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Review

Guarana: Revisiting a highly caffeinated plant from the Amazon

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ABSTRACT

Ethnopharmacological relevance: Guarana (*Paullinia cupana* Kunth var. *sorbilis* (Mart.) Ducke) has been traditionally consumed by indigenous communities of the Amazon region. It is valued mainly for its stimulant property because of its high content of caffeine, which can be up to 6% in the seeds.
Aim of the review: The purpose of this review is to revisit this typically Brazilian plant, addressing economic considerations, the chemical makeup of the seeds and pharmacological properties so far investigated.
Results: Guarana is primarily produced in the Brazilian states of Amazonas and Bahia, and approximately 70% of the production is used by the industry of soft and energy drinks. The other 30% becomes guarana powder for direct consumption in capsules or dilution in water, or it serves as a raw material for the pharmaceutical and cosmetics industries. In addition to its stimulant property, guarana has other therapeutic properties, which have aroused the interest of the scientific community.
Conclusion: This review shows that other guarana properties may be explored and how scarce are the studies regarding agronomic, plant pathology, physiology and breeding. So far, caffeine has been the main reason to study guarana and still will lead the researches because the demand for this alkaloid by food and pharmaceutical industry, and a strongly growing market related with beauty products. However, guarana has other components and there is great interest in studies designed to elucidate the effects of guarana's bioactive components and their potential pharmacological applications. Significant part of the guarana production in Brazil still comes from Indians tribes in the Amazon State, and any improvement in this plant, in any aspect, may propitiate a positive economic impact in their lives.

Contents

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1. Introduction

Guarana, also called *guaraná-da-amazônia*, *guaranaina*, *guaranauva*, *uarana* or *narana*, is a species native to the Amazon region known for its stimulant and medicinal properties and used for centuries by indigenous communities of the Amazon. The first report about the use of guarana as a beverage occurred in 1669 when, during the Jesuit expedition to the Amazon, the missionary João Felipe Bettendorf observed that the Sateré-Mawé Indians consumed a stimulating beverage that had diuretic properties and therapeutic effects against headache, fever and cramps (Maravalhas, 1965; Henman, 1986).

Guarana had two botanical classifications until 1897, at which point *Paullinia cupana* was retained as the scientific name because it was the first recorded, but Ducke (1937) described sufficient morphological differences to distinguish the populations of plants found in the upper Rio Negro from those found in Maués. Ducke's description thus complemented the description by Theodor Martius, who provided a description of *Paullinia sorbilis* as a variety of *Paullinia cupana*: *Paullinia cupana* Kunth var. *sorbilis* (Mart.) Ducke (Atroch, 2009). According to Ducke (1937) *Paullinia cupana* var. Typica is the Venezuelan guarana while var. Sorbillis is the Brazilian guarana, which is economically explored. This review will refer to this variety of guarana, which is the only one that is used commercially and has been the most thoroughly studied.

Fig. 1. Guarana fruits.

2. Characterisation of the species and cultivation of the guarana plant

The family *Sapindaceae* has approximately 140 genera and 2000 species distributed across three subfamilies; the guarana plant belongs to the subfamily *Sapindoideae* (Gentry, 1991; Souza and Lorenzi, 2008). The genus *Paullinia*, with approximately 200 species, is almost entirely restricted to tropical and subtropical America, with the exception of *Paullinia pinnata* L., which is also present in tropical Africa. In the Brazilian Amazon, in addition to guarana, there are more than eight reported species, including *Paullinia seminuda* Radlk., *Paullinia paullinoides* Radlk., *Paullinia verrucosa* Radlk., *Paullinia rufescens* Rich. ex Juss., *Paullinia caloptera* Radlk., *Paullinia selenoptera* Radlk., *Paullinia pinnata* L. and *Paullinia pseudota* Radlk. ex Warm. (Schmidt, 1941; Missouri Botanical Garden, 2012). These species have not been well characterized so far but depending on the phylogenetic relationship with guarana they might become a rich source of genetic variability for breeding purposes (Atroch, 2009).

There are controversies regarding the origin and distribution of the guarana plant (*Paullinia cupana* var. *sorbilis*). However, its natural habitat seems to be limited to the region of the Maués-Açu river basin, which coincides with the territory of the Sateré-Mawé Indians (Schmidt, 1941; Saldaña et al., 2002). The phylogenetic centre of origin of guarana would be, according to Ducke (1937), the upper Rio Negro, although some authors claim that the species follows the distribution of the genus *Hevea* (Pires, 1949).

The word *guarana*, *uarana* or *varana* means "vine" in various indigenous dialects, and it refers to the liana growth habit of this perennial plant, which has tendrils that can reach up to 10 m in length in the presence of trees that act as supports (Fig. 1). The stem is ridged and has a yellowish-brown colouring when lignified. The leaves are alternate and odd-pinnate. The well-developed sheaths are approximately 1.5 cm long. The main petiole (rachis) is 8 to 19 cm, and the petioles of the leaflets are very short. The leaflets have a roughly oval shape and a serrated apex, with width ranging from 10 to 14 cm and length from 27 to 33 cm. The leaflets are well spaced and have prominent underside veins. The leaves are dark green with glossy topside. At the base of each leaf, there is a vegetative and a reproductive bud (Lodewijks, 1986).

The guarana plant is a monoecious plant, with a raceme type of inflorescence that can be longer than 30 cm. Its flowers are small and zygomorphic, and they are laid out along the main axis of the inflorescence. The calyx is composed of five sepals, of which two are smaller and external, with the corolla formed by four white petals that have the shape of a hood or gutter and have, internally, crest-shaped coriaceous scales with yellow tips. The flowers are pseudo-hermaphrodites, of which those considered female have seemingly normal rudimentary stamens and indehiscent anthers, whereas those considered male have atrophied ovaries and a regressed stylus and stigma (Escobar, 1985; Souza et al., 1996; Lunguinho, 2007). Although the large number of flowers, approximately 95 per inflorescence, the ratio of male to female flowers is 4.5:1 and it may vary with each bloom. This variation occurs mainly because of genetic and environmental factors, which are directly related to the production of the guarana plant (Henman, 1982; Escobar, 1985; Lunguinho, 2007).

The fruit is a capsule with septicidal dehiscence and a developed peduncle. When immature, it has a dark green colour, and when ripe, its colour ranges from yellow-orange to yellow-red to bright red. The seeds (one to four per fruit) are dark brown with a crustaceous texture, and they are partially enveloped by a chalky white aril, which anatomically represents a sarcotesta that seems to protect the embryo against moisture loss (Polo, 2006). The open mature fruit exposes the white aril (Fig. 1). The dark seed, in contrast with the red colour of the shell, resembles a human eye, which represents a striking feature for the identification of guarana (Schmidt, 1941; Souza et al., 1996; Embrapa Agropecuária Ocidental, 2001; Smith and Atroch, 2007). When dried or roasted, the seeds can be used to produce commercial products with high caffeine content (2.5 to 6%); the caffeine content of guarana seeds is 2 to 5 times higher than that of Arabica coffee seeds (Cabral, 1932; Lyra, 1953; Souza, 2010).

Guarana plant propagation is accomplished by using seeds or cuttings. The use of cuttings is advantageous when the goal is to maintain the traits of cultivars, such as tolerance to pests and