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REVIEW ARTICLE

Stevia, ka'a he'e, wild sweet herb from South America - An overview

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Abstract

The use of *Stevia rebaudiana* Bertoni, perennial indigenous native plant from the tropical region of South America is presented, with a brief outlook on the history and uses of the wild plant by Guarani Indians, the crop domestication, and the authorization of its use as a natural sweetener in food and beverages. Other aspects considered are natural glycosides and physicochemical properties for food processing, nutritional information, medicinal properties, Stevia market and household uses. The future of this plant is promising but more research is needed to ensure use of leaves and steviosides, and also to study cultivation practices in various regions of the world.

Key words: *Stevia*, Steviosides, Uses, Properties

Introduction

Stevia Rebaudiana Bertoni (more commonly known as Stevia) is a wild herb, from the Asteraceae Family, a perennial indigenous native plant from the tropical region of South America, still in wild state in Paraguay, especially in the Department of Amambay, and Argentina's Misiones province. The name in Guarani language is ka'a he'e, which means sweet herb, and in Spanish is transcribed as "caaje'é".

The Guarani Indians had known for centuries about the unique advantages of ka'a he'e long before the arrival of the invaders from the Old World. These native people knew the leaves of the wild stevia shrub to have a sweetening power unlike anything else, they commonly used the leaves to enhance the taste of the typical beverage: “mate” a bitter infusion (a tea-like beverage), and medicinal potions, or simply chewed them for their sweet taste. The widespread native use of stevia was chronicled by the Spaniards in historical documents preserved in the Paraguayan National Archives in Asuncion. Historians noted that indigenous peoples had been sweetening herbal teas with stevia leaves since ancient times. In due course, it was introduced to settlers. By the 1800s, daily stevia consumption had become well entrenched throughout the region - not just in Paraguay, but also in neighboring Brazil and Argentina (Stevia net, 2012).

Stevia Rebaudiana Bertoni is one of the 154 genuses of Stevia, with elongate, lanceolate, or spatulate leaves shape, serrate margins from the middle to the tip and entire below (Figure 1). Maximum active principle for sweetening is found just prior to flowering. In wild conditions grows in sandy soils, acid infertile sand or muck soils (Madan et al., 2010).

Figure 1. *Stevia* in natural habitats of Argentina.
(Original photography from the author).

Stevia is named after the Spanish botanist Pedro Jaime Esteve (1500-1556) who found it in northeastern territory of modern Paraguay, later the Swiss naturalist Moises Bertoni described the

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species in the Upper Paraná, and then the Paraguayan chemist Ovid Rebaudi published in 1900 the first chemical analysis, and he found a glycoside able to sweeten 200 times more than refined sugar.

The *Stevia* plants use as a sweetener was first observed in 1889 and since then Stevia has become more widely produced for its natural sweetness as a no calorie, no carbohydrate alternative to sugar. These subtropical plants can be grown easily like most other vegetables, so they have been cultivated for decades due to their interesting properties, and it is important also that can be grown in small gardens, kitchen gardens or pots. Crop domestication began in the 1960´s, then it was introduced in Japan, Argentina, France, Spain, Colombia, Bolivia, Peru, Korea, Chile, Brazil, Mexico, United States, Canada and China.

In December 2008, the FDA of USA authorized its use as a natural sweetener in food and beverages. An ADI (average daily intake) of 0–4 mg/kg body weight/day was established (expressed as steviol). FDA notes that the equivalent ADI for rebaudioside A is 0-12 mg/kg bw/d, due to the relative molecular weights of rebaudioside A of 967 g/mol and steviol of 318 g/mol (FDA, 2009) . From December 2011 steviol glycosides extracted from high purity Stevia are permitted by regulation of the EU as a food additive sweetener with the number E-960 (EU 1131, 2011).

Natural glycosides and physicochemical properties for food processing

The leaves of wild Stevia plants contain several different natural glycoside compounds including dulcoside A & B, rebaudiosides A-E, steviolbioside and stevioside – these are the compounds responsible for producing the sweet taste sensation. The sweet Stevia extract is similar to other non-nutritive sweeteners, such as sucralose, in that it has zero calories, is 200-300 times sweeter than table sugar, is non-fermentable, and does not contribute to dental caries or plaque. Stevia is incredibly sweet in its raw form (Forsythe-Pribanic, 2012).

Stevia presents a mix of eight diterpene glycosides, which are mainly stevioside and rebaudioside. Stevioside could be described as a glycoside composed by steviol, which is adhered to sophorose through a carbon hydroxyl group.Its empirical formula is $C_{38}H_{60}O_{18}$, and its molecular weight is 804.98 (WHO, 1999).

The pattern of glicosilation heavily influences the taste perception of these intensely sweet compounds. The reactions generally start with steviol and end with rebaudioside A. In addition to the eight Stevia glycosides, the triterpens amyrin acetate and 3 esters of lupeol, and the sterols like stigmasterol, sitosterol and campesterol were also isolated from leaves (Madan et al., 2010).

Desirable physicochemical properties for food processing can include:

Heat resistance

Its structure is not altered by exposure to high temperatures and therefore does not lose its sweetness. It is suitable for hot or baked. Stable at normal temperatures used in food processing: pasteurization, sterilization, cooking. High solubility in water and hydroalcoholic solutions.

pH resistance

It is stable in a wide pH range, 3 to 9, even at 100°C. Above pH 9 there is a rapid loss of sweetness, food however show few values of pH> 9. In carbonated beverages that include in their composition citric and phosphoric acid, are detected loss of sweetness of 36% and 17%, respectively, when stored at 37°C.

Do not add calories

There are a large number and variety of patents of extraction and purification processes of stevioside, which may be summarized in the following steps: extraction of the leaves of Stevia rebaudiana with organic solvents, filtration, coagulation and precipitation of impurities by change of pH; clean-up on ion exchange resins, crystallization, drying. Importantly, if the process is not a product with acceptable taste (stevioside high concentrations exhibits somewhat bitter aftertaste), other treatments such as chemical or enzymatic modifications could be applied, but the resulting product could not be called natural (Fundación Tierra, 2008).

Besides the known extraction methods, new methods from glycoside-based extraction from Stevia were developed, and it was found that water can be very effective for extracting glycosides at selected pH and temperature (Madan et al., 2010).

Nutritional information

According to results presented by Encuentro Bariátrico (2009), dried stevia leaves contain about 42% of water-soluble substances (hence sweetens more mixed with liquids). The main active ingredient is the stevioside, buy it also contains protein, fiber, iron, phosphorus, calcium, potassium, zinc, rutin, vitamin A and C. Several laboratory tests have shown that Stevia has the following properties: rich in iron, manganese and cobalt, has no caffeine, pure crystal melting is at 238°C, presents no ferments.

Medicinal properties

Sweetener

Studies revealed that Stevia has been used throughout the world since ancient times for various purposes, for example, as a sweetener and a medicine. Stevia is likely to become a major source of high-potency sweetener for the growing natural food market in the future, and its use is recommended by various researchers. A Stevia leaf powder with no processing is highly safe to use, calorie free, and around 20-30 times sweeter than sugarcane. Although Stevia can be helpful to anyone, there are certain groups who are more likely to benefit from its remarkable sweetening potential. These include diabetic patients, those interested in decreasing caloric intake, and children (Geuns, 2004; Goyal et al., 2010).

Sugar blood

Stevia and natural sweetener steviosides have been used for many years in the treatment of diabetes among Indians in Paraguay and Brazil. Quality of life of diabetics (estimated over 135 million worldwide) could benefit from the regulatory properties of blood sugar level by tender leaves of stevia. The active principle of the plant induces pancreatic beta cells by themselves to produce large quantities of insulin, which helps to reduce blood glucose, which is the cause of diabetes mellitus 2 (Jeppesen et al., 2000; Gregersen et al., 2004).

Anti-cancer activity

Isosteviol (hydrolisis product of stevioside) were assayed for their inhibitory activity toward DNA metabolic enzymes and human cancer cell growth. It potently inhibited mammalian DNA polymerases and human topoisomerases II. It prevented the growth of human cancer cells (Madan et al., 2010).

Cardiovascular Action

A good deal of experimental work has been done on the effects of Stevia and stevioside on cardiovascular functioning in man and animals. Some of this work was simply looking for possible toxicity, while some was investigating possible therapeutic action, with no significant properties found by Humbolt (1978), only a slight lowering of arterial blood pressure at low and normal doses, changing to a slight rise in arterial pressure at very high doses.The most curious finding is a dose dependent action on heartbeat, with a slight increase appearing at lower doses, changing to a mild decrease at higher doses. The long-term use of Stevia would probably have a cardiotonic action, that is, would produce a mild strengthening of the heart and vascular system (Agricultural information, 2004). Chan et al. (2000) found that it acts as a cardiotonic agent (it regulates blood pressure and heart rate), and resulted in decreased systolic and diastolic blood pressure. Regulation of blood pressure and heartbeat could be associated with Stevia high richness of potassium (3.45%) and very low sodium (0.03%) level. In relation to effect on cardiovascular system, Sharma et al. (2009) reported that extract of Stevia has been found to reduce heart rate and mean arterial blood pressure, and that stevioside also lowers mean arterial blood pressure, an effect that is blocked by Indomethacin. This suggests that cardiovascular action of stevioside is mediated via a prostaglandin-dependent mechanism.

Anti-hypertensive

A 1-year, double-blind, placebo-controlled study of 106 individuals with high blood pressure evaluated the potential benefits of Stevia for reducing blood pressure. In the treated group, the average blood pressure at the beginning of the study was about 166/102. By the end of the study, this had fallen to 153/90, a substantial if not quite adequate improvement. In contrast, no significant reductions were seen in the placebo group (Chan et al., 2000).

Antiviral activity

Stevia rebaudiana extracts are potent anti-rotavirus inhibitors *in vivo* and *in vitro*. Activity of hot water extract showed inhibition of replication of all four serotypes of HRV (Anti-Human rotavirus) *in vitro* (Madan et al., 2010).

Antibacterial qualities

Stevia extracts have shown strong bactericidal activity against a wide range of pathogenic bacteria, including certain *Escherichia coli* strains. They also are very effective against bacteria in the oral mucosa and also the type *Candida albicans*, which causes recurrent vaginitis. Research clearly shows that *Streptococcus mutans*, *Pseudomonas aeruginosa*, *Proteus vulgaris* and other microbes do not thrive in the presence of the non-nutritive Stevia constituents. Also, it has shown to lower the incidence of dental caries, this fact, combined with the naturally sweet flavor of the herb, makes it a suitable ingredient for mouthwashes and for toothpastes (Pinheiro et al., 1987; Tomita et al., 1997; Agricultural information 2004; Matsukubo and Takazoe, 2006). Abou-Arab and Abu-Salem (2010) reported the importance of Stevia leaves and callus extracts for pharmaceutical uses and food

preservation due to their antioxidant and antimicrobial activities.

Toxicity and uses in non-traditional medicine

Acute and subacute toxicity studies revealed a very low toxicity of Stevia and steviosides. Stevia uses in folk medicine include against hypertension, diabetes, and as a contraceptive, and for obese persons intending to lose weight by avoiding sugar (Madan et al., 2010).

Digestive Tonic Action

In the literature of Brazil, Stevia ranks high among the list of plants used for centuries by the "gauchos" of the southern plains to flavor the bitter medicinal preparations used by that nomadic culture, and their "mate". Stevia made a significant contribution to improved digestion, and improved overall gastrointestinal function. Likewise, since its introduction in China, Stevia tea, made from either hot or cold water, is used as a low calorie, sweet tasting tea, as an appetite stimulant, as a digestive aid, as an aid to weight management, and even for staying young (Agricultural information, 2004).

Effects on the Skin

The Guarani and other people who have become familiar with Stevia report that it is effective when applied to acne, seborrhea, dermatitis, eczema. Placed directly in cuts and wounds, more rapid healing, without scarring, is observed. Smoother skin, softer to the touch is claimed to result from the frequent application of Stevia poultices and extracts. Stevia is also known for skin shining and tightening properties, and has found its way in several commercial skin tightening products or anti-wrinkle products (Agricultural information, 2004).

Precautions must be taken into consideration, as adverse cardiovascular and kidney/genitory-urinary effects have been documented with Stevia. Stevia extracts were found to decrease the fertility of male rats, while steviosides induced diuresis and natriuresis and a fall in renal tubular reabsorption of glucose (Madan et al., 2010).

Stevia market

Data from Leatherhead Food Research valued the world Stevia market (defined as including both crude extracts and high purity products such as reb A) at US$100m in 2010, up by nearly 27% from $79m the previous year. During this time, volume sales rose from less than 2,300 tonnes to 2,400 tonnes, with crude extracts accounting for up to 80% of this figure. At present, the US is thought to account for more than 80% of worldwide sales of reb A, with the market expected to reach up to $700m within the next five years. Furthermore, annual retail sales of US food and drinks promoted as containing stevia have grown from practically zero to over $1bn since regulatory approval was granted. Reb A could have the potential to penetrate up to 25% of the world sugar market, as sugar consumption has fallen in many parts of the world (Thomas, 2012).

Artificial sweeteners such as aspartame and Splenda have dominated the non-nutritive sweetener market, but according to the August 2011 report by the market research firm Mintel, the trend is turning toward natural sweeteners. Mintel estimated the global market for stevia sweeteners reached $500 million by mid-2011, and food consultant Zenith International expects the global market for stevia-derived products to reach $825 million by 2014. Coca-Cola, and PepsiCo have taken notice and have invested years of research and millions of dollars to find new ways to lower the calorie content in their brands without affecting the taste (Kawabe, 2012).

Household uses

Stevia is a new promising renewable raw stuff for the food market, with a high potential of development. This natural sweetener is used is used in products like biscuits, jams, chocolates, ice-creams, baked foods, soft drinks, soda, candies , and beverages like dip tea, coffee and herbal tea, in particular for diabetics and health conscious consumers. The leaves of Stevia impart a pleasant flavour apart from increasing the sweetness. The Stevia leaves or their powder are used in typical Indian dishes, and ground Stevia is excellent when sprinkled over cooking vegetable and meat, cereals and salads (Barathi, 2003).

Stevia is an ideal plant for autocultivation, in order to take advantage of each day leaves that have proven very beneficial effects on health. Stevioside obtained from leaves is a "white crystalline powder, odorless, non-hygroscopic, non-fermentable, sweeter flavor in very dilute solutions, very soluble in water". However, its main obstacle for marketing what is called an aftertaste, that to be removed requires expensive laboratory processes. The intake of fresh leaves is much more economical and equally healthy. The dose most commonly used is 4 tender leaves, eaten directly before or during lunch and 4 leaves, before or while dining, or a tea of dried leaf (an infusion in the morning and another in the evening). The infusion dose is one teaspoon of chopped dried leaf dessert per cup of infusion (Fundación Tierra, 2012).

Conclusions

More scientific research is needed to ensure use of Stevia leaves and steviosides, related to toxicity and health effects, and its application in food industry.

Furthermore, as it can be grown in different conditions, it is necessary to study cultivation practices in various regions of the world, in natural conditions or in greenhouse production, regarding propagation, planting density, adequate soil types, fertilization, irrigation, and net profit for small producers.

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