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RELATIONSHIP OF PHYSICAL PROPERTIES TO POSTHARVEST WATER LOSS IN PEPPER FRUITS (*CAPSICUM ANNUUM* L.)

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Abstract

Relationship between physical properties affecting postharvest water loss in pepper fruits were examined. Three pepper types viz., 'Keystone' (Bell Pepper), 'NuMex R Naky' (long green) and 'Santa Fe Grande' (yellow Wax) were significantly different in their initial water content, fruit surface area, fruit surface area to volume ratio, cuticle weight and epicuticular wax content. The rates of postharvest water loss at 8, 14 and 20°C were significantly different in the three pepper types. Postharvest water loss was not related to initial water content at any storage temperature or cuticle weight at 8°C. Large sized 'Keystone' fruits with small surface area to volume ratio and high epicuticular wax contents lost weight at significantly lower rate. No stomata on the surface of pepper fruits were found. Epicuticular wax was generally amorphous.

Introduction

Postharvest quality loss in pepper fruits is mainly due to water loss (Lownds & Bosland, 1988) which limits shipping of green peppers. Pepper varieties have shown significant differences in their rates of water loss during postharvest storage. The basis for these differences has not been studied.

Physical properties including water content at harvest, fruit surface area, fruit surface area to volume ratio and presence of stomata affect water loss in horticultural crops (Albrigo, 1972; Sastry *et al.*, 1978; Ben Yehoshua, 1987) which may be related to posthavest water loss in pepper fruits (Albrigo, 1972). Fruits, like other aerial plant parts, are covered with a cuticle, composed of biopolymer cutin and embedded wax with epicuticular waxes on the outer surface, which serves as the major barrier to moisture loss (Espelie *et al.*, 1982; Welker & Furuya, 1993). Thus, differences in surface morphology and/or epicuticular waxes may affect water loss and postharvest longevity. Studies were therefore, initiated to examine the relationship between physical and morphological properties of pepper fruits and the rate of water loss during postharvest storage in 3 pepper cultivars viz., 'Keystone', 'NuMex R Naky', and 'Santa Fe Grande' for better storage and transportation.

Materials and Methods

Plant Material: Fresh green mature fruits of 3 distinct pepper types viz., 'Keystone' (bell), 'NuMex R Naky (long green) and 'Santa Fe Grande' (yellow Wax) were

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harvested from plants grown under standard cultural practices at Leyendecker Plant Science Research Centre, Las Cruces, NM, USA during 1989. Standard sized fruits, free of visible defects were hand picked, placed in plastic bags and transported to the laboratory.

***Physical Parameters*:** Initial water content was determined by weighing freshly harvested fruits which were oven dried at 55^{o}C for 5 days and reweighed. To assure a constant dry weight, fruits were reweighed once again after 24 h. Thirty-six fruits of 'Keystone' and 'NuMex R Naky' (divided into 12 subgroups) and 90 fruits of 'Santa Fe Grande' (divided into 9 subgroups) were used.

Fruit surface area was estimated by covering 6 fresh peppers of each type with graph paper and carefully cutting the paper to match the surface area. Each fruit was measured twice to estimate error associated with this measuring technique. Fruit volume was determined by immersing 6 peppers of each type in a known volume of water and measuring the displacement. Fruit surface to volume ratio was then calculated.

Cuticle weight was determined using enzymatically isolated cuticles. Discs (2cm diam.) were removed from 24 fruits of 'Keystone' and'NuMex R Naky'; and 'Santa Fe Grande' (1.5cm diam.) using a cork borer. The cuticle was isolated enzymatically using 5% pectinase plus 0.2% cellulase at pH 4.0 buffered with dibasic sodium phosphate-citric acid (Leon & Bukovac, 1978). Discs were incubated for 12 days with the enzyme solution being renewed every third day. The membranes (cuticle) were separated from the discs by gentle agitation with distilled water, thoroughly rinsed, air dried and weighed. Three random discs from each pepper cultivar were chosen to be examined using light microscopy to assure freedom from cellular debris. Data were expressed as mg/cm^2.

Epicuticular waxes were removed by rinsing the outer surface of excised fruit discs for 5 seconds in 4 successive 80 ml portions of chloroform. Washing from 250 discs for each pepper type were evaporated to dryness at 40^{o}C and the wax weighed (Corey *et al.*, 1988). Data were expressed as ug/cm^2.

***Fruit Surface Morphology*:** Fruit surface was studied using scanning electron microscopy (SEM). Fruit discs (0.5 cm diam.) were frozen in liquid nitrogen dried in a lyophilizer for 48 h, mounted on aluminum stubs using a silver paint and coated with 60/40 gold-palladium alloy . Five to six randomly selected samples of each pepper type were observed using a Phillips SEM501B. Scanning electron micrographs were taken on Polaroid 665 type film.

***Weight Loss*:** 'Keystone' and 'NuMex r Naky' (2 fruits each) and 'Santa Fe Grande' (5 fruits) stored at 8 , 14 and 20^{o}C were weighed daily. Data were expressed as daily percent weight loss. Each cultivar was replicated three times.

Data for initial water content, fruit surface area, fruit surface area to volume ratio and cuticle weight were subjected to analysis of variance and treatment means were separated using LSD procedures. Regression equations to estimate weight loss were developed using general Linear Model (GLM) procedure of the Statistical Analysis System (SAS Institute, 1982).

Table 1. Initial water content, fruit surface area, cuticle weight and epicuticular wax content of three pepper types at harvest.

Pepper Cultivar	Initial water content (%)	Fruit surface area (cm^2)	Fruit surface area to volume ratio (mg/cm^2)	Cuticle weight ($\mu g/cm^2$)	Epicuticular wax
Keystone	92.1a[Z]	287.2a	0.88c	1.8c	129.6[Y]
NuMex R Naky	90.6b	130.7b	1.37b	4.4a	73.6
Santa Fe Grande	92.0a	42.4c	1.96a	2.4b	19.5

[Z]Means within the column followed by different letters are significantly different at P < 0.01 with LSD procedure.
[Y]Non replicated measurements.

Results

Physical parameters: The physical properties (Parameters) of water content at harvest, fruit surface area, fruit surface area to volume ratio and cuticle weight were significantly different ($P<0.01$) in the 3 pepper types (Table 1). Initial water contents for 'Keystone' and 'Santa Fe Grande' were 92.11% and 92.00%, respectively, and were significantly greater than 'NuMex R Naky' 90.56% ($P<0.01$)(Table 1). Fruit surface area for 'Keystone' was approximately 6- and 2-fold greater than 'Santa Fe Grande' and 'NuMex R Naky', respectively. Surface to volume ratios varied significantly between pepper types, being 1.96, 1.37 and 0.88 for 'Santa Fe Grande', 'NuMex R Naky' and 'Keystone', respectively . Cuticle weights also varied significantly for 'NuMex R Naky', 'Santa Fe Grande' and 'Keystone' being 4.4, 2.4 and 1.8 mg/cm^2, respectively. The quantity of epicuticular wax ranged from 129.6 ug/cm^2 for the pepper types examined.

Weight Loss: Postharvest weight loss was linearly related to storage time for all pepper types at each storage temperature (Table 2). Regression slopes for the 3 pepper types were significantly different ($P<0.01$) at 8, 14 and 20^oC indicating significant varietal differences in rates of water loss. The rate of water loss increased with increasing storage temperature. The highest intercept values for 'Santa Fe Grande' (Table 2) indicate that initial rate of water loss for 'Santa Fe grande' fruits was significantly higher as compared to 'Keystone' and 'NuMex R Naky' at each storage temperature. Postharvest rate of water loss was negatively correlated with fruit surface area and epicuticular wax at 8, 14 and 20^oC. It was positively correlated with surface to volume ratio at 8^oC and cuticle weight at 14 and 20^oC (Table 3).

Fruit Surface Morphology: SEM studies indicated that there were no stomata on the surface of any pepper fruits studied. In addition, epicuticular waxes were generally isolated globules with little fine structures. The majority of the fruit was smooth with no wax extrusions.

Table 2 Regression equations for % weight loss of three pepper types stored at 8, 14 and 20°C.

Cultivar	Storage temp. (°C)	Regression equation (% Weight loss =)[z]
Keystone	8	0.00 + 0.30 day [Y]
NuMex R Naky		0.61 + 0.43 day
Santa Fe Grande		1.10 + 0.69 day
Keystone	14	2.66 + 2.48 day
NuMex R Naky		3.57 + 4.44 day
Santa Fe Grande		7.91 + 4.17 day
Keystone	20	2.81 + 3.00 day
NuMex R Naky		4.10 + 5.10 day
Santa Fe Grande		8.37 + 4.49 day

[z] Probability value for regression equations = 0.0001

[Y] Regression slopes for 'Keystone','NuMex R Naky' and 'Santa Fe Grande' differ significantly from each other at $P < 0.05$ at each storage temperature.

Discussion

Our data show significant varietal differences in postharvest water loss rates for 'Keystone','NuMex R Naky' and 'Santa Fe Grande' fruits. Relationships between water loss and physical parameters may be useful in modifying handling techniques for extending postharvest longevity of pepper fruits .

One of the simplest and most apparent reasons for varying water loss rates would be differences in number and / or size of stomata. SEM studies showed that there were no stomata present on the surface of pepper fruits. Therefore, other physical parameters in relation to postharvest water loss rate in pepper fruits must account for the observed varietal differences.

Initial water content, may have an effect on water loss. One may expect fruits with lower water content to lose water at a slower rate relative to fruits with high water content. However, initial water content and postharvest rate of water loss were not correlated (Table 3) suggesting that water loss is not simply a function of water content, but there may be water permeability differences between cultivars. Permeability differences are also suggested by the inversc relationship between fruit surface area and postharvest water loss rate. Since water loss occurs primarily by diffusion (Fick's law) (Salisbury & Ross, 1985), increased water loss would be expected with increased surface (diffusional) area if permeability were equal. Our data show an inverse relationship suggesting marked permeability differences between cultivars (Table 3).

Table 3. Correlation between physical characteristics and postharvest rate of water loss in pepper fruits stored at 8, 14 and 20°C.

Physical Characteristics	Storage Temperature(°C) 8	14	20
Initial water content	0.1136[z]	-0.4400	-0.4961
Fruit surface area	- 0.9386	-0.880	-0.7950
Surface to volume ratio	0.8994	0.6414	0.5198
Cuticle weight	0.0100	0.7300	0.8316
Epicuticular Wax	- 0.9800	-0.8014	-0.6968

[z]Correlation values > 0.666 are significant at $P < 0.05$.

Surface to volume ratio is better indicator of rate of water loss than surface area alone (Sastry *et al.*, 1978). High surface to volume ratio would mean greater diffusional area per volume of water saturated space and therefore, one would expect to see greater water loss with an increassing ratio. This was true for pepper fruits stored at 8°C, but it became less important at 14 and 20°C (Table 3). Pepper fruits stored at 14 and 20°C initially lost water at significantly higher rates which may have caused an increased resistance to water loss (Sastry *et al.*,1978).

The cuticle is considered as the prime barrier to water loss. Our data, when expressed as weight per unit area indicate relative cuticle thickness. A negative correlation between cuticle thickness and water loss would be expected. We found no correlation between cuticle thickness and water loss at 8°C however, these parameters were positively correlated at 14 and 20°C (Table 3).

Generally the quantity of epicuticular waxes is inversely related to water loss (Welker & Furuya, 1993). Water loss at 8°C and epicuticular wax content were negatively correlated. The correlation was not as strong at 14 and 20°C (Table 3) which was primarily due to high initial rate of water loss and faster fruit ripening at higher temperatures due to greater water vapour deficit and high rate of respiration. The structure of epicuticular wax is also important and might influence water loss (Kolattukudy, 1980; Welker & Furuya, 1993). Uniform coverage with non-porous epicuticular wax structures would reduce rate of water loss more effectively than porous structures (Chambers & Possingham , 1963). The SEM results show that surface morphology of pepper types was quite similar. No distinct differences, that might be related to differences in water loss were observed.

The results show that fruit surfaces area was not the only physical property related to postharvest water loss, but the quantity and distribution of epicuticular waxes also had an effect on postharvest water loss.

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