Handling and Processing Section

FACTORS AFFECTING PEPPER FIRMNESS

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Abstract. **Firmness is one of the important factors determining market quality and consumer acceptance of peppers. A simple, rapid method was developed to identify the wide range in firmness found in market channels. Measured amounts of force were applied mechanically to compress a pepper, and the resulting deformation was precisely measured to calculate a firmness ratio. A ratio of 30 for firm peppers at harvest decreased to 6 for flabby peppers after a 12 percent weight loss. Firmness measurements made over locular spaces were lower than those made over carpel walls.**

Florida, as the nation's leading producer of sweet peppers, markets them over long distances, and loss of firmness is one of the principal forms of quality deterioration. Shoppers in a supermarket often squeeze peppers to estimate their freshness, and purchasing guides tell consumers to avoid soft, flabby peppers. The U.S. Standards for sweet peppers define a firm pepper as one that is not soft "although it may yield to slight pressure" (7).

The purpose of this work was to measure pepper firmness objectively and determine factors affecting these measurements. Instruments that account for the three properties of force, deformation and time may be difficult to use for vegetables because of their many variations in shape, size and composition. The outer wall of a pepper covers large locular air spaces and is supported by 3 or 4 carpel walls around the equatorial axis. Placental tissue and seeds are located in the center of the fruit and contribute little to the support of the wall. Hamson (2) showed that external tomato firmness measurements were affected by location of internal locular spaces.

One of the most satisfactory methods of measuring cherry firmness uses a dial micrometer for indicating deformation under a standard load (4). The instrument used for cherries, when modified with added weight for tomatoes, performed similarly with the Instron machine in measuring relative changes in compression (6). Textural qualities have been characterized as deformation under load up to the point of sudden tissue breakage (3, 5). However, peppers that have softened are not necessarily broken, so limits must be established for the amount of deformation during testing.

Materials and Methods

During the 1971, 1972 and 1973 seasons, small lots of unbruised peppers were obtained from growers in South and North Florida. These were mature green, well shaped, sweet peppers of the blocky type with 3 or 4 lobes and an approximate 1:1 ratio of diameter and length, but varieties were not identified. Whole peppers were placed with the stem-blossom axis horizontal on a flat platform of a Chatillon motorized compression tester, Model HTCM, equipped with a 10 pound capacity force gauge and a dial indicator graduated in 0.001 inch. Force was applied at the rate of 1 inch per minute, mid-way between the ends of the pepper with a 1/2 inch diameter horizontal rod extending across the fruit. Deformation readings were taken at 1 pound intervals.

Results and Discussion

Close examination of peppers in retail produce departments showed that peppers feeling distinctly soft and flabby often had some shriveling without tissue breakage. The first lot of 10 freshly harvested peppers that were obtained felt very firm when squeezed in the hand, and a maximum of 10 pounds of force was applied to each fruit. Deformations occurring at the 5, 7 and 10 pound levels were recorded, and the means

were 0.16, 0.24 and 0.36 inches as shown in lot no. 1 of Table 1. No further tests were made with 10 pounds of force because internal tissues were broken in several peppers at the 8 to 10 pound force range. The high standard deviation (SD) 0.11, the 31 percent coefficient of variation (CV) among the peppers compressed with 10 pounds of force, and the decrease in force-deformation (firmness) ratio from 31 at 5 pounds to 28 at 10 pounds were other indications that the maximum force had exceeded the point of tissue breakage.

Another lot of peppers obtained 4 days after harvest felt much less firm than those in lot 1. Deformations occurring at 1, 3, 5 *and 7 pounds* were recorded and the means of 0.09, 0.24, 0.37 and 0.48 inches are shown in lot 7 of Table 1. Although the SD increased with increased force, percent CV was no higher at 7 pounds than at 3 pounds, and no tissue damage was found.

The peppers in lot 2, measured at harvest with the same range of force as the 4-day peppers in lot 7, deformed only one-half as much at 7 pounds and one-third as much at 1 pound. The firmness ratios in Table 1 were proportionately higher for the lot 2 fresh peppers compared with those in lot 7, since the higher the values the firmer the product. For deformation, the smaller the readings the firmer the product at any identical force application. The firmness ratio used in this paper was recommended in measuring tomato firmness (6). Among the additional lots of harvest and postharvest peppers in Table 1, differences in deformation and firmness were very small.

Results reported in Table 1 were obtained with the force applied to the pepper wall over one of the locular spaces. One test was made with 44 peppers 4 days after harvest to compare firmness over a carpel wall with that over a locule. Average deformation at the two locations on each pepper showed significantly greater de-

Table 1. Pepper firmness measurements as affected by applied force and storage time.

Applied[z] force lb	Days after harvest	Lot[y] no	Deformation inches			Firmness lb/in
			Mean	SD[x]	CV[w] %	
1	0	2	.03	.01	33	33
	1	5	.04	.01	25	25
	3	6	.05	.02	40	20
	4	7	.09	.02	22	11
3	0	2	.09	.02	22	32
	0	3	.10	.02	20	30
	0	4	.10	.03	30	30
	1	5	.12	.03	25	25
	3	6	.16	.04	25	19
	4	7	.24	.06	25	13
5	0	1	.16	.04	25	31
	0	2	.16	.02	13	31
	0	3	.17	.04	24	29
	0	4	.16	.05	31	31
	1	5	.20	.04	20	25
	3	6	.26	.05	19	19
	4	7	.37	.09	24	14
7	0	1	.24	.06	25	29
	0	2	.23	.04	17	30
	4	7	.48	.12	25	15
10	0	1	.36	.11	31	28

[z]Force over one locule of uncut pepper.

[y]Each lot = 10 peppers.

[x]Standard deviation.

[w]Coefficient of variation.

Table 2. Effect of force applied over locule or carpel wall on the average[z] deformation and firmness of peppers.

Applied force lb	Deformation inches		Firmness lb/in	
	Locule[y]	Wall	Locule	Wall
1	.09	.06	11	16
2	.17	.13	12	16
3	.25	.19	12	16
4	.32	.26	13	16
5	.38	.32	13	16

[z]Calculated from 44 peppers 4 days after harvest.

[y]Significantly larger than wall deformation at the 1% level.

formation (using the "t" test) over the locules (Table 2). The firmness ratios for each of the carpel wall measurements from 1 to 5 pounds equaled 16, thus indicating exact linearity. The ratios for locule deformations increased from 11 at 1 pound to 13 at 5 pounds.

A very pronounced decrease in firmness was associated with increases in weight loss during 12 days storage of peppers at 60°F. and 55 to 100 percent relative humidity (Table 3). Weight losses of peppers stored in plastic bags averaged 2.2 percent and firmness measured over the locules ranged from 10 at 1 pound to 15 at 7 pounds. After 12 days in open cartons, weight losses averaged 11.7 percent and firmness ranged from 4 to 10.

Table 3. Effects of storage and weight loss on pepper firmness.

Storage Package	Days	Weight loss	Applied force[z] pounds 1	3	5	7
		%	Firmness-lb/in[y]			
Plastic bag	4	0.8	11	14	15	17
	7	1.4	11	13	15	16
	12	2.2	10	12	13	15
Open carton	4	4.7	6	9	11	13
	7	7.6	5	9	10	12
	12	11.7	4	6	8	10
None	12	16.6	2	4	5	--

[z]Force applied over one locule of uncut pepper.

[y]Average values from 10 peppers for each storage period.

These peppers and those with no packaging were so flabby that deformation into the locular space at the 5 and 7 pound levels probably reached some supporting placental tissue, and erroneously high firmness values resulted. Pepper firmness should be measured with force less than 5 pounds, particularly when a wide range of firmness exists. Low force application would reduce the danger of exceeding the tissue damage point, and Bourne (1) reported that resolution of differences in firmness is better at small forces and deformations.

The development of a firmness measuring procedure provides a better means of identifying quality for grades and standards, plant breeders and consumers. This study also showed that water loss from peppers which causes severe softening can be reduced by protective packaging.

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