Quality Characterization of Celery (*Apium graveolens* L.) by Plant Zones and Two Harvest Dates

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Abstract: The aim of this study was to characterize the quality of celery petioles (*Apium graveolens* L. cv Golden Clause) from the external, middle, and internal zones of each plant. Harvest dates were 93 (HD1) and 124 (HD2) days after transplantation. Total weight (TW), total length (TL), total leaves number (LN), and petiole length of leaves (PL) for the 3 zones were measured. Physicochemical (color, b^* and h; texture; total soluble solids, TSS; titratable acidity, TA; water content, WC), nutraceutical (ascorbic acid, AA; total quinones, TQ; browning potential, BP), and sensorial analysis (flavor, fibrosity, crunchiness) were done at harvest on petioles of each zone. No differences between harvesting dates were found in TW, TL, LN, and PL. Middle leaves had the highest PL. Harvest dates were not different in b^*, h, TA, AA, and WC. Texture, TSS, BP, and TQ resulted higher in petioles of HD2 than in HD1. Similar TSS and TA were found in leaves of different plant zones. The yellow color of both external and internal zones was significantly higher than in the middle zone. The texture and BP was similar between the external and middle zones but the WC was lower in the external zone. Similarly, the AA content as well as the TQ was also lower than in the middle zone. Harvest delay improved the nutraceutical value in terms of BP and TQ, even though it also resulted in pithiness and fibrosity of the leaves. This study therefore suggests that the petioles of the middle zone when harvested at HD1 are the most suitable for consumption.

Keywords: celery, maturity, nutraceutical, sensorial, quality

Practical Application: Celery is a vegetable reduced in calories, has a high nutritional value and its fresh petioles are mainly consumed in salads. The texture and flavor are the most important attributes that define consumers' acceptability. As nutritional value, texture, and flavor may change with plant age and different zones of the plant, harvest date plays an important role on quality. Results indicate that harvest delay improved the nutraceutical value even though it also resulted in pithiness and fibrosity of the stalks. Petioles of the middle zone, when harvested at 93 d after transplanting, are the most suitable for consumers' consumption.

Introduction

Celery is a vegetable highly appreciated for its reduced caloric input on the diet and high nutritional value related with the content of antioxidant compounds (Viña and Chaves 2006; Rizzo and Muratore 2009). It also contributes with vitamins, minerals, and bioactive substances (lutein and carotenoids) as well as with high flavonoids levels (Hertog and others 1992; Wada and Ou 2002) which have a primary role in the prevention of colon cancer and important antioxidant activity (Rice-Evans and others 1996). The presence of these bioactive compounds allows celery to be considered as a vegetable with nutraceutical properties since it has beneficial effects on human health.

The celery is composed of leaf-topped stalks arranged in a conical shape that are joined at a common base. The stalks have a crunchy texture, aniseed taste, and end in small leaflets with very intense flavor. For a plant to be considered of good quality it should be compact, with thick well formed petioles, slightly curved, with fresh appearance and light green color (Suslow and Cantwell 2002; Raffo and others 2006). Generally, the petioles are consumed fresh in salads, or both, the petioles and the leaflets, are used in the preparation of hot meals such as soups (Gómez and Artés 2004a).

The color and appearance play a decisive role at the time of purchase; however texture and flavor are the most important sensory attributes, which determine the consumers' acceptability (Raffo and others 2006). The petioles should be crispy and cracking, meaning that they should make a noisy crackling sound during mastication. Regarding to aroma and flavor, preferences vary according to the target market, as some consumers prefer celery with pronounced flavor; others prefer it with the least possible taste (Gómez, personal communication).

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A physiological undesirable disorder from the texture perspective is pithiness development, wherein the parenchyma of the petiole becomes white, porous, and vacuolated and appears dehydrated. This disorder is associated with several factors that include senescence, water, and chill stress, preinduction changes of the floral stem and root infections (Suslow and Cantwell 2002). Factors such as genotype and the physiological age of the plant at harvest have an impact on texture and flavor, and plants are subject to deterioration as a result of inadequate temperature and relative humidity management during postharvest storage. Celery may be stored at 0 °C and 98% to 100% relative humidity for 2 to 3 mo (Suslow and Cantwell 2002). Behavior during postharvest has also been associated with the stage of maturity and other preharvest factors, such as fertilization, irrigation, and salinity (Lin and Hall 2003).

The harvest maturity of perishable commodities has an important bearing on their quality and shelf life. Horticultural maturity is the stage of development in which a plant or plant part possesses the prerequisites for utilization by consumers for a particular purpose (Kader 1992). In most markets the law of supply and demand is the impulse force that motivates growers to choose the earliest or the latest moment of harvesting of any particular commodity; so it is important to know the impact that the maturity stage has on the initial product quality. A wide range of physical characteristics of commodities is used to asses their maturity stage. In the case of celery (*Apium graveolens* L.), it is defined based on the height of the plant, this attribute being routinely used to establish harvest date (Kader 1992). A late harvest results in reduced shelf life due to the process of senescence, development of undesirable aromas and flavors, and loss of texture because the tissues become too fibrous (Brecht 2003).

Little is known whether the morphological leaf arrangement of celery impact the bioactive substance distribution such as ascorbic acid and phenolic components as well as others quality indices such as color, soluble solid and titratable acidity, leaf crispness and cracking properties, and sensorial acceptability. Two main causes could probably affect the quality indices distribution, i.e. the different leaf exposure to environmental factors and the leaf maturity stage (outer older and inner undeveloped leaves). Differences in quality attributes could also have an impact on the shelf life of the product.

The aim of this study was therefore to characterize the quality of celery plants grown under cover, in three defined sections within the plant (external, middle, and internal) and assess the effect of two harvest dates (optimum maturity and late harvest) on the quality of leaves.

Materials and Methods

Plant material

Celery plants (*Apium graveolens* L.) of the self-whitening Golden Clause cultivar produced under cover were used. Experiments were conducted in "The Coyunco," Mar del Plata, Buenos Aires, Argentina (South Latitude 37 ° 57′, West longitude 57 ° 42′) during the spring of 2008. Celery plants were harvested at 93 and 124 d after transplantation (HD1 and HD2, respectively). HD1 plants harvested were of commercial weight, that is, they weighed 460 g and measured 57 cm in length; while the HD2 weighed 540 g with 54 cm length. Plants were placed in refrigerated bags, transported to the laboratory within 1 h of harvest and immediately analyzed.

Morphological plant characterization

At each harvesting date, 10 plants were weighed (TW) in a digital balance with an accuracy of 0.01 g. Total length (LN) was measured from the base of the plant to the distal end of the last leaflet. The plants were defoliated starting from the external section to the internal and the leaves were numbered in growing sequence. Zones within the plant were visually defined according to the length of the leaves, the degree of development and level of association. Outer leaves develop first and are larger in size than the smaller inner leaves. The first 4 to 6 leaves were considered external; these are longer, greener, and alternated leaves. The inner leaves have very little development and are linked to each other around the celery heart. The rest of the leaves, with less defined features, were classified as middle. For each leaf, petiole length (PL) was measured from the base of the petiole to the node where leaflets start (Figure 1), taking into consideration the section each leaf belongs to (external, middle, or internal).

Physicochemical analysis of petioles

From each plant leaf, a 15 cm sample of petiole was taken as sample, measured from the knot to the bottom of the petiole. This section of material corresponds to a 100% edible portion for minimally processed products. The sample was divided into 3 units of 5 cm each, known hereafter as the lower, middle, and higher portion, consistent with their position on the original petiole.

For color and texture determinations, 5 plants for each harvesting date (HD1 and HD2) were analyzed. The color was determined in the day of harvest with a chromameter (model CR-300, Konica Minolta Sensing Americas Inc., N.J., U.S.A.), calibrated with a white plate ($Y = 92$, $x = 0.3137$, $y = 0.3199$), using CIELab* color space (CIE, 1978). The parameter b^* was

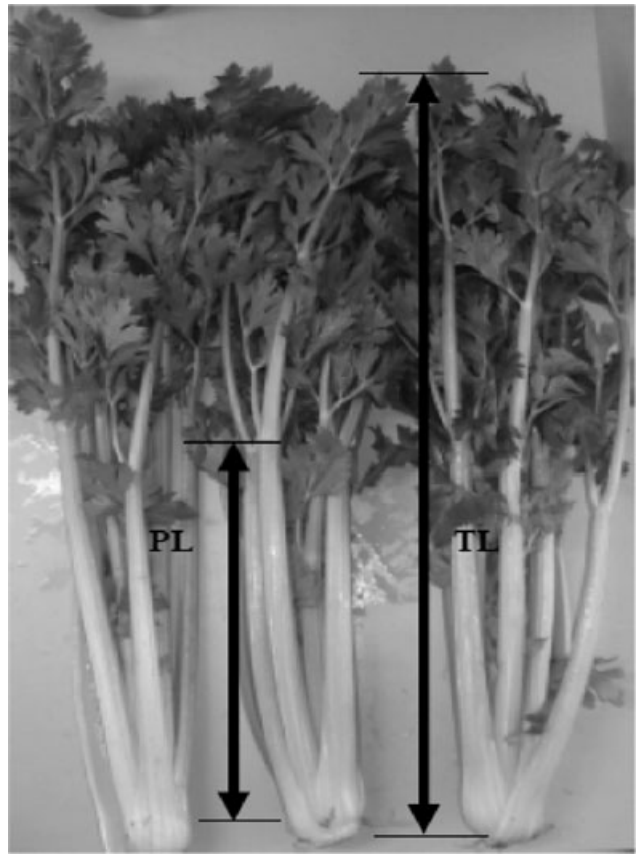

Figure 1–Celery plants. TL = total length of the plant; PL = petiole length.

analyzed, as it measures from blue to yellow (−60 = blue, +60 = yellow). The color was evaluated as hue angle ($h = \tan^{-1}[b^*/a^*]$), that corresponded to the color tone and is associated with the color perceived by human eye, where 0° = red, 90° = yellow, 180° = green, and 270° = blue (McGuire 1992). The color measurement in the lower, middle and higher portion of the petiole section (15 cm) showed no significant differences in terms of b^* and h, denoting that the color of the sample was uniform. Henceforth, the color measurement was taken only in the middle portion of the sample. For texture, upper and lower portions of the samples were used for determination of maximum force (kg) to shear the portion petiole, using a texture analyzer (model 500N BFG, QuantrolTM, Dillon/Quality Plus Inc., Kansas City, Mo., U.S.A.), equipped with a Warner-Bratzler shear blade (GR Manufacturing Co, Manhattan, Kans., U.S.A.), with a speed of 0.4 mm s^{-1}.

For the determination of total soluble solids (TSS) and titratable acidity (TA), the same 5 plants from the HD1 and HD2 samples were analyzed. The juice of each petiole sample of 15 cm was extracted with a juicer (model PHILIPS CUCINA HR-1820, Philips, Shangai, China). TSS of the juice was determined by a digital refractometer (model Atago Palette α Series, ATAGO Co. Ltd., Tokyo, Japan) and expressed as percentage (0 to 32). TA was measured in 10 mL of juice, with an automatic titrator (model TITRALAB 901, Radiometer Medical APS, Brønshøj, Denmark). The amount (mL) of 0.1N NaOH needed to achieve a pH of 8.2 was used to determine the titratable acidity as citric acid (g citric acid L^{-1}).

To determine water content other 5 plants recollected in each harvest date were used. The 15 cm sample portion of each leaf petiole was cut into small pieces with a sharp knife and blended with a standard blender (model MINIPIMER BRAUN MR 4050, Braun, España). From each portion, a 10 g sample was dried in a conventional oven at 80 °C for 24 h (Agüero and others 2008). The water content (WC) is expressed as gram of water per 100 g of fresh tissue, calculated using the following equation:

$$WC = \frac{(FW - DW)}{FW} \times 100$$

where FW means fresh weight and DW means dried weight.

Nutraceutical characterization of petioles

Determinations of the reduced ascorbic acid content (AA) and the total polyphenols content as total quinone (TQ) and browning potential (BP), were measured in 10 plants in each harvesting date (HD1 and HD2). Ascorbic acid was determined in the 15 cm sample portion of each leaf petiole, following the methodology described by Pelletier (1985). Briefly, a 10 g sample was homogenized in a 6% metaphosphoric solution and the homogenate was filtered. Aliquots of supernatant were titrated using 1.6-dicloroindofenol. Determinations were performed in duplicate. The content of AA was expressed as milligram of AA per 100 g of fresh tissue.

Phenolic compounds content was carried out using the methodology described by Loaiza-Velarde and others (1997), where the plant material were refrigerated for 24 h and thereafter a sample of 10 g fresh tissue was homogenized with 20 mL methanol (high-performance chromatography [HPLC] grade). The homogenate was filtered through fiberglass and centrifuged for 20 min at 15 × g. The absorbance of an aliquot of the filtered was read on a spectrophotometer UV-VIS (model SPECTRONIC 601 Milton Roy, Pa., U.S.A.) at 320 nm to determine the browning potential and at 437 nm to determine total quinone content as final product of the browning reaction (Cheftel and Cheftel 1976). Determinations were performed in duplicate and results were expressed as absorbance units per gram of fresh tissue.

Sensory evaluation

The analysis was conducted with eight judges, selected and trained according to IRAM 20005/1 standards. For the sensorial quality assessment of the petioles, the quantitative descriptive analysis (Stone and Sidel 1993) was used with unstructured scales of 10 cm in length, anchored at the ends with descriptive expressions (weak or strong for flavor; little or very crunchy for crispness; little fibrous or very fibrous for fibrosity). The samples were coded at random with three digit numbers. Each sensorial attribute was determined in triplicates from a 15 cm petiole section of middle celery leaves, because they represent approximately 60% of the edible portion of the plant (based on the number of leaves) (data not shown).

Statistical Analysis

A completely randomized design under factorial arrangement with two factors: harvest (HD1 and HD2) and zones (external, middle, and internal), considering in the model random effects (plant) and fixed (harvest date) and nested (zone in each plant) was employed. Differences between upper and lower portions of the samples were analyzed for texture. The sensory analysis was conducted in a completely randomized block design, since samples were provided to judges in randomized order and the whole experiment was repeated for each judge. Data were analyzed using SAS software version 8.0 (SAS 1999; PROC GLM, general linear model procedure). The Tukey–Kramer multiple comparison test was used when significant differences were found.

Results and Discussion

Morphological plant characterization

There was no significant difference in the total weight ($P = 0.1934$), total length ($P = 0.2426$), total leaf number ($P = 0.1302$); and petiole length ($P = 0.5591$) when HD1 and HD2 were compared (Table 1). In both harvesting dates, petiole length of internal leaves was significantly lower than the externals ones, whereas the middles ones resulted in the highest length ($P = 0.0493$) (26.6 ± 1.4, 28.5 ± 1.4, and 21.3 ± 1.5, for externals, middles,and internals, respectively).

Physicochemical characteristics of petioles

Leafy vegetables such as celery are susceptible to color loss due to degradation of chlorophyll, as a consequence of senescence. In celery, the amount of chlorophyll is directly related to the color of the petioles (Lancaster and others 1997), which leads to a yellow color that encourages consumers to reject (Artés and Gómez 2003). During the senescence of the plant tissue the structure of the cytoplasm and chloroplasts is damaged. Therefore, pigments are accessible to the attack of acids and enzymes of cellular degradation, favored by the presence of oxygen (Maunders and others 1983). Between harvest dates HD1 and HD2, changes in b^* parameter and h were not significant ($0.0881 < P < 0.0889$), although b^* and h differed between zones of the celery plant ($P = 0.0001$). We detected an increased on b^* moving inward from outer to inner petioles (Table 2); in terms of h, yellow color in petioles of external and internal leaves resulted higher than in the middle on each celery plant. These results indicate that consumers may be able to detect differences in petioles coming from different plant

zones based on the color, although this could be not distinguished on the two evaluated harvest dates.

Texture is an important index because it defines the quality of the product. It encompasses quality attributes such as turgidity, cohesion, size, and shape of cells, presence of supporting tissue and the composition of the plant. In celery, there is no formation of lignin or secondary growth, but the texture can be modified by the formation of air spaces (aerenchyma) in the different tissues. In general, a turgid tissue is crunchy, more rigid and offers less resistance to cutting (Smith and others 2003). For both harvesting dates no significant differences ($P = 0.8600$) in texture were found between upper and lower portion of each petiole, so data were combined and processed as a pool. Significant differences between harvest dates ($P = 0.0060$) were found in the petioles texture; the leaf petioles from HD2 showed a higher force to shear than HD1 (3.8 and 2.9 kg; respectively): at both harvesting dates, a lower force was determined in the petioles from the internal zone compared with the others sections (Table 2). The inner leaves are formed by young tissue still growing, more succulent and with a higher predominance of parenchyma cells, with collenchyma filaments which provides considerable flexibility and tension (Pantastico 1979). In contrast, petioles of the external and middle zones have sclerenchyma and collenchyma cells that cause more fibrous texture and increased the force necessary to shear the tissue. In this sense, it appears that the harvest delay affected adversely the texture index of celery.

Significant differences ($P = 0.0028$) between harvesting dates were found for TSS, being higher in petioles harvested in HD2 (3.96%) compared to HD1 (3.27%). This increase may be related to organic reserves transformation by which energy is made available for the catabolism uses, but it might be also associated with an aging product and with structural changes of carbohydrates as a result of the development of pithiness (Gómez and Artés 2004a, 2004b). Between the zones, the TSS were not significantly different ($P = 0.3786$) (Table 2). The TSS average for the 3 celery zones was high (3.61%) when compared with the 2.87% reported by Gómez and Artés (2004a, 2004b) for celery green cv. "Trinova." There was no significant difference in titratable acidity between harvesting dates ($P = 0.1252$), nor between zones of the plant ($P = 0.6566$). The average concentration of citric acid was 0.063%; this level of citric acid is similar to that reported by Gómez and Artés (2004a, 2004b) for the cultivar Trinova.

There were no significant differences in water content for the date of harvest ($P = 0.5909$), so data were combined. Interestingly, in both harvest dates significant differences ($P < 0.0001$) were found between zones of the plant (Table 2), where the external and inner leaves have the highest and lowest WC, respectively. These results are consistent with those reported by Agüero and others (2008), Barg and others (2009) and Goñi and others (2010) in investigations carried in lettuce. Differences in water content found between the zones could be attributed to the degree of development of the leaf tissue, as the inner leaves are undeveloped tissue, therefore more metabolically active (Barg and others 2009).

Nutraceutical value of petioles

No significant differences ($P = 0.5046$) were found for ascorbic acid content between harvesting dates, so data were combined and considered as a pool. Between the external, middle and internal zones significant differences ($P < 0.0001$) were found in AA, with the outer leaves having the lowest AA content (Table 3). In general, the ascorbic acid content decreases during development. Goñi and others (2010) found that outer lettuce leaves had lower ascorbic acid content respect to mid and inner leaves, attributing these results to the higher exposure of the outer leaves to environmental conditions. The exposure of the leaves to environmental factors such as external light, UV radiation, temperature, mechanical damage, could induce a response in the plant. These factors acting alone or in combination or in synchrony may accelerate the ascorbic acid degradation of the most exposed leaves resulting in physiological implications, both for the plant and its defence against oxidative stress (Hancock and Viola 2005). The oxidized form of vitamin C, dehydroascorbic acid, generally constitutes a larger proportion of the total vitamin C in the older leaves. Ascorbic acid has a higher reducing capacity and antioxidative potential than dehydroascorbic acid. In the present investigation, undeveloped inner leaves presented the highest AA contents attributing the differences to the maturity stage of the leaves. Other researchers also reported differences in acid ascorbic content between unripe and ripe stages in various horticultural crops (Audisio and others 1995; Lee and Kader 2000; Roura and others 2001).

Significant differences among harvesting dates were found, both for the browning potential ($P = 0.0002$) and for total quinones ($P = 0.0034$) as end products of phenolic metabolism (Table 3). For HD2 the browning potential and total quinones were higher

Table 1–Morphological indexes of celery plant harvested at 93 and 124 d after transplantation (HD1 and HD2, respectively).

		Morphological indexes			
		TW	TL	LN	PL
Harvest date	HD1	$458.62^{aA} \pm 30.9$	$60.4^{a} \pm 3.7$	$12.6^{a} \pm 0.7$	$26.2^{a} \pm 4.1$
	HD2	$539.86^{a} \pm 19.5$	$60.7^{a} \pm 2.3$	$14.2^{a} \pm 0.7$	$24.8^{a} \pm 3.4$

TW = total weight of the plant, in gram; TL = total length of the plant, in centimeter; LN = total number of leaves of the plant; PL = petiole length of leaves, in centimeter.
The reported values correspond to the mean with its standard error.
[A]Same letters in the same column indicate nonsignificant differences between harvesting dates, according to Tukey–Kramer test with $P = 0.05$.

Table 2–Physicochemical characteristics for celery petioles according to the plant zones.

		Physicochemical characteristics of petioles					
		Color					
		b^*	h	Texture (kg)	Total soluble solids (%)	Titratable acidity (%)	Water content (%)
Plant zones	External	$22.39^{cA} \pm 0.6$	$112.3^{b} \pm 3.0$	$3.59^{a} \pm 0.07$	$3.49^{a} \pm 0.06$	$0.064^{a} \pm 0.002$	$96.49^{a} \pm 0.3$
	Middle	$28.90^{b} \pm 0.6$	$115.1^{a} \pm 1.8$	$3.53^{a} \pm 0.08$	$3.61^{a} \pm 0.06$	$0.064^{a} \pm 0.001$	$96.11^{b} \pm 0.3$
	Internal	$33.76^{a} \pm 0.6$	$112.8^{b} \pm 2.6$	$2.91^{b} \pm 0.08$	$3.74^{a} \pm 0.06$	$0.061^{a} \pm 0.002$	$95.82^{c} \pm 0.4$

The reported values correspond to the mean of both harvesting dates with its standard error.
[A]Same letters in the same column indicate nonsignificant differences between zones of celery plant, according to Tukey–Kramer test with $P = 0.05$.

than those corresponding to HD1 (Table 3). Differences in browning potential and total quinones were also found between the plant zones ($P < 0.0001$ in both cases). The potential browning of the internal petioles was significantly higher than that of the externals and middles. Viña and Chaves (2006) working with a celery variety Golden Boy reported higher browning potential values compared with those reported in this study, however Loaiza-Velarde and others (2003) observed browning potential values which are in agreement with our results. Soluble quinones content were also significantly higher in the inner leaves; however, in this case, significant differences were found regarding the mid and the outer leaves (Table 3). The external zone presented the lower soluble quinones content.

These results coincide with previous studies on some fruits, where the highest levels of phenolics compounds were found at the earliest stages of development and quantities declined rapidly during ripening (Buta and Spaulding 1997; Ueda and others 2000; Zhen and others 2008). There is little information about phenolic content evolution during growth in leaves of different leafy vegetables. Bergquist and others (2005) demonstrated that the concentration of flavonoids decreased with age in spinach leaves. Pandjaitan and others (2005) found a highest level of total phenolics and total flavonoids in middle leaves of spinach plants, suggesting that these compounds were synthesized in leaves at early stages of maturity, decreasing or finalizing this process during the final maturity stages.

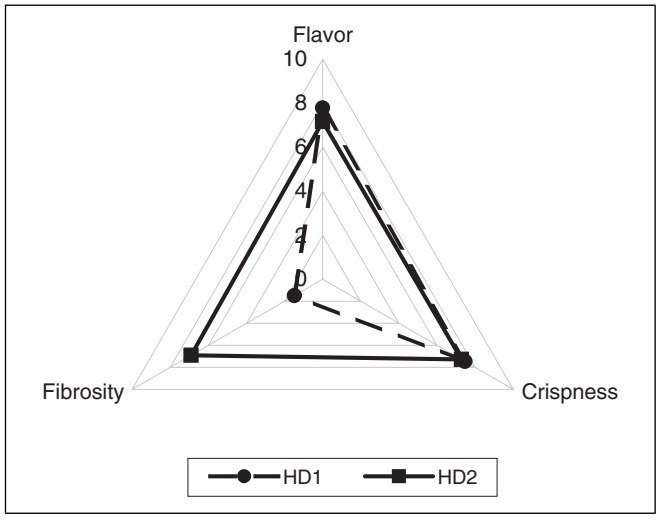

Figure 2–Sensory profile of celery (*Apium graveolens* L.) at HD1 and HD2.

Sensory evaluation

The panelist found a significant difference between harvesting dates only in fibrosity ($P < 0.0001$). Results for the sensory evaluation are shown in Figure 2. For the judges, the petioles resulted less fibrous in HD1 than in HD2 (1.5 and 6.9, respectively) and coincided with a lower cutting force in HD1 than in HD2. Similarly, Pantastico (1979) previously determined that a delay in harvest makes petioles more fibrous. Our findings confirm this notion. Fibrosity detected by judges in HD2 stalks could be considered excessive by consumers. The crispness is one of the key attributes of celery petioles quality (Viña and others 2007). This property is associated with the sound emitted by the petiole during the chewing; as celery ages and dehydrates the crispness is reduced, which is related to a quality loss. This attribute depends on several factors, including dehydration, the proportion of fibrous tissue and the degree of lignification, among others (Viña and Chaves 2003). No difference was found between harvesting dates for crispness ($P = 0.5818$), that may be associated with the similar water content of HD1 and HD2 celery plants.

Texture and flavor play a significant role in the acceptability by consumers (Raffo and others 2006). Although the difference between harvesting dates on the flavor perceived by the judges was not significant at 5% level ($P = 0.0749$), there was a loss in HD2 compared to HD1 (6.9 and 7.8, respectively), probably due to the pithiness development (Gómez and Artés 2004a, 2004b). Panelist detected a slight presence of hollowed tissue in the petioles of the plants of the late crop (HD2), while in HD1 the defect was absent, this fact may explain the lower flavor in HD2. The occurrence of pithiness in HD2 has been associated with a late harvest (Saltveit and Mangrich 1996). Celery plants in HD1 and HD2 were treated with the same agronomic management and evaluated following the same procedure, so it appears that this defect could be attributed to a late harvest of plants in HD2.

Conclusions

The quality characterization in celery plants by zones recognized differences in color (in terms of b^* and h), texture, water content, and nutraceutical value (ascorbic acid, browning potential, and total quinones). Internal petioles had lower cutting force and lower water content but higher content of total soluble quinones and browning potential than the middle and the external zones, while the ascorbic acid content was higher in the middle and the internal than in the external zone.

No differences in the morphological characteristics measured (total weight, total length, total leaf number and petiole length) were found between the two maturity stages (HD1 and HD2). The harvesting date did not modify the measured color, ascorbic acid, and water content. Nutraceutical value was enhanced by a late harvest, but more mature plants showed petioles with higher cutting force, more fibrous and with the presence of pithiness. This study provides basic information about the physical, chemicals, and nutritional quality of the celery plant associated with

Table 3–Nutritional value of celery petioles according to the zone of the plant and harvest dates.

		Nutraceutical value of petioles		
		AA	**BP**	**TQ**
Plant zones	External	$4.43^{bA} \pm 1.01$	$0.0912^{b} \pm 0.031$	$0.0258^{c} \pm 0.006$
	Middle	$6.33^{a} \pm 1.36$	$0.1115^{b} \pm 0.052$	$0.0322^{b} \pm 0.007$
	Internal	$6.72^{a} \pm 1.28$	$0.3274^{a} \pm 0.123$	$0.0462^{a} \pm 0.008$
Harvest dates	HD1	$5.57^{a} \pm 1.73$	$0.1019^{b} \pm 0.043$	$0.0268^{b} \pm 0.005$
	HD2	$5.97^{a} \pm 1.13$	$0.2516^{a} \pm 0.095$	$0.0427^{a} \pm 0.005$

AA = ascorbic acid, milligram per 100 of fresh tissue; TQ = total quinones content, in AU per gram fresh tissue; and BP = browning potential, in AU per gram of fresh tissue. The reported values correspond to the mean with its standard error.
[A]Same letters in the same column and factor (zones of the plant or harvest dates) indicate nonsignificant differences, according to Tukey–Kramer test with $P = 0.05$.

harvest maturity stage and leaf position within the plant. Future research including more different stages of celery development will elucidate the changes associated with plant maturity. These findings are essential to determine the optimum maturity stage at harvest with which the highest quality of the product is achieved. For products IV and V gamma, it would be advisable to use petioles of HD1, belonging to the middle zone, due to improved texture, less fibrosity, and no hollow development.

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