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Revisión | Review

Enterolobium cyclocarpum (Jacq.) Griseb.: The biotechnological profile of a tropical tree

[*Enterolobium cyclocarpum* (Jacq.) Griseb.: El perfil biotecnológico de un árbol tropical]

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Abstract
Enterolobium cyclocarpum is a tropical tree that has played a fundamental part in the development of rural man living from southern Mexico to the middle part of the South American subcontinent. The purpose of this review is to describe the relevant biotechnological aspects of this benefactor and generous comrade in life, the taxonomic classification and geographical distribution and introduction to other continents, the basic aspects of their biology and ecology, the importance in the traditional agroforestry systems. Also, its role as material in the construction and manufacture of wooden utensils, in food and pharmaceutical biotechnology, in traditional medicine, in culinary regional folklore and its symbolic social importance.

Keywords: *Enterolobium cyclocarpum*, phytochemistry, biotechnology

Resumen
Enterolobium cyclocarpum es un árbol tropical que ha sido fundamental en el desarrollo del hombre rural que habita desde el sur de México hasta la parte media de subcontinente Sudamericano. El propósito de esta revisión es describir los aspectos biotecnológicos relevantes de este árbol benefactor y generoso compañero de vida, la clasificación taxonómica y distribución geográfica e introducción a otros continentes, los aspectos básicos de su biología y ecología, la importancia en el sistema agroforestal. También, su rol como material de construcción y de utensilios, en la biotecnología de alimentos y farmacéutica, en la medicina tradicional, el folklore culinario regional y su importancia emblemática.

Palabras Clave: *Enterolobium cyclocarpum*, fitoquímica, biotecnología

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INTRODUCTION

Successful drugs are a support of economic power in the international pharmaceutical market and obviously in the clinical treatment of health problems. Many of them have their origin in plants and they have been obtained through drug exploration in traditional medicine. Ethnobotanical surveys within local communities have revealed the use of some native plant and their economic potential. It is estimated that there are 250,000 to 500,000 species of terrestrial plants on the planet, of which 1,650 have been used as food by native groups in the American continent, and 2,564 have been used in traditional medicine (Klink, 1997). Only 6 % of the plants have known biological activity and 15 % of them have been evaluated for their phytochemistry (Miller, 2011). It is true that few countries possess a vast biodiversity and Mexico is one of them, having a terrestrial flora of 20,000 to 30,000 species and for this fact it globally ranks fourth place in floristic diversity; it is estimated that 52 to 65% of species are endemic plants (Rzedowski, 1978, 1991; Toledo, 1988). Today as always, the plants are a fundamental basis in the development and comfort of the man. Some aspects of its fundamental biology of the plants are known and less about their secondary metabolites that are an apparently inexhaustible source of active ingredients and drugs.

Some plants are important in traditional use, for their physical, mechanical, and culinary properties and as traditional medicine. However, efforts have been extended to search beyond of the limited number of medicinal plant. All of them require phytochemical studies detailed in the search for its active ingredients. With the purpose of use some plants as alternatives for the production of novel or know active ingredients, or to validate their bio-active properties, or to accept or to rule out their traditional use.

A relatively small number of plants have closely accompanied the evolution, development and splendor of the human race, for example species from Asia, Europe and North Africa, such as condiments, ornamental and fruit trees. However, even fewer plants that have accompanied to man in its local development and of which we do not know much of their biology, ecology and phytochemistry, such is the case of *Enterolobium cyclocarpum* (Jacq.) Griseb. an important tree in pre-Columbian and modern, Central American cultures that have lived in the American isthmus. However, recently the social and biological importance of this tree has transcended beyond of the American continent. The *Enterolobium* genus, *E. cyclocarpum* is the best-known species mainly due to the versatility of applications in various fields of human activity. This is an update to the knowledge of this species.

Taxonomic classification and geographical distribution of E. cyclocarpum

This tree was first described in 1809 and 1887 in New Spain; it became known with the name of *Mimosa cyclocarpa*. Then, the British Jacq and Griseb classified it as *Enterolobium cyclocarpum* (Jacq.) Griseb. (Standley, 1924). *E. cyclocarpum* belongs to Phylum Magnoliophyta; Class Magnoliopsida (Dic). Order Fabales. Family Leguminosae (Mimosaceae). Genus *Enterolobium*. Species *cyclocarpum.* Synonyms: *Albizia longipes* Britton and Killip; *Feuilleea cyclocarpa* (Jacq.) Kuntze; *Inga cyclocarpa* (Jacq.) Willd; *Mimosa cyclocarpa*, (Jacq); *Mimosa parota* Sesse and Moc; *Pithecellobium cyclocarpum* (Jacq) Mart; *Prosopis dubia* Kunth.

In an initial approximation to know the number of species of the *Enterolobium* genus, De Lima Mesquita (1990), considered that in the tropical America are distributed up to 22 species: *E. barinense*, *E. barnebianum*, *E. benebianum*, *E. blanchetii*, *E. contortisiliqua*, *E. cyclocarpum*, *E. contortisiliquum*, *E. ellipticum*, *E. glaucescens*, *E. guaraniticum*, *E. gumiferum*, *E. glaziovii*, *E. jamboril*, *E. maximum*, *E. monjollo*, *E. mongollo*, *E. oldemannii*, *E. schomburgkii* var. *schomburgkii*, *E. schomburgkii* var. *glaziovii*, *E. tamboril*, *E. timbouva* var. *canescen* and *E. timbouva f. minor*. While Barneby and Grimes (1996) reported 12 members of this genus: *E. barinense* (Cárdenas and Rodríguez), *E. barnebianum* (Mesquita and MF Silva), *E. contortisiliquum* (Vell) Morong, *E. cyclocarpum* (Jacq.) Griseb., *E. ellipticum* (Benth), *E. glauziovii* (Benth) Mesquita, *E. gumminferum* (Mart) J.F. Macbr, *E. maximum* (Ducke), *E. monjollo* (Bent), *E. oldemanii* (Barneby & J.W. Grimes), *E. schomburgkii* (Benth) Benth and *E. timbauva* (Mart), establishing an apparent controversy in the number of species present in the American continent, where to interpret taxonomic keys may cause confusion to determinate the species of this genus. As well, e.g. *E. mangense* was recently re-located in the *Chloroleucon* genus as *C. mangense* var. *mangense* (Barneby and Grime, 1996). Although interestingly work has been started to understand their phylogeny and molecular taxonomic classification with descriptions of five proteins; maturase, PsbA, phytochrome A-type protein, phytochrome E, and phytochrome A and the analysis of the gene sequence of the chloroplast genes; *trnK*, *matK*, *psbA*-*trnH*, *trnL*/*trnF* and the intergenic spacer regions *trnL*-*trnf* and *trnL* genes (Lavin *et al*., 1998; Luckow *et al*., 2000; Miller *et al*., 2003; Wojciechowski *et al*., 2004). Also, it has been shown that this species is polymorphic and variable in the number of alleles by locus in the range of 5 to 15, where isolated micro satellite loci with which in the future of this species may be improvement (Peters *et al*., 2008).

The representative species of the *Enterolobium* genus are *E. contortisiliquum* and *E. cyclocarpum*, of which we begin to know their biology and ecology, also the phytochemistry, the biocidal and pharmacological activities and agroforestry characteristics.

Such is the importance of this species in the life of pre-Columbian and modern societies that it inhabits the land bridge connecting North and South America, which can be observed by the names given to this tree in different native languages (Pennington and Sarukhan, 2005; Corral López, 1985).

The significance of this tree in the social life of the natives is reflected in the fact that it has been given its vernacular name to the towns and provinces along of the continental bridge. In some places it has come to be regarded as the emblematic national tree, such is the case of Costa Rica in which it is known by the common names of guanacastle and chorejas. Also, in this Central American country in the 20th century (1975), coins were minted with the logo of the tree *E. cyclocarpum* (Vargas Zamora and Gómez Laurito, 2004).

Currently three species present in Mexican territory have been reported: *E. mangese*, *E. schomburgkii* and *E. cyclocarpum* distributed in the States of the Mexican southeast (Schery, 1950; Cowan, 1983; Sousa and Cabrera, 1983; Cüe Bar *et al*., 2006). In Mexico, *E. cyclocarpum* is widely distributed on the slope of the Gulf of Mexico, from the South of Tamaulipas State to the Yucatan Peninsula, while on the slope of the Pacific it is found from Sinaloa State to Chiapas State and from the south border of Mexico to the North of Brazil (Peninngton and Sarukhan, 2005). The index value of importance (IVI) of *E. cyclocarpum* in the Mexican Southeast varies in the range from 5.9 to 17.5%, this value indicates that the natural abundance is from 1 to 32 trees per hectare. It was among the 16 Mexican trees that have a value in the range of 5 to 16%. *E. cyclocarpum* is a species with a real existence per hectare considered to be low, so the annual utilization is low, according to the forestry system inventory of Mexican geographic information (SIG: Mexican acronym) (Torres Rivera and Burgos Herrera, 2008).
Today, *E. cyclocarpum* inhabits other latitudes. The history of introduction of this tree in other tropical places remains poorly documented and it is unclear how widely is distributed this species in the world. A possible explanation is given by early work about plant diversity from American continent done by biologists from European powers of last centuries, *e.g*. British biologists made botanic gardens and seed collections from American tropical plant species where *E. cyclocarpum* was included. This species was introduced to Africa and other continents through the far-flung outputs of those European powers.

Then, at middle XX century a deteriorating food situation happened in many African countries and other developing areas caused by the overpopulation, climatic change, increasing spread ecological degradation and energetic crisis. At this time, *E. cyclocarpum* and other multipurpose trees were reassessment for the Food and Agricultural Organization (FAO) of United Nations (UN). Several global economic agencies between them the FAO established development policies and approaches concern to cover the basic needs of the poorest of the poor, especially to the rural poverty. Agroforestry policies that included the introduction and culture of exotic multipurpose trees were applied in several West African countries and since this tree has been included in the local culture.

Interaction of E. cyclocarpum with native human being.

Timber industry

Wood presents differences in color between the sapwood and the heartwood, the sapwood is white with chesnut-brown streak and furrows. The heartwood is light brown in color, pronounced veining, medium brightness, coarse texture, interlocked and growth ring defined only when there are marginal parenchyma bands and it has a spicy taste and strong characteristic odor.

The pores are visible to the naked eye, with scarce and diffuse distribution and groups of 3-5 pores with tangential medium diameter. Vessel elements are short in length, its walls alternate bordered with coalescent apertures and plate perforated simple pits, some sealed with rubbers. Axial parenchyma is visible to the naked eye, axial parenchyma is of vessel centric and confluent bands types. It presents tiny crystals of rhomboidal type, in the oil-like specialized cells. The spokes are only visible with magnifying glass the cross-sections and simple view in the radial faces, are homogeneous series 1 to 3 with rubber bands of brown color, being most abundant in 2; uniseriate rays are 2-17 cells in length and 7 cells are more abundant.

The fibers are of two types: libriforms and fiber tracheids, chambered in length and average diameter and thin walls. The wood is light, hard and with low resistance to static bending, compression parallel and perpendicular to grain; their total volumetric contraction is very low, the tangential contraction is average and the radio is low, it is dried in a span of 7 days with a content of initial humidity of 100% up to a moisture content of 10 to 12%. The wood is of rough texture with an intertwined fiber; the sapwood of *E. cyclocarpum* is hard, it is susceptible to decay and insect attack but the heartwood is resistant to decomposition and dry wood termite attack (Chudnoff, 1984; Raya González *et al*., 2007).

By the physical and mechanical properties wood from the heartwood is easy to work it. It is used to retrieve tables and beams for rural buildings, for the production of kitchen utensils for domestic use; it was formerly used for the construction of canoes and cart wheels (see table 1). The wood is used for the manufacture of staves, wood furring, veneer, and wooden decks. It is used for the production of handmade miscellaneous items such as: furniture in various styles and forms, works of art by hand carved doors, railings of stairs, protective bars, screens, musical instruments, packaging, construction and decoration of houses.

Table 1

Mechanical and physical properties of heartwood from *E. cyclocarpum*.

Parameters	Values
Density (weigh anhydrous/volume green)	0.34 - 0.56 g/cm^3
Dimensional stability	High
Radial contraction (β_r)	2%
Tangential contraction (β_t)	5%
Volumetric total contraction (β_y)	7.2%
Modulate of Elasticity (MOE)	71,000 - 100,000 kg/cm^2
Modulate of Resistance (MOR)	401 - 1350 kg/cm^2
Resistance to the compression parallel to Grain	301 - 450 kg/cm^2
Resistance to the compression perpendicular to Grain	Low
Maximum Resistance to the Compression (MCS)	343 kg/cm^2
Hardness Janka wings (green)	159 kg
Hardness Janka ends (green)	172 kg
Hardness Janka wings (dry)	235.9 kg
Hardness Janka ends (dry)	Low

Pulp and papermaking characteristics along with total biomass yield of a fast growing tree species such as *E. cyclocarpum* have been evaluated. The fiber length of 1 mm and low lignin content of 20% accompanied by other normal characteristics have been highlighted for its favorable use as hardwood in pulp and papermaking. Pulping by chemical sulfate process requires 15% of active alkali with an unbleached pulp yield of 50.5%. Bleaching by CEH sequence shows pulp yield of 43.4% and brightness of 81.2%. The strength properties are discussed vis-a-vis quality of paper **(**Brahmam *et al*., 1993).

The wood from *E. cyclocarpum* has anatomical structure and physical properties and chemical that makes it an interesting constructive component with possibility of to competes with other materials. Wood *E. cyclocarpum* exhibits technical challenges such as the manufacture of articles and furniture with curved pieces to produce innovative designs, *e.g.* the heartwood has an average density value of 450 kg/m^3, while curved pieces of wood have a density value equal or greater than 600 kg/m^3 (Corral López 1985; Hwang *et al.*, 2002; Makinaga *et al.*, 2007). Also, their incorporation in the manufacture of instruments and acoustic structures is other challenge. Therefore, of the wood *E. cyclocarpum* is necessary to know and to integrate factors such as the plasticity in the presence of an aqueous ingredient, temperature and moisture content in relation to the thickness of the piece, the radius of curvature and orientation of growth ring.

Agro-forestry use of E. cyclocarpum

The traditional knowledge of alternative uses of trees on this land bridge allows a broad view of the usefulness of this natural resource. For example in Michoacán a Mexican state, its major use is as firewood 28.3%, poles for fences 25.2%, medical human 15.2%, development tools of 14.6%, human consumption 13.5% and medicinal 3.3% (González Gómez *et al.*, 2006).

It is a tree very appreciated and perhaps in some places is protected by man and has several uses such as a shade tree in livestock or agricultural lands. For the forest, agricultural crops and animal production, ancestral techniques of use and management of soils have been combined and they have been successfully applied (Mahecha, 2002). Traditional knowledge in rural societies about the use of fodder trees is broad and shows the multiple functions of cultural, economic and service orders. This tree is essential in the integrated production systems, which are used deliberately with perennial woody species (trees, shrubs, palms, etc.). For example 80 trees are used as forage in the Michoacán region, which includes the species *E. cyclocarpum* using the seeds and leaves as a nutritional supplement for animals and whose bromatological analysis showed that it has a good food value; the seeds of this tree contain approximately 36% protein. The crude protein (CP) content ranged from 112 to 266 g/kg dry matter (DM). The neutral detergent fiber (NDF) content ranged from 283 to 515 g/kg DM and from 166 to 402 g/kg DM, (see table 2) (Monforte Briceño *et al*., 2005). This practice has been observed in several Mexican states where cattle production is of dual purpose and dominated by extensive and semi-extensive management systems (Gómez Castro *et al*., 2002).

This tree quickly generates great amount of fodder and hence carbon pools in the soil that support the growth of other plants used as pasture for cattle feed. Pasture response to seasonal change was more pronounced, in terms of the flow of CO_2 and herbaceous productivity than the response of a plantation. Storage systems below ground systems contained more than 40% of the total number of sampled biomass (Potvin *et al*., 2004).

Although the fodder derived from *E. cyclocarpum* is nutritionally good, it also favors a moderate methane production by microbial fermentation in the rumen and has a ruminal anti-protozoaric effect, possibly due to the content of saponins (Bobayemi, 2006; Soliva *et al*., 2008; Rodríguez *et al*., 2009). The presence of antinutrient factors especially in the seeds of *E. cyclocarpum* could be a major constraint in their use as food for poultry. However, the food properties of different parts of *E. cyclocarpum* are useful as ruminant nutrient (Iyayi *et al*., 2006).

Concern to use of this tree, the agroforestry practices are doing in natural wild, disturbed environmental and anthropogenic areas. In Mexican territory is notable that gathering is the common practice. It was observed that some time at some places gathering include actions such as selection of desirable phenotypes, changing the order in which gathering areas are used in order to allow a higher availability of products and restricting harvesting in the event of a decrease in number of individuals of the species. However, it is necessary for *E. cyclocarpum* to design and to implement forms of management such as, tolerance, protection, promotion and *ex situ* cultivation. It is advisable to know the best management forms to this tree into each area.

At Africa the agroforestry stage is different, here, it has been designed and implemented management forms of exotic multipurpose tress such as *E. cyclocarpum*, *e.g.* alley cropping is a promissory agroforestry technology for not only the humid lowlands but also the subhumid to semiarid zones. Alley farming involves growing perennial trees in systematic rows, and the production of arable crops between these rows. They implemented exotic growing trees and food crops on the same farmland. Depending on the tree species, such practices has help to improve soil fertility, hold soil particles together and prevent erosion, and produce shade, browse for livestock, poles, fuel wood, and other forest products.

E. cyclocarpum is a good fixative of carbon measured by the seasonal variation of the values of $\delta^{13}C$ stable isotope, with a differential behavior in the setting of the isotope that depended on the position of the leaves on the tree (Holtum and Winter, 2005). The distribution of carbon storage in the form of starch was in the axial inner fibers, parenchyma, and in the living xylem fibers associated with enzyme activity of phosphatase in the xylem of *E. cyclocarpum*. The content of starch diminished at morning and later increased. The new increase of free starch in the xylem was held up for a long period of time. In parenchyma cells, especially at the tips to the vessels there is a great activity of acid phosphatase (AP). The activity of AP indicates the secretion of sugars into the vessels. This can cause an osmotic pressure in the stem, which could prompt the transport of water during the period of reduction of perspiration due to the high humidity of air (Fink, 1982).

The seeds of *E. cyclocarpum* are extensively collected and consumed for the nutritional content rich in amino acids, carbohydrates, minerals and proteins, by the animals of the forest and man, therefore a shortage of seeds should be presented in the field for the generation of new individuals. The survival of the seeds depends on the abortion of the seed in the fruit of *E. cyclocarpum* related to the position within of the fruit; there is a marginal difference in the rate of abortion among these sections and also among trees. In general, the distal section has the highest rate of abortion in relation to the other sections. This pattern of abortion may be caused by competition for food resources within the pod and not by genetic differences between them (Villalobos and Bianchi, 2000). The seeds of *E. cyclocarpum* are characterized by a hard covers that make them impermeable to water and probably to gases. Inhibition of the abortion process could be speeded up, trying to seed with concentrated sulfuric acid or by mechanical processing. The seed under mechanical processing showed an increase in fresh weight of the embryo and a decrease in dry weight of cotyledons that was parallel to an increase of the dry weight of the pre-implantation axis. A starch content decrease was observed in the cotyledons, which was followed by an increase in the reducing sugars. In the same way the total N decreased, it was accompanied by an increase in the content of soluble N. The total P in cotyledons content declined as germination proceeded. Changes in the content of starch were confirmed with anatomical studies. The vessels of the xylem in pre-implantation axis appeared perfectly differentiated at 72 h after germination (Hernández Gil and García, 1980).

This tree is found in zones of vegetation apparently disturbed of high perennial forest and medium sub perennial forest in primary associations, but it is difficult to relate to this species with some kind of primary vegetation. In areas of cattle production with double purpose and dominated by extensive and semi-extensive management with low productivity systems, it is advisable to promote the cultivation of this species for its incorporation to existing agroforestry systems. This includes tree fodder, fruit, and timber in livestock systems to help to reforestation and restoration of degraded areas. Mulch and pruning from *E. cyclocarpum* no release phytotoxic compounds this it allowing the establishment and growth of other plant species (Kamara *et al*., 2000). In Mexico a group of 14 trees that including to *E. cyclocarpum* has been proposed for reforesting perturbed areas. It has a natural frequency of 59.7%, it can grow in wide altitude intervals (0 - 942 m), temperature (22.3 - 26.9° C) and precipitation (860 - 2600 mm) and is adapted to diverse soils (Gómez Castro *et al*., 2006).

The importance of this species in the restoration of soils depends on the survival of the seed. Recently, the importance of the predation of seeds by animals in the distribution and density of mangrove species has been established by several studies. A correlation was observed between the density of the predator and the removal and mortality of germinated seeds. Predation of the seeds and plants and the secondary covered canopy are also important factors that affect the establishment of this tree (Lindquist and Carrol, 2004).

The pattern and rates of gene movement across the field are key factors in the development of genetic structures under natural condition as well as those modified by man. It seems clear that pollination is not panmitic, but is quite extensive in *E. cyclocarpum*. Also, it is expected that pollinating consistency year after year for a parental seed has an average annual crossing with small pollen pool values. Parental seeds with a high number of pollen donors have been found. If is considered that the pollen flows at considerable distances through the countryside (Smouse *et al*., 2005).

E. cyclocarpum interacts with bacteria such as *Bradyrhizobium* and fixes nitrogen in association with these cells; large amount of ureids compounds associated with globular nodules was found (Van Kessel *et al*., 1983; Goi *et al*., 1984). *E. cyclocarpum* in association with endomycorrhizae and growing in de-mineralized and poor soils is able to absorb phosphorus and other nutrients (Kang *et al*., 1995). It was noted that this microbe-tree association gives a favorable response for the enrichment of phosphorus in poor soils (Habte and Musoko, 1994). Not all microbial associations that this tree establishes are beneficial, recently the presence of the fungus

Acremonium sp. (*Cephalosporium*) was reported in tumors in *E. cyclocarpum* and this fungus was associated with the xylophage insect *Nasutitermes rippertii* (Isoptera:Termitidae) (Pérez Miranda *et al*., 2009). Other negative association of *E. cyclocarpum* with insects was observed. It was reported that the tree presented a severe infestation with *Maconellicoccus hirsutus* (Green), pink hibiscus mealybug (González Gaona *et al*., 2010).

Traditional use of by-products obtained from E. cyclocarpum

The rubbery exudates are of great economic importance in rural areas, due to its use in industries such as: food, pharmaceutical, textile, cosmetics, and wine (Klose and Glickman, 1975; Whistler and BeMiller, 1993). Average rubber yields seen in *E. cyclocarpum* are 36.10 g/specimen/week, solubility is 4 g/100 mL and its intrinsic viscosity is 100 mL/g, this parameters were determined at 25° C (Rincón *et al*., 1999). Polymers, hydrocolloids, hetero polysaccharides, and acids are excreted by species that grow in tropical and subtropical areas in response to a wound at the level of the stem, removal of branches, or by the presence of insects, bacteria and fungi. The bark contains tannins and is used in the tannery to treat fur. The green fruit contains saponins and is used locally as a substitute for soap to wash clothes (Niembro Rocas, 1990).

The seeds of *E. cyclocarpum* are part of the diet of rural people and it is a typical food in the Mexican States: Morelos, Guerrero and Michoacan. Where, seeds are consumed as roasted seeds or ground or mixed with different meats in chili sauces and the immature fruits are used in the preparation of soups (González, 1984; Gómez Pompa, 1985). Additionally, it was reported that *E. cyclocarpum* contains low values of thermolabile antinutrient factors, which do not constitute a risk to consuming seeds boiled in water (Serratos Arévalo *et al*., 2008).

This is a reason for analyzing the relationship between man and native foods of plant origin as the source of micronutrients is that today there are many people with “hidden hunger”, whose characteristics is micronutrient deficiency. From the second decade of the twentieth century came a change in eating habits of the world population mainly in countries in process of development. A cheap way of to satisfy the body’s caloric demand, man increased his food consumption based on refined grains and tubers poor in micronutrients such as minerals and vitamins. At same time, man divested the expensive native foods rich in micronutrients. The result of the change in dietary habits was to encourage the emergence of the epidemic of metabolic diseases related to human lifestyle. Also, it is important to establish government measures at the economic, cultural and health levels for the control of micronutrient malnutrition in the population of developing countries; it is an investment that will bring social benefits.

Pharmacological activities observed with the use of derivatives of E. cyclocarpum

Components extracted from hardwood were assessed in the protection of other woods against biodegradation by fungi, using the method described in standard ASTM D2017-71 (Anonymous, 1971). Tropical woods have a natural resistance to fungi and insects, e.g., heartwood from *E. cyclocarpum* was extracted with acetone, ethanol, hexane or water. Wood susceptible to biodegradation was treated with every type of extract and then exposed to fungal cultures. The aqueous extract of *E. cyclocarpum* had a reasonably good inhibitory activity of fungal growth. Extracts can be used for wood protection during storage and transportation to minimize losses in timber, pulp and paper industries (Bravo García and Amador Ramírez, 1992; Raya González *et al*., 2012b). This tree is used in the Mexican states, Mexico, Sonora and Veracruz for the treatment of respiratory ailments such as colds and bronchitis. The remedies are prepared with various parts of the tree such as the fruit, gum and the bark (in syrup) as well as the extract of the plant. Another uses are for skin asepsis and to heal the grains and pimples of the skin, they baths with the extract of the bark. Also, it is use for glucose decrease in blood, diarrhea, purifying, and for good digestion. It use of *E. cyclocarpum* to cure hemorrhoids has transcended beyond the American continent (González, 1942; Mendieta and Del Amor, 1984; Brook, 2000; Lawal *et al*., 2010). Although recently reported an infusion from heartwood was innocuous for the dimorphic fungus and pathogen *C. albicans* and other organisms of different trophic levels (Raya González *et al*., 2008). This apparent discrepancy may be due to natural variability that is present each individual.

Products derived from *E. cyclocarpum* had other pharmacological effects such as: a reduction in the population of ruminal protozoans and increased the presence of fungi in cattle fed with its leaves (Rosales *et al*., 1989; Navas Camacho *et al*., 1993). Saponins of this tree have shown hemolytic and spermaticide activity when applied to the vaginal mucosa of rats

(Abd Elbary and Nour, 1979). Extracts from *E. cyclocarpum* heartwood obtained with acetone or with a mixture of acetone:hexane:water (55:44:2 v/v) had insecticidal activity against subterranean termite *Coptotermes formasanus* Shiraki (Carter *et al*., 1975). Also, it was found that the aqueous extract of *E. cyclocarpum* has components that inhibit the activity of the Dihydrofolate reductase, a central enzyme in the metabolism of folates from fungi and other organisms (Damián Badillo *et al*., 2008).

Biotechnology use of E. cyclocarpum

Gum from *E. cyclocarpum* has interesting chemical and structural properties; it is soluble in water, exhibiting a high viscosity (100 mL/g). The polysaccharide that has been isolated from this rubber is made up of monomers such as; galactose, arabinose, rhamnose, glucuronic acid and their 4-*O*-methyl derivatives. The main chain corresponds to a β-D-(1-3) galactan (León de Pinto *et al*., 2000). *E. cyclocarpum* gum has been used as an additive, partial substitute for Arabic gum, also, it has been used in the preparation of ice cream, semi-decream liquid yogurt, and nectars of peach [*Prunus persica* (L) Batsch], which provides a viscosity better than mixtures of commercial gums, improved the stability of emulsions and prevented the formation of ice crystals of objectionable size, optimal capacity to produce foam and intensity of the color, best body and texture; all these features are of economic importance in food technology (Abu-Lehia *et al.*, 1989; Townsend and Nakai, 1983; Rincón *et al.*, 2005, 2006; Del Monte *et al.*, 2006).

The rubbery exudates are complex polymers that plants excrete in adverse conditions of temperature and humidity. These natural products are composed of a set of monosaccharides which can be exploited to the growth of fungi. Due to these characteristics a mixture of rubbery exudates of *Acacia glomerosa* and *E. cyclocarpum* had been used as culture medium for the identification of the fungal species such as; *Sincephalastrum racemosum*, *Monoascus ruber* and *Trichophyton mentagrophytes* (Mesa *et al*., 2000). These results corroborate the virtues of the culture media based in exudates of rubbery plants, for studies of isolation and identification of fungi.

Recently, it the *E. cyclocarpum* gum patented, the invention relates to a solid compound for intra-oral delivery of insulin, comprising insulin, a hydrophilic polymer matrix, providing insulin bioavailability of at least 5%. The compound is suitable for oral transmucosal delivery via buccal, gingival, lingual mucosa and/or sublingual mucosa **(**Pinhasi and Gomberg, 2006).

Our group reported that an aqueous heartwood extract form *E. cyclocarpum* protected perishable woods from *Pinus* spp and *Quercus* spp against deterioration caused by the drywood termite *Incisitermes marginipennis* (Latreille) (Raya González *et al*., 2012b). The polar nature of the extract and potential industrial use led to determine possible acute toxicity to man, it was noted that the aqueous extract of heartwood of *E. cyclocarpum* is harmless to humans (Raya González *et al*., 2008; Martinez Muñoz *et al*., 2009).

Phytochemistry of E. cyclocarpum

The heartwood from *E. cyclocarpum* is one specimen with richness in polar extractive substances containing 32.4%. Sequential extractions with different solvents indicated the following yield percentages: 14.88 acetone; 0.64 ethanol-water; 4.6 methanol and 1.98 water. *E. cyclocarpum* is a species that has been studied intermittently from the chemical point of view, from which several metabolites (see table 2) and for some of them the biological activities have been described. Betulinic acid inhibits growth of colon cancer cells and tumors and downregulates Sp transcription factors through activation of proteasome-dependent (SW480 cells) and proteasome-independent pathways (RKO cell) (Yogeeswari and Sriram, 2005; Chintharlapalli *et al*., 2011). Machaerinic acid lactone and derivates exhibit several pharmacologic effects such as, hypoglycemic, antinociceptive and analgesic effects (Yosikawa *et al*., 2001; Huo *et al*., 2006). By hydrolysis of this saponin was obtained the veracruzol (24-norolean-5-en-3-ol) (Domínguez *et al*., 1979). Albizziine was isolated from the seeds of *E. cyclocarpum* yielded on acid hydrolysis to L-(+)-2,3-diaminopropionic acid (Gmelin *et al*., 1959). Albizziine is a non-proteinogenic aminoacid and glutamine analog occurring in higher plants. It acts as a competitive inhibitor of asparagines synthetase with respect to glutamine, glutamate synthase and glutamine metabolism in mammalian cells, ectomycorrhizal fungal and other microbes, respectively. However albizziine does not compete with glutamine for the active site of glutaminyl-tRNA synthetase (Schroeder *et al*., 1969; Andrulis *et al*., 1985; Dura *et al*., 2002). Also, it has insecticidal and herbicidal properties (Navon and Bernays, 1978; Williams and Hoagland, 2007).

Recently, our group described that this tree produces D-(+)-pinitol (Raya González *et al*., 2008). It is a cyclitol compound that exhibit the ability to attenuate o suppress oxidative stress and the inflammatory process *e.g.* it is used as a nutritional supplement in patients with type II diabetes mellitus. It exhibits a hepatoprotective, immunosupresor and cardiovascular disease-preventing effects in Swiss albino mice and Wistar rats (Greenwood *et al*., 2001; Kim *et al*., 2005: Zhou *et al*., 2008; Chauhan et al. 2011).

Pinitol also, has been linked with insect larvicidal, oviposition stimulant in insect and antiviral activities (Papaj *et al*., 1992; Chaubal et al., 2005; Zhan et al., 2006).

Table 2
Phytochemical analysis and some biological effect of *E. cyclocarpum*.

Plant extract/metabolite	Organ	Biological effect	Reference
Viscous and agglutinant liquid	Green pod	Agglutinant and emulsifier	Espejel and Martínez, 1979
2,3-diamine propionic acid, Albizziine	Seeds		Gmelin *et al*., 1959
Triterpene saponin, veracruzol	Pulp and shell seed	Ichthyotoxic and bactericide	Domínguez *et al*., 1979
Galactose, arabinose, glucose, rhamnose, glucuronic acid	Trunk gum		León de Pinto and de Corredor, 1986, León de Pinto *et al*., 1994
Trypsin inhibitors, cianogenic glycosides, saponins	Seeds and foliage	biocide	Sotelo *et al*., 1980; Aguilar and Zolla, 1982
Threonine, lysine, leucine, valine, asparagine, glutamine, serine, histidine, glycine, arginine, alanine, tyrosine, methionine, valine, phenylalanine, isoleucine, luecine, tryptophan	Seeds	Positive feeding effect	Giral and Echegoyen, 1949; Massiu *et al*., 1950
Lionoleic, oleic, palmitic, linolenic acids	Seeds	Positive feeding effect	Ezeagu *et al*., 1998
Iron, Calcium, Phosphorus, ascorbic acid	Mature pod	Positive feeding effect	Espejel and Martínez, 1979
Albumins, globulins, prolamins, glutelins-1,	Seeds	Positive feeding effect	Serratos Arévalo *et al*., 2008.
Protoantocianidins, phenolic compounds, procianidins and flavonoids	Heartwood	Not determinated	
Pentanic extract		Antitermite	Carter *et al*., 1975
Hexanic extract	Bark	Fungitoxic	Rutiaga *et al*., 1995
Essential oils, phenolic compounds, terpenes, acetophenones	Heartwood	Antifeeding and antibacterial.	Raya González *et al*., 2012b.
D-(+)-pinitol	Heartwood	Antigluceamic, antiviral	Raya González *et al*., 2008.

As well as, some essential oils in the wood of heartwood (Raya Gonzalez *et al*., 2012a) among them the major components are the D-limonene that exhibits several benign effects such as anti-inflammatory, anti-tumorigenic of experimental skin tumor and anti-hyperlipidemic (Yoon *et al*., 2010; Chaudhary *et al*., 2012). The *p*-cymene exhibits an antifungal activity (Masotii *et al*., 2003). The butyrate hydroxytoluene is a well-know antioxidant compound. *p*-cymene-8-ol is a compound defense of the soldier *Curvitermes strictinasum* Mathews (Baker *et al*., 1981) and both it as α-terpineol are used as flavor and fragrance agents. In the volatile and non-volatile components secondary metabolites were found that can potentially be responsible for the protection of the dry wood of *Pinus* spp.

E. cyclocarpum exhibit a remarkably wide range of chemical diversity and a multiplicity of biological properties. By centuries, it has been in use for combating several human ailments. It contains small molecules with stereochemistry complex that have a significant pharmacological role in *e.g.* cancer and diabetes therapies. These features make to the natural products very specific for particular targets.

Plants used in traditional medicine to treat diseases including cancer and diabetes, indicating that there might still be valuable the ethnopharmacology approach to drug discovery. The screening of plant extracts is still an active area of research throughout the world, and it is entirely possible that novel pharmacologic agents, including those amenable to a semi-synthetic approach will be discovered in the future from *E. cyclocarpum*.

CONCLUSIONS

From *E. cyclocarpum* continued us learning the principles of their basic biology, as well as the use that has been given in traditional medicine, in agroforestry, in typical food given by the nutritional content of its leaves and seeds, biotechnological properties of gum that exudes and of the secondary metabolites as antiseptic, food, pharmacological and insecticides. Also, we have not understood the chemical basis of the great natural durability and resistance to the biodeterioration and biodegration showed for the heartwood of this species, whose knowledge could help us find new antiseptics and novel molecules.

E. cyclocarpum is a valuable natural resource which is involved in important areas of the human predatory character: (1) the tree has a restorative effect on degraded land and for controlling the erosion, fixing nitrogen, as ornamental specie it is preference for their huge glasses and beautiful foliage is used as forage. (2) It is a timber species of great craft value for its hardness and resistance of the heartwood to damage by fungi and termites so it is logged and extracted from the forest to transform in various articles. These circumstances have led to intensifying the investigation of the aspects of its basic biology, phytochemistry, ecology and agroforestry production, aiming at the rational exploitation of this natural resource of tropical and subtropical forests of the world.

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