GLOBAL STEVIA INSTITUTE®

STEVIA SAFETY REVIEW

Foreword

THE SAFETY OF ANY INGREDIENT IS PARAMOUNT to the benefits it presents. Stevia, a natural origin sweetener, offers the safety support of hundreds of years of use plus the rigorous scientific research and evaluation necessary for an ingredient to be approved for use in foods and beverages today. Stevia is used across the globe for its no calorie, plant based sweetness in foods and beverages. We've compiled a summary of the extensive database of science supporting stevia as a safe, no calorie sweetening choice.

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Contributors

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Dr. Jean-Michel Cohen is a nutrition specialist in France and an award-winning and best-selling author on the subjects of nutrition and obesity. Dr. Cohen first introduced the use of triglyceride perfusion in France for intensive care and created the first inter-departmental consultation center on obesity in France. Many of Dr. Cohen's books are considered food analysis references and he is an expert on food component regulation and food display.

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Contents

I. Introduction

The management of a healthy weight is challenging for many individuals, as shown by the increasing prevalence of overweight and obesity worldwide. A balanced diet with controlled calorie intake and an active lifestyle are essential for successful weight management.

Low calorie sweeteners can play an important role in calorie control by offering consumers a choice to enjoy sweet foods or beverages, and reduce calorie intake as part of a healthy diet approach. Stevia (purified stevia leaf extract) is a unique choice among non-caloric sweeteners, because its sweetness is plant-based. The stevia plant, though new to many, has been used for centuries for its natural sweetness. Today, the safety of purified stevia is widely supported by rigorous scientific research.

The focus of this paper is to summarize the current scientific research supporting the safety of purified stevia leaf extract for the general population and special subpopulations.

II. Stevia and Purified Stevia Leaf Extract

Stevia is produced from the stevia plant native to South America, where it was traditionally used as a sweet herb in foods and beverages by indigenous peoples for centuries. The stevia leaf contains natural, sweet compounds called steviol glycosides, which are filtered and purified to produce stevia leaf extract that is typically 200–300 times sweeter than sucrose.

Purified stevia leaf extract (also known as high purity stevia) generally describes stevia that has 95% or greater steviol glycoside content. This purity specification was set as part of a thorough safety review by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 2008, and is supported by several regulatory authorities including the US Food and Drug Administration (FDA) and the European Commission. These agencies have also established an Acceptable Daily Intake (ADI) for steviol glycosides.

There are crude stevia extracts often sold as dietary supplements in some countries, but it is important to note that only purified stevia leaf extract has been evaluated and approved for use as an ingredient in foods and beverages by the leading regulatory agencies.

EXTRACTION AND PURIFICATION

Extracting and purifying stevia's steviol glycosides, the sweet compounds of the leaf, allows stevia producers to reduce off-flavor notes from other naturally occurring compounds in the plant for better tasting stevia ingredients. Steviol glycosides are removed from the stevia leaf through water extraction. The water extract then undergoes filtration to separate the steviol glycosides from plant biomass, and is further purified with either water or food-grade alcohol, followed by drying. This extraction and purification process gives purified stevia leaf extract a cleaner, more sugar-like taste than crude stevia extracts. The extract can then be further purified to an extract that contains one or more specific steviol glycosides. The steviol glycosides remain intact and unchanged throughout the process.

There are many steviol glycosides naturally present in the stevia leaf, but there are 11 main steviol glycosides that are typically focused on due to their abundance. At a molecular level, steviol glycosides share a common diterpene steviol backbone. The arrangement and number of glucose units bonded to the steviol backbone give each steviol glycoside a unique sweetness and taste profile. Rebaudioside A and stevioside are the most abundant steviol glycosides in the leaves. Rebaudioside A is also one of the sweetest glycosides, and is one of the first steviol glycosides to be purified and commercially available on a mass scale for use as a sweetener.

STEVIA METABOLISM

Steviol glycosides pass through the body without any significant caloric impact or accumulation in the body. Steviol glycosides are not digested and pass through the upper gastrointestinal tract fully intact. Gut bacteria in the colon hydrolyze steviol glycosides into steviol by snipping off their glucose units. Steviol is then absorbed via the portal vein and primarily metabolized by the liver forming steviol glucuronide, and then excreted in the urine. (Gardana *et al.*, 2003)

III. Stevia—A Sweetener with Strong Safety Support

The safety of purified steviol glycosides has been evaluated through rigorous scientific research, which supports the safety of purified stevia leaf extracts for use as a sweetener.

The safety of purified stevia leaf extract is supported by:

- Stevia's historical use dating back centuries in South American countries and for over four decades in Japan;
- Years of rigorous scientific research on purified steviol glycosides, the sweet components of the stevia leaf; and
- The positive scientific statements of several food safety and regulatory authorities, including JECFA and the European Food Safety Authority (EFSA) which support the safety of purified stevia leaf extract for use in foods and beverages.

INGREDIENT SAFETY ASSESSMENT

The safety assessment for food ingredients by regulatory agencies is an extensively detailed and lengthy process, designed to ensure that a new food ingredient, such as a non-caloric sweetener, does not pose a risk for any consumers, including children and pregnant women.

The protocols that must be used for safety studies have been established over many years, by independent international experts, and are globally accepted. The results from toxicology or safety studies are used to establish the Acceptable Daily Intake (ADI). The ADI is defined as the amount of a food ingredient that people can consume on a daily basis during their lifetime without any appreciable risk to health. The ADI is established from long-term animal studies, in which animals are fed diets containing increasing levels of the food ingredient for the majority of their lifetime, through stages of development and growth. Detailed assessment of the animals' health is completed, and the highest dose that resulted in no adverse effects is called the no observable adverse effect level (NOAEL). To adjust for any possible individual differences (intra-species) or

differences between the test species and humans (inter-species), the NOAEL level is divided by 100 (10X for intra-species and 10X for inter-species). This is called a safety factor, and is designed to provide even more assurance that the ADI level will be safe for all consumers.

Animal studies are critical to the safety assessment, as it is not ethical to test a new ingredient in humans without determining the level that is safe. Animals can be given very high doses, which are used to increase the likelihood of detecting any adverse effect the ingredient may cause, and to be able to determine how the body uses the ingredient. Lower doses are used to determine the amounts that can be consumed every day with no adverse effect. Once animal studies determine the amount that is safe, additional studies are done in humans to confirm the validity of the animal studies.

The next step in the approval process is to estimate the likely consumption of the food ingredient, by different segments of the population. This includes different age groups and sexes. The consumption estimates are based on consumer surveys on consumption of the foods and beverages that will contain the ingredient. These data are used to set limits on the levels of the ingredient allowed in each type of food and beverage, to ensure that no consumer will be exposed to more than the Acceptable Daily Intake in their diet.

The ADI is a conservative safe exposure level and does not represent a maximum allowable daily intake level and should not be regarded as a specific point at which safety ends and possible health concerns begin. Because the ADI has a built-in safety margin and is based on a chronic lifetime exposure, occasional consumption in amounts greater than the ADI would not cause adverse effects or concern.

After approval, regulatory agencies continue to monitor scientific literature for new studies or reports of adverse effects of ingredients, and will carefully review the results to ensure on-going safety of the use of the new ingredient.

Research has also shown that purified stevia leaf extract is safe for consumption by special populations including pregnant women, lactating mothers, and children.

SAFETY RESEARCH SUMMARY

There are over 200 research studies that support the safety of purified steviol glycosides. These studies present biological, toxicological, and clinical data and have been assessed by a number of reviewers (Carakostas et *al.*, 2008; Geuns, 2003).

The body of scientific evidence supports that purified stevia leaf extract has no adverse effects in humans and is safe for the general population at the levels used in foods and beverages. Research has also shown that purified stevia leaf extract is safe for consumption by special populations including pregnant women, lactating mothers, and children. Furthermore, long-term carcinogenicity studies show that purified stevia leaf extract consumption is not associated with increased cancer risk.

Specifically, based on the similar metabolism of glycosides in rats and humans, an ADI level of 0 to 4 mg/kg body weight (bw), as steviol equivalents, was established by JECFA, the Food Standards Australia New Zealand (FSANZ), and the European Food Safety Authority (EFSA). The ADI for steviol glycosides was based on a thorough review of toxicology and tolerance studies. The specific NOAEL was supported by a pivotal two-year study in rats (Toyoda *et al.*, 1997) in which the NOAEL was 388 mg steviol equivalents/kg bw/day (d). A safety factor of 100 was applied, to result in an ADI of 0 to 4 mg/kg bw as steviol equivalents. This ADI was established for steviol equivalents

as opposed to steviol glycosides for a consistent unit. It is important to remember that the ADI is a reference for safe long-term exposure and is defined as the amount of a substance that people can consume on a daily basis over a lifetime without any appreciable health risk. Consumption estimates (estimated daily intake) are included in the Appendix. Studies in humans have demonstrated that daily doses of the steviol glycosides up to 1000 mg/person/day were well-tolerated by individuals with normal glucose metabolism or type-2 diabetes mellitus. This dose is equivalent to 16.6 mg/kg bw/day for a 60 kg person and (corresponds to approximately 330 mg steviol equivalents/person/day or to 5.5 mg steviol equivalents/kg bw/day). (Maki *et al.*, 2008)

While crude stevia extracts have not been approved for use as an ingredient, several researchers have studied its consumption. Some animal research studies on crude stevia extracts indicate adverse effects associated with its consumption, however several of these studies report contradictory results. The adequacy of these studies has been questioned by scientific authorities due to limited data, study design limitations, and relevancy. Moreover, these effects were not observed with purified stevia leaf extract approved for food and beverage use. (Mazzei-Planas and Kuc, 1968; Nunes and Pereira, 1988; Oliveira-Filho *et al.*, 1989; Melis, 1999; Shiotsu, 1996; Sinchomi and Marcorities, 1989; Saenphet *et al.*, 2006).

PIVOTAL LONG-TERM TOXICOLOGY STUDIES IN ANIMALS

STUDY AREA	METHODOLOGY REVIEW	MAIN FINDINGS
Long-Term Carcinogenicity study, Toyoda *et al.*, 1997	Stevioside (95.6% purity) provided to rats in dose levels 0, 2.5 and 5% of the diet for 104 wk, resulting in consumption levels of 0 to 2387 mg/kg/bw/d. NOAEL (mg/kg bw/d): 969 males and 1120 females	No observable adverse effects at dosage level of 969 and 1120 mg/kg bw/day in males and females respectively with long-term exposure.
Two-Generation Reproductive Study on Rebaudioside A (Reb A), Curry *et al.*, 2008	Rats received up to 2,273 mg/kg bw/day of rebaudioside A (>97% purity). Reb A 97% given via diet to rats for two generations. Body weight, body gain, food consumption were monitored. Growth and development, survival, reproductive performance and sexual maturation were also assessed. NOAEL (mg/kg bw/day): 2048 and 2567 for males (F0, F1) 2273 and 2768 during premating, 2322 and 2124 during gestation, 3811 and 4091 during lactation, for females.	No reproductive or developmental effects were observed in any of the generations at highest dose NOAEL.

Additional studies have been conducted. More references are listed in appendix.

HUMAN EVIDENCE

Several studies in humans have been conducted to evaluate metabolism, pharmacokinetics, and the safety/tolerability of purified steviol glycosides for people with and without diabetes. Research shows that steviol glycosides are safe for people with diabetes, and that purified steviol glycosides have no effect on blood pressure when consumed within recommended levels.

STUDIES WITH HUMANS

STUDY AREA	METHODOLOGY REVIEW	MAIN FINDINGS
Chronic consumption of Rebaudioside A by men and women with type 2 diabetes mellitus, Maki *et al.*, 2008	Randomized, double blind, placebo controlled clinical trial. Subjects (diabetic adults, n=112) were administered 1000 mg/d Reb A (97% purity) in 250 mg capsules or placebo for 16 wks. Fasting glucose, C-peptide, body weight, blood pressure, fasting lipids, and dietary intake were measured.	Chronic intake of Reb A had no effect on blood glucose levels or blood pressure. No significant clinical differences in serum chemistry and hematological parameters.
Consumption of steviol glycosides by healthy men and women with low-normal systolic and diastolic blood pressure Maki *et al.*, 2008	Randomized, double blind, placebo controlled clinical trial. Subjects were administered 1000 mg Reb A/day for 4 wks (n=100). Blood pressure, diet, serum chemistry, and hematology parameters were measured.	High intake consumption of of up to 1000 mg/day Reb A had no clinically significant effects on blood pressure. No statistically significant differences in haematology and urinalysis results between groups.

Additional studies have been conducted with humans. More references are listed in appendix.

KEY POINTS

- Research has shown that purified stevia leaf extract is safe for use in food and beverages for the general population, pregnant women, children, and children and adults with diabetes.
- Clinical studies indicate that, at the levels approved for use in foods and beverages, purified stevia leaf extract has no pharmacological effects.
    - Steviol glycosides have no effect on blood pressure in individuals with normal and low-normal blood pressure.
    - Steviol glycosides have no effect on glucose homeostasis.
- Leading independent expert evaluations support the weight of safety evidence for purified stevia leaf extract.

REGULATORY STATUS

Purified stevia leaf extract is recognized as a safe sweetening ingredient at the established ADI level by all global food safety and regulatory authorities. JECFA, Codex Alimentarius Commission, FDA, FSANZ, French Food Safety Agency (AFSSA), (EFSA) and Health Canada are just a few of the agencies that have concluded that stevia is safe for use as a sweetener. In fact, stevia is approved by regulatory authorities in over 70 countries, including all countries in the North and South America, all major European countries, Australia, Japan, China, and many more.

IV. Stevia as a Tool for Calorie Reduction

Leading health and nutrition organizations around the world have published positions and recommendations on sweeteners, including stevia as a safe, acceptable choice.

Recently, leading health and nutrition organizations around the world have published position papers and recommendations on sweeteners, including stevia as a safe, acceptable choice. International Food Information Council Foundation (IFIC) concluded that non-nutritive, or low-calorie, sweeteners such as stevia offer a way to reduce calories in foods and beverages and help manage weight. IFIC assures that the zero calorie sweetener stevia does not cause increased appetite or preference for sweet tasting foods and that stevia offers a way for people with diabetes to decrease overall carbohydrate intake.

The European Food Information Council (EUFIC) cites support of EFSA's thorough regulatory framework for assessment and approval of low calories sweeteners, indicating that sweeteners such as stevia are a safe and, in many cases, beneficial dietary component. EFSA states that foods and drinks with low calorie sweeteners are likely to continue to be a growing part of the European diet, helping to provide choice for people who wish to consume fewer calories and maintain a healthy weight.

North American based organizations have also released position papers on sweeteners. In 2012, The Academy of Nutrition and Dietetics (AND) released their position that consumers can safely enjoy a range of nonnutritive sweeteners (NNS) if they follow current federal nutrition recommendations. AND highlights stevia among seven NNS approved for use in the United States. The National Cancer Institute also purports that there is no clear evidence that the NNS available commercially in the United States, including stevia, are associated with cancer risk in human beings, and that several studies have been conducted, which support the safety of sweeteners as food ingredients.

In 2012, the American Diabetes Association (ADA) and the American Heart Association released a joint position paper that maintains sugar alcohols and nonnutritive sweeteners are safe when consumed within the FDA-established daily intake levels, and may help people reach and maintain a healthy body weight. They also recognize choosing NNS, such as stevia, is an effective method to assist with glucose control, an important focus for diabetics. We may see other health organizations publish their position on low calorie sweeteners as their use continues to grow in foods and beverages around the world.

V. Role of Stevia in a Healthful Diet

People have an innate preference for sweet tastes, which is thought to confer an evolutionary advantage. Sweet foods tend to be a source of carbohydrates needed for energy. For centuries, people satisfied this taste preference with sweet foods found in nature.

Today, the consumption of sugars in excess may contribute to an energy imbalance in the diet. Dietary imbalance is often accompanied with sedentary lifestyle and limited physical activity. A positive energy balance may contribute to overweight or obesity and related chronic diseases such as diabetes.

Diet and lifestyle modifications are necessary for the prevention of these conditions. These modifications may be challenging, but simple changes to diet and lifestyle

can be an effective and sustainable way to help manage weight. It may be beneficial to reduce excess added sugars for improved energy balance and weight management. Purified stevia leaf extract is safe for people of all ages. Including stevia as part of a healthful, balanced diet in addition to regular physical activity can help people reach their weight loss or weight management goals.

STEVIA IN FOODS AND DRINKS

Purified stevia leaf extract can be found in hundreds of foods and beverage products around the world. People may find stevia-sweetened teas, soft drinks, juices, yogurt, soymilk, granola and snack bars, and baked goods. Stevia is also found in snacks, cereals, salad dressings, savory sauces, alcoholic beverages, chewing gum, canned fruit and jams, confections, and as a table top sweetener.

Stevia can be the sole sweetener in a product or blended with other natural caloric sweeteners or other non-caloric sweeteners.

VI. About the Global Stevia Institute

The Global Stevia Institute (GSI) is an educational resource dedicated to providing science-based information on stevia and its safety to consumers, healthcare professionals, public policymakers, and the food industry. The GSI is led by an Advisory Board of internationally recognized nutritionists, medical doctors and health educators. This group counsels on current and future stevia scientific research; applicability to health and nutrition in consumers of all ages; and provides the GSI with a solid backbone rooted in science.

PureCircle, a leader in purified stevia leaf extract production, established the GSI in 2010 in order to support the education and awareness of stevia as a safe, naturally sourced, sweet ingredient for consumers by sharing accurate and consistent science-based information around the world. PureCircle continues to fully fund the Global Stevia Institute.

VII. Appendix

TOXICOLOGICAL STUDIES IN ANIMALS WITH PURIFIED STEVIOL GLYCOSIDES

REFERENCE	STUDY	DOSE	NOAEL
Curry & Roberts, 2008	Dosage study in 4 wk-old rats	1, 12 500, 50 000, 100 000 mg/kg diet (consumption levels up to 9938 and 11,728 mg/kg bw/d for males and females.)	100 000 mg/kg diet (equals 9938 and 11 728 mg/kg bw/d for males and females)
Curry & Roberts 2008	13-wk rat study with 97% Reb A prep	1,12 500, 50 000 mg/kg diet at wks. 1 and 13.	50 000 mg/kg diet (4161 mg/kg bw/d for males and 4645 mg/kg bw/d for females)
Nikiforov & Eapen, 2008	13-wk rat study with 97% Reb A prep	0, 500,1000, 2000 mg/kg bw/d.	2000 mg/kg bw/d
Aze *et al.*, 1991	13-wk rat study with stevioside (95.6% SG)	0, 155, 310, 625, 1250, and 2500 mg/kg bw/d	2500 mg/kg bw/d
Curry *et al.*, 2008	Preliminary reprod. Rat study; 97% Reb A	0, 4711, 8021, 9484 mg/kg bw/d for first 4 days, or 0, 6291, 10 045, 11 386 mg/kg bw/d at day 17– 20 in lactation	Dosage study with NOAEL not established. Authors state issues with food palatability.
Curry *et al.*, 2008	Two-gen. repro/devep rat study; >97% Reb A	0, 586, 975, 2048 mg/kg bw/d in males; 0, 669, 1115, 2273 mg/kg bw/d in pre-mating females; 0, 648–713, 1119–1169, 2263–2381 mg/kg bw/d in gestation; & 0, 715–1379, 1204–2388, and 2602–5019 mg/kg bw/d during lactation.	2 048 and 2 567 mg/kg bw/d in males F0–F1; 2273 & 2768 mg/kg bw/d F0, F1 during premating, 2322 & 2124 mg/kg bw/d in F0, F1 during gestation, 3811 & 4091 mg/kg bw/d F0, F1 during lactation, females
Charles Rivers Laboratories, 2008	Teratology study in rabbits with steviol glycosides preparation (Reb A ≥ 97%) from day 6 to 28 of gestation.	0, 350, 700 and 1400 mg/kg bw/d	1400 mg/kg bw/d* (*Adverse effects observed. NOAEL concluded by authorities due to known high susceptibility of rabbits to alimentary tract disturbances. These disturbances are commonly observed in sweetener studies with rabbits.)
Mori *et al.*, 1981	Fertility study in rats with stevioside (95.98%) before and during mating for a 60 day period (m) and for 14 days before mating and 7 days during gestation (f).	0, 100, 480, 2100 mg/kg bw/d in males; 0,120, 530, 2100 mg/kg bw/d in females	2100 mg/kg bw/day (3%)
Usami *et al.*, 1995, Tanaka *et al.*, 1991 (unpub)	Repro/Develop. Toxicity study in rats with stevioside (95.6%) between day 6 to 15 of gestation	0, 25, 500, or 1000 mg/kg bw/d	1000 mg/kg bw/d

HUMAN STUDIES: IN VIVO, METABOLIC STUDIES WITH PURIFIED STEVIOL GLYCOSIDES

REFERENCE	STUDY	DOSE	RESULTS	CONCLUSIONS
Maki *et al.*, 2007	Randomized, double blind, placebo-controlled clinical trial with healthy and diabetic men and women (n=45, n=48)	500, 750, 1000 mg in meal tolerance tests or placebo	No significant differences in pre-meal blood glucose, insulin, C-peptide, glucagon, BP	Acute consumption of rebaudioside A has no clinically important acute effects on glucose homeostasis or blood pressure; Reb A was well-tolerated
Maki *et al.*, 2008	Randomized, double blind, placebo-controlled clinical trial on chronic consumption in diabetic men and women with diabetes (n=122)	1000 mg Reb A 97% in 250 mg capsules for 16 wks. or placebo 0, 350, 700 and 1400 mg/kg bw/d	No significant differences in fasting glucose, insulin, C-peptide, BW, blood pressure, fasting lipids, dietary intake; No significant clinical differences in serum chemistry and hematological parameters	No significant adverse effects reported; Chronic intake of Reb A does not alter blood glucose levels or blood pressure changes; Reb A is overall well-tolerated
Maki *et al.*, 2008	Randomized, double blind, placebo-controlled clinical trial with healthy and men and women with low-normal systolic and diastolic BP (n=100)	1000 mg Reb A for 4 wks. or placebo	No significant clinical differences in blood pressure, diet, serum chemistry and hematology parameters	No significant adverse effects reported; High intake consumption well-tolerated with no clinically significant effects on BP
Gregerson *et al.*, 2004	Paired, cross-over study with diabetic men and women (n=12)	1 g capsule of 91% stevioside and 4% Reb A	Post-prandial glucose levels significantly decreased in stevia-treated group; Significant increase in insulinogenic index after ingestion; NSD in AUCs fir glucose, glucagon response or urine output	Authors stated stevioside may potentiate insulin secretion in individuals with type 2 diabetes mellitus
Temme *et al.*, 2004	Intake study with healthy males (n=9) for 3 days	750 mg total 97% stevioside in 250 mg capsules for 3 days	No significant differences in pre and post-prandial plasma glucose, insulin, blood pressure, serum chemistry and hematological parameters, or urine output and analysis compared to baseline	No significant differences compared to control group

ESTIMATED DAILY INTAKE OF STEVIOL GLYCOSIDES

AGENCY	ESTIMATED DAILY INTAKE (EDI) (IN STEVIOL EQUIVALENTS)	METHOD
JECFA (2008A)	0.9–3.5 mg/kg bw/day (Average-intake consumers) 3.0–5.8 (high-intake consumers)	For general population, all ages (GEMS*) of Europe, Latin America, Africa & Asia High level (90th percentile) intakes for Japan and the US Based on per capita replacement of all dietary sugars for general population results in very conservative estimates. Generally, 20–30% replacement is a more accurate replacement model. *WHO Global Environment Monitoring System Food database.
Renwick (2008)	0.4 and 0.7 mg/kg bw/day (Average intake general population and Children) 1.1 and 1.7 mg/kg bw/day (High-intake Adult and Children) 1.5 mg/kg bw/day (High-intake Diabetic Children)	High intake consumption of of up to 1000 mg/day Reb A had no clinically significant effects on blood pressure. No statistically significant differences in haematology and urinalysis results between groups.

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