

Myrtillocactus (cactaceae): botanical, agronomic, physicochemical and chemical characteristics of fruits

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Myrtillocactus (cactaceae): botanical, agronomic, physicochemical and chemical characteristics of fruits.

Abstract — Introduction. In Mexico, the *Myrtillocactus* fruit production levels are substantial, yet fruits are often under-used. Although the focus of interest is on their potential as food colourings, the fruits deserve more attention for their other food properties but information on their physico-chemical composition is scarce. To offer a baseline for the development of *Myrtillocactus* cultivation, we reviewed the information so far available. **Botanical description.** Four *Myrtillocactus* species have been identified and reported in the literature. They differ in shape, colour and other phenotypic characteristics. In Mexico, the predominant species is *M. geometrizans*, but *M. schenckii* also grows abundantly throughout the arid and semi-arid lands of the country. Cytological analyses performed on *M. geometrizans* showed that the plant is diploid ($2n = 22$). **Agronomic aspects.** *Myrtillocactus* species belong to the Cactaceae family. Because of their Crassulacean acid metabolism, they are able to grow in the arid and semi-arid highlands of Mexico. *Myrtillocactus* species have been propagated asexually by explants or cloning. Under controlled conditions, *in vitro* micropropagation from apical and basal explants gives rise to high yields. For cultivation, attention should be paid especially to minimum winter temperatures. **Description of fruits and biochemical characterisation.** The edible fruit is globular, with diameters reaching 1.5 cm. The pulp is gel-like, ranging in colour from glowing red to bluish. Chemical characterisation has mainly focused on betalain compounds, the predominant ones of which are betanin and betaxanthins. Contents are reported to be about 2.3 mg betalain · 100 g⁻¹ of pulp. Colour appears to be more stable than for red beets. **Human consumption and commercial importance.** In the production season (June to September), the fruits are found in all public markets in the states where they are grown. They are eaten either fresh or in processed forms. The commercialisation of the fruit is restricted mainly to rural production areas in certain states of Mexico. **Conclusions.** Our review establishes that published information on *Myrtillocactus* species is scarce and incomplete. The plant is under-utilised, despite its nutritional properties and commercial potential. Because they adapt easily to severely dry conditions, the *Myrtillocactus* species merit much more research.

Mexico / *Myrtillocactus* / fruits / pigments / agronomic characters

Caractéristiques botaniques, agronomiques, physico-chimiques et chimiques des fruits de *Myrtillocactus* (cactaceae).

Résumé — Introduction. Au Mexique, la production de fruits de *Myrtillocactus* est importante, pourtant ceux-ci sont souvent sous-utilisés. Bien qu'ils soient essentiellement exploités pour leur potentiel de colorants alimentaires, les fruits mériteraient davantage d'attention quant à leurs autres propriétés pour l'alimentation, mais les informations sur leur composition physico-chimique sont rares. Afin de disposer d'éléments de base pour le développement de la culture de *Myrtillocactus*, nous avons étudié les informations accessibles à ce jour. **Description botanique.** Quatre espèces de *Myrtillocactus* ont été identifiées et rapportées dans la littérature. Elles diffèrent par la forme, la couleur, et d'autres caractéristiques phénotypiques. Au Mexique, l'espèce prédominante est *M. geometrizans*, mais *M. schenckii* se développe également abondamment dans toutes les terres arides et semi-arides du pays. Les analyses cytologiques effectuées sur *M. geometrizans* ont montré que la plante était diploïde ($2n = 22$). **Aspects agronomiques.** Le genre *Myrtillocactus* appartient à la famille des cactacées. En raison de son métabolisme crassulacéen acide, la plante peut se développer dans les montagnes arides et semi-arides du Mexique. Les espèces de *Myrtillocactus* sont propagées asexuellement par explants ou par clonage. En conditions contrôlées, la micropropagation *in vitro* d'explants apicaux et basaux donne de hauts rendements. Pour la culture, une attention particulière doit être apportée aux températures hivernales minimales. **Description des fruits et caractérisation biochimique.** Le fruit comestible est globulaire, avec un diamètre atteignant 1,5 cm. La pulpe est colloïdale, sa couleur va du rougeoyant au rouge bleuâtre. La caractérisation chimique a principalement porté sur la composition en bétalaines, dont les composés prédominants sont la bétanine et les bétaxanthines. La teneur en bétalaines serait de 2,3 mg · 100 g⁻¹ de pulpe. Le colorant semble être plus stable que celui des betteraves rouges. **Consommation humaine et importance commerciale.** Pendant la saison de production (juin à septembre), les fruits sont trouvés sur tous les marchés de leur lieu de production. Ils sont mangés frais ou transformés. La commercialisation du fruit est limitée principalement aux zones de production rurales dans certains états du Mexique. **Conclusions.** Notre synthèse a établi que les informations publiées sur *Myrtillocactus* étaient rares et incomplètes. La plante est sous utilisée, en dépit de ses propriétés alimentaires et de son potentiel commercial. Comme les espèces de *Myrtillocactus* s'adaptent facilement dans des conditions de grande sécheresse, elles mériteraient de faire l'objet de beaucoup plus de recherche.

Mexique / *Myrtillocactus* / fruits / pigment / caractère agronomique

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Received 3 January 2008
Accepted 16 April 2008

Fruits, 2008, vol. 63, p. 269–276
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DOI: 10.1051/fruits:2008042
www.fruits-journal.org

RESUMEN ESPAÑOL, p. 276

Figure 1.
Plant of *Myrtillocactus*
geometrizzans (Console, 1897).



Figure 2.
Plant of *Myrtillocactus*
schenckii (Britton and Rose,
1920).



1. Introduction

Mexico is richly biodiverse, having 10% of the planet's total biodiversity. This includes various endemic species that are particularly well adapted to the edapho-climatic conditions found in specific regions of the country. For example, cacti of the *Myrtillocactus* genus grow in northern Mexico, which has arid or semi-arid regions that are unsuitable for agriculture. Because these plants have high nutritional value and can produce well without formal agronomic management, they are also suitable for niche fruit markets. *Myrtillocactus* species are also known as the blueberry or whortleberry cacti, being named after these plants for the similarity in size and colour of their respective fruits. Locally, they are known as *garambullo*. Production levels in Mexico are substantial, yet fruits are often under-used or consumed only locally. The agri-food sector's recent



Figure 3.
Plant of *Myrtillocactus*
eichlamii (Britton and Rose,
1920).

and growing interest in novel foods makes assessing the commercial potential of cactus fruits relevant. Although the focus of interest is on their potential as food colourings, the fruits deserve more attention for their other food properties. Information on the physico-chemical composition of *Myrtillocactus* fruits is scarce. Nor has much information been assessed to evaluate the agri-food chain. Nothing has been published on processing to obtain added-value products. These areas must be researched if a more formal production sector for *Myrtillocactus* fruits is to be developed. To offer a baseline for such a project, we reviewed the information so far available.

2. Botanical description

Four *Myrtillocactus* species have been identified and reported in the literature: *Myrtillocactus geometrizzans* [1] (figure 1) and *M. schenckii* [2] (figure 2), which grow in the arid and semi-arid lands of Mexico; *Myrtillocactus eichlamii*, a species endemic to Guatemala [2] (figure 3); and *M. cochal*, which grows in Todos Santos Bay, Baja California, Mexico [3] (figure 4).

The four species differ in shape, colour and other phenotypic characteristics (table I). The predominant *Myrtillocactus* species growing in the Tehuacán Valley near Mexico City is *M. geometrizzans* [4, 5]. This species is also reported as prevalent in the arid and semi-arid regions of the states of Guanajuato, Hidalgo, Querétaro and San Luis Potosí, and in highly restricted areas of the states of Chihuahua, Jalisco, Michoacán, Oaxaca, Puebla and Tlaxcala [6] (figure 5). Even so, no botanical evaluation has yet been performed [5]. *Myrtillocactus schenckii* also grows abundantly throughout the arid and semi-arid lands of Mexico [2].

The biodiversity of *Myrtillocactus* species in Mexico is now being analysed. Preliminary results, using molecular marker methodology (amplified fragment length polymorphism or AFLP), have confirmed the presence of only two differentiated species. These probable correspond to *M. geometrizzans* and *M. schenckii*. Cytological

Table 1. Phenotypic description of four *Myrtillocactus* species: *M. geometrizans*, *M. eichlamii* and *M. cochal*.

Plant structure	Height (m)	Branch diameter (cm)	Colour of branch	Ribs	Areoles	Spines	Flowers	Fruit
<i>M. geometrizans</i> (Console, 1897)	Commonly 2, rarely 4	6 to 10	Blue-green	5 to 6, 2-3 cm high	Along ribs	Radials: 5, rarely 8-9, 2-10 mm long Central: one, 1-7 cm long	White	Ellipsoid 2.8 cm long 2 cm diameter Purple
<i>M. shenckii</i> (Britton and Rose, 1920)	2, rarely 4.	6 to 10	Dark green	5 to 6, 2-3 cm high	Along ribs	Radials: 1-4 mm Trees without radial spines are common Central: 1, up to 2 cm, rarely 5 cm long	White	2 cm long 1.5 cm diameter Winecoloured and purple
<i>M. eichlamii</i> (Britton and Rose, 1920)	-	-	Dark green or slightly glaucous	4 to 5 (obtuse)	Along ribs (2 cm large)	Radial: 5 Central: 1	-	Globular up to 6 mm wine-coloured.
<i>M. cochal</i> (Britton and Rose, 1909)	1 to 3	-	-	6 to 8 (obtuse)	Along ribs	Radial: 5 Central: 1, 2 cm long	-	-



Figure 4. Plant of *Myrtillocactus cochal* (Britton and Rose, 1909).



Figure 5. States of Mexico where *Myrtillocactus geometrizans* and *M. shenckii* grow.



Figure 6. External and internal aspects of the fruit of *Myrtillocactus*.

analyses performed on *M. geometrizans* showed that the plant is diploid. Its chromosome count is $2n = 22$, where $n = 11$ [7].

3. Agronomic aspects

Myrtillocactus species belong to the Cactaceae family. Because of their Crassulacean acid metabolism, they are able to grow in the arid and semi-arid highlands of Mexico, where drought conditions are prevalent [8]. Field observations suggest that extreme freezing temperatures and high winter rainfall limit the distribution of these cacti in the Chihuahuan Desert [9] and other regions of Mexico. Otherwise, these species grow on mountain slopes with low-fertility soils, sometimes in competition with other plants. *Myrtillocactus* species also grow easily in good, well-drained, loamy soils, and tolerate the full summer sun [8]. Because of this ability, attempts have been made to introduce *Myrtillocactus* into other arid environments. Studies to evaluate their vegetative growth are now being conducted in the United Arab Emirates [10].

Myrtillocactus species have been propagated asexually by explants or cloning [11]. Although seed propagation is possible [12], the germination rate is very low, lower than in other common Cactaceae species [13]. However, both smooth and rough soil crusts have been found to positively affect seed germination in *M. geometrizans* [4]. Under controlled conditions, *in vitro* micropropagation of *Myrtillocactus* from apical and basal explants gives rise to high yields [14]. In some home gardens, young plants have been reproduced from seed or by grafting from branches of old plants.

According to Flores and Yeaton [9], when determining areas for plant cultivation, attention should be paid especially to minimum winter temperatures. If temperatures fall below 10 °C, a *Myrtillocactus* plant may not necessarily die, but its epidermis becomes irretrievably damaged, with dark marks appearing that eventually develop into unproductive cork-like tissue. Exposure to full sunlight encourages the glaucous colouring of the stem.

Céspedes *et al.* [6] reported that the common *M. geometrizans* is resistant to insect attack, a property that is apparently conferred by terpenoids (peniocerol 1, macdougallin 2 and chichipegenin 3). All these have been isolated from the plant's roots and aerial parts. Indeed, terpenoid extracts have shown insecticidal and insect-growth regulatory activity against two pests with wide distribution in Mexico: the fall armyworm (*Spodoptera frugiperda*), an important pest of maize crops; and *Tenebrio molitor* (Coleoptera) or mealworm beetle, a storage pest that attacks flours, ground meal and grains.

4. Description of fruits and biochemical characterisation

The fruits of *Myrtillocactus* species are globular in shape, and generally deep purple to bluish in colour when mature (figure 6). *Myrtillocactus geometrizans* yields the largest fruits, averaging 1.5 cm in diameter. The peel is thin and the flesh, which has a glowing red-wine colour, has a gel-like structure. The fruit contains numerous small black seeds (< 1 mm) spread throughout the fruit's volume. The complete physico-chemical characterisation of the fruit has not yet been published, as most research has focused on the water-soluble red pigments, despite the fruit presenting other interesting physico-chemical characteristics. For example, as in other species of Cactaceae such as *Opuntia ficus-indica*, the mucilage and juice appear very useful for their rheological properties and as sources of dietary fibre [15, 16].

The water-soluble pigments of *Myrtillocactus* are betalains. Content in fresh fruit is reported to be 2.3 mg·100 g⁻¹ [17], which is similar to that of fresh cactus pear of *Opuntia* (2.1 mg·100 g⁻¹ [18], ranging from 5.12 mg·100 g⁻¹ for a fully red variety [19] to only 1.04 mg·100 g⁻¹ in a yellow variety). In contrast, betacyanin content in *Myrtillocactus* is much lower than the 40 mg·100 g⁻¹ found in another cactus species known as the red pitahaya (*Hylocereus* sp.) [20], or even the 30–60 mg·100 g⁻¹ reported for red beet [21].

Analysing *Myrtillocactus* juice with HPLC shows four peaks, which correspond to betaxanthins (18.7%), betanin (71.60%), isobetanin (3.09%) and an unidentified compound (6.61%) [17]. The authors speculate that it may correspond to phyllocactin, a betacyanin found only in cactus fruit and flowers [22]. In contrast to the red pitahaya [20], the yellow pigment betaxanthin is present in *Myrtillocactus* juice.

Myrtillocactus juice, spray-dried at high temperatures and hydrated in acidified water solution at 0.014% (w/v), was very stable over 5 d of storage at room temperature. That is, colour losses were only 7% at pH 4, 1% at pH 5 and 4% at pH 6 versus 70%, 35% and 20%, respectively, for red beet juice treated under the same conditions [17]. Betacyanin from *Myrtillocactus* was surprisingly stable (10%–15% loss over 5 d) under conditions of daylight, at 25 °C, pH 5.5 and 0.1% ascorbic acid. The highest yields of betalain extracts were obtained by using an ethanol-HCl solution (99:1). However, the pigments were much less stable than when extracted with water [23].

Betalains from *Myrtillocactus* appeared most stable at pH 4.8–5.2, where their average half-life at 25 °C was 11,413 min (about 8 d) and at 60 °C, 83.5 min. Ascorbic acid at 0.1% was the best catalytic agent for stabilising the compounds tested. The presence of 0.1% ascorbic acid helped double the half-life and decrease the energy of activation from 25.8 kcal·mol⁻¹ to 22.1 kcal·mol⁻¹ [23].

5. Human consumption and commercial importance

Myrtillocactus fruits are widely grown, usually with no or poor agronomic management. Farmer-gatherers from Otomí Indian communities in Hidalgo State (Mexico) traditionally use this natural resource for their own consumption and for commercialisation [24]. In the production season (June to September), the fruits are found in all public markets in the states where they are grown. Usually, the fruits are eaten either fresh or in processed forms such as ice cream, jam, and, more rarely, a sun-dried raisin-like

product. *Myrtillocactus* flowers are also used to prepare a type of soup in some rural areas [5]. No literature exists on post-harvest physiology and technology; however, our preliminary results suggest a non-climacteric status of *Myrtillocactus* fruits; as a result, the fruit shows a short shelf life (2 d at room temperature; 5 d stored at 5 °C). On the other hand, we are currently developing technologies for the industrialisation of *Myrtillocactus* fruit to produce fruit powder, marmalade, raisin concentrates and juices.

The commercialisation of the fruit is restricted mainly to rural production areas in the states of Guanajuato, Hidalgo, Querétaro and San Luis Potosí. In these regions, almost 90% of adult rural dwellers say they are familiar with or have tasted the fruit, and 50% of children eat this fruit frequently [5]. Some analyses to test the innocuousness of the fruit's extracts were performed, using Wistar rats [25]. No toxicological or toxicokinetic effects were found for any dosage tested, which were as high as 5 g·kg⁻¹ body weight. Neither did the fruit extracts show any metabolic effect; that is, over 7 h, hepatocytes did not degrade betalain at any of the dosages tested. This showed that these components are not metabolised by hepatic cells. Moreover, the heartbeat rate of rats before and after ingestion of as much as 5 g·kg⁻¹ of *Myrtillocactus* betalain extracts did not reveal significant differences. On the contrary, the betalains should demonstrate beneficial effects for human health, as suggested by the high antioxidant activity found for other Cactaceae species such as those of the *Hylocereus* genus [20].

6. Conclusions

This review establishes that published information on *Myrtillocactus* species is scarce and incomplete. This crop demonstrates high potential for drought-affected areas with relatively poor soils in Mexico and elsewhere in the world. In a global warming context, drought-resistant crops that efficiently use water and produce edible fruits

deserve more attention. More research should therefore be carried out to assess the potential marketing interest of these fruits, particularly as the best way of preserving them and their biodiversity may add to their commercial value.

An international project (Producing Added Value from Under-utilised Crops or PAVUC), funded by the EU, is now assessing the entire biochemical composition of this fruit. As mentioned above, previous research has focused only on the colouring pigments to the exclusion of, for example, other phenolic compounds, vitamins or polysaccharides. Functional potential has not been assessed at all, even for Indian farmer-gatherers, for whom the fruits have high ethnic and traditional importance. Uses in traditional pharmacopoeia have not been described.

Studies to demonstrate antioxidant capacity and protective effect against certain diseases should also be addressed, particularly as the growing "functional" food market avidly seeks novel foods. In addition, the fruit supply chain itself should be studied to determine the possibilities of its development and integration into a regional or even international agribusiness supply chain. Likewise, the development of new derived products is important if convenient alternative uses in agro-industries are to be found. All these research lines would help to add value to a crop that may offer development alternatives to poor regions suffering drought, and, at the same time, provide food alternatives for consumers who want to improve and vary their diet with bio-diverse products.

Acknowledgements

Financial support from "Producing Added Value from Under-utilized Tropical Fruit Crops with High Commercial Potential" (PAVUC) (FP6-2003-INCO-DEV-2; Contract 015279. Sixth Framework Programme, Commission of the European Union) is acknowledged.

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***Myrtillocactus* (cactaceae): las características botánicas, agronómicas, fisicoquímicas y químicas de sus frutos.**

Resumen — Introducción. En México, el nivel de producción de fruta de *Myrtillocactus* es importante, no obstante la fruta es subutilizada. A pesar de que el foco de interés se centra en su potencial como pigmento para alimentos, el fruto merece mayor atención debido a sus propiedades como alimento que presenta; sin embargo, la información sobre la composición fisicoquímica que existe es muy escasa. Con el fin de ofrecer una base para el desarrollo del cultivo de *Myrtillocactus*, ofrecemos la información disponible a la fecha. **Descripción botánica.** Se han identificado y reportado en la literatura cuatro especies de *Myrtillocactus*. Estas especies difieren en forma, color y otras características fenotípicas. En México, la especie predominante es *M. geometrizans*, pero *M. shenckii* también crece abundantemente a lo largo de las áreas áridas y semiáridas del país. Un estudio citológico realizado en *M. geometrizans* mostró que la planta es diploide ($2n = 22$). **Aspectos agronómicos.** La especie *Myrtillocactus* pertenece a la familia Cactaceae. Debido a su metabolismo ácido *Crassulacean*, son capaces de crecer en las zonas altas áridas y semiáridas de México. Las especies de *Myrtillocactus* han sido propagadas asexualmente a través de explantes o por clonación. Bajo condiciones controladas, la micropropagación *in vitro* de explantes apicales o basales da buen rendimiento. Para su cultivo, se debe poner especial atención a las bajas temperaturas invernales. **Descripción del fruto y caracterización bioquímica.** La fruta comestible es globular, con un diámetro que alcanza 1.5 cm. La pulpa presenta una consistencia gelatinosa, de color que va de rojo a morado intenso. La caracterización química se ha enfocado principalmente en los compuestos betaláinicos, de éstos predominan las betaninas y betaxantinas. Se han reportado contenidos de hasta 2.3 mg de betaalina·100 g⁻¹ de pulpa. Aparentemente el pigmento es más estable que el de la remolacha. **Consumo humano e importancia económica.** Durante la época de producción (Junio a Septiembre), la fruta se puede encontrar en todos los mercados públicos en los estados donde crece. El fruto se consume fresco o procesado en diferentes formas. La comercialización del fruto se restringe principalmente a las zonas rurales de producción en algunos de los estados de México. **Conclusiones.** Nuestra revisión establece que la información publicada sobre las especies de *Myrtillocactus* es escasa e incompleta. La planta es subutilizada, a pesar de sus propiedades nutricionales y potencial económico. Dado que se adapta fácilmente a condiciones severas de sequía, las especies de *Myrtillocactus* merecen mayor investigación.

México / *Myrtillocactus* / frutas / pigmentos / características agronómicas