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Changes in the Postharvest Quality of Datil Hot Peppers as Affected by Storage Temperature

Elena E. Lon Kan[1*], Steven A. Sargent[1*], Amy Simonne[2], Nicole L. Shaw[1], and Daniel J. Cantliffe[1]

[1]*Horticultural Sciences Department, University of Florida/IFAS, Gainesville, FL 32611*

[2]*Family, Youth and Community Sciences Department, University of Florida/IFAS, Gainesville, FL 32611*

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Two datil hot pepper selections (*Capsicum chinense*), named 'Wanda' and 'Super Datil Pepper', were grown hydroponically in a greenhouse. On day of harvest ripe (yellow) peppers were packed in vented clamshells and stored for 14 days at 5, 10, or 20 °C then transferred to 20 °C for 4 days. General appearance, moisture content, weight loss, respiration rate, soluble solids content (SSC), acidity (TTA), pH and carotenoids (HPLC) were evaluated. Respiration rates for 'Wanda' at 5, 10, and 20 °C were at 22, 29, and 71 mg CO_2·kg^{-1} per hour, respectively; and for 'Super Datil Pepper' at 5, 10, and 20 °C were 33, 37, and 99 mg CO_2·kg^{-1} per hour, respectively. Respective weight loss for 'Wanda' and 'Super Datil Pepper' between 4 and 14 days + 4 days, ranged from 1.6% to 15.1%, and 0.9% to 7.8% at 5 °C; 2.9% to 18.0%, and 1.4% to 8.5% at 10 °C; 10.9% to 40.1%, and 5.7% to 20.1% at 20 °C. Carotenoid content was higher for 'Wanda' after 14 days at each storage temperature + 4 days at 20 °C. Lutein content for 'Wanda' and 'Super Datil Pepper', respectively, stored at 5 °C was 68.7 and 52.4 µg·g^{-1}; at 10 °C, 94.5 and 49.7 µg·g^{-1}; and at 20 °C , 100.6 and 48.1 µg·g^{-1}. Beta-carotene content for these respective types at 5 °C was 31.5 and 6.4 µg·g^{-1}; at 10 °C, 43.9 and 6.7 µg·g^{-1}; and at 20 °C, 15.6 and 6.5 µg·g^{-1}. There were no typical chilling injury symptoms in either pepper selection after 14 days storage at 5 °C. Some 'Wanda' peppers stored at 10 °C had signs of shriveling by 12 days; both types stored constantly at 20 °C were unmarketable by 11 days due to shriveling and decay. Compared to other pepper types, 'Wanda' and 'Super Datil Pepper' were not sensitive to visible chilling injury symptoms for up to 14 d at 5 °C, which could allow them to be commercially shipped with high quality.

Chili peppers (*Capsicum* species) were among the most widespread plants domesticated, cultivated, and traded among indigenous peoples in the New World as long as 6000 years ago (Perry et al., 2007). Christopher Columbus took peppers to Europe 500 years ago. A yellow hot pepper type, named datil (*Capsicum chinense*), has been grown on a small scale in the coastal area of St. Augustine, FL, for more than 200 years (Andrews, 1995), although no named cultivars exist. Datil peppers have a characteristic conical form from 20 to 60 mm long. Howard et al. (2000) described the distribution of carotenoids present in bell peppers, and on the importance in nutrition of individual carotenoids such as beta-carotene, lutein, zeaxanthin, and others. Also, Gross (1987) and Hornero-Mendez and Minguez-Mosquera (2001) reported data for beta-carotene, zeaxanthin, and other carotenoids present in pepper types.

The stability of carotenoids is highly variable; in some fresh crops degradation occurs in only a few days, while dried crops retained more than 50% of the carotenoids even after 3 years of storage. A number of factors affect the rate of carotenoid loss, including the specific pigment, crop type, storage temperature, moisture content, and prestorage treatments. The breakdown of carotene is of special concern due to its role as a precursor of vitamin A (Kays and Paull, 2004). As a group, xanthophylls, such as lutein, are characteristically more stable than the carotenes, where the former is esterified, apparently enhancing stability in contrast to the carotenes.

No published information is available on production and postharvest handling of fresh datil pepper. The purpose of this study was to determine the retention of selected quality parameters for two selections harvested ripe and stored under simulated commercial conditions.

Material and Methods

Seeds from two datil pepper selections were obtained. One selection was named 'Wanda' (source: W. Chapman, Jacksonville, FL 32211) and the other is known as 'Super Datil Pepper' (source: Datil Dew, Green Cove Springs, FL 32043). The plants were grown hydroponically using standard production techniques in a passively ventilated greenhouse at the University of Florida/IFAS Protected Agriculture Project in Citra (Shaw et al., 2007). Fruits were hand-harvested twice between Nov. 2006 and Jan. 2007. The first harvest was used for initial quality analyses and the second for the storage test. Average dimensions for length and diameter are, respectively, for 'Wanda': 39 and 13 mm (at equator), and for 'Super Datil Pepper': 65 and 29 mm (at stem end). Fruits were transported about 40 km to the Horticultural Postharvest Laboratory at the University of Florida in Gainesville. Fruits were sorted and dusted with delicate task wipes (Kimwipes), then randomly selected and packed in vented clamshells (Ultrapac MLPS, no. 3535-1, recycled PETE, Rogers, MN) for storage. Clamshell dimensions were 8.5 cm × 8.0 cm × 7.0 cm (base); 9.0

*Corresponding authors; email: elonkan@ufl.edu; sasa@ufl.edu; phone: (352) 392-1928, ext. 215.

Table 1. Appearance rating scale used for quality assessment of datil peppers during storage.

Score	Quality	Description
1	Severe	Serious surface shriveling, black spots, and/or microbial growth.
2	Poor	Obvious surface shriveling and softening; unmarketable.
3	Fair	Minimal surface shriveling; limit of marketability.
4	Good	No surface shriveling. Stem shriveled.
5	Field fresh	Highly marketable with shiny/glossy appearance.

cm × 9.0 cm × 2.5 cm (lid), with 12 vent holes arranged in the lid and base. Following packing, fruits were rapidly cooled (Sargent et al., 2006) by leaving the clamshells lids open for 1 h at 10 °C, then closed and transferred to the pre-assigned temperatures (5, 10, or 20 °C). The following parameters were measured to assess fruit quality during storage.

General appearance. Entire clamshells from each storage temperature were evaluated daily for visual quality during a 14-d storage period and after transfer to 20 °C for 4 d using a subjective rating scale from 1 to 5 (Table 1). A single rating was given for the three replicate clamshells in each treatment at each observation.

Moisture content and weight loss. For moisture content determination, calyx, seeds and placental tissue were excised from 6 to 12 fruits, and 2 to 3 g of pericarp tissue was placed in an aluminum pan and dried in a vacuum oven at 70 °C for about 2 d until a constant, final dry weight was obtained (AOAC, 2000). The percent moisture content was calculated using the following formula:

$$\% \text{ moisture content} = \frac{(\text{initial fresh wt} - \text{final dry wt}) \times 100\%}{\text{initial fresh wt}}$$

The weight loss (fresh weight basis) was determined during storage by weighing each clamshell, on days 4, 5, 6, 14, and 14 d + 4 d from each storage temperature. Weight changes were calculated using the following formulas:

$$\% \text{ weight loss} = \frac{100\% - (\text{storage peppers wt} \times 100\%)}{\text{initial fresh wt}}$$

Respiration. Respiration rates were determined by respectively placing 10 and 4 weighed fruits of 'Wanda" and 'Super Datil Pepper' in 292- and 487-mL glass containers, three-container replicates per storage temperature. The containers were then stored at 5, 10, and 20 °C with loose caps. To obtain headspace samples, the container lids (fitted with rubber septa) were sealed for approximately 60 min prior to sampling. Three headspace samples (0.5 mL) were withdrawn per container and were measured by injecting samples into a gas chromatograph (GowMac, 580 series, Bridgewater, NJ), equipped with a thermal conductivity detector. Readings were taken on days 4, 5, 6, 14, and 14 + 2 d and averaged to obtain final values expressed as milligrams of CO_2 per kilogram per hour.

Soluble solids content, total titratable acidity, and pH. For initial analysis of soluble solids content (SSC), acidity and pH, a composite was made using 40 to 60 whole fruits (calyx removed). Samples were sliced and blended at high speed for 2 min; then the juice was extracted with hand-pressure using four layers of cheesecloth. The pH and acidity were determined by diluting 6 g of sample with 50 mL of deionized water and titrating with 0.1 N of NaOH using an automatic titrator (719 Titrino, Brinkmann, Herisau, Switzerland). Results of acidity were expressed in grams of citric acid per 100 g of sample. SSC (°Brix) were determined using a refractometer with temperature compensation (Abbe Mark II model 10480, Cambridge Instruments, Inc., Buffalo, NY).

Carotenoids content. Carotenoids were determined following the respective storage treatment plus 4 d at 20 °C by reversed-phase high performance liquid chromatography (HPLC) using isocratic elution.

Sample preparation. Fruits from each variety were randomized into one composite of 12 fruits for 'Wanda' (due to its small size) and six fruits for 'Super Datil Pepper'. Calyx, seeds, and placental tissue were removed from the fruits, and only pericarp tissue was used for the analyses of carotenoids. Each pericarp composite was blended for 10 s under yellow light (Sylvania Gold F40/GO, 40 W, General Electric, Sunnyvale, CA) to minimize photooxidation (Simonne et al., 1997), then two subsamples were taken from each composite for determination of moisture content and carotenoids content.

Saponification and extraction. To duplicate the analyses, two 4-g samples (based on preliminary work) were taken from each composite and placed into two glass tubes, then saponified and extracted. Twenty milliliters of 6% pyrogallol (in isopropanol) and 30 mL of deionized water were added to each tube, then the contents were blended with a homogenizer (Polytron 3100; Brinkmann Instruments, Inc., Westbury, NY) for about 1 min on a speed setting of four. After blending, 5 mL of 60% potassium hydroxide were added to the each tube and flushed with nitrogen (N_2) for 1 min and the contents were saponified at 70 °C for 30 min. After the saponification, the samples were extracted with hexane containing BHT. The extract was quantitatively evaporated to dryness with continuous flow of nitrogen. The residue was dissolved in the mobile phase and filtered using 13-mm syringe filters, 0.2-um, Nylon (Fisher brand) (Simonne et al., 2002).

HPLC conditions. The extracts were injected into a reversed phase HPLC [Water Alliance system 2695 Separation Module, 996 Photo-Diode-Array Detector; auto injector (injection volumes = 10 to 30 µL), and column temperature regulator; Water Milford, MA]. Separations were accomplished using a reversed phase C_{30} polymeric analytical column (ProntoSil® 250 mm × 4.6 mm i.d., 5-µm particle diameter, MAC-MOD Analytical, Inc., PA). Isocratic mobile phase consisted of methyl tert-butyl ether (MTBE), methanol (MeOH), and ethyl acetate (EtOAc) in a ratio of 40:50:10 (by volume), respectively (Ishida et al., 2001). Flow rate was set at 1 mL·min^{-1}; column temperature was maintained at 28 °C. Identification of carotenoids was done by retention time and spectral comparison, and quantification was completed at 450 nm. Concentration, purity, and stability of carotenoid standards were monitored by a photo-diode array spectrophotometer (Beckman Model DU 640) using the molar absorptivities published by Davies (1976). All sample preparation steps and analyses were made quickly and by the same trained person, following protocols for carotenoids analysis (Rodriguez-Amaya, 2001).

Data analysis. The experiment was set up using a completely randomized design (CRD) and data were analyzed by variety using SAS statistical software program (SAS Institute Inc., Carey, NC). Standard error was calculated from pepper means for each treatment and parameter by datil pepper selection.

Results and Discussion

General appearance. According to the appearance rating scale, both datil pepper selections stored at 5 °C were marketable after 14-d storage plus 1 d at 20 °C (Table 1). At that time, fruit quality was rated as good (rating = 4) in contrast to fruit stored at 10 °C, where fruit were rated as fair (rate = 3), after 12-d storage ('Wanda') or after 14-d storage plus 1 d ('Super Datil Pepper'). After 14-d storage at 5 °C plus 2 d at 20 °C, both datil types were unmarketable, as was 'Super Datil Pepper' stored 14 d at 10 °C plus 2 d at 20 °C. The main cause of quality loss was shriveling; their glossy and shiny appearance remained unchanged. Following 11 d storage at 20 °C, most peppers from either datil type were unmarketable due to shriveling, softening and some microbiological growth (mold decay). Cantwell (2007) reported good quality could be maintained in bell peppers for 3 to 5 weeks at 7.5 °C.

Previous research has reported peppers (*Capsicum* spp.), habanero (*Capsicum chinense*), and other hot peppers as sensitive to chilling injury when stored below 7 °C (Ashby, 2000; McGregor, 1989; Welby and McGregor, 2004). In this study, no typical signs of chilling injury were observed in ripe-harvested 'Wanda' or 'Super Datil Pepper' peppers during the 14-d storage period at 5 °C plus 4 d at 20 °C. This behavior differed from green bell peppers which were reported to show chilling injury after 2 weeks at 5 °C (Cantwell, 2007). However, sensitivity to chilling injury varies with fruit ripeness, where ripe fruit are less chilling sensitive than peppers harvested green (Gonzales-Aguilar, 2004).

Table 2. Average moisture content (%) of datil pepper pericarp tissue after 14 d-storage at 5, 10 or 20 °C plus 4 d at 20 °C.

	Temp (°C)		
Datil selection	5	10	20
Wanda	84.02[z] ± 0.12	82.77 ± 0.16	78.67 ± 0.01
Super Datil Pepper	88.09 ± 0.08	87.87 ± 0.06	88.64 ± 0.14

[z]Means ± standard deviation (n=2).

After 14-d storage at 5 or 10 °C plus 4 d at 20 °C, black areas (about 10 mm in diameter and up to 40 mm long) became apparent on the epidermis of some fruits; fruit stored at 10 °C had smaller black spots (from 0.2 to 0.5 cm). These were not caused by decay, but may have been due to the Maillard reaction, a nonenzymatic browning reaction between amino acids and reducing sugars. Nonenzymatic browning is a quality factor of color deterioration for freeze-dried red pepper. Red pepper has high reducing sugars and amino acids contents making it an optimum medium for Maillard reaction during its processing and storage due to low water activity and ambient storage temperatures (Gogus and Eren, 1998).

Moisture content and weight loss. Average moisture content values were slightly lower for 'Wanda' than for 'Super Datil Pepper', and the former lost moisture at a faster rate as storage temperature increased (Table 2). The weight loss was almost 100% higher for 'Wanda' at all temperatures when compared to 'Super Datil Pepper' (Fig. 1). There were no significant differences in weight loss for 'Super Datil Pepper' at 5 or 10 °C; however, weight loss was significant during storage at 20 °C. Although not determined in this study, the thickness of the epicuticular wax may have been thicker on 'Super Datil Pepper', retaining more moisture during storage.

Respiration rate. Ripe 'Wanda' and 'Super Datil Pepper' exhibited typical non-climacteric respiratory pattern, as cited by Kader (2002) for peppers in general. Our results for respiration rates ranged from 19–83 mg $CO_2 \cdot kg^{-1}$ per hour ('Wanda') and 29–126 mg $CO_2 \cdot kg^{-1}$ per hour ('Super Datil Pepper') for storage at 5 and 20 °C, respectively (Fig. 2). These values are significantly higher than those reported for *Capsicum* spp. by Gonzales-Aguilar (2004), where respiration rates at 5 and 20 °C averaged 8 and 34 mg $CO_2 \cdot kg^{-1}$ per hour, respectively. When compared to the respiration rate classifications for vegetables cited by Kader (2002), these datil pepper selections had "high" respiration rates, whereas bell pepper types have "medium" respiration rates.

Soluble solids content (SSC), total titratable acidity (TTA) and pH. 'Wanda' was much sweeter at harvest than 'Super

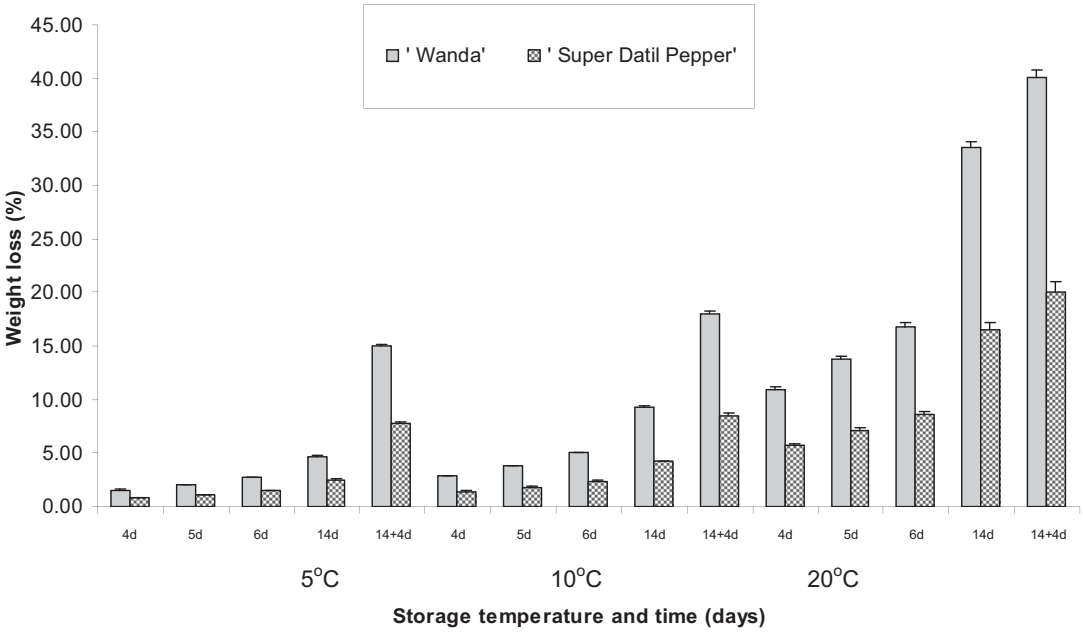

Fig. 1. Effect of storage temperature and time on weight loss for two datil pepper selections. Note: Days = 4, 5, 6, 14, and 14 d at the respective temperature + 4 d at 20 °C. Vertical bars are means (n=3) with error bars by individual variety, day and temperature.

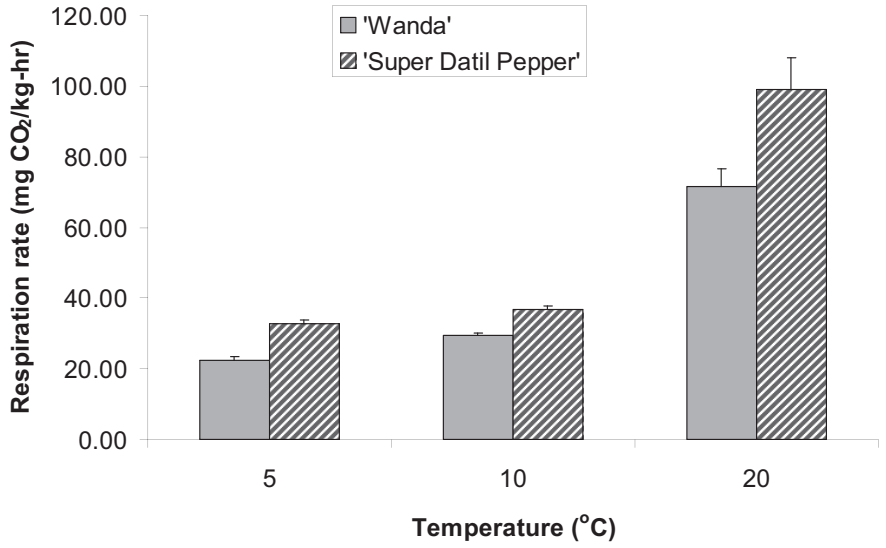

Fig. 2. Respiration rates for two datil pepper selections stored at three temperatures. Note: Days = 4, 5, 6, 14, and 14 d at the respective temperature + 4 d at 20 °C. Vertical bars are means (n=3) with error bars by variety and temperature.

Table 3. Chemical composition of datil pepper selections at harvest.

Datil selection	SSC[z]	TTA[y]	pH
Wanda	13.07[x] ± 0.05	0.29 ± 0.02	5.44 ± 0.07
Super Datil Pepper	7.60 ± 0.00	0.17 ± 0.02	5.75 ± 0.10

[z]Soluble solids content (°Brix).
[y]Total titratable acidity.
[x]Means ± standard deviation (n=3).

Datil Pepper', having approximately 58% more SSC; however, both datil varieties exhibited similar values for pH and percent TTA (Table 3). Values for 'Super Datil Pepper' were similar to those reported for 'Kelvin' yellow bell pepper, where SSC = 6.68 to 6.73 °Brix; TTA = 0.19% to 0.23%, and pH = 5.07 to 5.24 (Molinari et al., 1999).

Carotenoids content. Lutein was the major carotenoid in both datil selections and was not affected by storage temperature. Average lutein content for 'Wanda" was about 75% higher than that for 'Super Datil Pepper' (87.92 and 50.11 $\mu g \cdot g^{-1}$, respectively) (Fig. 3). The beta-carotene content for 'Wanda' was significantly affected by storage temperature, where values were: at 5 °C = 31.51 $\mu g \cdot g^{-1}$; at 10 °C = 43.86 $\mu g \cdot g^{-1}$; at 20 °C = 15.65 $\mu g \cdot g^{-1}$. Average beta-carotene content for 'Super Datil Pepper' was much lower (6.53 $\mu g \cdot g^{-1}$). Studies with freshly harvested orange bell peppers (*Capsicum annuum* L) reported lutein content of 25 $\mu g \cdot g^{-1}$ (Rodriguez-Amaya, 2001), and beta-carotene contents of 4.38 and 8.9 $\mu g \cdot g^{-1}$ (Simonne et al., 1997, and Rodriguez-Amaya, 2001, respectively). Carotenoids contents in this study would have been somewhat higher than those of freshly harvested samples (not measured in this study) due to weight loss during the 14-d

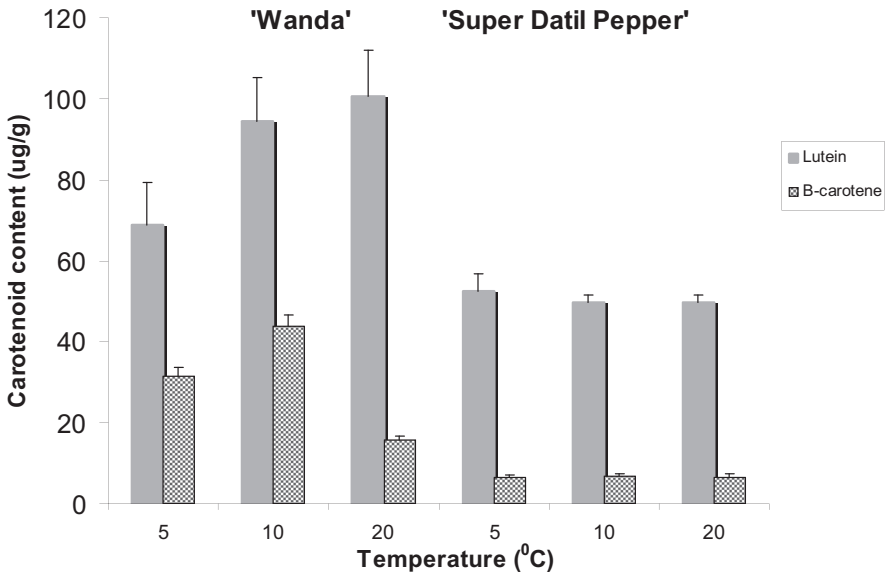

Fig. 3. Effect of the temperature on carotenoid content in two datil pepper selections after 14-d storage + 4 d at 20 °C. Vertical bars are means (n=4) with error bars of individual carotenoid by selection and temperature.

+ 4-d storage period. In non-yellow pepper types beta-carotene was the main component present while lutein was absent in *C. annuum*, varieties 'Ancho' (reddish brown) and 'Guajillo' (red) (Collera-Zuniga et al. (2005). However, lutein was a minor component in 'Mulato'(dark color, almost black).

Conclusions and Recommendations

'Wanda' and 'Super Datil Pepper' retained good quality and marketability up to 14 d at 5 °C plus 1 d at 20 °C. Fair quality was maintained during storage at 10 °C for 12 to 14 d depending on the datil pepper type. After 14 d at 5 °C + 4 d at 20 °C, final weight loss was high, ranging from 20% to 40% for both datil types; however differences were significant only at 5 and 10 °C for 'Wanda'. 'Wanda' had higher lutein and beta-carotene contents than 'Super Datil Pepper'. Storage temperature did not affect lutein content in either selection, however, beta-carotene content increased significantly for 'Wanda' with increased storage temperature. As respiration rate increased with increasing storage temperature, direct quantitative losses in quality occurred, including increased weight loss, and degradations in appearance, textural quality, and nutritional quality. From these results, it can be concluded that 'Wanda' and 'Super Datil Pepper' selections are not sensitive to visible chilling injury symptoms for up to 14 d at 5 °C plus 1 d at 20 °C. Subsequent tests should include storage at closer temperature intervals (2, 5, 7, 10 °C) during a longer period (3 weeks) to examine potential effects of chilling temperatures on postharvest quality of immature and mature datil peppers.

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