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Fruit Characteristics during Growth and Ripening of different *Hylocereus* Genotypes

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Summary

Purple-fleshed *Hylocereus* genotypes with a considerable potential for the European fruit market were investigated with respect to fruit development in their natural habitat. Commonly commercialised genotypes in Central America such as 'Nacional', 'Orejona', 'Rosa' and 'San Ignacio' were analysed 17, 21, 24, 28 and 32 days after anthesis. Parameters evaluated were fruit dimensions, fruit and skin weight, skin and flesh firmness, total soluble solids, pH, titratable acidity and skin colour. Upon ripening, skin colour changed from green to red accompanied by a decrease in fruit weight, firmness and titratable acidity. The behaviour of the genotypes allowed to group them in two categories: 'Nacional' and 'Orejona' bearing smaller fruits with shorter ripening time belong to the first, whereas the second comprise the genotypes 'Rosa' and 'San Ignacio' with larger fruits and delayed fruit ripening. Moreover, comparisons between genotypes at the initial stage of colour change indicated that flesh firmness may be a suitable parameter to assess fruit maturity. From the findings obtained, fruits from 'Nacional' are considered more suitable for processing, whereas those from 'San Ignacio' may be preferred for fresh fruit consumption.

Key words. *Cactaceae* – fruit analysis – fruit quality – fruit chemistry – pitahaya – pitaya

Introduction

Fruits from the *Cactaceae* are gaining importance on the European market, especially as fresh fruit. Similar to cactus pear (*Opuntia ficus-indica*) in Italy (Inglese et al. 2002), semi-arid regions in southern Europe might be adequate for cultivating pitayas (*Hylocereus* sp.). Commercial plantations in Israel (Mizrahi and Nerd 1999) and overseas dependencies of European countries, such as the Reunion Island in the Caribbean, have a great potential for producing pitayas for international trade (Le Bellec et al. 2006).

The genus *Hylocereus* (Britton & Rose) belongs to the vine cacti from the subfamily Cactoideae within the *Cactaceae* (Raveh et al. 1993). The plant is characterised by elongated three-ribbed stems which cling to trees and rocks, bearing medium to large oblong berries with large fleshy scales (Nerd and Mizrahi 1997). The edible fruits, varying in size, taste and colour are commonly known as pitahaya or pitaya (Raveh et al. 1998; Nerd et al. 2002).

The most widely cultivated vine cactus is the red pitaya, *Hylocereus undatus* [(Haworth) Britton & Rose] (red skin, white flesh). Although red pitaya is native to Central America, fruits for the Asian and European markets are produced in Vietnam and Israel (Nerd et al. 2002). Further commercial species include *H. polyrhizus* [(F.A.C. Weber) Britton & Rose] and *H. costaricensis* [(F.A.C. Weber) Britton & Rose], both exhibiting red skin and purple flesh (Mizrahi and Nerd 1999; Esquivel 2004).

Similar to cactus pears (*Opuntia ficus-indica*), purple-fleshed pitayas (*Hylocereus polyrhizus*) have been recently suggested as a viable betalain source (Wybraniec et al. 2001; Stintzing et al. 2002). Considering its promising use in the European juice industry, studies have been carried out evaluating pigment content (Esquivel et al. 2006; Stintzing et al. 2003) and pigment stability of pitaya juice as a natural pigment for the food and cosmetics industry (Herbach et al. 2006a, b). However, knowledge on the genetic variability of pitayas is still scarce.

In Central America, where the fruits are originally native to, particular names have been assigned to *Hylocereus* genotypes depending on their fruit morphology, scale number and shape. 'Orejona', 'Rosa' and 'San Ignacio' are common genotypes in Nicaragua, where pitaya production is high. However, only scattered information on these genotypes is currently available (Le Bellec et al. 2006).

As for many other fruit, harvesting time greatly influences fruit quality because sugar content, acidity, texture, colour and aroma among others are dependent on the respective ripening stage (Kader 2002; Siriwoharn et al. 2004; Glew et al. 2005; Kreck et al. 2005; Serrano et al. 2005; Kafkas et al. 2007; Soares et al. 2007). Although fruits reach their best quality when allowed to ripen on the plant, some are picked unripe so that they better withstand postharvest handling. Immature fruits show erratic ripening and may not develop full flavour and aroma. Thus, effects to determine optimal harvest maturity are critical (Kreck et al. 2005; Serrano et al. 2005; Jha et al. 2006).

According to current conception, vine cacti should be harvested close to full ripeness, evidenced by a change of external colour from green to red-purple (NERD et al. 2002). Only a few studies have been published on the interrelationship between quality and fruit development in *Hylocereus* fruits. TO et al. (2002) evaluated total soluble solids, titratable acidity and colour in *H. undatus* from Vietnam and found optimal maturity 28–30 days after flowering. NOMURA et al. (2005) studied seasonal changes in skin colour, sugars and acids of *H. undatus* over 45 days, with differences between summer- and autumn-pollinated fruit. NERD et al. (1999) investigated growth and ripening of *H. undatus* und *H. polyrhizus* in the Israeli Negev desert in ventilated greenhouses after manual pollination. The first colour change (from green to red) was found 24–25 and 26–27 days after anthesis in the two species *H. undatus* and *H. polyrhizus,* respectively.

Determination of variations among genotypes concerning fruit development and characteristics should allow appropriate crop production management. Therefore, the present work compared fruit development of four Latin American genotypes of purple-fleshed *Hylocereus* sp. aiming at discerning genotypes as well as determining viable parameters for assessing the appropriate harvest time. We expect that such differences could be used as a reliable tool for genotype selection aiming at choosing fruits appropriate for handling and storage for industrial processing or fresh fruit consumption.

Materials and Methods

Plant material

Three-year-old plants of 'Nacional', 'Orejona', 'Rosa' and 'San Ignacio' cultivated organically in Barranca, Puntarenas, Costa Rica (N 9 ° 57.566 '; W 84 ° 43.217 ') were used for this work. Samples of each analysed genotype

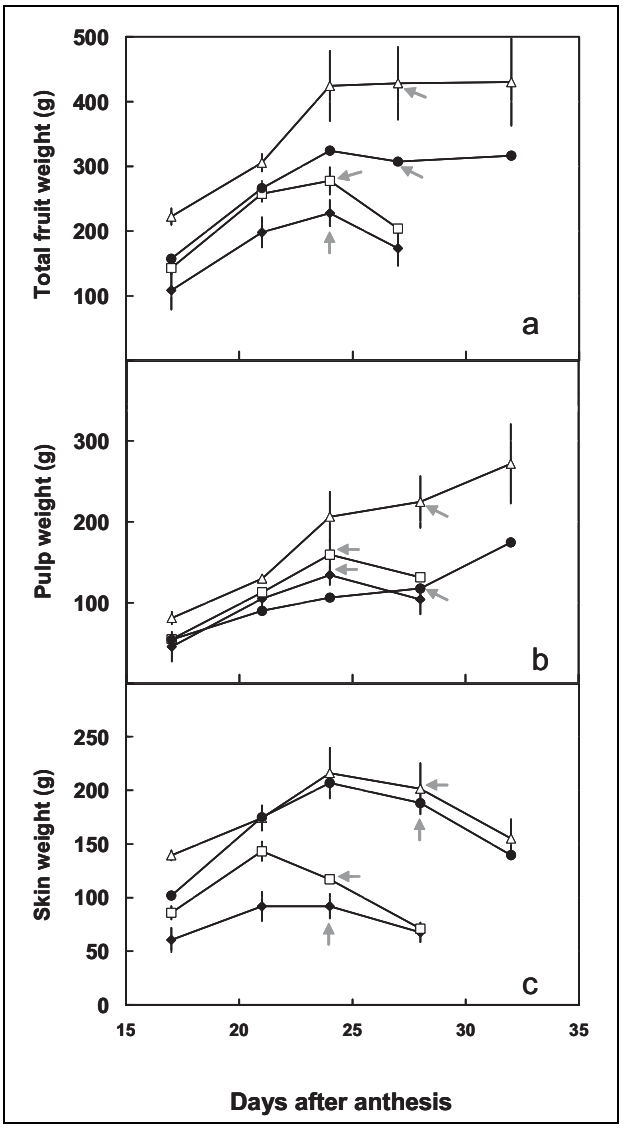


Fig. 1. Total fruit weight (a), fruit flesh weight (b), skin weight (c) during development of *Hylocereus* fruits from different genotypes: (-♦-) 'Nacional', (--) 'Orejona', (-Δ-) 'Rosa' and (-●-) 'San Ignacio'. First colour change is indicated (↑).

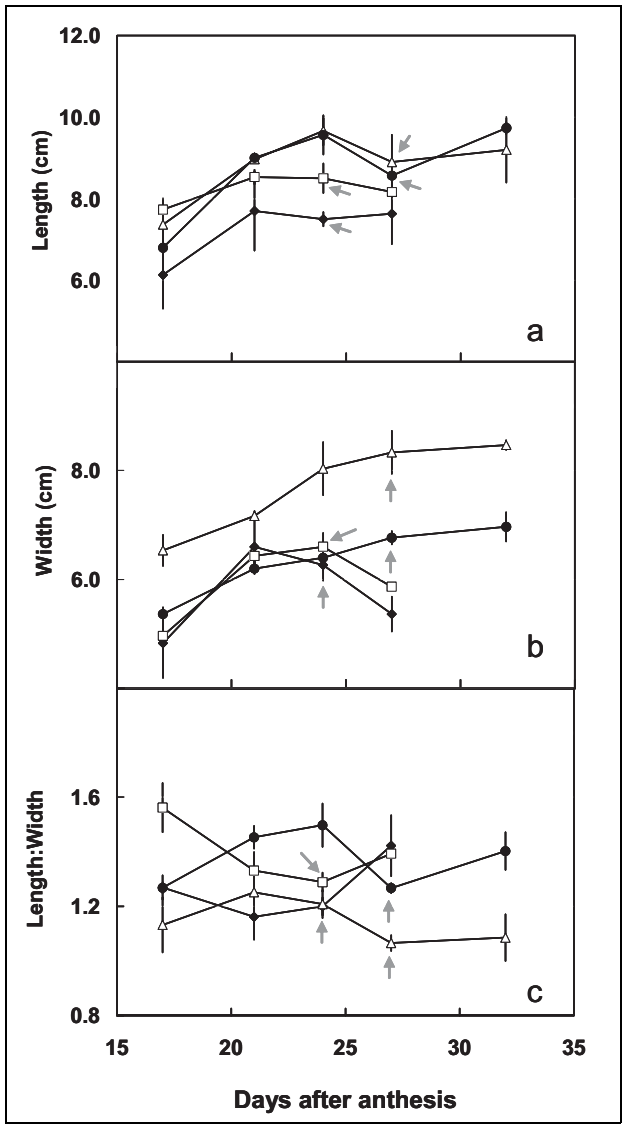


Fig. 2. Fruit length (a), width (b) and shape (c) (length: width-ratio) during development of *Hylocereus* fruits from different genotypes: (-♦-) 'Nacional', (--) 'Orejona', (-Δ-) 'Rosa' and (-●-) 'San Ignacio'. First colour change is indicated (↑).

were deposited at the Herbarium at the Universidad de Costa Rica (USJ), where they received the following accession numbers: 'Rosa' 88680, 'San Ignacio' 88681, 'Nacional' 88682, and 'Orejona' 88684.

Flowers were tagged at anthesis on May 2005 and allowed to be pollinated by nocturnal insects. Fruits were sampled 17, 21, 24 and 28 days later in the four genotypes, and additionally 32 days later in 'Rosa' and 'San Ignacio'. During this period an average temperature of 26.5 °C and a total precipitation of 462.2 mm prevailed. Taking into account the impact of diurnal changes in Crassulacean Acid Metabolism (CAM) photosynthesis on the compositional pattern (NOMURA et al. 2005), pitayas were collected early in the morning. Fully-ripe fruit were harvested at the onset of colour change according to commercial practices. A second set of fruit was collected and stored at room temperature for four days until they were fully coloured (n=5 fruit per cultivar). This procedure was necessary to obtain undamaged fully ripe pitayas, because fruits not collected at the first appearance of colour change attract birds and other animals. At each sampling date, five fruits of one particular genotype were analysed separately and each one was considered a biological replicate. To allow comparison between genotypes, all of them were cultivated under the same conditions.

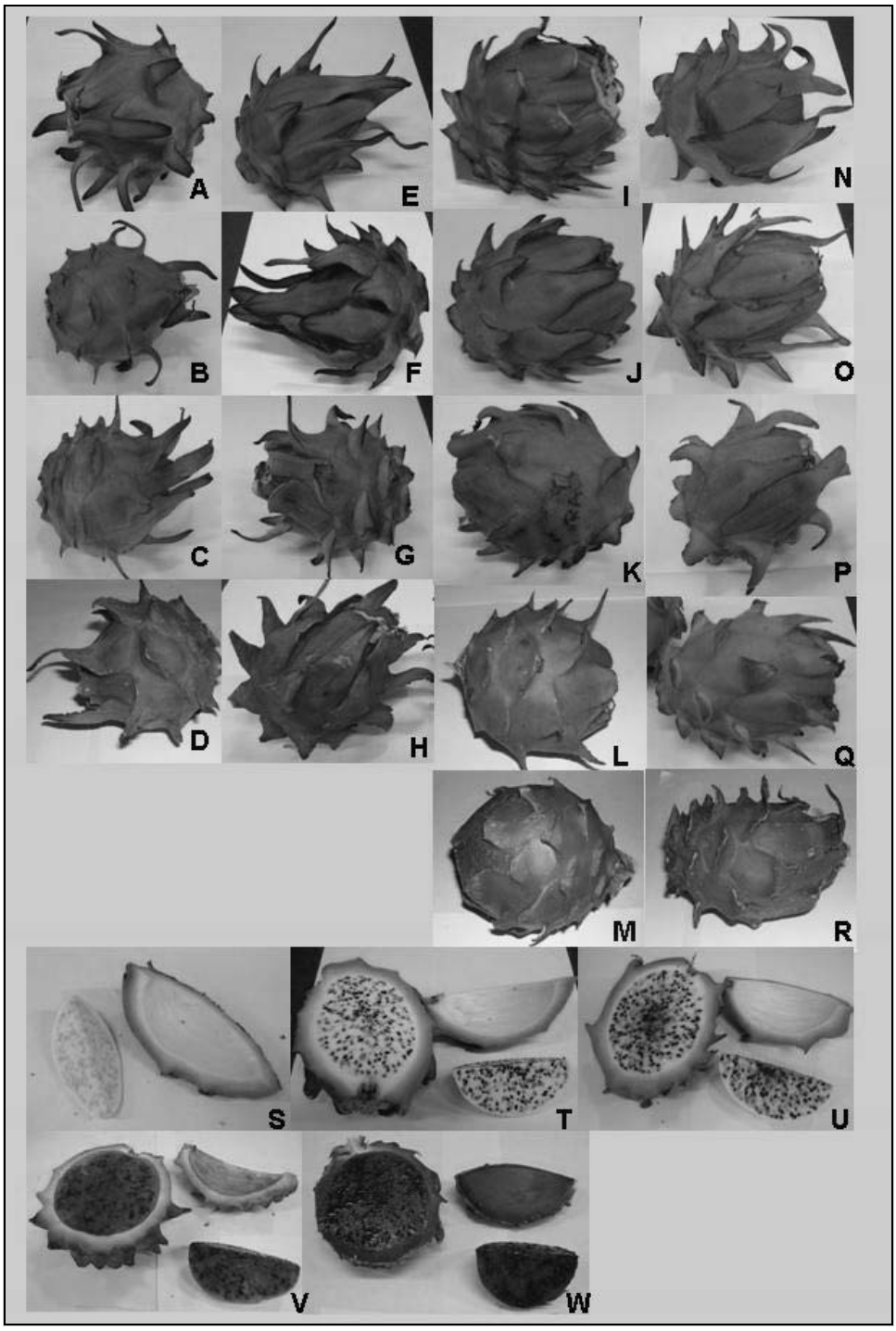


Fig. 3. Different colour stages of external skin for the genotypes 'Nacional'. 17 (A), 21 (B), 24 (C) and 28 (D) days after anthesis, for 'Orejona' 17 (E), 21 (F), 24 (G) and 28 (H) days, for 'Rosa' 17 (I), 21 (J), 24 (K), 28 (L) and 32 (M), for 'San Ignacio' 17(N), 21 (O), 24 (P), 28 (Q) and 32 (R) days. Internal colour changes observed for 'Rosa' 17 (S), 21 (T), 24 (U), 28 (V), 32 (W) days after anthesis.

Morphological traits

Total fruit, skin and flesh weight together with length and diameter were assessed at each collecting date for each genotype. The length:diameter-ratio was calculated as an estimate of the overall fruit shape.

Skin colour

At five points on the fruit perimeter, external skin colour was determined with a Colourflex (Hunterlab, VA, USA) instrument using illuminant type D_{65} and 10 ° observer angle. Colour was expressed as lightness (L*), redness (a*), greenness (b*), chroma ($C^* = (a^{*2}+b^{*2})^{1/2}$) and hue angle ($h° = \arctan b^*/a^*$) as described by STINTZING et al. (2003).

Texture

Fruit firmness was determined at six different points on the equator of each fruit using a Texture Analyser TA.XT Plus (Stable Micro Systems, Surrey, UK) equipped with a 2 mm wide stainless steel probe. The operating conditions were: pre-test speed of 2.0 mm s^{-1}, test speed 2.00 mm s^{-1} and post-test speed of 10 mm s^{-1}. A penetration distance of 15 mm was applied. The maximum force value (N) observed during skin penetration was defined as skin firmness, while the average force value of the plateau observed after skin penetration was considered fruit flesh firmness.

Total soluble solids

The soluble solids concentration (°Brix) of the juice was determined in duplicate using a refractometer (NAR-1T, Atago, Japan).

pH value and total titratable acids

The pH of the fruit flesh was determined in duplicate with a pH meter (Model 430, Corning, NY, USA) in 10 g of flesh homogenised in 100 ml of distilled water. For titratable acidity determination, 10 g of flesh were homogenised in 100 ml distilled water, titrated with 0.1 N NaOH to pH of 8.1 in duplicate analyses and expressed as g malic acid per 100 g fruit (IFU 1995).

Statistical Analysis

Analysis of regression was conducted using the JMP Version 6 Software (SAS Institute, Raleigh, N.C., USA) to determine the effect of genotype and collecting time on the

Table 1. L* a*b*-values of the external skin from fruits of different *Hylocereus* genotypes during growth and ripening.

Days after anthesis	Genotypes			
	'Nacional'	'Orejona'	'Rosa'	'San Ignacio'
			L*	
17	37.25±1.79 A	34.45±1.60 A	38.21±1.44 A	39.12±0.50 A
21	44.66±2.30 A	44.07±1.37 A	47.94±0.80 A	51.15±0.83 A
24	32.25±0.70 A	33.54±0.55 A	38.69±1.89 A	37.09±0.88 A
28	29.03±3.13 BC	26.40±1.65C	38.53±0.26 A	34.32±0.91 AB
32	–[b]	–[b]	23.67±0.42 A	28.80±1.85 A
Equation	L*=52.63–0.77t	L*=50.66–0.88t	L*=56.87–0.91t	L*=58.88–0.99t
R^2	0.359	0.630	0.589	0.762
p	0.0394[c]	0.0001[c]	0.0001[c]	0.0001[c]
			a*	
17	–6.32±0.45 A	–7.39±0.15 A	–7.23±0.85 A	–6.80±0.75 A
21	0.48±4.49 A	–4.10±0.22 A	–6.14±0.70 A	–6.20±0.15 A
24	4.16±6.2 A	–4.55±2.49 A	–7.60±0.57 A	–8.98±0.51 A
28	21.61±3.32 B	29.9±0.9 A	–7.11±0.27C	–8.03±0.64C
32	–[b]	–[b]	41.0±1.0 A	40.8±0.8 A
Equation	$a^*=-3.34+1.73e^{-11t}$	$a^*=-5.83+2.47e^{-11t}$	$a^*=-7.57+6.15e^{-13t}$	$a^*=-8.25+6.21e^{-13t}$
R^2	0.730	0.978	0.990	0.994
p	0.0004[c]	0.0001[c]	0.0001[c]	0.0001[c]
			b*	
17	21.89±1.51 A	20.74±0.73 A	21.85±0.78 A	22.34±0.56 A
21	19.62±1.59 A	14.54±0.30 A	19.82±1.05 A	19.84±0.33 A
24	17.20±1.26 A	19.15±0.55 A	24.50±1.12 A	23.43±0.94 A
28	9.60±1.00 B	8.26±1.26 B	26.20±0.10 A	21.99±0.99 A
32	–[b]	–[b]	4.88±1.01 B	5.66±2.25 A
Equation	$b^*=22.60-9.00e^{-12t}$	$b^*=18.28-6.23e^{-12t}$	$b^*=23.95-2.78e^{-13t}$	$b^*=22.78-2.39e^{-13t}$
R^2	0.742	0.768	0.966	0.962
p	0.0003[c]	0.0001[c]	0.0001[c]	0.0001[c]

[a] Different letters describe significant differences between genotypes at the same development stage
[b] Not determined
[c] Significant effect of the development stage on firmness ($p<0.05$)

particular quality parameters. Comparison of means within each sampling date was performed between genotypes using the Tukey HSD test of the same software.

Results and Discussion

Fruit weight and components

Total fruit weight initially increased with time until day 24. Afterwards it either declined ('Nacional' and 'Orejona') or remained unchanged ('Rosa' and 'San Ignacio') (Fig. 1a). Weight differences among genotypes were observed from the beginning and increased during the evaluation period. Genotypes with heavier fruit ('Rosa' and 'San Ignacio') had longer growth period before skin colour changed. Fruit of 'Rosa' were the largest (430 g) and those of 'Nacional' were smallest (174 g). In comparison, NERD et al. (1999) reported average weights at the first colour change of 400 g and 300 g for *H. undatus* and *H. polyrhizus*, respectively, while higher values were observed at full colour.

The flesh (pulp) constituted the major portion of the fruit (Fig. 1b), gradually increased until day 32 in 'Rosa' and 'San Ignacio', while declined in 'Nacional' and 'Orejona' after 24 days. As earlier found for *H. undatus* and *H. polyrhizus* (NERD et al. 1999), a constant decrease in skin weight after day 20 was observed for 'Nacional' and 'Orejona', and after day 24 for 'San Ignacio' and 'Rosa' (Fig. 1c).

Initially, average flesh percentage was about 40 % and increased up to 60 % at the final evaluation for 'Nacional' and 'Orejona', and 52 % and 38 % for 'Rosa' and 'San Ignacio', respectively. Similar results were reported by NERD et al. (1999).

Fruit size and shape

Both genotype and fruit development affected length and width of the *Hylocereus* fruits studied in the present work ($p<0.05$) (Fig. 2a, b). The last stages of the sigmoidal course during fruit growth for *H. polyrhizus* as described by NERD et al. (1999) could be confirmed with respect to fruit length. Whereas a strong increment was observed at initial stages, the relative increase became smaller with progressive fruit development (Fig. 2a). Length increased along development until day 21 after anthesis in 'Orejona' and 'Nacional' and until day 24 in 'Rosa' and 'San Ignacio'. Width declined up to day 28 for the genotypes 'Nacional' and 'Orejona' and increased throughout growth and ripening of the fruits in the other genotypes (Fig. 2b). The shape of the fruits as expressed by the length:width-ratio did not change significantly within the development period ($p>0.05$) (Fig. 2c).

Morphological differences were significant between genotypes ($p<0.05$). Fully developed fruits exhibited length values ranging between 9.7 cm for 'San Ignacio' and 6.1 cm for 'Nacional', and between 8.5 cm for 'Rosa' and 4.8 cm for 'Nacional' for width. NERD et al. (1999) reported similar final length values between 8 to 9 cm and 9 to 10 cm for *H. undatus* and *H. polyrhizus*, respectively, both exhibiting width values between 7 and 8 cm.

Colour parameters. The external skin colour break in 'Nacional' and 'Orejona' was visually noted after 24 days, while in 'San Ignacio' and 'Rosa' changes occurred only after 28 days (Fig. 3). Others noted the first colour break 24–25 days after anthesis for *H. undatus* and 26–27 days for *H. polyrhizus* (NERD et al. 1999). In addition to the visually perceived colour changes, objective colour parameters such as L*-, a*-, b*-, C*- and h°-values were mon-

Table 2. Chroma (C*) and hue angle (h°) values of the external skin from fruits of different *Hylocereus* genotypes during growth and ripening.

Days after anthesis	Genotypes			
	'Nacional'	'Orejona'	'Rosa'	'San Ignacio'
		C*		
17	22.84±1.55 A	22.04±0.73 A	23.06±0.96 A	23.37±0.75 A
21	24.95±2.80 A	15.16±0.30 A	20.78±1.17 A	20.86±0.36 A
24	20.60±0.87 A	20.00±0.92 A	25.68±1.15 A	25.10±1.06 A
28	23.99±2.58 B	32.31±0.97 A	27.19±0.12 AB	23.42±1.14 B
32	–[b]	–[b]	42.21±0.79 A	42.78±0.44 A
Equation	C*=22.96+0.05t	$C^*=19.12+8.54e^{-12t}$	$C^*=24.93+2.05e^{-13t}$	$C^*=24.02+2.16e^{-13t}$
R^2	0.004	0.833	0.899	0.943[d]
p	0.8547	0.0001[c]	0.0001[c]	0.0001[c]
		h°		
17	106.09±0.95 A	109.60±0.58 A	108.04±1.66 A	106.77±1.33 A
21	96.92±2.22 A	105.55±0.77 A	106.71±1.16 A	105.95±0.05 A
24	61.90±11.47 A	102.52±6.97 A	107.11±1.21 A	110.95±0.36 A
28	25.70±5.61 B	15.05±2.14 B	104.97±0.53 A	110.00±0.81 A
32	–[b]	–[b]	6.62±1.33 A	7.62±3.05 A
Equation	$h°=96.54-4.92e^{-11t}$	$h°=107.29-6.20e^{-11t}$	$h°=105.81+3.25e^{-12t}$	$h°=108.14-3.26e^{-12t}$
R^2	0.749	0.984	0.999	0.999
p	0.0003[c]	0.0001[c]	0.0001[c]	0.0001[c]

[a] Different letters describe significant differences between genotypes at the same development stage
[b] Not determined
[c] Significant effect of development on firmness ($p<0.05$)

Table 3. Skin (SS) and flesh (FS) softening during growth and ripening of fruits from different *Hylocereus* genotypes.

Days after anthesis	Genotypes			
	'Nacional'	'Orejona'	'Rosa'	'San Ignacio'
	Skin firmness (N)[a]			
17	14.3±0.6 A	13.1±0.1 A	12.1±0.1 A	15.0±0.8 A
21	15.1±0.6 A	16.0±0.6 A	15.0±0.4 A	16.3±0.5 A
24	11.2±1.2 A	14.5±0.9 A	13.8±0.4 A	14.7±0.5 A
28	9.6±1.3 B	5.4±0.1C	13.0±0.2 AB	15.6±0.8 A
32	–[b]	–[b]	6.5±0.5 B	8.1±0.2 A
Equation	SS=24.23–0.49t–0.04 (t–22.5)^2	SS=31.02–0.68t–0.214 (t–22.5)^2	SS=22.88–0.34t–0.089 (t–24.4)^2	SS=25.18–0.37t–0.08 (t–24.4)^2
R^2	0.608	0.964	0.944	0.788
p	0.0147[c]	0.001[c]	0.0001[c]	0.001[c]
	Flesh firmness (N)[a]			
17	2.7±0.1 A	2.2±0.1 A	2.0±0.2 A	2.3±0.1 A
21	1.6±0.1C	2.5±0.2 BC	2.1±0.1 BC	3.6±0.6 AB
24	0.6±0.1 A	0.9±0.2 A	1.8±0.3 A	3.2±0.2 A
28	0.6±0.0 B	0.4±0.0 B	1.0±0.2 B	2.6±0.2 A
32	–[b]	–[b]	0.6±0.0 A	0.6±0.1 A
Equation	FS=5.87–0.20t	FS=5.77–0.19t	FS=4.20–0.11t	FS=5.89–0.12t
R^2	0.862	0.718	0.760	0.107
p	0.0001[c]	0.0005[c]	0.001[c]	0.234

[a] Different letters indicate significant differences between genotypes at the same development stage
[b] Not determined
[c] Significant effect of development on firmness ($p<0.05$)

itored during development of the various *Hylocereus* genotypes (Table 1 and 2). Skin colour was significantly affected by genotype and sampling date, except for chroma values for which no significant differences were detected. During fruit growth, a light increase was observed between days 17 and 21. Subsequently, a decrease was registered reflecting a darker sample colour. At day 32, 'Rosa' and 'San Ignacio' reached the same values that 'Orejona' and 'Nacional' exhibited after 28 days. The a*-value increased, i.e. the green chlorophyll colour disappeared with progressing betacyanin gain. In the same line, the b*-values decreased sharply 28 days after anthesis for 'Nacional' and 'Orejona'. For the other genotypes these changes were observed only after 32 days (Fig. 3). The different colour development are described by the corresponding equations for each genotype (Table 1). Maximum chroma indicating colour saturation was registered in 'Rosa' and 'San Ignacio' only after 32 days, in 'Orejona' after 28 days, while no significant changes were observed in 'Nacional' during the whole evaluation period. With respect to hue angle values, no differences between genotypes were observed at the initial stages, all exhibiting yellow-green shades. An important decrease was registered at day 24 for 'Nacional', 28 for 'Orejona' and 32 for the other genotypes. The similarities of chroma and hue-values between 'Rosa' and 'San Ignacio' are expressed by the equations shown in Table 2.

Texture analyses

In most fruit, the major cell wall polysaccharides are modified during ripening along with a reduction of skin and flesh firmness. Generally, softening has been associated with alterations of the middle lamella and cell wall structure (Huber 1983; Brady 1987; Carrillo-López et al. 2002).

Skin firmness (Table 3) decreased after 28 days in 'Nacional' and 'Orejona', or after 32 days in 'San Ignacio' and 'Rosa'. Skin firmness was highly correlated to development time based on a polynomial fit of second power for 'Orejona' and 'Rosa', while correlation diminished for 'San Ignacio' and especially 'Nacional'. As observed by Nerd et al. (1999), the softening of the skin took place between colour break and full colour, except for 'Nacional' in which softening occurred earlier. Mean daily firmness losses after the first colour change amounted to 2.26, 1.54, 1.90, and 0.40 N in 'Orejona', 'Rosa', 'San Ignacio' and 'Nacional', respectively.

Skin firmness decreased later than flesh firmness (Table 3) in most genotypes. Flesh softening was noticeable after 21 days for 'Nacional', and after 24 days for the other genotypes. Flesh softening exhibited a mean daily decrease of 0.02 N in 'Nacional' between first colour change and full colour, while 0.13, 0.06, and 0.50 N were registered for 'Orejona', 'Rosa' and 'San Ignacio', respectively. 'Nacional' had the firmer skin at full colour which can probably be related to a better postharvest storage potential (Carrillo-López et al. 2002). In contrast, all genotypes exhibited similar flesh texture when fully ripe.

Total soluble solids content

Total soluble solids (TSS) increased during development (Fig. 4a). In 'Nacional', the maximum value was reached after 24 days, while 28 days were required for the other genotypes. For *H. undatus* and *H. polyrhizus* total soluble solids of 10 % and 6 % have been reported at first colour change, or 15 % and 10 % at full colour, respectively

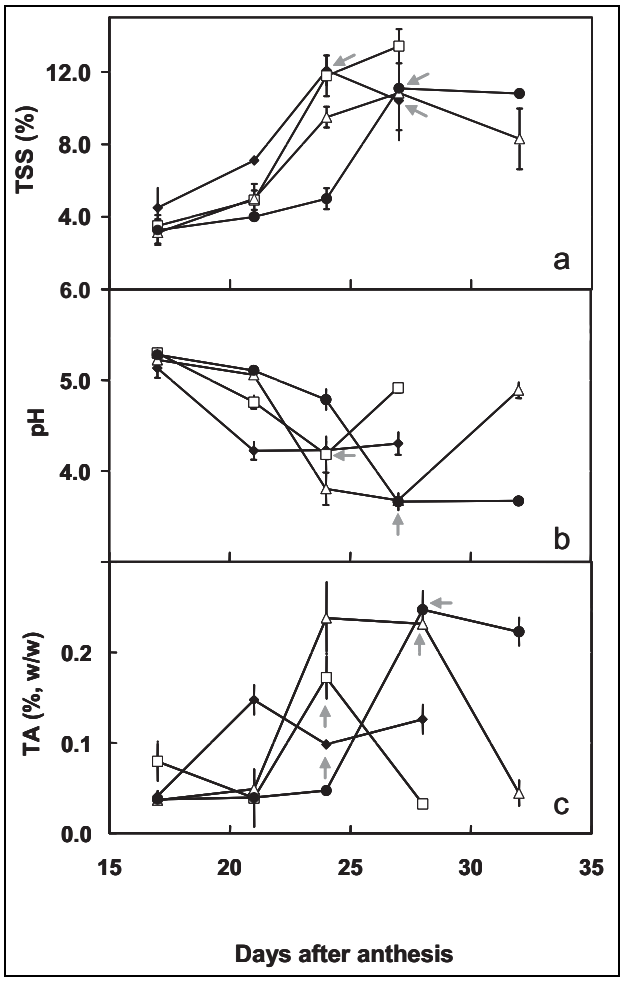


Fig. 4. Content of total soluble solids (TSS) (a), pH values (b) and titratable acidity (TA) (c) during development of *Hylocereus* fruits from different genotypes: (-♦-) 'Nacional', (--) 'Orejona', (-Δ-) 'Rosa' and (-●-) 'San Ignacio'. First colour change is indicated (↑).

(Nerd et al. 1999). It is interesting to note that after 24 days when colour change was still unnoticeable in 'Rosa' (Table 1 and 2), total soluble solids content already increased (Fig. 4a), being delayed in 'San Ignacio'.

Titratable acidity and pH values

With the exception of 'San Ignacio', pH values initially decreased followed by an increase (Fig. 4b). 'Nacional' reached the minimum value after 21 days, 'Orejona' after 24 days, 'Rosa' and 'San Ignacio' after 28 days, respectively. For 'Rosa' and 'Orejona', acidity increased until a maximum was reached, followed by a dramatic drop, being different for 'San Ignacio' and 'Nacional' (Fig. 4c). Maximum acidity generally coincided with minimum pH values. 'Orejona' and 'Rosa' had similar low values, followed by 'Nacional' and then 'San Ignacio'. In accordance with Nerd et al. (1999), the highest acidity was found at the first colour change, except in 'Nacional', where the acidity peak was registered earlier. Acidities of 3.4 and 2.7 to 4.3 g l^{-1} have been elsewhere reported for *H. polyrhizus* and *H. undatus* (Nerd et al. 1999).

Ripening behaviour as compared to cactus pears and potential maturity parameters for Hylocereus *fruits*

Lower skin firmness values 1.8–3.3 N were determined for cactus pear by Silos-Espino et al. (2003) compared with the results obtained for *Hylocereus* in the present work. However, comparison between different studies appears to be rather difficult because different methods were applied: While Barbera et al. (1992), Nerd et al. (1999), Felker et al. (2005) and Hoa et al. (2006) used penetrometers with dissimilar diameter heads, Silos-Espino et al. (2003) employed a Texture Analyser, but with a different setup than in the present work. When compared with *Hylocereus,* softening of the skin was slower after harvest in *Opuntia* varieties, i.e. 0.30 N per day in 'Naranjona' and 0.02 N per day in 'Charola' (Carrillo-López et al. 2002).

Similar to data reported for *Hylocereus*, the total sugar content of cactus pears increased up to fruit maturity with values of 6 to 14 % at full ripeness (Sawaya et al. 1983; Barbera et al. 1992). Contrary to the present findings on *Hylocereus*, Silos-Espino et al. (2003) and Felker et al. (2002) did not find significant differences in pH and soluble solids among cactus pear morphospecies and clones.

Since it would be most valuable for growers to rely on an appropriate parameter of maturity, different parameters previously reported for other fruits (Nerd and Mizrahi 1999; Felker et al. 2002; Siriwoharn et al. 2004; Duru and Turker 2005; Nomura et al. 2005; Jha et al. 2006) were assessed. From the data presented, it is obvious, that all parameters evaluated are appropriate and will dramatically change between colour break and full colour within each genotype. However, only flesh firmness exhibited consistent values for all genotypes at full colour. Therefore, the latter represents the only parameter that may be universally applied for *Hylocereus* maturity evaluation. Inversely, genotypes may be differentiated by the remaining maturity parameter values.

Differences among genotypes to be considered for crop production

The general behaviour of the fruits from the genotypes analysed in this work allowed to group them in two categories. While the first one bearing smaller fruits and including 'Nacional' and 'Orejona' exhibited a shorter ripening phase, the second group comprising 'Rosa' and 'San Ignacio' produced larger fruits and had a longer ripening period. This information could be useful for crop breeding and production, allowing prediction of the optimum harvest date for the particular genotypes.

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