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ICARDA

Little-known and under–utilized edible Cacti

Editors:
Aroldo Cisneros, Loreto Prat and Carmen Sáenz

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FOREWORD

Plant genetic resources are the basis of global food security. It is therefore of the utmost importance to maintain the genetic diversity of traditional and regional varieties, improved cultivars and wild plants; as well as its interrelation with the environment that surrounds them. The Cactaceae family, commonly known as cacti, is a flowering plant family within the order Caryophyllales. The family of cacti includes about 2,000 species and 139 genera and its center of origin is distributed from southern California to northern Argentina and Chile with some exceptions, being Mexico the country with the highest diversity of species within this family, as well as a high level (78 %) of endemism. Among the above–mentioned numbers of cacti species and genera are the pitahayas (*Hylocereus* spp.), copao (*Eulychnia acida* Phil.), rumba (*Corryocactus brevistylus*), pitayas (*Stenocereus pruinosus*), ucles and mandacaru (*Cereus* spp.), saguaro (*Carnegiea gigantea*) and erect cactus pear (*Opuntia dilleniid*), among other mores, which are considered as *Little-known and under–utilized edible Cacti*.

In the middle of the eighties of the last century, some of those species were starting to appear in the international market, for example, Colombia was the first country that made the pitahaya known as an exotic fruit with the yellow pitahaya. Later other countries, especially Guatemala, Nicaragua and Mexico, attended the same market with red pitahayas of the genus *Hylocereus*. Due to the own growth of the world population and to the climatic changes that are observed nowadays, the cacti for its high efficiency in the use of water and the CAM type metabolism (Crassulacean acid metabolism) constitutes an attractive variant for its study and development as an exotic fruit crop. Due to that, it is necessary to establish a good management strategy of the cacti that can include the genetic resources conservation and preservation, to avoid genetic losses by the irresponsible exploitation.

The main management aims must be oriented to conserve the biodiversity of cacti, as well as to promote and stimulate the development and large-scale production of cacti around the world, with a view to its subsequent commercialization. In the medium and long term, this will represent an improvement in the social and living standards of the producers of these exotic fruit crops, due to a substantial increase in their income derived from the sale of their harvests. It will also contribute to the general food availability for the population, as well as to the strengthening and availability of marketable products at the international level, given the high added value that these fruits achieve in European, Asian, and American markets.

In this specific newsletter we are taking into consideration some genotypes from different cacti species which are used as edible cacti but on a small scale as regional food to feed the outstanding population in the countries where they are produced.

We decided to entitle this newsletter as *Little-known and under–utilized edible Cacti* with the aim to provide different topics with a simple language and reliable information about the multiple's new uses of cacti species. Topics such as genetic resources, hybridizations, alternative food compound for human feeding, edible cacti with future, growing cacti in northern Argentina, fruits as food for livestock and humans, properties and uses of new cacti for food and functional ingredients in drylands, are presented here.

By editors:

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Pitahaya´s genetic resources characterization, hybridizations and its different progeny traits

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Introduction

The pitahayas are night-blooming, hemi-epiphytes plants, endemic to the Americas, and belong to Cactaceae, subfamily Cactoideae, tribe Hylocereeae (Britton and Rose) Buxbaum. According to the New Cactus Lexicon, the genus *Hylocereus* comprises 14 species, and they are widely distributed in tropical and subtropical regions of the Americas from Mexico to northern Argentina (Mizrahi and Nerd, 1999; Bauer, 2003; Merten, 2003).

Hylocereus species are characterized by elongated, normally three-angled stems, and large flowers that are mostly white (rarely, pink or red), with large scales covering the ovary and tube (Nerd and Mizrahi, 1997). *Hylocereus monacanthus* (Lem.) Britton and Rose and *Hylocereus undatus* (Haw.) Britton and Rose are diploids ($2n = 2x = 22$), bearing large red scaled fruits (200-600 g) with purple and white flesh, respectively (Tel-Zur et al., 2004). *Hylocereus monacanthus* was reported to be self-incompatible (Lichtenzveig et al., 2000). *Hylocereus megalanthus* (Vaup) Bauer (Schumann ex Vaupel) Moran], resembles *Hylocereus* in its vegetative appearance, but it is a self-compatible tetraploid ($2n = 4x = 44$), bearing delicious but smaller fruits (80-200 g) with a spiny yellow peel. Seed viability varies among different *Hylocereus* species and within the same species. The pollen source influences fruit weight, and a positive correlation was found between fruit mass and total seed number. In addition, a high percentage of viable seeds (80-100%) were observed in *H. monacanthus* and *H. undatus* after cross-pollination. In *H. megalanthus,* the seed set was similar in self- and cross-pollination (Dag and Mizrahi, 2005).

Agronomical characterizations of different *Hylocereus* species

The genetic diversity in cultivated cacti is limited by the small number of progenitors and the loss of genetic variation during cultivation (Nobel 2002). Most of the domesticated cacti grown for fruit or ornamental flowers apparently originated from a relatively narrow germplasm base. Cacti are between the most threatened taxonomic groups assessed to date by the loss and degradation of their habitat; and one of the most important factors causing the loss of biodiversity is the intensive land uses and illegal collection (Goettsch et al., 2015).

A germplasm collection that includes 20 taxonomically identified species of the genera *Hylocereus*, *Selenicereus* and *Epiphyllum* was established in 1984 at Ben-Gurion University of the Negev (BGU), Israel (Mizrahi and Nerd, 1999; Tel-Zur et al., 2004; http://www.bgu.ac.il/life/Faculty/Mizrahi/Gene.html) for developing potential crops for sustainable agriculture in semi-arid and arid lands (Mizrahi, 2014).

Table 1 summarizes the results of average fruit weight, yield estimation (based on a plant density of 6250 plants per hectare, considering 80 cm between plants and 2.0 m distance between planting lines) and minimum days to ripen in different *Hylocereus* species.

Among the 35 pitahaya accessions from 10 *Hylocereus* species studied, a wide range of fruit weight was found. The lowest values of the average fruit weight were recorded for *H. megalanthus*; while the heaviest fruits average (474 g) was recorded for *H. undatus* accession 70-02-07.

Estimated yield per hectare showed the highest value for *H. monacanthus* accession 97-404 with 81.2 t/ha, whereas the lowest values were registered for *H. megalanthus* accession 96-667 (2.8 t/ha). In general, *H. megalanthus* showed lower performances, thus it is considered not profitable under Israeli cropping conditions. Among the evaluated species, *H. undatus* (accession 89-024) and *H. monacanthus* (accession 89-028) registered good yields, which are one of the most used species as commercial pitahaya fruit crops around the world. Figure 1 shows a sample of fruit diversity observed among the species and genotypes studied.

In the diploids *Hylocereus* species the minimum number of days until fruit maturation varied from 28 days in *Hylocereus* sp. accession 70-02-08 to 41 days in *H. triangularis*. Whereas flowers of the tetraploid *H. megalanthus* that blooming in early autumn (September – October) matured in 90 days while those that bloomed later (November – December) matured in 160 days. Ripening time is genotype-specific with considerable variability among *H. megalanthus* accessions. In general, ripening is relatively fast, about a month for most *Hylocereus* species and between two to three months for *Selenicereus* and *Epiphyllum* species (Tel-Zur et al., 2011).

High levels of variation for the agronomical traits were observed even among accessions of a single species, e.g., *H. undatus*. Average fruit weight is one of the most important agricultural traits, which may increase yield being, frequently, the target trait in breeding programs. However, big size fruits are often undesirable by consumers. In pitahaya, number of seeds per fruit was relatively high in most of the accessions with high viability. The seeds are small with a black testa, and their presence or absence can affect the fruit size and taste (Cisneros et al., 2011; 2013). Lower temperatures affected ripening time in the tetraploid *H. megalanthus*, making this process prolonged.

Figure 1. Samples of fruit diversity observed among the species and genotypes located at the Gene-Bank at Ben Gurion University of the Negev in Israel.

Hybridizations in *Hylocereus* species

Hybridization has played a major role in genetic differentiation of progeny, which is influenced by a combination of genetic introgression and evolutionary processes (Freeland et al., 2011). With the new era of genomic tools and next generation sequences (NGS) applied in genomic analyses nowadays it is possible to identify divergent taxa from different genetic contributions that can generate new genotypes with adaptation to specific environments, or with favorable agronomical traits (Cisneros and Tel-Zur, 2012; Cisneros et al., 2013).

Polyploidization has been the principal process in diversification and speciation of the plant kingdom. It has two forms, autopolyploidization and allopolyploidization. Autopolyploids can arise from a spontaneous, naturally occurring genome doubling, such as *Galax urceolata*

(Soltis et al., 2007). Allopolyploids result from the combination of two genetically and evolutionarily different genomes, as the case of *Triticum turgidum* (Zhang et al., 2010).

Table 1. Characterization of *Hylocereus* accessions: flowers per plant, fruit weight, potential yield and minimum number of days to fruit ripening.

Species	Accession number	Average fruit weight (g)	Estimated yield per hectare (t/ha) *	Minimum days to ripen
H. costaricensis	73-12-32	450	35.4	30
	89-023	270	26.3	
	99-854	286	29.0	
H. monacanthus	88-029	280	24.1	34
	89-028	379	55.4	30
	97-401	232	13.0	31
	97-403	187	27.3	30
	97-404	394	81.2	31
	99-856	126	6.1	37
H. undatus	70-02-07	474	48.0	29
	72-06-06	356	16.0	29
	88-027	293	29.6	32
	89-024	372	58.5	28
	89-026	147	19.2	32
	92-053	403	22.6	29
	95-004	343	27.0	33
	98-334	439	51.0	36
H. ocamponis	89-025	214	7.2	32
	94-031	370	5.5	35
H. triangularis	71-05-03	269	9.1	41
H. bronxensis	99-856	152	17.1	31
H. escuintlensis	99-853	160	6.6	38
H. guatemalensis	70-11-07	295	5.5	30
H. zabinski	99-855	345	32.3	30
H. megalanthus	88-023	86	3.5	90 days flowering in autumn 160 days flowering in winter
	88-054	96	7.6	
	90-001	77	4.6	
	90-002	99	6.3	
	90-003	267	16.0	
	93-003D	102	8.0	
	96-667	82	2.8	
	96-676	111	4.1	
Hylocereus sp.	70-02-08	424	49.2	28
	73-03-41	301	22.6	39
	98-337	359	20.2	35

* Estimated yield per hectare was calculated based on a plant density equal to 6250 plants

Crosses between the tetraploid *H. megalanthus* as the female parent and the diploid *H. undatus* or *H. monacanthus* as the male parent yielded about 5% of truth pentaploid, hexaploid and 6x-aneuploid hybrids, while the reciprocal cross, using *H. monacanthus* as the female parent, yielded a higher number (about 92%) of truth triploid and 3x-aneuploid hybrids (Tel-Zur et al., 2004). Endosperm breakdown is widely believed to be the cause of seed failure; however, seed abortion in vine cactus was probably due to a genomic imbalance between the seed parent and the embryo, rather than the maternal: paternal genome ratio in the endosperm (Tel-Zur et al., 2005; Cisneros and Tel-Zur, 2012; Cisneros et al., 2013). Endosperm dysfunction was the primary reason for hybrid abortion in a range of angiosperm families. Nowack et al. (2010) showed that the fertilized egg transmits a signal for development, but it cannot continue without the fertilization of the central cell.

Morphological traits of the *Hylocereus* progeny

In pitahaya breeding program, the use of morphological traits (such as tolerance to extreme temperature, fruit taste, spiny peel, etc.), described here for interspecific-interploid crosses (IH) and backcrosses (BC) increases our knowledge of the genetic variability available and facilitates the understanding of hybrid performance against the ploidy level. Variability in hybrid sensitivity to low and high temperatures exists among genotypes, and there are no genetic barriers among *Hylocereus* species that avoid crossing, breeding may solve these problems (Tel-Zur et al., 2004). Another important marketing barrier that might be solved with breeding programs is the poor taste of the red pitahayas, *H. monacanthus* and *H. undatus*. The delicious yellow pitahaya, *H. megalanthus*, can tolerate high temperatures better than the other species, but the fruits are smaller and spiny peel (Dag and Mizrahi, 2005).

Besides that, new interspecific-interploid crosses were carried out to obtain improved new hybrids. Morphological and agronomical fruit traits from a collection of IH and BC, are presented here. Variations in fruit form, from round to elongated ellipse, were observed based on the dissimilarities of the fruit shape index. Fruit shape is an important trait for marketing purposes since the consumers prefer to eat fruits with elongated form instead of round due to the more visually attractive fruit shape (Mizrahi, 2014).

A progeny of 78 plants including interspecific-interploid hybrids (IH) and backcrosses (BC), was evaluated during four consecutive evaluation seasons. Where, the number of flowers per hybrid per year that set fruits ranged from one (in three plants) to 21 (IH-052) flowers. Fruit weight ranged from 31 (BC-101) to 273 (IH-002) grams, which is considered as low as self-pollination fruits from the tetraploid *H. megalanthus* to similar than those obtained in the allotriploid hybrids used as female parents the 12-31 (264.8 g) and S-75 (248.2 g) reported in Tel-Zur et al. (2005).

The potential yield per plant, an important agricultural trait and a target trait in breeding programs, was calculated based on the number of flowers per year and mean fruit weight. Two accessions revealed a high potential yield, IH–003 and IH–052 with 3.25 and 3.72 kg/plant/year, respectively. The number of viable seeds/fruits was quantified in several hybrids studied, showing a very high percentage of viable seeds (more than 80%) in hybrids with ploidy level less than tetraploid; whereas this percentage was drastically reduced (up to 54%) when ploidy level was higher than tetraploid. Although the heritability of these traits has yet to be studied, and some are likely to have a substantial environmental component, the variations observed here suggest that pitahayas have a high potential as exotic fruit crops, intrinsically adapted to dry areas (Tel-Zur et al., 2011).

On the other hand, this progeny shows a flowering season from August to November. The time to full ripeness was extremely variable among the studied plants. The minimum number of days from anthesis until ripening was ranged from 52 days in IH–011 to 176 days in BC–024. This trait showed variation within IH and BC belonging to the same cross, for example, in the cross 12–31 × *H. undatus* fluctuated from 52 to 156 days, or in the cross S–75 × *H. monacanthus* varied from 61 to 170 days; which was, in some cases more than twice fold or similar to the observed in *H. megalanthus* (Table 1) like in the BC (12–31 × *H. megalanthus*) with 94 to 165 days.

Studying the inheritance and the fixing of agronomic characteristics was possible in the F_1 hybrids and BC descendants. Studies of the *Hylocereus* germplasm to obtain artificial variability followed by selection are needed and extremely useful to obtain new improved varieties. The results obtained are encouraging findings, which indicate that the studied characteristics are overall, under strong genetic control and that a genotype with a given performance could be selected and genetically improved (Figure 3).

Figure 3. Fruits traits in the F1 hybrids and BC progeny obtained in the evaluation and phenotypic selection processes.

Conclusions

Phenotypic characteristics of the vine cactus accessions indicated a high level of variability for most of the traits studied. Although the heritability of these traits has yet to be studied, and some are likely to have a substantial environmental component, the levels of variation reported here constitute a strong suggestion that these accessions have high potential for breeding programs as an exotic fruit crop intrinsically adapted to dry areas.

Hybridization is an important source for improved genotypes for cultivation. The results presented here showed the successful production of viable, interspecific–interploid hybrids which provides new avenues for the creation of potentially superior hybrids for commercial applications.

References

Bauer R (2003) A synopsis of the tribe *Hylocereeae*. F. Buxb. Cactaceae Syst. Init. 17:3–63

Cisneros A, Benega Garcia R, Tel-Zur N (2011) Ovule morphology, embryogenesis and seed development in three *Hylocereus* species (Cactaceae). Flora 206:1076–1084

Cisneros A, Tel-Zur N (2012) Evaluation of interspecific-interploid hybrids (F_1) and Back Crosses (BC_1) in *Hylocereus* species (Cactaceae). In: *Meiosis: molecular mechansims and cytogenetics diversity.* A. Swan (ed.) *In Tech* Publishers pp: 367–388

Cisneros A, Benega Garcia R, Tel-Zur N (2013) Creation of novel interspecific-interploid *Hylocereus* hybrids (Cactaceae) via embryo rescue. Euphytica 189:433–443

Dag A, Mizrahi Y (2005) Effect of pollination method on fruit set and fruit characteristics in the vine cactus *Selenicereus megalanthus* (''yellow pitaya''). J. Hortic. Sci. Biotech. 80:618–622

Freeland JR, Kirk H, Petersen SD (2011) Molecular Ecology. John Wiley and Sons, Chichester (UK)

Goettsch B, et al. (2015) High proportion of cactus species threatened with extinction. Nature plants 142:1–7. doi: 10.1038/nplants.2015.142

Lichtenzveig J, Abbo S, Nerd A, Tel-Zur N, Mizrahi Y (2000) Cytology and mating systems in the climbing cacti *Hylocereus* and *Selenicereus*. Am. J. Bot. 87:1058–1065

Merten S (2003) A review of *Hylocereus* production in the United States. J PACD 5:98–105

Mizrahi Y, Nerd A (1999) Climbing and columnar cacti: New arid land fruit crops. In: Perspective in new crops and new uses, Janick J (ed), ASHS Press, Alexandria, VA, pp: 358–366

Mizrahi Y (2014) Vine-cacti pitayas - the new crops of the world. Rev. Bras. Frutic. 36(1):124–138

Nerd A, Mizrahi Y (1997) Reproductive biology of cactus fruit crops. Hortic. Rev. 18:321–346

Nobel PS (2002) Cacti, biology and uses. Cambridge University Press, New York, USA

Nowack MK, Ungru A, Bjerkan KN, Grini PE, Schnittger A (2010) Reproductive cross-talk, seed development in flowering plants. Biochem. Soc. T. 38:604–612

Soltis DE, Soltis PS, Schemske DW, Hancock JF, Thompson JN, Husband BC, Judd WS (2007) Autopolyploidy in angiosperms: have we grossly underestimated the number of species. Taxon 56:13–30

Tel-Zur N, Abbo S, Bar-Zvi D, Mizhrahi Y (2004) Genetic relationships among *Hylocereus* and *Selenicereus* vine cacti (Cactaceae): Evidence from hybridization and cytological studies. Ann. Bot. 94:527–534

Tel-Zur N, Abbo S, Mizrahi Y (2005) Cytogenetics of semi-fertile triploid and aneuploid intergeneric vine cacti hybrids. J. Hered. 96:124–131

Tel-Zur N, Mizrahi Y, Cisneros A, Mouyal J, Schneider B, Doyle JJ (2011) Phenotypic and genomic characterization of vine cactus collection (Cactaceae). Genet. Resour. Crop Ev. 58:1075–1085

Zhang LQ, Liu DC, Zheng YL, Yan ZH, Dai SF, Li YF, Jiang Q, Ye YQ, Yen Y (2010) Frequent occurrence of unreduced gametes in *Triticum turgidum–Aegilops tauschii* hybrids. Euphytica 172:285–294

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The pitahaya (*Hylocereus spp.)* as an alternative food compound for human feeding

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Introduction

Pitahaya belongs to the *Cactaceae* family, and it is divided into two genera: *Hylocereus* and *Selenicereus* (Verona et al., 2020). García et al. (2015) mention that Britton and Rose (1920; 1963) recognized 18 species of *Hylocereus*, and Backeberg (1976) listed 24, with several authors having studied its systematics. The genus *Hylocereus* is native from southern of California (Unite State of America) to Central and South America. It also appears to be cultivated in various tropical and subtropical countries, including Ecuador, Colombia, Venezuela, Costa Rica, and Brazil; in some of them, the pitahaya grows wild. It is cultivated in Thailand, Australia, Taiwan, southern China, Malaysia, Israel, the United States, and Vietnam, where it is grown on a large scale and known as "Thanh Long" or "the green dragon" (Verona et al., 2020).

Pitahaya, also known as "Dragon fruit," is an exotic fruit that has gained popularity in recent years because of its success in the international market. It is considered a functional fruit. A functional fruit is a complete fruit: it provides nutritional properties and benefits human consumption. It also has high commercial value. Species of the genus *Hylocereus* have been the subject of significant research due to their use of food sources in traditional markets and their cultural significance. In some cases, they are also used for medicinal purposes.

The pitahaya fruit (Figure 1 A – B) consists of a peel with a beautiful color and protruding scales, a soft pulp that represents between 60% and 80% of the total weight, and edible black seeds embedded in the pulp (Figure 1C). Fruit acts as an antioxidant, helping to strengthen the immune system. Verona et al. (2020) conducted a comparison between the species *Hylocereus megalanthus* and *Hylocereus undatus*, with the latter standing out for its high vitamin C content, which contributes to the formation of collagen, red blood cells, bones, and teeth. Additionally, it is a low-calorie fruit. It also contains 14.84 grams of crude protein, 21.50 grams of crude fiber, and 39.94 grams of essential minerals.

Figure 1. The pitahaya fruits (*Hylocereus spp.*) at different stages of the process. Ripped pitahaya fruit on the plant branches (A); collected fruits from pitahaya in the lab (B), and fruit halves showing the seeds embedded the fruit flesh (C).

Thanks to its exotic fruit, which boasts a nearly unique flavor and shape, as well as its significant nutritional properties, *Hylocereus spp.* has established a strong position in the international market in recent years, leading to an increase in its commercial cultivation and the implementation of new techniques in plantations. However, there is still a lack of information among consumers about dietary alternatives for consuming this fruit and the benefits it offers. In this paper we are going to show additional applications of pitahaya products used as a human food and to explain about it.

Alternatives to pitahaya–based food and its benefits

Pitahaya (*Hylocereus spp.)* has a wide range of applications, including use in pharmaceutical applications, cosmetology, as an ornamental plant in homes, in the textile industry as a natural dye, and in food, both as a byproduct and in its natural form, including as a plant-based colorant. These uses are due to the many benefits this plant offers. For example, its stem and flower are consumed as salad in some rural areas of Mexico. Its seeds contain essential fatty acids that aid in skin nutrition and hydration. The pulp was studied in Sri Lanka by Jayasinghe et al. (2015) to produce yogurt integrated with pitahaya pulp, which was well received by consumers and showed nutritional properties. Even the peel is consumed and has been the subject of new technologies and studies due to its nutraceutical properties.

In several countries, pitahaya peel flour has begun to be implemented for food consumption. One example is the Faculty of Pharmacy and Biochemistry at the Universidad Nacional Mayor de San Marcos (UNMSM) in Peru, where researchers developed a functional bread using pitahaya peel as an alternative to traditional bread, which often contains additives that may be harmful to health. They noted that the fruit's residues contain a high amount of dietary fiber and other bioactive compounds.

Hernawati et al. (2018) conducted a study to investigate the role of pitahaya peel powder in male BALB/c mice (albino lab mice) with hyperlipidemia. The results showed that pitahaya peel powder helped to reduce total cholesterol, triglycerides, and low-density lipoprotein cholesterol (LDL-c) in the blood.

Pawde et al. (2020), in their research titled "Development of Fiber-Rich Biscuit by Incorporating Dragon Fruit Powder," developed biscuits using flour from pitahaya pulp (*Hylocereus undatus*) to increase fiber content. They studied the fiber and phenolic content that they could obtain from pitahaya in the biscuits. Four biscuit formulations were created by mixing pitahaya flour (MFP), which showed a high fiber content (15.7%) compared to refined wheat flour (RWF = 1.35%). The biscuit samples with MFP were prepared in ratios of 30:70, 40:60, 50:50, and 60:40 (% w/w MFP: RWF). The biscuits made with pitahaya flour (MFB) were compared to a control biscuit made with 100% refined wheat flour. The results showed that the biscuit made with a 50:50 ratio (MFP: RWF) had the highest fiber content (7.81%) compared to the control biscuit (1.33%). They concluded that consuming 100 g of MFP – based biscuits per day can meet up to 20% of the recommended daily intake (MDI) of fiber.

In our experience, we were working in cookies preparation on the base of pitahaya flour (Figure 2). Also, we were comparing the formulation with the proportional addition of pitahaya flour (PF) combined with wheat flour (WF). The ratio percentage used were 100:0; 95:5; 90:10 and 85:15 w/w (WF:PF), and the rest of compound (i.e., sugar, vinegar, egg and butter) were added in the same amount to each treatment. As a result, the cookies from the treatment combining 90:10 w/w WF:PF was considered the best combination. Because, that treatment obtained the highest qualification in likes with 93.3% followed by the others two PF treatment with 84.1% of likes, and in the last place was the control containing only WF (80.4% of likes).

In addition to the taste, we also checked the protein content based on the Kjeldahl method and the treatment with PF at 95:5, 90:10 and 85:15 increased the total protein content over the control – with only WF – at 40, 100 and 140%, respectively. Also, the fiber content was increased, as was reported previously by Pawde et al (2020).

Figure 2. After, the pitahaya peel was converted into pitahaya flour and used in the food elaboration. Cookies prepared with 90:10 w/w of wheat flour (WF): pitahaya flour (PF), at the tasting time (A), and a phase of protein quantification from the cookies by Kjeldahl method (B).

As well as the cookies, we were working with pitahaya fruit flesh to prepare gelatin and trying to reduce the normal gelling agent needed (Figure 3). In Figure 3, an example is shown of the first try with crashed white pitahaya fruit flesh (Figure 3A) which was added to the gelatin and after it was gelled, this food was considered with satisfactory taste and likes. Also, it is possible to observe a clear pink color (Figure 3B), due to the rest of the inner layer of the fruit peel which is rich in fiber and antioxidant agents. Anyway, this work is under analyses, and we continue working on it to determine its characteristics, nutrimental values and the benefices to the health and the human feeding.

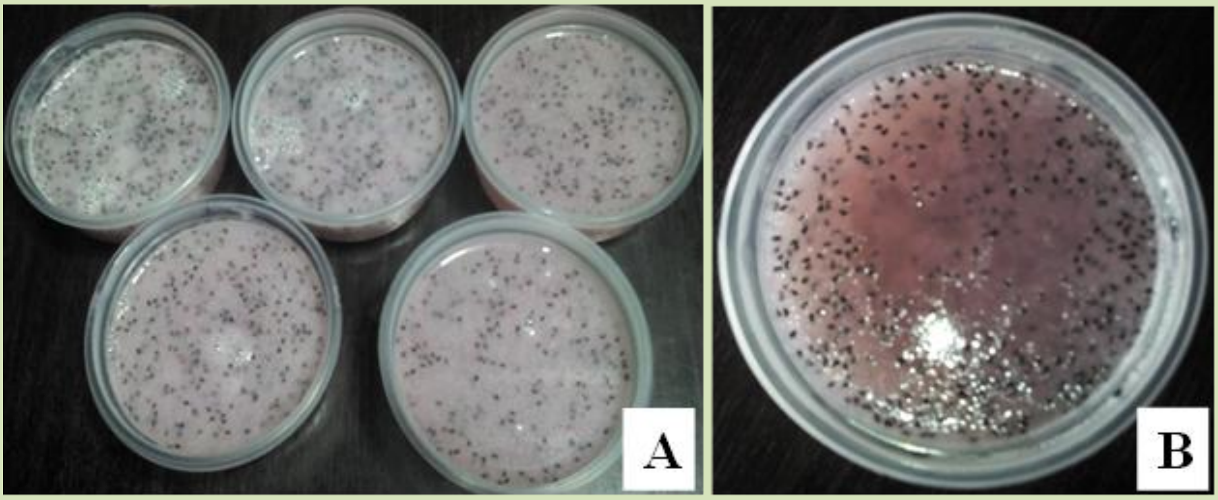

Figure 3. Pitahaya fruit flesh used in the food elaboration as a gelling in gelatin preparation. Gelatin prepared with crashed white pitahaya flesh after gelled (A), and the gelatin remain with a pink color due to the inner layer of the peel (B).

Conclusions

In conclusion, the results from some studies conducted on pitahaya-based foods (*Hylocereus spp.*) demonstrate that even what we sometimes consider 'waste' can also be utilized as a source of food that offers benefits, not just the fruit itself. There are many alternatives (among the numerous options available) that can be incorporated into our daily meals to lead a healthier life.

Integrating pitahaya into our daily diet will benefit us by providing vitamin C, which helps in collagen production. It also supplies iron to prevent anemia, as well as Omega-3 and Omega-9. It is an antioxidant that helps prevent chronic diseases and certain types of cancer, while also nourishing and hydrating the skin. Using pitahaya peel powder as a dietary supplement (e.g., in smoothies, yogurt, or juices) can help prevent hyperlipidemia and provide dietary fiber and essential nutrients.

References

García, R. L., Vargas, P. O., Ramírez, M. F., Munguía, L. G. and Corona, O. C. (2015). Distribución geográfica de *Hylocereus* (Cactaceae) en México. Bot. Sci. 93(4), 921-939. DOI: https://doi.org/10.17129/botsci.282

Hernawati, S., N., Shintawati, R. and Priyandoko, D. (2018). The role of red dragon fruit peel (*Hylocereus polyrhizus)* to improvement blood lipid levels of hyperlipidaemia male mice. J. Physics: Confer. Series 1013: 012167. DOI: 10.1088/1742-6596/1013/1/012167

Jayasinghe, O., Fernando, S., Jayamanne, V. and Hettiarachchi, D. (2015). Production of a novel fruit-yoghurt using dragon fruit (*Hylocereus undatus* L.). Eur. Sci. J. *ESJ*, *11*(3). Retrieved from https://eujournal.org/index.php/esj/article/view/4998

Pawde, S., Talib, M. I. and Parate, V. R. (2020). Development of Fiber-Rich Biscuit by Incorporating Dragon Fruit Powder. Int. J. Fruit Sci. *20*(sup3), S1620–S1628. DOI: https://doi.org/10.1080/15538362.2020.1822267

Verona, R. A., Urcia, C. J. and Paucar, M. L. (2020). Pitahaya (*Hylocereus* spp.): Culture, physicochemical characteristics, nutritional composition, and bioactive compounds. *Scientia* Agropecuaria, 11(3), 439-453. DOI: https://dx.doi.org/10.17268/sci.agropecu.2020.03.16

CACTUSNET

ICARDA

Copao and rumba: two similar edible cacti with future

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Introduction

Copao (*Eulychnia acida* Phil.) and Rumba (*Corryocactus brevistylus (K.Schum. ex Vaupel) Britton & Rose)* are native cactus species distributed in Northern Chile and a few in Central Perú, Bolivia and north Argentina. Those cacti produce edible fruits with chemical and functional components as phenolic compounds, dietary fiber, and antioxidant activity, suitable for human consumption as fresh fruit or for the food industry. By their external shape, although the rumba is larger, these cacti are similar.

The aim of this article is to provide information on some aspects of cultivation and characteristics of their fruits, which will encourage steps towards the domestication of these cacti.

Agronomic characteristics and management

The fruits of *Eulychnia acida* exhibit significant variability in size and weight across different populations in the Coquimbo Region (Masson et al., 2011). While propagation by seed is indeed possible and yields good germination rates with appropriate pretreatments, reliance on seeds alone is problematic due to this high fruit-trait variability. As a result, vegetative propagation through cuttings becomes essential for ensuring uniformity and preserving superior genotypes. Well adapted to stony soils and limited water availability, this species can be successfully established in the field with practices such as drip irrigation and wide planting spacing (plant spacing of 3–4 m); moreover, early protection of seedlings against herbivory and basic management practices like pruning and reducing interspecific competition help enhance growth and facilitate harvesting. Fruits are highly perishable and require careful handling, including de-spiny and cold storage to prolong shelf life. Overall, agronomic research underscores the necessity of sustainable cultivation protocols that reduce the pressure on wild populations while promoting the copao as a promising crop for both fresh and processed markets (Salvatierra et al., 2009).

Until now, rumba has not been cultivated, only the fruits are harvested, so that, although it is an interesting fruit, it is a longer way to go for its cultivation compared to copao.

Chemical, physical and functional composition of edible fruits

Copao is probably the closest to domestication for non-wild production on a larger scale in Northern Chile. It is a little round up to oval fruit, with a polar diameter of 5.7 cm and equatorial diameter of 5.8 cm with a weight average of 107.3 g (Jana et al., 2017) (Fig. 1). The mesocarp (pulp) represent 47.1-50.4 % of the fresh fruit weight and contain numerous seeds (Salvatierra et al., 2010). The fruit has a thick succulent shell green or pink skin, with small scales; the color is not related to the ripeness of the fruit. The ripeness of the fruit can be recognized by the bright color of the peel, turgidity and the separation of the scales on the skin (Arancibia and Salvatierra, 2018). It has a wide variability in weight and size. Like other cacti, it consists of more than 90% water and has an acidic taste, which likely explains its scientific name (*Eulichnia acida*). Its flavor resembles a mix of kiwi and lemon, and the pulp is soft, containing small, crunchy black seeds. It is sold as fresh fruit by small-scale farmers in northern Chile, while its industrial processing remains artisanal and incipient. Surveys in the region indicate that the species is distributed over approximately 430,000 hectares, with around 32,000 hectares considered suitable for harvesting. Based on these figures, the estimated production is just over 7,500 tons of fresh fruit during the summer season, specifically from December to March, with peak yields occurring between January and February. The commercialization of copao has been a regional tradition for two to three decades (FIA, n.d.).

Rumba is a big fruit with an average weight at maturity of 371 ± 64 g. The shape of the fruit is almost round with a polar diameter of 8.3 ± 0.6 cm and an equatorial diameter of 8.5 ± 0.5 cm. Pulp is white when unripe and turns green when ripe. The mesocarp (pulp) represent 62.0 ± 6.3 % of the fresh fruit weight and contain numerous seeds (Fig. 1) (Prat et al., 2025). This fruit is quite like the one produced by *Eulychnia acida*, only that it weighs three times more and has a higher percentage of pulp (Masson et al., 2011)

Figure 1. *Corryocactus brevistylus*-rumba mature plant (a); cross section of the fruit (b). *Eulychnia acida*- copao (c) (Photos rumba: R. Pinto/C. Sáenz and Copao: S. Figueroa)

The chemical and functional properties of the fruits are shown in Table 1. The pH of the fruit pulp is 2.6 ± 0.01; acidity is 2.2 ± 0.02 %; soluble solids are 2.3 ± 0.1 °Brix; and the ratio ss/acidity = 1.0. The pH, acidity, and vitamin C content of this fruit (35.9 ± 1.1 mg/100 g) are comparable with the 'Eureka' lemon juice (32.4 – 36.4 mg AA/100 mL); with unusually low soluble solids content (Marti et al., 2009). Important attributes for the acceptability of the fruit, both as juice or as fresh fruit, are the acidity and the sugar content, being both fruits similar in acid content (INIA, 2016); the soluble sugar/acidity ratio usually determines the harmony of flavor, being the fruits of higher acidity tasted as fresher compared to those with low acidity. Those attributes (acidity and °Brix) with a high pulp yield in both fruits make them suitable for refreshing beverages, where we can add honey or other natural sweeteners instead sugar, to make them more palatable. *C. brevistylus* is a fruit that contributed with an important vitamin C content (35.9-57.1 mg/100 g), compared with *E. acida* (18-33 mg/100 g) (Romero-Orejón et al., 2015). The total phenolic content was 16 mg GAE/100 g, lower than reported by Matos-Chamorrro et al. (2010) for different extraction conditions; by Areche et al. (2020) of 25.9-101.2 mg EAG/100 mL The antioxidant capacity 654 µm eq. Trolox/100 g was higher than the values reported by Matos-Chamorro et al. (2010); Areche et al. (2020) for different extraction conditions of 266.32 – 439.11 µg Trolox/g for antioxidant capacity in fruits from Perú. Both total polyphenol content and antioxidant capacity are lower than reported for cactus pear of 169 mg EAG/100 g pf and 1953 µmol ET/100 g pf, respectively (Portal antioxidantes.com, 2015). Both fruits are typical of the desert, where they contribute a high percentage of water and acidity and can therefore be used as a basis to produce soft drinks.

Artisanal uses

Although copao and rumba fruits are mainly consumed fresh, only copao is used in artisanal food production at the local level. Among the products made from it are marmalades, ice creams, juices, pulps, dressings, yogurts, and some baked desserts. These products could also be made from rumba.

Table 1. Chemical and functional characteristics of Copao and Rumba from Northern Chile (% fresh weight).

Parameter	*Corryocactus brevistilus* (rumba)*	*Eulichnia acida* (copao)**
Fresh weight (g)	371	169.4
High (cm)	8.3	6.54
Width (cm)	8.5	6.36
Pulp yield (%)	62	50.4
pH	2.6	2.7
Acidity (g /100 g citric acid)	2.2	2.4
Soluble Solids (°Brix)	2.3	2.9
ss/acidity	1.0	1.2
Total phenolic (mg GAE/100 g)	16	65.6
Vitamin C (mg AA/100 g)	35.9	30
Antioxidant capacity (µm eq. Trolox/100 g)	654	___

*Prat et al. (2025); **INIA (2016); Masson (2011)

Conclusions

Both copao and rumba fruits possess characteristics and bioactive compounds that make them attractive for fresh consumption and industrial processing. Therefore, it would be advisable to promote their domestication to increase fruit availability. In the long term, exchanges could also be established with other regions that have endemic cacti with potential for fresh consumption and food industry applications

References

Arancibia, V. and Salvatierra, M.A. (2018). Instructivo para la elaboración de mermelada de Rumpa o Copao. Instituto de Investigaciones Agropecuarias, Informativo N°82, 4 p. Centro Regional de Investigaciones Intihuasi, La Serena, Chile.

Areche, A., Hernandez, M., Cano, T., Ticona, J., Cortes, C., Simirgiotis, M., et al. (2020). *Corryocactus brevistylus* (K. Schum. Ex Vaupel) Britton & Rose (Cactaceae): Antioxidant, gastroprotective effects, and metabolomic profiling by ultrahigh pressure liquid chromatography and electrospray high resolution orbitrap tandem mass spectrometry. Front. Pharmacol. 11:417. doi:10.3389/fphar.2020.00417

FIA, n.d. Ficha de valorización de resultados 92. Potencial productivo y económico del Copao (*Eulychnia acida* Phil). 4 p.

INIA (2016). Antecedentes y productos elaborados de *Eulychnia acida* Phil. RUMPA o COPAO. Instituto de Investigaciones Agropecuarias. Chile.

Jana, C., Salvatierra, A., Díaz, D. and Martínez, L. (2017) Morphological and genetic characterization among wild populations of copao (*Eulychnia acida* Phil.), cactus endemic to Chile. Chilean JAR 77 (1): 3-14.

Martí, N., Mena, M., Cánovas, J.A., Micol, V., Saura, D. (2009). Vitamin C and the role of citrus juices as functional food. Nat. Prod. Commun. 4(5):677-700.

Masson, L., Salvatierra, M.A., Robert, P., Encina, C., Camilo, C. (2011). Chemical and nutritional composition of copao fruit (*Eulychnia acida* Phil.) under three environmental conditions in the Coquimbo region. Chilean JAR. 71(4):521-529.

Portal Antioxidantes.com. (2025). Base de Datos de Actividad Antioxidante (ORAC) y de Contenido de Polifenoles Totales (PFT) en Frutas.

https://portalantioxidantes.com/base-de-datos-de-actividad-antioxidante-orac-y-de-contenido-de-polifenoles-totales-pft-en-frutas/

Prat, L., Pinto, R., Apablaza, E., Carmona, J.C., Arancibia, D., Muñoz, C., and Sáenz, C. (2025). Cacti from Northern Chile with potential for domestication: Morphological, chemical, and functional haracterization of their fruits. Chilean JAR, *85*(2):232-244.

Romero-Orejón, F.L., Muñoz, A.M., de la Fuente-Carmelino, L., Jimenez-Champi, D., Contreras-López, E., Best, I., et al. (2022). Secondary metabolites of edible cacti (Cactaceae) from the South American Andes. In Vijayakumar, R., Raja, S. (eds.) Secondary metabolites-trends and reviews. IntechOpen. doi:10.5772/intechopen.102419.

Salvatierra, M.A., Masson, L, Encina, C. y Osorio, A. (2010). Copao (*Eulychnia acida* Phil.*)* Cactácea Endémica de Chile: Información Nutricional de sus Frutos y recomendaciones Generales. 32 p. Boletin N°212. Instituto de Investigaciones Agropecaurias. Centro Regional de Investigaciones Intihuasi, La Serena, Chile.

Salvatierra, M.A., Osorio, A., Massón, L. 2009. Caracterización de frutos de Eulychnia acida [copao, rumpa] y manejo agronómico básico de poblaciones naturales de la especie presente en la región de Coquimbo, Chile. VII Simposio de Recursos Genéticos para América Latina y el Caribe. v. 1: (p. 248-249). *https://hdl.handle.net/20.500.14001/35173.*

CACTUSNET

ICARDA

Possibilities for growing cacti in northern Argentina: *Cereus* spp. 'Ucles'

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Introduction

Northern Argentina is painted with colors during the months of December to March, not only because of the cactus pears, but also because of other cacti that adorn the environment with spectacular flowers and fruits, including the 'ucles' (*Cereus* spp.), which deserve attention both as food and as decoration. The beauty of the flowers of these tree-like cacti is even known in the lyrics of folk songs. In Argentina, they are distributed from the province of La Rioja to Jujuy, reaching as far as Bolivia.

In this scenario, where climate change is forcing us to generate new knowledge for the development of agriculture in marginal ecosystems, one of the strategies consists in recovering and valuing native and naturalized food genetic resources, in this case cacti, a representative component of the dynamics of arid and semi-arid environments (Bravo-Hollis, 1978), providing not only food and water, but also preventing the erosion and desertification of the soils where they thrive. *Cereus forbesii* and *Cereus stenogonus* (Otto ex C. F. Först) are part of this group and are found in north-western Argentina. (R. Kiesling, personal communication, 2025).

C. forbesii (Figure 1), known as 'ucles' by the people of north-western Argentina, is a columnar cactus with cylindrical, branched stems that can reach up to 7 meters in height. It has four to eight deep ribs and thorns. The flowers are 13 cm long with white-pink petals.

They open at night and are unscented. Fruits can grow in clusters of 4–8 per branch. The fruits are up to 12 cm long and 7 cm in diameter. They are oval and wine-red in color inside and out. They are succulent with red pulp and little flavor due to their low sugar content. They contain small, numerous black seeds (Ochoa et al., 2010).

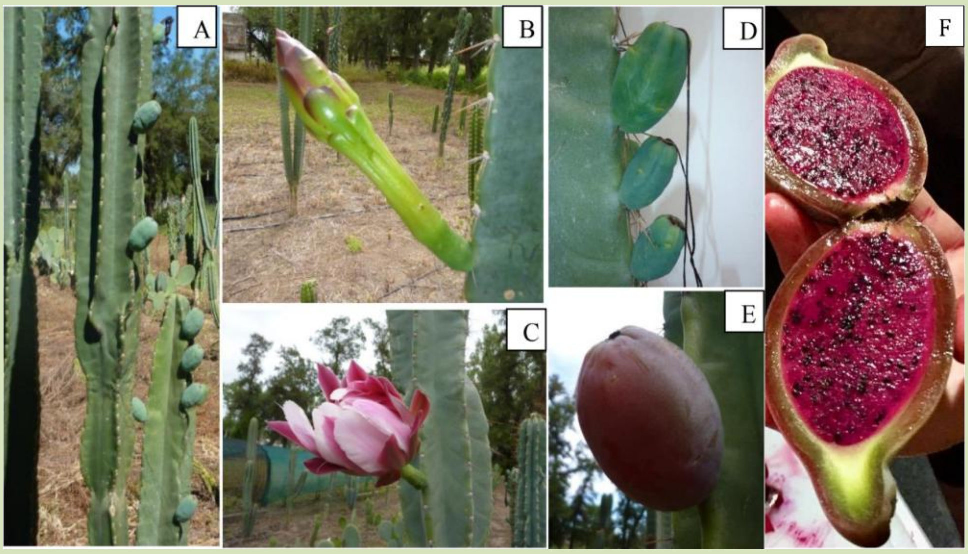

Figure 1. *Cereus forbesii.* (A) Plant, (B) Flower primordium, (C) Open flower, (D) Unripe fruits, (E) Ripe fruit and (F) Interior of a ripe fruit.

*C. stenogonus (*Figure 2), is a tree species that grows up to eight meters tall and has many branches. Its trunk is 1–2 meters long, 55 cm in diameter and very thorny. The branches are 8 cm in diameter, blue grey in color and have four to five ribs. The flowers are 20–22 cm long. The dark red fruits are 10 cm long and 3.5–4.5 cm in diameter, with pink or white flesh. (Hunt, 2006). Occasionally, the plants undergo a modification that causes the ribs to curl.

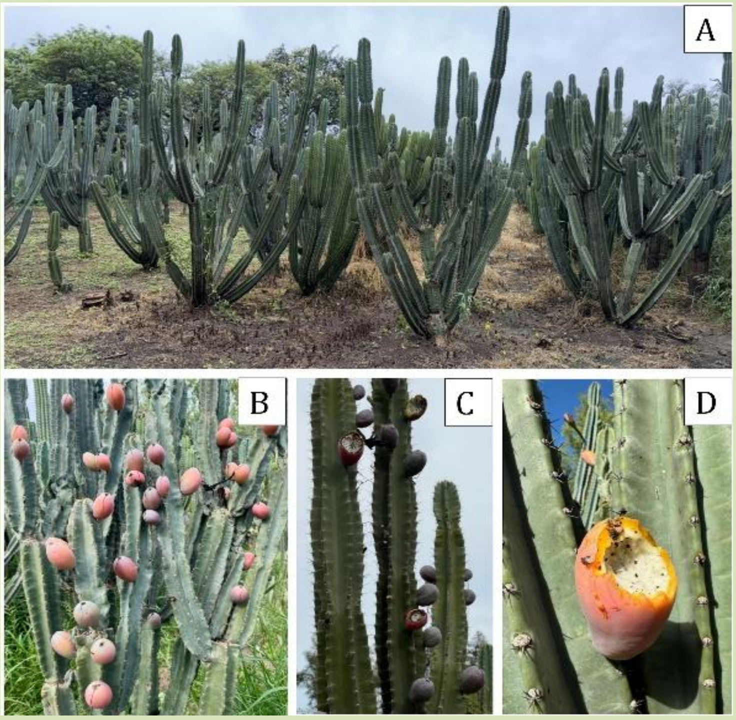

Figure 2. *Cereus stenogonus*. (A) Adult plants, (B and C) Plants with fruit and (D) Fruit damaged by birds.

The following are among the vernacular and potential uses of Cereus:

Food: it produces an edible fruit with red skin and pulp, which turns urine red when ingested. The fruit's skin can be red, orange or pink. The fruit can be used to make syrups and jellies. In Salta, the ashes are used to make a paste (yicta) that is chewed with coca leaves. **Medicinal**: Fresh fruit is sought after by those suffering from heat. The juice relieves intestinal pain caused by bile or cholera. **Handicrafts:** The thorns are removed from the stems, which are cut into 10 cm pieces, hollowed out, and used as candlesticks at wakes. The fruits are used to dye feathers and wool. **Ornamental:** It is easy to grow in well-drained soil in full sun. (Figures 3.A and 3.B). **Erosion control:** They make effective 'defense walls' to slow down sand dunes or control erosion in fragile soils. **Fences:** They make excellent living fences that attract numerous pollinators. (Figures 3.C and 3.D).

Figure 3. *Cereus* sps. (A and B) Ornamental use and (C and D) Used as a living fence.

Cereus sps: as a functional food

Studies indicate that consuming fruit and vegetables reduces the risk of contracting diseases related to oxidative processes, an effect attributed to their antioxidant properties. The fruits of this genus have moderate anti-radical activity, with values of 85 mg of vitamin C equivalent to per 100 grams of fresh fruit. As they are low in sugar (8.2º Brix), to improve consumer acceptance they are used in the production of jams, syrups and jellies, products that retain their anti-radical properties, can be consumed outside the normal harvest season and can be stored without refrigeration (Ochoa et al., 2010).

Some local research on the potential of its production

Since 2004, the FAyA of the UNSE has been carrying out various activities to generate information and greater knowledge about *Cereus* (*stenogonus* and *forbessi*) in a demonstration plantation (Figure 4) located in the school field (27º 45' S, 64º 18' W, 170 m above sea level).

This production system has the following characteristics.

Planting frame: 2.5 m x 1.5 m

Pruning: Carried out in the 4th year to break apical dominance and remove poorly located cladodes.

Weed control: Manual or with a weeder.

Organic fertilizer: Cow and/or goat manure 3 kg per plant, August-September.

Figure 4. *Cereus* sps. Plantation at the FAyA training field.

Physicochemical characteristics: The measurements taken on the fruits are summarized in Table 1,

References: Color: RHS Color Chart. Total weight: digital scale (Mettler Toledo). Diameter: manual caliper. Pulp (%): weight difference. SST: handheld refractometer (Atago). Firmness: manual penetrometer (Effegi).

Table 1. Characteristics of C. *forbessi* fruits measured over two seasons.

Variable	Year 1	Year 2
Epidermis color	GP 183 A (violet)	GP 183 A (violet)
Total weight (g)	191.74 ± 17.46 (a)	175.21 ± 21.04 (b)
Polar diameter (cm)	8.75 ± 0.44 (a)	7.85 ± 0.36 (b)
Equatorial diameter (cm)	6.66 ± 0.24 (a)	5.69 ± 0.30 (b)
Pulp (%)	51.27 ± 2.15 (a)	41.38 ± 1.77 (b)
SST (%)	11.36 ± 0.32 (a)	12.31 ± 0.38 (b)
Firmness (kg cm^{-2})	Not evaluated	1.74 ± 0.19

Phenological evolution

According to the work carried out by Miranda (2017), the growth of new cladodes (cylindrical vegetative segments) of *C. forbesii* takes place between November and February. On the other hand, the appearance of flowers is distributed over two distinct periods. The first period begins with the flowering buds in December-January and the second period in February-March, with a flowering period lasting from two weeks to one month. Fruit set occurs during the night, when the flowers open. Table 2 summarizes the information mentioned in this paragraph.

Table 2. Evolution of the phenological phases of *C. forbessi* in the teaching field of the Faculty of Agronomy.

Phases	*Cereus forbesii*
Sprouting	Nov.–Dec. and January–February
Flowering	Dec.–January and February–March
Flowering habit	Nocturnal
Fruit setting	January and March.
Ripening	March and June

References

Bravo-Hollis, H. 1978. Las cactáceas de México Vol I. National Autonomous University of Mexico, Mexico.

Hunt, D. R., Taylor, N. P. & Charles, G. 2006. The New Cactus Lexicon. dh books, England, Milborne Port, pp. 37–42.

Miranda, F. N. (2017). Characterisation of *Harrisia pomanensis* (ulúa) and *Cereus forbesii* (ucle), edible cacti of agronomic interest for the province of Santiago del Estero. Final project for the degree of agricultural engineer. Faculty of Agronomy and Agro-industries – National University of Santiago del Estero, Argentina.

Ochoa, M. J., Corvalán, D. B. and Nazareno, M. A. (2010). Cacti of Santiago del Estero. National University of Santiago del Estero, Argentina.

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ICARDA

Saguaro Plants and Fruits as Food for Livestock and Humans

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The Saguaro (*Carnegiea gigantea*) is a columnar cactus of the Sonoran Desert which towers over arid landscapes in southwestern Arizona and western Sonora, including a few of the easternmost islands in the Sea of Cortez (Wilder et al., 2008). Suitable habitat may extend as far south as the Río Fuerte valley in northern Sinaloa (Shreve and Wiggins, 1964). These giants, which can live for more than two centuries and reach over 12 meters in height, are emblematic of the region and have a deep cultural significance that extends far beyond their native range. Long the subjects of scientific study, their iconic silhouettes have also captured the imagination of the broader public, inspiring protections not only of the plants themselves but also vast swaths of terrain they inhabit. These plants feature prominently in local lore, while their fruits and flowers can play important roles in the food webs and traditional economies of the region.

Here, I explore historical and contemporary uses of the saguaro as food for humans and highlight the plant's importance to wildlife. (I have found no reliable accounts of saguaro plants or fruit being used as livestock fodder, other than records of their seeds occasionally being fed to poultry (Bruhn, 1971), and even then, apparently only after the fruit has been extracted for human consumption.). Saguaro flesh, unlike that of sympatric cactus pears (*Opuntia* spp.), has not been traditionally or commercially used as livestock forage.

For the Indigenous Peoples of the Sonoran Desert, the ripening of saguaro fruits signals what for some is the most culturally important annual harvest. Tohono O'odham and Akimel O'odham Peoples traditionally mark the beginning of their new year with the Saguaro Harvest Moon (Bruhn, 1971; Crosswhite, 1980; Rae, 1991). Saguaro fruits begin to ripen, turning from green to red, starting in mid-June to early July (Turner, 2005), just before the onset of the summer monsoon. This is typically the hottest and driest period of the year, when air temperatures in the shade are commonly above 35 °C for over 12 hours a day (Wolf, 2003). The fleshy saguaro fruits provide a reprieve during parched conditions when few other plants are fruiting.

The saguaro plant provides not only a fruit crop, but also the tools for reaching it. Traditional harvest of saguaro fruits is done with long hooked poles, fashioned from saguaro ribs and used to knock the fruits down from the lofty branch tips and crown (Manuel, 2020). The sweet pulp of saguaro fruits may be consumed fresh during harvest, cooked down into a jam or a thick syrup (Manuel, 2020), or pressed into cakes and dried in the sun for later use (Buckley, 2011). Juice from the fruits may also be consumed fresh as a cool drink (Manuel, 2020) or reduced into syrup and fermented into a low-alcohol content (~5%) wine used in ceremonies such as the prayers for summer rains (Castetter and Underhill, 1935; Bruhn, 1971; Crosswhite, 1980; Rae, 1991). Seeds are sometimes separated from the flesh, dried, and ground into meals that is mixed with water for oil extraction, used to make seed cakes, or cooked into mush or porridge (Bravo-Hollis, 1991). There are early accounts of seeds being valuable enough that they were sieved from dung for secondary use (Bruhn, 1971; Wolf et al., 2002). Archeological evidence suggests that the Hohokam people (300 CE - 1450 CE) used the slightly acidic saguaro wine for etching objects (Bruhn, 1971; Ceotto, 2009; Desert Archeology, 2024). Three alkaloids have been isolated from saguaro, which Bruhn (1971) states are similar in structure to those found in peyote though he notes that there is no evidence for (and I have found no further accounts of) humans having used these compounds psychoactively. The alkaloids are responsible for the "bitter" and "unpleasant" taste of the juice of the cactus flesh as reported by travelers who have sought it out as a source of water (Bruhn, 1971). The Native American Ethnobotany Database lists approximately 100 published accounts of Indigenous use of saguaro fruits and seeds (Moerman, 1998).

Humans are not the only denizens of the desert who look to the saguaro as a food source. Many wild animals feed upon the nectar, flowers, fruits, seeds, and even the flesh of this dominant species. Bats, particularly the lesser long-nosed bat (*Leptonycteris yerbabuenae*), feed on saguaro nectar and, while doing so, pollinate the flowers. Coyotes (*Canis latrans*), collared peccary (*Pecari tajacu*), and gray foxes (*Urocyon cinereoargenteus*) consume fallen fruit. Rodents feed upon juvenile saguaro plants (Niering, 1963; Turner, 1969; Steenbergh, 1977; Milchunas, 2006) that have not yet developed protective spines and toxic oxalates. White-throated wood rats (*Neotoma albigula*) are unusual among rodents in that they can digest the oxalates found in older saguaro (Shirley, 1967; Steenbergh, 1977; Hayes, 2013). In drought years, desert bighorn sheep (*Ovis canadensis*), jackrabbits (*Lepus* spp.), and other mammals have been documented gnawing on stem tissue or consuming the moist pulp of damaged saguaros (U.S. NPS, 2025). Desert bighorn sheep purportedly but their horns against the trunk to get at the soft flesh inside (Merlin and Lazaroff, 1998). Drezner's (2014) review lists over 100 animals that have been associated with saguaro. Among those which have economic relevance are the honey bee (*Apis mellifera)* and other hymenopteran pollinators, as well as a number of commonly-hunted species including white-winged doves (*Zenaida asiatica*), which migrate north specifically to feed on saguaro blossoms and fruits, dispersing seeds in the process, mourning doves (*Zenaida macroura*); Gambel's quail (*Callipepla gambelii*); antelope jackrabbit (*Lepus alleni*); black-tailed jackrabbit (*Lepus *californicus*); desert cottontail (*Sylvilagus auduboni*); desert bighorn sheep; collared peccary; coyote; and the gray fox. Tabulated, the reviewed list of associated species is impressively long; however, Drezner (2014) explicitly notes that it is only a partial tally, with many missing species.

Saguaro fruits contain valuable sugars, water, and dietary fiber. Individuals produce an average of 300 flowers each season, each producing 0.25 g of pollen (with 6 kJ energy) and 1 ml of nectar (3 kJ) per evening. Each fruit contains an average of 19.4 mL of water and 6.6 g of dry mass fruit pulp and seeds (90 kJ) (Wolf and Martinez del Rio, 2003). There may be as many as 2000 or more tiny black seeds per fruit (~992,000 seeds per kg), making up nearly half of the fruit's dry weight (Niering et al., 1963). These seeds are rich in carbohydrates (54% dry mass), oils (30%) and protein (16%) (Bruhn, 1971, Wolf and Martinez del Rio, 2003). This combination of carbohydrate-rich pulp and protein-rich seeds gives the saguaro fruit high nutritional value in what might be an otherwise lean diet for desert-dwelling animals and humans alike (Yetman, 2007).

In addition to being a rich source of nutrients, energy, and water—for a brief time in the hottest, driest part of the year—saguaro fruits are also incredibly abundant (Fig. 1). Wolf and Wolf and Martinez del Rio (2003) calculate that a one-hectare stand (with approximately 20 saguaro plants) can produce enough resources to fuel 35 white-winged doves for about 60 days. Perhaps this pulse of energy into the system accounts for the 40 or so species of birds that breed in the Arizona Sonoran Desert during the summer (Wolf and Martinez del Rio, 2003).

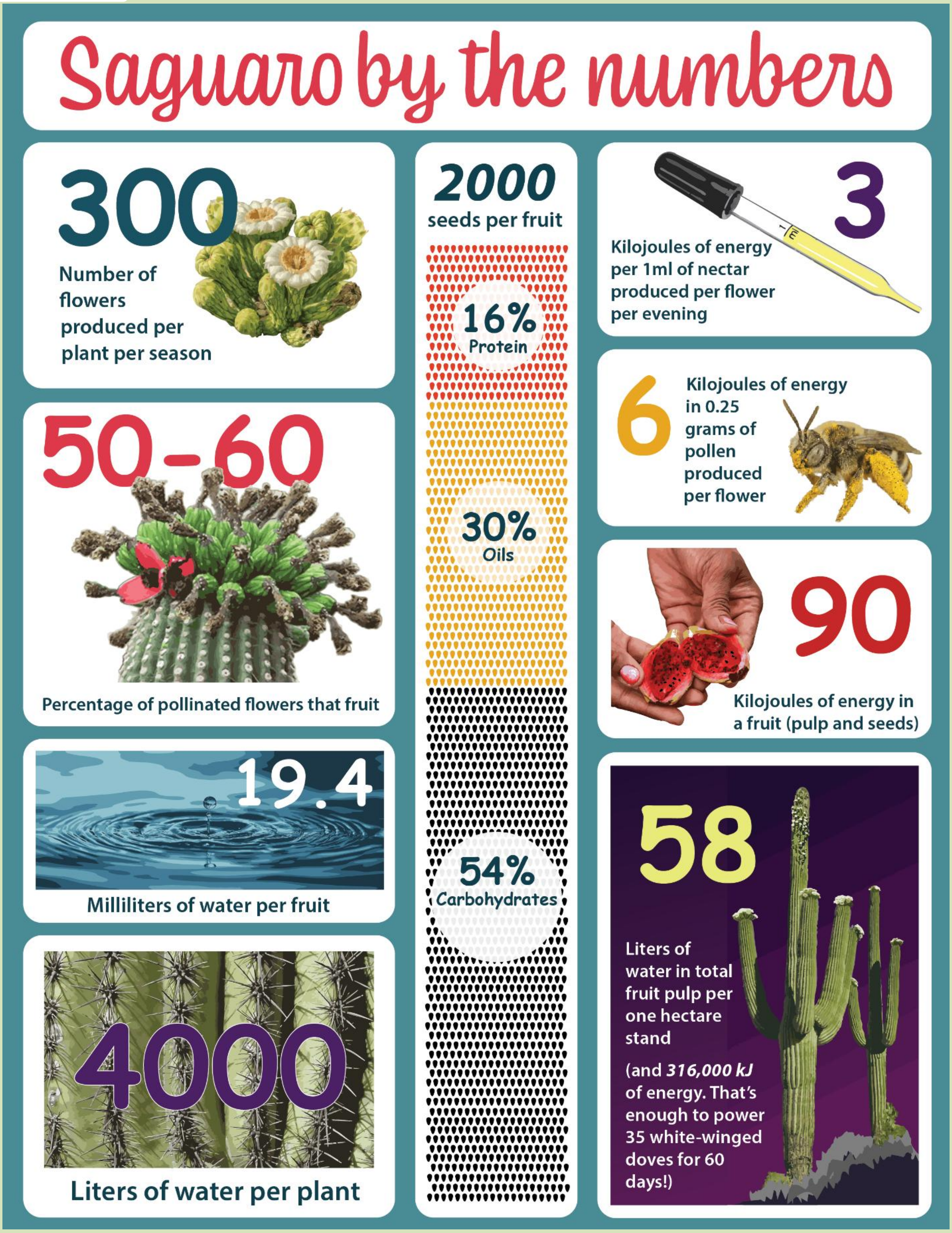

Figure 1. In the Sonoran Desert region, saguaro plants provide an invaluable source of water, nutrition, and energy during the hottest and driest season of the year. Numbers are approximate and based on Wolf et al. (2002); Wolf and Martinez del Rio (2003); Niering et al. (1963); Bruhn (1971); and Yetman (2007).

In contrast to other cactus species in the region, and despite saguaro's ecological role as a "keystone species" providing nutrition for people and wildlife, there are no accounts of these plants having been used traditionally or commercially for livestock fodder, other than the seeds secondarily being fed to poultry. Like many cactus species, saguaros can store a great amount of water, some authors have estimated that saguaro stems may hold as much as 4000 liters of water, calculated by the estimated percentage of water by the stem fresh weight (Wolf and Martinez del Rio, 2003). Species in the cactus family use Crassulacean Acid Metabolism, which is four to five times more efficient in converting water to dry matter than even the most efficient grasses (Russell and Felker, 1987). Across the Sonoran Desert and adjacent arid areas there are long traditions of feeding cactus to livestock. Cactus pear pads (*Opuntia spp.*) and, in some cases, cholla (*Cylindropuntia* spp.) are sometimes burned or chopped to remove spines and then fed to cattle, sheep, or goats as emergency forage. Such practices are well documented in Mexico, Brazil, and the southwestern United States (Russell and Felker, 1987; Nobel, 1994). Modern agricultural extension literature continues to promote cactus pear as a drought-resilient forage crop because of its high-water content, palatability, and ease of cultivation. However, saguaros have never been managed in this way.

There are a few possible explanations for why saguaro has not been used as wildlife fodder. First, saguaros grow extremely slowly, taking decades to reach fruiting size. Unlike Opuntia, which can be propagated easily and harvested within a few years, saguaros are ecologically and temporally unsuitable as a renewable forage source (Crosswhite, 1980). Second, there may be cultural protections. Traditionally, for local Indigenous groups, the fruit harvest is a sacred activity tied to community identity and ritual. Saguaros are sometimes referred to as "people" in oral traditions, and harvesting is governed by protocols that respect the plant's role in desert cosmology. There are accounts of local Peoples curving roads during construction to avoid disturbing saguaro plants (Small, 2014). It is apparently a crime among the Tohono O'odham to cut a saguaro down (Drezner, 2014). This cultural framework contrasts with the utilitarian approach to cactus pear, which was domesticated and bred into spineless forage varieties in Mexico and elsewhere. Saguaros were never subjected to this type of domestication pressure; instead, they remained emblematic of desert heritage and identity. Finally, there are modern legal protections. Since the mid-20th century, laws in Arizona and Mexico have prohibited cutting or damaging saguaros without special permits (Marshall, 2011). Today, saguaros are protected by state and federal laws in the U.S. and by environmental regulations in Mexico (Small, 2014). In Arizona, the Native Plant Protection Act requires permits for moving, cutting, or collecting any part of a saguaro. In Mexico, saguaros are listed as "amenazada" (threatened) under NOM-059-SEMARNAT-2010, restricting their harvest. As a result, saguaros are not only impractical but also illegal to use as fodder for livestock. Their role has been — and remains — symbolic, cultural, and ecological, rather than agricultural. Particularly in the face of a changing climate and ecological conditions (Albuquerque et al., 2018; 2025), saguaro's future lies in conservation, cultural preservation, and continued ecological study rather than agricultural exploitation.

While cactus forage remains a vital adaptation strategy to climate stress in arid ranching systems, not all cacti are candidates. For cactus researchers and practitioners, this distinction is important. The saguaro reminds us that some species must be protected for their ecological and cultural roles, while others, like cactus pear, can be harnessed for sustainable fodder. Recognizing and respecting these differences ensures that cacti-based agriculture develops in ways that aligns with conservation and cultural values.

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References

Albuquerque, Fabio, et al. "Potential changes in the distribution of *Carnegiea gigantea* under future scenarios." Peer J 6 (2018): e5623.

Albuquerque, Fábio Suzart de, et al. "Integrating habitat suitability, disturbance, and biotic interactions into the ecological restoration of the saguaro (*Carnegiea gigantea*) in drylands of the southwest of the United States and northern Mexico." Restor. Ecol. 33.6 (2025): e14357.

Bravo-Hollis, Helia. "Las cactáceas de México." *Mexico: UNAM.* 3 (1991): 404p.

Bruhn, Jan G. 1971. Carnegiea gigantea: The saguaro and its uses. Economic Botany. 25(3): 320-329.

Buckley, Steve (2011) (First published 2009). Common Plants of Saguaro National Park (PDF). National Park Service; Sonoran Desert Network. p. 63. Archived from the original (PDF) on February 11, 2017.

Ceotto, Enrico. "Cultivation of *Carnegiea gigantea* from seeds: a journey in desert ecology." Desert Plants 25.1 (2009): 10.

Crosswhite, Frank S. (1980) "The annual saguaro harvest and crop cycle of the Papago, with reference to ecology and symbolism." 2(1), University of Arizona, USA.

Desert Archeology, Inc. 19 November 2024. Ancient Technologies: Hohokam Etched Shell. https://desert.com/etched-shell/#:~:text=The%20fermented%20saguaro%20juice%20would,design%20that%20would%20be%20visible. Accessed 5 September 2025.

Drezner, Taly Dawn. 2014. The keystone saguaro (*Carnegiea gigantea*, Cactaceae): A review of its ecology, associations, reproduction, limits, and demographics. Plant Ecol. 215(6): 581-595.

Hayes, C. L.; Talbot, W. A.; Wolf, B. O. 2013. Woodrat herbivory influences saguaro (Carnegiea gigantea) reproductive output. J. Arid Environ. 89: 110-115.

Manuel, Dodie. Baidaj Harvesting. 5 August 2020. O'Odham Action News. https://oan.srpmic-nsn.gov/baidaj-harvesting/. Accessed 5 September 2025.

Marshall, Laura Lee. Flora of Usery Mountain Regional Park and Pass Mountain Region of Tonto National Forest, Arizona and Distribution of Saguaro (*Carnegiea gigantea*) on Pass Mountain in Southern Tonto National Forest. Diss. Abtr. Int. (49):05. 2011.

Merlin, Pinau, and David W. Lazaroff. "Hooved Animals." Arizona-Sonora Desert Museum, 1998, www.desertmuseum.org/books/nhsd_hooved.php. Accessed 5 Sept. 2025.

Milchunas, Daniel G., ed. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Moerman, Daniel E. *Native american ethnobotany*. Vol. 879. Portland, OR: Timber press, 1998. Accessed 5 September 2025. http://naeb.brit.org/

Niering, W. A.; Whittaker, R. H.; Lowe, C. H. 1963. The saguaro: A population in relation to environment. Science. 142(3588): 15-23.

Nobel, Park S. Remarkable Agaves and Cacti. Oxford University Press, 1994.

Russell, Charles E., and Peter Felker. "The prickly-pears (Opuntia spp., Cactaceae): A source of human and animal food in semiarid regions." Econ. Bot. 41.3 (1987): 433-445.

Rea, Amadeo M., 1991, Gila River Pima Dietary Reconstruction, Arid Lands Newsletter 31:3-10

Shirley, Emily K.; Schmidt-Nielsen, Knut. 1967. Oxalate metabolism in the pack rat, sand rat, hamster, and white rat. J. Nutr. 91(4): 496-502.

Shreve, Forrest; Wiggins, Ira L. 1964. Vegetation and flora of the Sonoran Desert. Stanford, CA: Stanford University Press. 2 vols. 1740 p.

Small, Ernest. 2014. Blossoming treasures of biodiversity 44. Saguaro - threatened monarch of the desert. Biodiversity 15(1): 39-53.

Steenbergh, Warren F.; Lowe, Charles H. 1977. Ecology of the saguaro: II. Reproduction, germination, establishment, and survival of the young plant. National Park Service Scientific Monograph Series Number 8. Washington, DC: U.S. Department of the Interior, National Park Service. 242 p.

Turner, Raymond M.; Alcorn, Stanley M.; Olin, George. 1969. Mortality of transplanted saguaro seedlings. Ecology. 50(5): 835-844.

Turner, Raymond M.; Bowers, Janice E.; Burgess, Tony L. 2005. Sonoran Desert plants: An ecological atlas. Tucson, AZ: The University of Arizona Press. 504 p.

U.S. National Park Service. "The Saguaro Cactus." National Park Service, 10 June 2025, https://www.nps.gov/sagu/learn/nature/saguaro.htm. Accessed 5 Sept. 2025

Wilder, Benjamin T., Richard S. Felger, and Humberto Romero Morales. "Succulent plant diversity of the Sonoran islands, Gulf of California, Mexico." Haseltonia 2008.14 (2008): 127-160.

Wolf, B. O.; Martinez del Rio, C. 2003. How important are columnar cacti as sources of water and nutrients for desert consumers? A review. Isot. Environ. Health Stud. 39(1): 53-67.

Wolf, Blair O.; Martinez del Rio, Carlos; Babson, Jeffery. 2002. Stable isotopes reveal that saguaro fruit provides different resources to two desert dove species. Ecology 83(5): 1286-1293.

Yetman, David. The great cacti: ethnobotany & biogeography. University of Arizona Press, 2007.

Zhong, Raymond. Even Cactus Might Not Be Safe From Climate Change. New York Times. 14 April 2022. https://www.nytimes.com/2022/04/14/climate/cactus-climate-change.html

Opuntia dillenii fruit: Properties and uses

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Opuntia dillenii (Ker-Gawl.) Haw., is a member of the Cactaceae family, widely distributed in tropical and subtropical regions. This cactus species is recognized for its distinctive fleshy cladodes and brightly colored fruits, which are often consumed fresh or processed into various food products. Beyond its culinary applications, the fruit has attracted scientific attention due to its nutritional richness, phytochemical profile, and ethnomedicinal heritage.

Origin, distribution, and ecology

Opuntia dillenii, commonly referred to as Erect Prickly Pear or Dillen's Prickly Pear, is a cactus specie native to the southeastern United States, eastern Mexico, and the West Indies. It has been introduced to northern South America and is now widespread in warm, dry climates worldwide. Notable wild populations can be found along the Gulf Coast of Texas, throughout the southeastern coastal region of Brazil, in Ecuador, and in various locations, including the Mediterranean, Canary Islands, Madagascar, Mauritius, northern Yemen, India, Southeast Asia, and Australia (Sharma et al., 2015; Díaz-Delgado et al., 2024). In many regions, it is recognized as an invasive plant species. Ecologically, it is one of the most common *Opuntia* species in dry coastal scrub vegetation, sandy dunes, edges of maritime forests, and areas associated with tropical plants, reflecting its adaptability to saline soils and arid coastal environments. This plant is suitable for light (sandy) and medium (loamy) soils. It prefers well-drained soil and can thrive in nutritionally poor conditions. The ideal pH range for growth includes mildly acidic, neutral, and mildly alkaline soils. It cannot grow in shaded areas and prefers dry or moist environments, although it is also tolerant of drought conditions.

Morphological Characteristics

This shrubby cactus is characterized by its flat, fleshy cladodes, which are elliptic to obovate and can grow up to 40 cm in length. The plant features stout, yellow-brown spines that range from 1.5 to 6 cm in length, as well as prominent tufts of barbed bristles, known as glochids, emerging from its areoles (Figure 1). The bright yellow flowers are hermaphroditic and bloom predominantly on the upper sections of the cladodes. After flowering, the plant produces fleshy, pear-shaped berry fruits that measure between 4 and 7 cm in length and turn reddish-purple as they mature. The surface of the fruit is covered with glochids, which must be carefully removed before consumption due to their irritating nature. The fruit's pulp is juicy and sweet, but when not fully ripe, it results in a gentle acidity. It contains numerous hard seeds embedded within the mesocarp, which can make it less convenient for eating raw. Its vibrant coloration is attributed to the presence of betalain pigments, which also contribute to its antioxidant properties.

Nutritional and Functional Properties

The fruit of *Opuntia dillenii* is a rich source of carbohydrates, dietary fiber, vitamin C, total phenolics, and essential minerals such as potassium, magnesium, calcium, chromium, and iron (Díaz Medina et al., 2007). It also contains significant amounts of betalain (betacyanins and betaxanthins) pigments, carotenoids, and flavonoids, which account for many of its health-promoting effects (Gómez-Maqueo et al., 2021; Gómez-López et al., 2021). The specific compounds identified include betanin, isobetanin, neobetanin, indicaxanthin, piscidic acid, and isorhamnetin glycosides. Seeds are rich in polyunsaturated fatty acids, sterols, vitamin E, and phenolic compounds (Ghazi et al., 2013; Ali Alsaad et al., 2019), while cladodes are high in mucilage polysaccharides, phenolic and flavonoid contents (Kalegowda et al., 2017; Ben Lataief et al., 2021).

Figure 1. *Opuntia dillenii (Ker-Gawl.) Haw.*

In recent years, research on food-derived bioactive compounds has gained considerable momentum due to their proven benefits against various diseases. These molecules found in different parts of the plant (fruit, seed, flower, or cladode) exhibit diverse biological activities (Figure 2), including antioxidant (Betancourt et al., 2017; Gómez-Maqueo et al., 2021; Santana-Farré et al., 2025), anti-inflammatory, lipid-lowering (Besné-Eseberri et al., 2024), anti-adipogenic effects (Gómez-López et al., 2024), immunomodulatory (Lu et al., 2023), hypoglycemic, antibacterial, antifungal, antidiabetic, and anti-lipid peroxidation properties (Loukili et al., 2022). Evidence also suggests their ability to reduce hepatic steatosis (Serrano-Sandoval et al., 2025) and improve insulin resistance, thereby playing a critical role in lipid metabolism. Beyond the fruit itself, other parts of *O. dillenii* also exhibit notable pharmacological activities (Figure 2). Its flowers display anti-inflammatory, analgesic, antioxidant, antiviral, and antimicrobial properties. Moreover, seed oil has antidiabetogenic and antihyperlipidemic activities, strongly associated with its phenolic content and antioxidant capacity (Lu et al., 2023). *O. dillenii* cladodes showed interesting antioxidant and antimicrobial effects against *S. aureus*, *M. luteus*, and *F. oxysporum*, and cytotoxic potential against Caco-2 colon cancer cells (Ben Lataief et al., 2021). The cladodes inhibit arachidonic acid metabolites and cytokines, conferring anti-inflammatory, hypotensive, and antihyperglycemic benefits. The mucilage with anti-obesity properties may help obese individuals lose weight naturally by using cladode powder in their food, instead of relying on potentially harmful anti-obesity drugs (Kalegowda et al., 2017).

Figure 2. Biological activities.of different parts of *O. dilleniid*

Food and Industrial Applications

In addition to direct consumption, the fruit is processed into juices, jams, syrups, wines, and fermented beverages. Its betalain pigments are exploited as natural food colorants, providing an eco-friendly alternative to synthetic dyes. The oil extracted from its seeds, rich in polyunsaturated fatty acids, has proven effective as a natural preservative in bakery products, reducing lipid oxidation compared to synthetic antioxidants (Bouazizi et al., 2023). Polysaccharides obtained from cladodes have been used as edible coatings to extend the shelf life of minimally processed vegetables (Zhang et al., 2014). Recent advances in cosmetics highlight the incorporation of fruit extracts into skincare products, valued for their hydrating, antioxidant, photoprotective, and antimelanogenic activities (Zhou et al., 2025). From a pharmaceutical perspective, recent research has confirmed anti-diabetic, anti-inflammatory, anti-obesity, anti-steatotic, and anti-hyperlipidemic activities, opening the possibility of developing phytotherapeutic products (El-Samahy et al., 2022). Furthermore, in arid regions, the fruits and cladodes serve as valuable supplementary fodder for livestock. Farmers often plant the pads closely together to form living fences, which not only delineate and protect farmland but also help prevent soil erosion and provide shelter from harsh winds. Finally, *O. dillenii* seeds have been successfully employed in environmental applications as bioadsorbents for removing textile dyes, offering a sustainable alternative to conventional wastewater treatment methods (Bouazizi et al., 2023). Accordingly, *O. dillenii* represents a strategic high-value crop, whose utility spans the food, pharmaceutical, cosmetic, and environmental sectors, highlighting its multifaceted economic and ecological potential.

References

Ali Alsaad, A.J., Altemimi, A.B., Aziz, S.N. and Lakhssassi, N. (2019). Extraction and Identification of Cactus *Opuntia dillenii* Seed Oil and its Added Value for Human Health Benefits: Pharmacogn. J. 11: 579-587. https://doi.org/10.5530/pj.2019.11.93.

Ben Lataief, S., Zourgui, M.N., Rahmani, R., Najjaa, H., Gharsallah, N. and Zourgui1, L. (2021). Chemical Composition, Antioxidant, Antimicrobial and Cytotoxic Activities of Bioactive Compounds Extracted from *Opuntia dillenii* Cladodes: J. Food Meas. Charact. 15: 782-794. https://doi.org/10.1007/s11694-020-00671-2

Besné-Eseverri, I., Martín, M.Á., Lobo, G., Cano, M.P., Portillo, M.P. and Trepiana, J. (2024). Antioxidant and Anti-Inflammatory Effects of *Opuntia* Extracts on a Model of Diet-Induced Steatosis: Antioxidants 13(11): 1416. https://doi.org/10.3390/antiox13111416

Betancourt, C., Cejudo-Bastante, M.J., Heredia, F.J. and Hurtado, N. (2017). Pigment Composition and Antioxidant Capacity of Betacyanins and Betaxanthins Fractions of *Opuntia dillenii* (Ker Gawl) Haw Cactus Fruit: Food Res. Int. 101: 173-179.

Bouazizi, E., Zouari, M., Fakhfakh, N. and Abid, Y. (2023). Nutritional and Functional Properties of *Opuntia dillenii* Seeds and their Use in Food Preservation and Wastewater Treatment. Nutrients: 15(13): 2962. https://doi.org/10.3390/nu15132962

Díaz-Delgado, G.L., Rodríguez-Rodríguez, E.M., Ríos, D., Cano, M.P. and Lobo, M.G. (2024). Morphological Characterization of *Opuntia* Accessions from Tenerife (Canary Islands, Spain) Using UPOV Descriptors: Hortic. 10(7): 662. https://doi.org/10.3390/horticulturae10070662

Díaz Medina, E.M., Rodríguez Rodríguez, E.M. and Díaz Romero, C. (2007). Chemical Characterization of *Opuntia dillenii* and *Opuntia ficus indica* Fruits: Food Chem. 103(1): 38-45. https://doi.org/10.1016/j.foodchem.2006.06.064

El-Samahy, S.K., Abd El-Hady, E.A., Habib, H.M. and Ramadan, M.F. (2022). Pharmacological Potential of Cactus Pear (*Opuntia dillenii*) Extracts: Antidiabetic, Anti-inflammatory, and Antihyperlipidemic activities: J. Food Biochem. 46(8): e14123. https://doi.org/10.1111/jfbc.14123

Ghazi, Z., Ramdani, M., Fauconnier, M.L., El Mahi, B. and Cheikh, R. (2013). Fatty Acids Sterols and Vitamin E Composition of Seed Oil of *Opuntia Ficus Indica* and *Opuntia Dillenii* from Morocco: J. Mater. Environ. Sci. 4 (6): 967-972.

Gómez-López, I., Lobo-Rodrigo, G., Portillo, M.P. and Cano, M.P. (2021). Characterization, Stability, and Bioaccessibility of Betalain and Phenolic Compounds from *Opuntia stricta* var. Dillenii Fruits and Products of Their Industrialization: Foods 10 (7): 1593. https://doi.org/10.3390/foods10071593

Gómez-López, I., Eseberri, I., Cano, M.P. and Portillo, M.P. (2024). Anti-Obesity Effect of Different *Opuntia stricta* var. dillenii's Prickly Pear Tissues and Industrial By-Product Extracts in 3T3-L1 Mature Adipocytes: Nutrients 16(4): 499. https://doi.org/10.3390/nu16040499

Gómez-Maqueo, A., Soccio, M. and Cano, M. P. (2021). In Vitro Antioxidant Capacity of *Opuntia* spp. Fruits Measured by the LOX-FL Method and its High Sensitivity Towards Betalains: Plant Foods Hum. Nutr. (Dordrecht, Netherlands) 76(3): 354-362. https://doi.org/10.1007/s11130-021-00914-7

Kalegowda, P., Chauhan, A.S., and Nanjaraj Urs, S.M. (2017). *Opuntia dillenii* (Ker-Gawl) Haw Cladode Mucilage: Physico-Chemical, Rheological and Functional Behavior: Carbohydr. Polym. 157: 1057-1064. https://doi.org/10.1016/j.carbpol.2016.10.070

Loukili, E., Bouchal, B., Bouhrim, M., Abrigach, F., Genva, M., Zidi, K., Bnouham, M., Bellaoui, M., Hammouti, B. and Addi, M. (2022). Chemical Composition, Antibacterial, Antifungal and Antidiabetic Activities of Ethanolic Extracts of *Opuntia dillenii* Fruits Collected from Morocco. J. Food Qual. 2022: 9471239. https://doi.org/10.1155/2022/9471239

Lu, W.-C., Chiu, C.-S., Chan, Y.-J., Mulio, A.T. and Li, P.-H. (2023). Recent Research on Different Parts and Extracts of *Opuntia dillenii* and its Bioactive Components, Functional Properties, and Applications: Nutrients 15(13): 2962. https://doi.org/10.3390/nu15132962

Santana-Farré, R., Buset-Ríos, N. and Makran, M. (2025). Antioxidant Potential of Opuntia dillenii: A Systematic Review of Influencing Factors and Biological Efficacy: Nutraceuticals 5(3): 22. https://doi.org/10.3390/nutraceuticals5030022

Serrano-Sandoval, S.N., Parralejo-Sanz, S., Lobo, M.G., Cano, M.P. and Antunes-Ricardo, M. (2025). A Bio-guided Search of Anti-steatotic Compounds in *Opuntia stricta* var. dillenii by Fast Centrifugal Partition Chromatography: Food Chem., 464(Pt 2): 141682. https://doi.org/10.1016/j.foodchem.2024.141682

Sharma, C., Rani, S., Kumar, B., Kumar, A. and Raj, V. (2015). Plant *Opuntia dillenii*: A Review on its Traditional Uses, Phytochemical and Pharmacological Properties: EC. Pharm. Sci. 1 (1): 29-43.

Zhang, W., Xu, W., Huang, X. and Yu, J. (2014). Polysaccharides from *Opuntia dillenii* Cladodes as Edible Coatings for Postharvest Preservation: Food Sci. Technol. Res. 20(7): 1184-1192. https://doi.org/10.3136/fstr.20.1184

Zhou, Y., Li, H. and Wang, J. (2025). Cosmetic Applications of *Opuntia dillenii* Extracts: Photoprotection and Antimelanogenesis Effects: J. Cosmet. Dermatol. 24(2): 321-332. https://doi.org/10.1111/jocd.16021

NEW CACTI FOR FOOD AND FUNCTIONAL INGREDIENTS IN DRYLANDS

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Cactus species of the genus *Cereus*, popularly known in Brazil as Mandacaru, are native to the semi-arid regions of South America, adapted to survive and thrive in dry lands. Due to their medicinal properties, these plants have been used for centuries by rural and Indigenous communities in Brazil. Even today, they play a vital role in the subsistence and economy of communities in areas of severe drought, serving as fodder and human food (Da Silva Santos et al., 2021).

The genus *Cereus* comprises 25 species, 12 of which are found in Brazil, making the country a major center of diversity. The fruits of these species are edible, showy and colorful, with a sweet and juicy pulp, as in *Cereus jamacaru* with red fruits, *Cereus fernambucensis* with magenta fruits, and *Cereus hildmannianus* (synonym of *Cereus peruvianus*), which produces fruits in shades of red, orange, and yellow (Figure 1a-j) (Carneiro et al., 2016).

Sustainable cultivation and management

The flowers of *Cereus* species are white, nocturnal, and require cross-pollination for fruit production (Figure 2a). In Brazil, the flowering period of *Cereus* plants begins in the warm season, from November to February, and fruit harvesting can be carried out until April. In Israel, where this genus was introduced, flowers are produced throughout the warm season, and from June to October, flower buds, flowers, and fruits at various developmental stages can be observed.

In nature, pollination depends on nocturnal pollinators, such as moths, which are attracted by abundant nectar and floral scent (Figure 2b) (Eggli and Giorgetta, 2015). In commercial orchards, pollination is performed manually, by collecting pollen with vacuum cleaners, mixing it among clones, and applying it to the flowers with a brush. Manual pollination results in over 95% of fruit set and fruits 40% larger than those obtained by open pollination (Figures 2c, d) (Mizrahi, 2014).

Figure 1. Plant (a) and red fruits of *Cereus jamacaru* (b, c, h); plant of *C. fernambucensis* (d) with magenta fruits (e, f); and plant of *C. hildmannianus* (g) with orange (i) and yellow (j) fruits.

The cultivation of *Cereus* plants is relatively simple, as they can grow with minimal water – less than 10% of that required by traditional fruit crops. In experiments conducted in Israel, orchards irrigated with approximately 100 mm/year achieved yields of 20-25 t/ha/year using balanced fertigation (NPK + micronutrients). No pests have been reported, and the crop is commonly grown organically, using animal manure as fertilizer and covering the soil with plastic sheets to avoid the use of herbicides (Mizrahi, 2014).

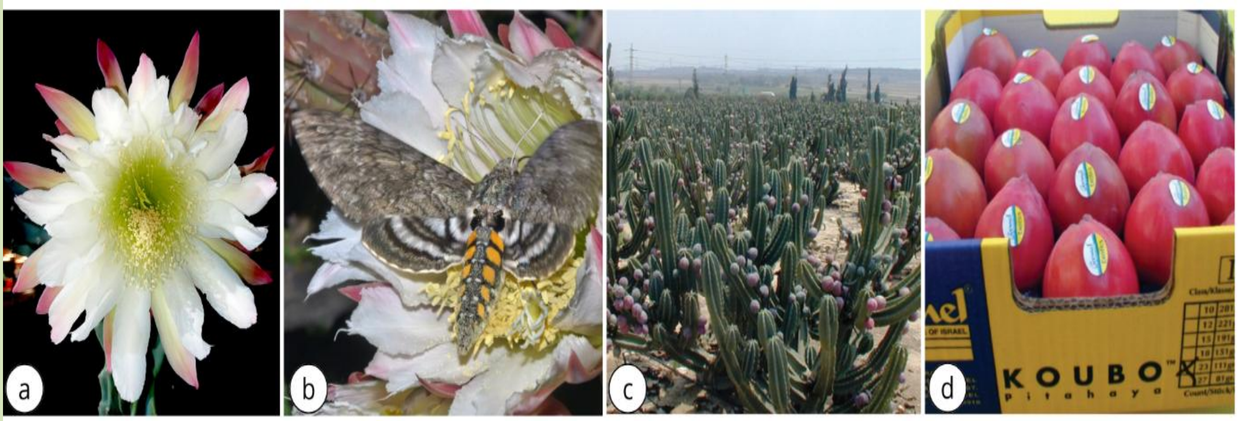

Figure 2. Flower of a *Cereus* plant (a) (author), visited/pollinated by a moth of the species *Manduca sexta*; a fruit orchard (c); and fruits packaged to the fresh fruit market (d).

Cereus species are propagated by cuttings, which involves burying segments of the stem to encourage root formation (Figure 3a, b). This form of propagation, known as vegetative propagation, is effective in arid conditions, where seed germination is difficult (Mizrahi, 2014). In Brazil, laboratory propagation methods have been developed using tissue culture (Figure 3c) to increase the production of *C. peruvianus* seedlings, which are currently maintained at the Experimental Botanic Garden at the State University of Maringá, Paraná State, Brazil (Figure 3d) (Mangolin et al., 2009).

A major challenge in the cultivation of *C. peruvianus* is fruit cracking, which can compromise up to 90% of production. Treatments with gibberellic acid (GA) have shown good results in increasing pericarp resistance without delaying ripening, ensuring intact fruits until harvest.

The commercialization of *Cereus* fruits in Brazil is still limited to small local markets. In Israel, *C. peruvianus* is produced on a commercial scale and exported to Europe under the name "Koubo," valued as an exotic fruit (Figure 2d). This highlights the potential of this group of cacti as a new agricultural alternative for arid regions.

Figure 3. Propagation by cuttings (a, b) (Mizrahi, 2014), laboratory tissue culture (c), and plants at the Experimental Botanic Garden of the State University of Maringá, Brazil (author).

Technological and functional potential

Besides their rusticity in the field, the great advantage of *Cereus* plants is the production of bioactive compounds in their stems, called cladodes, and in their fruits. Recent studies have shown that the mucilage extracted from cladodes forms stable gels, allowing the production of biodegradable films and edible coatings, applicable in sustainable packaging and even as matrices for natural capsules.

The fruit peel contains high levels of compounds that have the potential to neutralize the negative effects of oxidation and free radicals in the body. The pulp of the fruit is a source of essential minerals such as potassium, calcium, and magnesium, as well as fiber and natural antioxidants (Dos Santos et al., 2025). The seed oil stands out for its health-promoting composition (De Souza Mataruco et al., 2023).

Food products developed from *Cereus* fruits include jams, dry slices, and aromatic liqueur (*C. peruvianus*) (Mizrahi, 2014), ice cream and yogurt (*C. jamacaru*) (Fidelis et al., 2015), and even supplementation in wort and beer (Da-Silva et al., 2023). This versatility demonstrates the potential of the plant and its fruits to provide a range of innovative ingredients, aligned with global trends toward healthy foods and sustainable approaches.

Promoting the cultivation of Mandacaru can enhance the value of native resources, strengthen family farming, improve food security, and create new income opportunities for communities in semi-arid regions. Alongside other well-known cacti, such as pitaya (*Hylocereus*) and prickly pear (*Opuntia*), Mandacaru emerges as a "new cactus" for the future of food in dry lands, combining cultural tradition, technological innovation, and sustainability.

References

Carneiro, A. M., Farias-Singer, R., Ramos, R. A. and Nilson, A. D. (2016). Cactos do Rio Grande do Sul. FZB-RS.

Da Silva Santos, É., Braz de Oliveira, A. J., Machado, M. F. P. S., Mangolin, C. A. and Gonçalves, R. A. C. (2021). *Cereus hildmannianus* (K.) Schum. (Cactaceae): Ethnomedical uses, phytochemistry and biological activities. J. Ethnopharmacol. 10(264): 113339.

Da-Silva, J. R., Correia-Lima, L., Fernandes, G., Ribeiro-Filho, N., Madruga, M. S., dos Santos Lima, M. and Muniz, M. B. (2023). Mandacaru fruit pulp (*Cereus jamacaru* DC) as an adjunct and its influence on Beer properties. Food Chem. 406: 135066.

De Souza Mataruco, L., Da Silva, L. H. M., Stevanato, N., Da Silva, C., Fink, J. R., Filho, L. C., Pimentel, T. and Barão, C. E. (2023). Pressurized n-propane extraction improves bioactive compounds content, fatty acid profile, and biological activity of Mandacaru (*Cereus jamacaru* DC.) seed oil. Ind. Crop. and Prod. 195: 116367.

Dos Santos, E., Gomes, R. G., Mangolin, C. A. and Machado, M. F. P. S. (2025). A review of mandacaru fruit phytochemicals, its pharmacotherapeutic benefits and uses in food technology. Food Sci. Biotechnol. 34(9): 1789-1803.

Eggli, U. and Giorgetta, M. (2015). Flowering phenology and observations on the pollination biology of South American cacti. 2. *Cereus aethiops*. Haseltonia. 21: 19-40.

Fidelis, V. R. D. L., Pereira, E. M., da Silva, W. P., Gomes, J. P. and Silva, L. A. (2015). Produção de sorvetes e iogurtes a partir dos frutos figo da índia e mandacaru. Rev. Verde Agroecol. Desenvolv. Sust. 10(4): 29.

Mangolin, C. A., Collet, S. O., Oliveira, A. B. O., Gonçalves, R. C. and Machado, M. F. P. S. (2009). In vitro cell and tissue culture of *Cereus peruvianus* Mill. (Cactaceae) for the conservation and management of biodiversity: current status. Acta Hort. 811: 249-254.

Mizrahi, Y. (2014). *Cereus peruvianus* (Koubo) new cactus fruit for the world. Rev. Bras. de Frut. 36(1): 68-78.

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