

Stevia on the other hand traces its origin to being a perennial herb in Paraguay and Brazil in South America. Moises Santiago de Bertoni, the Swiss botanist discovered this plant in 1899 and named it *Eupatorium rebaudianum*. Although Bertoni elaborated the superiority of Stevia over saccharin along with its health promoting properties, but its first commercial sweetener was only discovered by the Japanese scientists in the early 1970s, post which it quickly became extremely popular.

The term "Stevia" encompasses the entire Stevia plant (*Stevia rebaudiana* Bertoni formerly known as *Eupatorium rebaudianum* Bertoni)[22] and the leaves containing the sweet components. The plant belongs to the chrysanthemum family which is a subgroup of the *Asteraceae* or ragweed family. In this family, the genus Stevia contains about 200 species of herbs and shrubs and the plant *Stevia rebaudiana*, is one representative of the genus. This plant produces long aromatic leaves having a prominent midriff. In order to improve the aroma of the leaves, the small white flowers which appear in clusters on the plant are removed. These sweet tasting leaves also called as "sweet herb" have long been used by the native Gurani people for sweetening the yerba mate[23,24] (the Brazilian and the Paraguay tea) and in their traditional medicines. The leaves were also sometimes just chewed for the sweet taste. In the present times, these leaves can be used fresh, in the dried form, or in the powdered form after processing for the purpose of sweetening beverages or desserts as per the requirement. Stevia is available as Truvia which is a blend of Rebaudioside-A (Reb-A) and erythritol, or as Stevia in the Raw (which is a blend of Reb-A and dextrose or maltodextrin (Bakers Bag)), Sugar in the Raw, Pyure Organic Stevia, Pure Via Stevia etc.

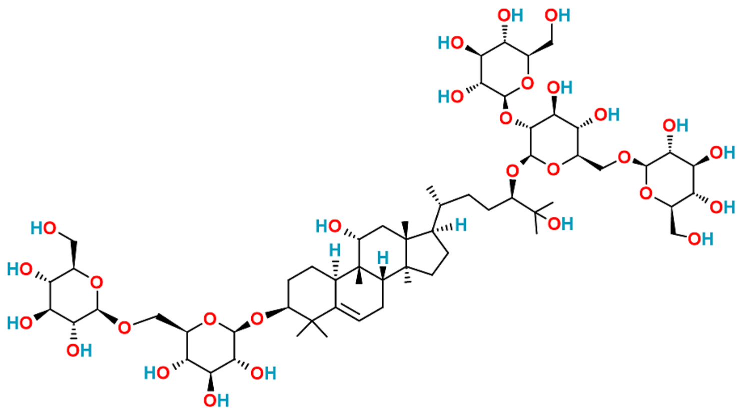


Structure 1: Mogrol (backbone)

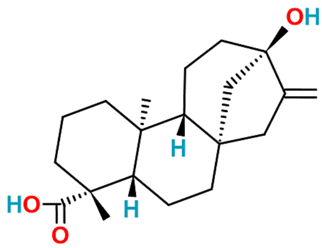
Structure

The first crude mogrosides were extracted from *S. grosvenorii* in 1974 by American Lee Chihong. In 1977, Japanese researcher Takemoto Tsunematsu started studying how to isolate pure mogrosides and figured out their corresponding chemical structures. After that more than 40 analogues were isolated one after the other. It was found that all the mogrosides have different number of glucose units attached to the mogrol, [10-cucurbit-5-ene-3,11,24R,25-tetraol], backbone (Structure 1).

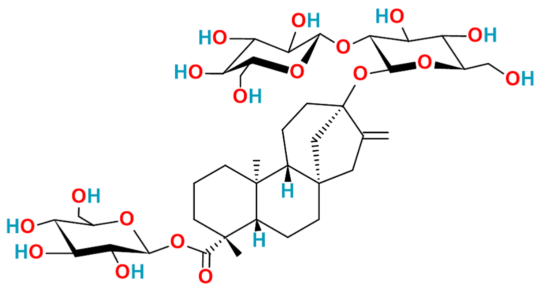
The steviol backbone's (Structure 3) chemical makeup is responsible for the steviol glycosides (Structure 4) present in stevia plants. The placement of the different glycoside molecules, leads to the variety of steviol glycosides found in the leaf.



Structure 2: Mogroside V (main constituent of *Siraitia grosvenorii* fruit)



Structure 3: Molecular structure of steviol, showing the substituted hydrogens on the carboxyl group (bottom) and the hydroxyl group (top)



Structure 4: Basic chemical structure of all steviol glycosides

Sweetness

Monk fruit sweeteners are extremely sweet, almost 100-250 times sweeter than sugar. Although it contains glucose and fructose, the sweetness of monk fruit is not because of these natural sugars as in most other fruits. Its sweetness comes from compounds called mogrosides which have mogrol as the backbone and glucose units attached to it as glycosides. The Mogrosides are present in the juice extracted from the fruit and are rich in antioxidants. They are separated from the juice during their processing and therefore the sweetener has no traces of the sugars like fructose and glucose. Mogroside V (Structure 2) is the main mogroside amongst the monk fruit sweeteners. Mogroside V at 1/10000 concentration is about 425 times sweeter than 5% sucrose. Sometimes the mogrosides are mixed with other products like inulin or erythritol to balance the intense sweet taste of the sweetener. But now it is mostly being used alone as a sweetener or as a component of the mixture of sweetener blends to enhance the taste of food products. The monk fruit extract has a subtle fruity caramelized taste and it does not give much of an aftertaste. However, it is quite likely that the foods containing the monk fruit sweeteners taste different than those having sugar because sugar apart from providing sweetness also plays a role in enhancing the taste and texture of the food. It is also noteworthy that monk fruit sweeteners remain stable at higher temperatures and therefore can be used in baked foods with ease. They are therefore very useful alternatives for use in a variety of foods and beverages like soft drinks, juices, candies, cakes, biscuits, and many other desserts.[25]

Stevia owes its intense sweetness to the steviol glycosides (Structure 4) present in its leaves. The more the number of Stevioside units, the higher the corresponding sweetness. Though *S. rebaudiana* leaves have more than 20 steviol glycosides, stevioside and rebaudioside A are the prominent ones and make up approximately 90% of the total content. Based on the glycoside, the sweetness of stevia varies; for instance, rebaudioside A is 150–320 times sweeter than sucrose while stevioside is 100–270 times sweeter. The sweetener is available in various forms like powder, dissolvable tablets or liquid drops and thus can be used suitably as per the requirement. It is being used in various juices, beverages, and desserts etc. It is heat tolerant and remains stable at elevated temperatures and thus can be used comfortably in the bakery products as well. However, it has been observed that foodstuffs containing Stevia may leave a little aftertaste which is slightly bitter or metallic. This aftertaste is attributed to stevioside since Rebaudioside A is reported to have no aftertaste.[26] Some users feel it tastes like menthol. This happens particularly when the stevia extract is used in larger quantities. The modern processing techniques are now ensuring that products containing stevia have delectable tastes.

Extraction

The skin and seeds of Monk fruit are first removed and the fruit is then crushed and filtered. The mogrosides are extracted both into the liquid and the powdered extracts. Amongst the extracted compounds, mogrosides are the primary constituents with mogroside V comprising a major part of almost 25%. Quite often the monk fruit extract is mixed with erythritol to give a blend which gives the appearance of sugar and even tastes like it. Erythritol is a carbohydrate, often called as the sugar alcohol. It is a water-soluble polyol and has a natural occurrence in quite a few vegetables as well as fruits.

The extraction of stevia can be done in a variety of ways. The leaves of *Stevia rebaudiana* plant when grown at home can be used as such to sweeten the different food items and beverages as required. However, to prepare an extract on an industrial scale[27, 28] these leaves are dried, crushed and extracted with hot water. This extract has almost 50% of rebaudioside A along with some other glycosides. All these glycosides are then separated from the extract, concentrated with the help of exchange resins, and purified by crystallization. Usually, methanol and ethanol are used as solvent for crystallization. On drying, almost 90% steviol glycosides are obtained from the extract.

At home, the stevia sweetener can be extracted by boiling half measure of crushed stevia leaves in 1 measure of water. After removing from heat, the mixture is steeped for 40 minutes, covered. It is then strained through a cloth or a coffee filter and poured into a clean dark jar and refrigerated. This stevia extract can be stored for 1-2 weeks. An even better method of extraction is with alcohol. Fresh stevia leaves are washed, slightly crushed, and covered with alcohol in a clean glass container which is then screwed tightly. The glass container is kept in a dark and cool place and left to steep for around 36 hours. This mixture is shaken thoroughly from time to time during this period. It is then filtered to give a brown coloured liquid which is heated over a small fire while stirring it for about 30 minutes. This allows the alcohol present in the mixture to evaporate leaving the flavours infused in the concentrated stevia extract which can be stored in a dark bottle for up to 3 months. A few drops of this extract can be used to sweeten the required product.

Metabolism and Effect on Microbiome

The research on the effects of monk fruit and stevia on the gut microbiome is very limited and most of it has been conducted on animals. However, there is no strong evidence which links low- calorie sweeteners to any adverse effects.

According to a study, monk fruit sweeteners do not have any negative effect on the gut microbiome. In fact, the extract Mogroside V, found in monk fruit may have prebiotic potential and hence may promote the growth and activity of beneficial bacteria in the digestive tract.[29] After consumption the mogrosides straightaway pass to the colon without getting absorbed in the gastrointestinal tract. This is the primary reason for no gain of calories on using the monk fruit sweeteners. The *in vitro* studies reveal that gut bacteria of the colon break down mogroside V into secondary mogrosides that have antioxidant properties and promote the growth of good bacteria like *Bifidobacterium* and *Lactobacillus*. They also inhibit the growth of disease-causing bacteria like *Clostridium* XIVa.[30] The gut microbes use the energy from the glucose after cleaving it off the mogrosides.

The remaining mogrol and the metabolites are excreted from the colon, whereas a minor amount which is absorbed in the blood is excreted in the urine. On the other hand, the erythritol present in some of the monk fruit sweeteners is absorbed in the small intestine and almost 90% of it is excreted in the urine within the span of one day. Some studies have suggested that mogroside V increases the production of bacteria-produced metabolites like acetate, propionate, and butyrate which may act as an energy source for the cells lining the colon called colonocytes. This can be beneficial to health in several ways such as regulating inflammation and maintaining the intestinal epithelium intact and functional. However, more evidence is needed to confirm gut health-promoting properties of Monk Fruit in humans.

The metabolism of sweet compounds in stevia known as steviol glycosides is the same as that of the mogrosides. They are not absorbed and broken down in the gastrointestinal tract and pass intact through the stomach and small intestines till they reach the large intestine. Here the gut microbes, degrade them into glucose and steviol. They are then absorbed in the liver, where stevia combines with glucuronic acid and metabolizes to steviol glucuronide and many other metabolites which are then excreted in the urine.[31-33] A 2024 study was conducted on healthy adults with normal body mass index (BMI) who were randomly assigned to receive stevia. It was found that 12 weeks of regular stevia consumption did not significantly change the composition of the human gut microbiota.[34, 35] In fact, some of the studies revealed that the erythritol in commercially available stevia products could even help increase levels of butyric acid in the human gut, which is a crucial fatty acid created when good bacteria break down dietary fiber. This effect may be beneficial in promoting good colon health, particularly for individuals with Crohn's disease and irritable bowel syndrome.[36]

Safety for Consumption

General Aspects

For hundreds of years Monk Fruit has been used as a food with no reported side effects from eating it. Even in some animal studies, no adverse effects were observed on feeding very high levels of Monk fruit extract.[37-39] Nonetheless, since it is new to the market as a sweetener, there aren't enough scientific studies examining the effects of Monk Fruit. However, Monk fruit sweetener is recognized and approved for use as a food additive in several countries. In 2010, the U.S.Food and Drug Administration (FDA) has categorized Monk Fruit as GRAS (Generally Recognized as Safe),[40] hence giving its approval for use by everyone including women and children. A detailed study by the panel on Food Additives and Flavouring (FAF) of the European Food Safety Authority (EFSA) was published in 2019.[41] The study concluded that the available toxicity data on Monk Fruit extract was insufficient for EFSA to arrive at a decisive conclusion on the safety of its use in various foods. However, Health Canada[42] permits its use in tabletop sweetener with a maximum of 0.8% mogroside V. Japan[43] includes monk fruit (Luohanguo) extract on the list of Existing Food Additives, allowing unrestricted use due to its long history of consumption there. In China,[44] it is classified as a natural flavouring substance in the National Food Safety Standard for uses of Food additives, without limitation on its application or concentration. Food Standards Australia New Zealand[45] (FSANZ) also approved the use of monk fruit extract as an intense sweetener. Although the Acceptable Daily Intake (ADI) for Monk Fruit has not been established, its use is permitted in many countries around the world.

Like Monk Fruit, Stevia Glycosides are also considered healthy and safe sugar substitutes with the potential of reducing blood sugar levels, calorie intake and tooth decay. Toxicity studies of Stevioside and its metabolite steviol on some common laboratory animal species have indicated no major adverse reactions.[46] Refined extracts of Stevia like rebaudioside A have been generally recognized as safe (GRAS) by the FDA.[47] However, whole leaf and raw stevia leaf extracts have higher potential of inducing hypersensitivity and allergies compared to their refined high purity counterparts. This is because the crude extracts may contain plant derived allergens from the *Asteraceae* family like ragweed, mugwot, dandelion, echinacea etc.[48] Since there is no substantial research available to support or oppose the above fact, their safety remains ambiguous. Hence, the crude extracts of stevia are not approved as additives in food products by the FDA.

The Acceptable Daily Intake (ADI) of Steviol Glycosides has been defined as 4 mg per kg of body weight by FDA, EFSA, World Health Organization (WHO), Food and Agriculture Organization of United Nations (FAO) and the Joint Expert Committee on Food Additives (JECFA).[49-53] This is equivalent to 12 mg/kg of body weight per day of rebaudioside A and 10 mg/kg of body weight per day of Stevioside. Other health regulatory agencies world over like Food Standards Australia New Zealand, Japan's Ministry of Health etc have also reviewed and supported the safety evidence and determined that stevia sweeteners are safe for the general population including pregnant and nursing women, when consumed within ADI limits. Hence, more than 60 countries around the world are currently permitting the use of Stevia as a sweetener. The above defined ADI is based on rigorous evaluation of more than 200 studies examining the effects of Steviol glycosides on animals and humans. Although there is limited information available, the global intake of Stevia sweeteners is estimated to be below ADI levels. This estimation can be well explained with the help of a simple calculation. A person weighing 50 kgs is allowed to consume 50x12=600mg of Steviol glycosides per day as per the ADI limits. If a packet of table top Stevia contains 20 mg of Steviol Glycoside, the person can consume 600/20=30 packets of the sweetener per day and would need to consume more than 30 packets to exceed the ADI limits. Studies suggest that there has been no concern raised since 2008 for exceeding ADI limits of Stevia sweeteners in the general population.[54,55]

It may be noted that some studies have indicated reduction of fertility in rats treated with Stevia extracts[56,57] and some others have found steviol to be mutagenic.[58] However, these effects have not been confirmed and supported by other studies. The safety of stevia is majorly established by the fact that it has been used for many centuries by the people of Paraguay and in recent times by the Japanese with no reports of any adverse effects.[59] Further, many other investigations on the effects of stevia on humans have not reported any side effects from its use.[60-62]

Safety for Children

In order to reduce the intake of refined added sugars, the consumption of low-calorie sweetener containing food and beverages by children and adults has increased in recent times.[63] Although there are no reported harmful effects of consumption of low-calorie sweeteners (LCSs) in children, a 2018 science advisory by the American Heart Association (AHA) does not support regular and long-term consumption of LCS beverages by children suggesting water and milk as the healthy alternatives. However, an exception has been made for children with diabetes consuming a balanced diet who can avoid blood glucose shoot ups by consuming LCS beverages instead of the sugar sweetened ones.[64]

The American Academy of Paediatrics (AAP) in its 2019 statement advices against the consumption of low-calorie sweetened food and beverages by children under two years of age. However, the AAP statement also identifies and acknowledges the health benefits of low-calorie sweeteners for children with obesity and diabetes and in reducing the occurrence of dental caries.[65] Similar to the AAP statement, the 2020-2025 Dietary Guidelines for Americans also does not recommend the consumption of low-calorie sweeteners by children below two years of age.[66]

Like other low-calorie sweeteners, Monk Fruit and Stevia add sweetness to the food and beverages consumed by children without the additional calories and harmful effects.[67] Both these sweeteners are not cariogenic so they do not cause tooth decay. Monk Fruit sweeteners are generally considered safe for consumption by children.[68] No harmful effects have been reported so far, although detailed research in this regard has not been published. On the other hand, the metabolism of high purity stevia sweeteners is the same in children and adults.[69] Hence, the FDA and JECFA have recognized them as safe for children when consumed within ADI limits.

Safety for Pregnant and Lactating Women

Pregnant and lactating mothers have high requirements for energy to support the growth of their baby and production of breast milk. According to Health Canada using sugar substitutes during pregnancy is not harmful, but they should be used in moderation to ensure they don't replace the essential nutrients for a healthy pregnancy.[70] Pregnant woman who need sugar substitutes are recommended to follow the acceptable daily intake (ADI)[71] guidelines. The same guidelines apply to novel natural sweeteners Monk fruit and Stevia. These sweeteners are considered safe for consumption by pregnant and lactating women within the recommended limits. The European Food Safety Authority (EFSA) suggests that the existing toxicity data on monk fruit is inadequate to definitively confirm its safety as a food additive. However, several studies on mice suggest no negative reproductive or developmental effects to a mother or offspring, even when animals were exposed to very high daily dosage of mogroside V (much higher than the recommended levels) over a long period. Research on consumption of stevia during pregnancy has also been mainly conducted on animals,[72-73] with no observed negative effects. Although, no published research specifically examines stevia's effect on pregnant and lactating women but animal studies suggest no adverse effects on mothers and the babies even at levels exceeding 100 times the ADI daily over extended periods.

Despite limited human studies, extensive animal research and regulatory reviews support the safety profiles of Monk fruit and Stevia. However, these sweeteners should complement a healthy balanced diet and not substitute nutrient dense foods.

Therapeutic Uses

Monk Fruit has traditionally been used for the treatment of sore throat, tonsilitis, and asthma.[74-75] It has also been found that the fruit *S. grosvenorii* possesses expectorant, antioxidant,[76] antimicrobial, antitussive, hypoglycaemic, immunologic, hepatoprotective and anti-inflammatory activities. Mogroside is also suggested to treat obesity as well as non-alcoholic fatty liver disease. In addition, Mogroside V is said to have anti-cancer activities particularly for pancreatic cancer.[77] It is noteworthy that the primary clinical treatment for lung and throat disorders now primarily involves pharmaceutical preparations containing this plant.

The antihyperglycemic[78] potential and the hipotensor[79] effect of *Stevia rebaudiana*'s extracts and infusions are among the medicinal benefits associated with the plant. It also exhibits antidiarrhea,[80] diuretic[81] and anticancer[82] effects. Leaves of *Stevia rebaudiana* are found to contain polyphenolic compounds which exhibit antioxidant properties. Further stevia products have been observed to stimulate insulin production, improve polycystic kidney disease, exhibit chemotherapeutic actions and possess anti-inflammatory, anti-hypertensive, antibacterial and immunomodulating properties.[83-90] However, more research is needed to identify active compounds and clarify the molecular mechanisms behind these benefits.

Benefits for Diabetic Individuals

Monk fruit extract (MFE) and stevia sweeteners are gaining attention as natural alternatives to sugar for individuals managing diabetes. Consumption of non-nutritive sweeteners, such as stevia[91] and monk fruit, does not raise blood glucose levels hence they show promise as attractive low-calorie sweetener options that align with dietary preferences for managing diabetes. Human and animal studies indicate potential benefits, including improved glycemic control and other therapeutic properties.

MFE has emerged as a promising option for integrating natural sweetness into dietary interventions in diabetes management due to its natural origin and ability to modulate glucose metabolism, lipid profiles and oxidative stress. It offers low glycemic alternative to sugar, potentially making it a valuable adjunctive therapy in the multifaceted approach to diabetes care.[92-97] Experts in nutrition suggest that monk fruit can be used as a natural, low-calorie sweetener. Various studies have explored its impact on blood sugar levels, liver enzymes and overall metabolic health thus showing its potential benefits and safety.

Clinical research has demonstrated that monk fruit extract does not significantly affect blood sugar levels. In a cross over study[98] with ten participants, MFE consumption showed no impact on blood sugar levels, in contrast to sucrose, which caused a 70% increase shortly after ingestion. Moreover, the consumption of beverages sweetened with artificial and non-nutritive sweeteners including monk fruit has minimal influence on total daily energy intake, postprandial glucose and insulin levels compared to sucrose sweetened beverages.

Studies on animals, have further elucidated the benefits of MFE in managing diabetes. Liu *et. al*[99] found that MFE reduces hyperglycemic and hyperlipidemic symptoms in diabetic mice by improving insulin sensitivity. Another study[100] demonstrated that monk fruit-sweetened yogurt played an active role of in preventing and managing type 2 diabetes in rats by improving liver phospholipids and regulating metabolic pathways, highlighting its potential as a functional food for diabetes management. MFE has also shown promise in reducing pancreatic cell damage and balancing the immune system in insulin-dependent diabetic mice.[101] It improved early symptoms and biochemical issues indicating its potential in treating diabetes. The extract also reduces high blood sugar, cholesterol and triglyceride levels while increasing beneficial HDL cholesterol and restoring antioxidant enzymes in the liver, demonstrating strong antioxidating effect.[102] These studies highlight monk fruit as a natural sweetener with significant health benefits especially for diabetic patients.

Stevia, specifically in the form of rebaudioside A and stevioside, has been studied for its potential therapeutic benefits in managing type 2 diabetes, yielding mixed results. In a clinical trial, individuals with diabetes taking very high doses of rebaudioside A did not show significant effect on glycosylated hemoglobin (HbA1c) or glucose homeostasis. It was well-tolerated without harmful effects on blood pressure or body weight.[103] Another study suggested that stevia sweetened tea did not impact blood glucose, HbA1c, insulin or lipid levels in patients. Hence, it could be a healthier option for maintaining glycemic control making it a viable alternative to sucralose for diabetic patients.[104-105]

Research on animals has shown even more promising results. In diabetic rats, stevia leaves exhibited hypoglycemic effects, reduced liver and kidney damage and lowered oxidative stress.[106] Stevioside has demonstrated antihyperglycemic, insulinotropic, and glucaganostatic effects in type 2 diabetic rats, suggesting its potential as a therapeutic agent.[107] One study suggests that steviol glycosides enhance potentiation taste perception and insulin secretion, hence can prevent high-fat-diet induced diabetic hyperglycemia in mice.[108] Additionally, stevia extracts significantly reduced food intake, body weight gain, and glucose levels while improving insulin and liver glycogen levels in diabetic rats.

Extensive research indicates stevia sweeteners do not raise blood glucose levels or adversely affect blood glucose management. Recent consensus statements from nutrition and medical experts suggest that low-calorie sweeteners like stevia can contribute to better glycemic management when used in moderation. The 2022 American diabetes association standards of medical care[109] recommend non-nutritive sweeteners as an acceptable substitute for sugar-sweetened products for some people with diabetes, provided they do not compensate with additional calories from other sources. Diabetes Canada and diabetes UK[110-111] offer similar endorsements. Stevia has more extensive research supporting its efficacy and safety compared to monk fruit. However, both sweeteners offer viable alternatives to sugar for diabetes management.

Effects on Appetite and Weight Management

Stevia and Monk fruit have garnered attention as alternatives to both sugar and artificial sweeteners, with monk fruit specifically showing potential in preventing weight gain and improving metabolic health in animal studies. Many studies show that there isn't any strong evidence which suggests that substituting sugar with non-nutritive sweeteners like stevia and monk fruit can make people hungrier.[112-114] However, they are often recommended as part of weight management strategies because they can help reduce calorie intake without spiking blood sugar levels. Observational studies show mixed results. Some indicate that these non-nutritive sweeteners reduce food intake and may assist with weight control[115] whereas others suggest that they may stimulate appetite[116] (Blundell & Hill, 1986) and thereby leading to weight gain. However, Randomized Control Trials (RCT's) support the efficacy of these natural sweeteners in weight management. They have been found effective in modestly reducing body weight, body mass index (BMI), fat mass and waist circumference by lowering overall calorie intake in some RCTs.[117-118]

As far as Monk Fruit Sweeteners are concerned, they help satisfy sweet cravings without adding to overall caloric consumption, potentially reducing total energy intake. Some studies suggest that they may help regulate appetite by influencing satiety hormones. By avoiding spikes in blood glucose, monk fruit can help prevent rapid fluctuations in energy levels and hence help avoid overeating and subsequent weight gain. In animal studies, monk fruit has shown promising effects in preventing weight gain, insulin resistance and fat accumulation. Studies with high-fat diet (HFD) mice revealed that

Monk Fruit Extract (MFE) could prevent weight gain and improve sensitivity. The anti-inflammatory properties of MFE enhances fat metabolism and antioxidative defenses thus making it a better alternative to artificial sweeteners as intake of artificial sweeteners for long period of time is linked with increased obesity risk. Monk fruit's active components, mogrosides, have demonstrated potent inhibitory effects on pancreatic lipase, an enzyme crucial for fat digestion. By inhibiting this enzyme, monk fruit can reduce dietary fat absorption, leading to lower body weight and fat mass in animals. Thus, mogrosides reduce obesity and non-alcoholic fatty liver disease in mice. MFE has shown potential in treating hyperglycemia and hyperlipidemia in obese type 2 diabetes mellitus rats. Thus, animal research suggests that monk fruit may help prevent obesity and improve overall metabolic health by reducing fat accumulation and enhancing lipid metabolism. In a randomized control trial (RCT) of beverages project SWEET, it was found that blends of Non-Nutritive Sweeteners (NNS) and sweetness enhancers like stevia and mogrosides V improved acute glycemic control compared to sucrose, without significantly affecting food intake or body metabolism. This study supports the potential role of stevia and mogrosides V in diabetes prevention and weight management as a part of a comprehensive lifestyle approach.[119-125]

Despite promising results from animal studies, there is lack of direct human research examining monk fruit's effects on body weight. Most studies assessing low-calorie sweeteners collectively evaluate various types, making it difficult to isolate monk fruit's specific impact. However, comparative studies involving natural sweetener i.e. stevia & monk fruit and other NNSs have shown similar effects on weight management. For instance, an RCT comparing stevia, monk fruit and aspartame found that all three sweeteners led to reduced energy intake and modest weight loss over 16-week period. Monk fruit performed comparably to other sweeteners supporting its efficacy in weight management. A small 2017 randomized controlled trial was conducted to investigate and compare the effect of monk fruit sweetened beverage with other sweeteners such as aspartame and sucrose. The results showed that the consumption of monk fruit sweetened beverages have minimal influence on total calories intake as compared with a sucrose-sweetened beverage.[126] This indicates that monk fruit may have superior effects in preventing metabolic disease, reducing body weight, and improving gut health. Similar effects have been observed with the intake of Stevia. It influences appetite and satiety primarily through its interaction with sweet taste receptors. Hence, it helps satisfy the sweet cravings and reduce overall calorie intake. It can help maintain stable energy levels, which may reduce the likelihood of overeating and subsequent weight gain by avoiding sudden rise in blood glucose levels.[127-135]

Research on animals has shown that stevia plays a role in reducing body weight gain, improving lipid profiles, and enhancing glucose metabolism. In a study involving rats, those consuming stevia sweeteners exhibited lower body weight gain and better lipid profiles compared to those consuming sugar. Further, Randomised Controlled Trials, which are considered the gold standard for assessing causal effects, have supported the idea that substituting LCSs like stevia for regular-calorie versions leads to modest weight loss. An RCT[127] involving healthy adults found that daily consumption of stevia-sweetened products led to a significant reduction in overall energy intake without compensatory increases in calorie consumption later in the day. Participants who consumed stevia maintained their body weight more effectively than those consuming sugar-sweetened products. This suggests stevia can help prevent weight gain in non-habitual users of Non-Nutritive Sweeteners. In another RCT, over 300 participants consumed either water or low-calorie sweetened beverages for a year as part of a weight loss and maintenance program. The group consuming low-calorie beverages, including those sweetened with stevia, lost an average of 6.21 Kg compared to the 2.45 Kg lost by the water group. These RCTs are substantiated by the ones investigating the effect of consumption of stevia on hunger. A 2018 study discovered that eating cookies made with stevia sweeteners reduces the appetite compared with regular cookies.[136] Another RCT from 2020 which investigated the effect of stevia on hunger and food intake concluded that when compared to those who drank plain water, subjects who drank water sweetened with stevia felt less hungry before a meal.[137] A more recent one conducted in 2023 found that consuming stevia before meals can lower hunger levels and reduce the amount of food consumed during meals, thus lowering the total energy intake compared to water and caloric beverages.[130]

Thus, both animal studies as well as RCTs demonstrate that stevia can help reduce appetite and hence overall caloric intake, therefore supporting weight management efforts. These findings also suggest potential mechanisms through which stevia might exert its weight management benefits, such as reducing fat accumulation and improving metabolic health.

Global Sales, Consumption and Market Size

Due to their safety and beneficial effects, the global sales and consumption of Monk Fruit and Stevia have shown marked increase in recent years. Different Market reports and industry analysis have projected substantial increase in the market size of both these sweeteners in the coming decade. According to Maximise Market Research, the Monk Fruit sweetener market size was valued at USD 218.3 million in 2023 and expected to reach USD 336.2 million by 2030, at a Compound Annual Growth Rate (CAGR) of 6.36%[138] whereas another research report of Future Market Insights revealed that the global Monk Fruit sales increased at 3.3% CAGR during 2018 to 2022 and is expected to witness a CAGR of 5.2% during the forecast period from 2023 to 2033.[139] A leading market research firm Grand View Research published the global monk fruit market size to US$ 353.7 million in 2023 and anticipated a CAGR of 7.7% during the period 2024-2030.[140] Further, many other research reports have predicted the global market of monk fruit to continue growing at a substantial rate.[141-143]

Stevia has also shown a consistent growth with a larger market size as compared to monk fruit. According to Grand View Research, the global stevia market size was valued at US$ 513.4 million in 2023 and is projected to grow at a CAGR of 11.9% from 2024 to 2030.[144] The Future Market Insights also predicted the growth of stevia market from USD 405.6 million in 2024 to USD 739.4 million by 2034 with a surge in CAGR of 6.2%.[145] Another popular firm, The Allied Market Research published both quantitative and qualitative analysis of stevia market which predicted the market size to reach USD 876.5 million by 2034 from USD 534.2 million in 2023 growing at a CAGR of 4.8% from 2024 to 2034.[146] This upward trend in high consumption of stevia have been reported in various research reports147-149.

Conclusion

While artificial sweeteners are widely used to manage insulin resistance in diabetic individuals, evidence supporting their effectiveness is limited. As people look for healthier alternatives, natural sweeteners like monk fruit and stevia are gaining popularity. This comprehensive article has delved into the various aspects of Monk fruit and Stevia, highlighting why natural sweeteners are preferable to synthetic options. Both these sweeteners offer promising alternatives to sugar and artificial sweeteners. While stevia has been more extensively studied, particularly in human trials, monk fruit's benefits are primarily supported by animal studies and need further investigation.

Current studies provide a good foundation; however, comprehensive human trials are needed to confirm these benefits. Both these sweeteners are quite similar with regard to their advantages, nutrient make up and health benefits. Consumers can consider different variables, price, flavor and side effects to make a choice between them. Since monk fruit is more difficult to cultivate, harvest, and extract in the final sweetener form, it costs more than stevia. Additionally, limited availability raises the price. Further, monk fruit sweeteners are new to the market and hence might not be as accessible. In contrast, stevia is more widely available and has been used as a sweetener for a longer period. However, Stevia may give some people a metallic or bitter aftertaste, especially if they use it in larger amounts. The aftertaste of stevia products can differ depending on the brand and type. On the other hand, people who are sensitive to the taste of stevia prefer monk fruit extract because it typically has a milder aftertaste. Monk fruit sweetener has no after taste and no adverse effects. As a natural fruit with good health benefits, it has been used for many years. This makes it a better option as compared to other sweeteners. However, more evidence is required to definitively place it alongside or above other established sweeteners in terms of efficacy and safety. As consumers are becoming more mindful of sugar related health risks like diabetes and obesity, companies are likely to focus on improving taste and affordability while expanding product options. Advancements in food technology may also enhance the functional benefits of these sweeteners, positioning them as key players in the evolving landscape of healthier eating choices. Overall, although replacing sugar with these natural no calorie sweeteners can aid in reducing caloric intake, it should be combined with other life style and behavioral practices such as eating a balanced diet, exercising regularly, getting adequate sleep and maintaining social support networks.

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