Effectiveness of the Pressure-Load Meter in Measuring Firmness of Tomato Fruit[1]

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Abstract. The Pressure-Load (P-L) Meter, a small portable instrument, was as sensitive as an Instron Machine in measuring firmness of ripening tomato fruit. Firmness, as measured with the P-L Meter, was significantly correlated with changes in water and NaOH-soluble pectic substances of ripening fruit.

In the last 20 years many types of instruments have been developed for measuring firmness of fruit. Some instruments macerate the fruit at the time of measurement whereas others leave the fruit intact. The latter types are desired when fruits are needed for continuing studies. One has been described (4), that measures firmness on the basis of single point compression, without sacrificing the fruit, and many (4), measure firmness on the basis of multipoint compression. These included the Firm-o-meter, (5), McCollum Firmness Meter, and the Asco Firmness Meter. Perhaps a more accurate measurement is obtained with instruments that are controlled electronically and have a potentiometric recorder (8). However these instruments are extremely expensive, bulky and not portable. In seeking a portable and sensitive instrument to measure firmness, the Pressure-Load (P-L) Meter, which was used for cherry fruits (10), was modified and evaluated for tomato. In this study we compare the P-L Firmness Meter to an Instron and also the relationship between firmness, as measured with the P-L Meter, and changes in pectic substances.

The P-L Meter. The instrument (Fig. 1) operates on a creep principle in which a known weight is applied and the resulting displacement measured. It consists of a reverse reading dial gauge, lowering mechanism, stand and a series of assorted probe tips and load weights. The dial gauge, model D81T, was modified by the manufacturer (Federal Products Corporation, Providence, Rhode Island) to operate on a creep principle by removing the return spring from the shaft. The shaft is lowered by an adjustable air dashpot lowering mechanism (Airpot Corporation, Norwalk, Connecticut). The sample holder consists of a 4 x 4 inch brick plate fashioned with a 3 inch diam concave depression suitable for securing large or small fruits. The fruit was positioned with the calyx to stylar plane horizontal to the base of the stand.

In the present studies a 200 g weight and a 1/4-inch radius convex probe tip were used. The total load weight of the shaft (i.e. the total weight placed on the fruit) was 220 g. To measure firmness the probe was lowered and an initial reading (D_1) of the dial gauge was made at the moment the probe made contact with the fruit. To avoid variation in the rate of lowering, the probe was elevated after it made fruit contact and was lowered under the control of the dashpot lowering mechanism. The lowering mechanism disengaged when the probe came in contact with the fruit. A second reading (D_2) was taken 15 sec after the lowering mechanism disengaged.

Firmness was measured as a function of force and deformation by the following equation:

$$K = \frac{F}{D_1 - D_2}$$

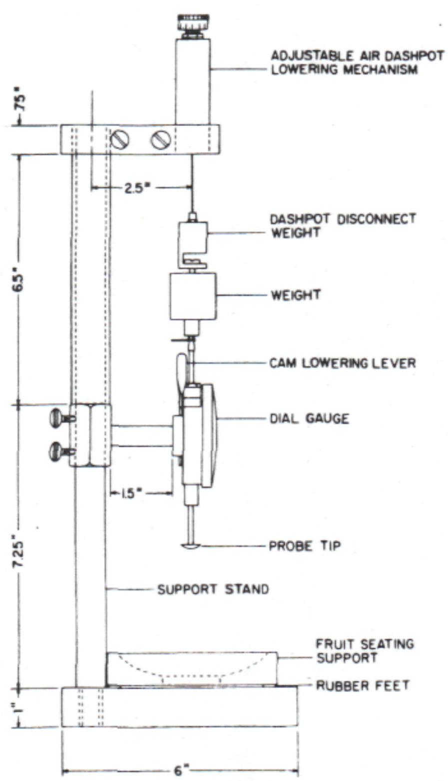

Fig. 1. Physical description of Pressure-Load Meter.

where F is the load weight (220 g), D_1 is the initial dial gauge reading, D_2 is the final reading and K is the elastic stiffness reading in g/cm. The elastic stiffness reading (K) was used as an index of firmness.

A comparison of P-L Meter and Instron machine. The Instron machine is controlled electronically (9). The probe, which is regulated by a hydraulic unit, moves at a constant speed and measures resistance by an electronic load cell in series with the probe. Resistance was recorded continually during penetration of the probe by a potentiometric recorder. Firmness of the fruit was determined from the force deformation curve of the sample. A 1/2-inch radius spherical probe tip was used to measure firmness.

The P-L Meter was compared with the Instron Machine by measuring the largest diam of 500 'Manhattan' tomato fruit with both instruments. Fruit maturity ranged, according to the criteria of Workman et al. (12), from the mature-green to table-ripe stage. Each category contained 100 fruit.

The P-L Meter and the Instron performed similarly in measuring relative changes in compression (Fig. 2). The compression, measured by the P-L Meter, of a light pink and table-ripe fruit was 40 and 23%, respectively, of that of a mature-green fruit and 41 and 25%, respectively, with the Instron. The coefficient of correlation between the 2 instruments was 0.77 which was significant at the 1% level. The compression values at different stages of maturity differed significantly when measured by either instrument.

The diam of the fruit tested ranged from 4.78 to 8.64 cm and averaged approx 7.24 cm. The coefficient of correlation between the compression values as measured by the P-L Meter and fruit diam was 0.10. Therefore, within the diam range studied, P-L Meter measurements were not affected by fruit size.

The P-L Firmness Meter is as effective as the Instron Machine for measuring changes in firmness of ripening tomato fruit. Although the actual firmness reading obtained with both instruments are not comparable, the relative differences in firmness of ripening fruit measured by both instruments were similar. The P-L Meter has a definite advantage over an Instron Machine or any other hydraulic and/or electronically controlled machine in cost, size and speed of measurement. As with other instruments (3), measurements with the P-L Meter are not affected by fruit size.

Firmness in relation to changes in pectic substances. The relationship of firmness, as measured with the P-L Meter, to the quantitative changes in pectic substances was studied with

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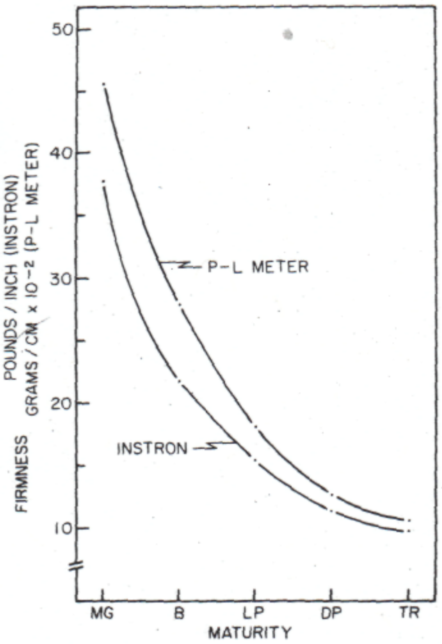

Fig. 2. Firmness of ripening 'Manhattan' tomato fruit as measured with P-L Meter and Instron. MG (mature green), B (breaker), LP (light pink), DP (dark pink), TR (table ripe).

ripening fruit of 5 tomato lines that differed in marketable shelf life (7). Measurements were made on fruit harvested at the mature-green and breaker stage, and of fruit held 2, 4 and 6 days at 22°C following harvest at the breaker stage. The tomato lines used were 'Manhattan', 'West Virginia 63' and 3 T-lines (7) homozygous recesive for either high pigment (*hp*), crimson (og^c), or both.

The pectic substances soluble in water, ammonium oxalate, and sodium hydroxide were extracted by the procedures outlines by Rouse and Atkins (11). Water-soluble pectic substances have sufficiently high methoxyl content to be termed pectins (6). Ammonium oxalate-soluble pectic substances are the insoluble salts of pectic acid and the low-methoxyl pectinic acids and are called pectates and pectinates, respectively. The sodium hydroxide-soluble pectic substance represents the protopectin fraction. The different pectic fractions were analyzed for galacturonic acid content by the carbazole-hexuronic acid-sulfuric acid method of Dische (2) as modified by Atkins and Rouse (1).

The rate of softening, as measured with the P-L Meter, differed among tomato lines (Table 1). The compression value of 'West Virginia 63' was relatively high (7026 g/cm) at the mature-green stage but was the lowest (1162 g/cm) among the lines at 6 days following the breaker stage. This was approx an 82% loss in firmness. The compression value of 'T-3640' decreased from 6063 g/cm at the mature-green stage to 2543 g/cm at 6 days following the breaker stage, which was a 58% loss in firmness. The remaining lines lost about 72% of their compression within the same period of time.

The water-soluble pectic substances increased significantly during ripening of fruit of all tomato lines (Table 1). A continual increase occurred with ripening in 'T-3640' and 'West Virginia 63'; whereas a drop was observed after the 2nd to 4th day following the breaker stage in the remaining lines. The increase observed in fruit showing incipient color was significant only with 'T-3585'. In other lines, the increase became significant after the fruit showed incipient color.

The pectic substances soluble in ammonium oxalate increased with ripening up to 2 days following the breaker stage (data not shown). The increase noted in fruit at the breaker stage was significant in all lines except 'Manhattan'. The increase in 'Manhatten' became significant after the fruit passed the breaker stage.

The pectic substance soluble in sodium hydroxide decreased with ripening in all lines (Table 1). As noted with the water-soluble pectic substance, only 'T-3585' had a significant reduction in this fraction as fruit showed incipient color. In all other lines the decrease was significant after the fruit passed the breaker stage. Analysis of the pectic substances was continued at 2-day intervals up to 12 days following the breaker stage. All lines except 'T-3640' showed a continual decrease in the NaOH-soluble pectic substance, although the decrease in the advanced stages of ripeness (4 and 6 days) was not statistically significant for the 'Manhattan', 'T-3640' and 'W. Va. 63' cultivars.

Loss of firmness is one of the attributes in determining the holding quality of fruit. Tomato lines in this study differed in firmness and in the rate of softening. A larger percentage of original firmness was maintained by 'T-3640' which was reported to have a very long shelf life (7). The remaining lines softened rapidly and were reported to have a shorter shelf life. Perhaps the holding quality of a line can be

Table 1. Firmness and water and sodium hydroxide-soluble pectic substances in ripening fruit of 5 tomato lines.

		Maturity			
			No. of days after breaker stage		
Tomato line	Mature Green	0	2 (--light pink--)	4	6 (dark pink)
			Firmness		
Manhattan	4888 a[z]	4550 b	2751 c	1461 d	1386 d
T-3640 (*hp* og^c)	6063 a	5909 a	4181 b	2693 c	2543 c
W. Va. 63	7026 a	4664 b	2503 c	1785 d	1162 e
T-3624 (*hp*)	7229 a	4489 b	2828 c	2596 c	1995 d
T-3585 (og^c)	6198 a	4694 b	2828 c	2241 d	1735 e
	Pectic substances (µM d-glacturonic acid/100g fresh wt)				
			Water soluble		
Manhattan	78 a	515 a	324 b	387 b	377 b
T-3640 (*hp* og^c)	65 a	154 a	378 b	399 b	469 c
W. Va. 63	81 a	139 a	349 b	357 b	438 b
T-3624 (*hp*)	47 a	139 a	368 b	498 c	410 b
T-3585 (og^c)	54 a	242 b	407 d	338 cd	270 bc
			Soluble in sodium hydroxide		
Manhattan	439 a	420 a	180 b	132 b	89 b
T-3540 (*hp* og^c)	488 a	405 a	188 b	138 b	118 b
W. Va 63	366 a	371 a	112 b	65 b	72 b
T-3624 (*hp*)	526 a	528 a	249 b	200 c	78 d
T-3585 (og^c)	486 a	270 b	149 c	89 c	74 c

[z]Means within each row followed by the same letter are not significantly different at the 5% level (Duncan's New Multiple Range test).

Table 2. Coeffiecient of correlations between firmness and pectic substances in fruit of 5 tomato lines.

	Coefficient of correlation		
		Pectic substance soluble in:	
	Water	$(NH_4)_2C_2O_4$	NaOH
Manhattan	.919*	.768*	-.921*
T-3640 (*hp* og^c)	.846	.684	-.833*
W. Va. 63	.916*	.662	-.836*
T-3624 (*hp*)	.841*	.654	-.750*
T-3585 (og^c)	.918*	.775*	-.962*

*Significant at the 5% level.

estimated by measuring the rate of softening with the P-L Meter.

Pectic substances may not be completely responsible for firmness; nevertheless, softening of the fruit has been associated with changes in pectic substances. The relationship of firmness, as measured with the P-L Meter, with changes in various pectic fractions were compared and found similar in all lines. Firmness was negatively correlated with changes in water soluble pectic substances (Table 2). The coefficients of correlation between firmness and the ammonium oxalate-soluble fraction were significant only with 'Manhattan' and 'T-3585'. Changes in firmness were correlated significantly with pectic substances soluble in NaOH. The coefficient values ranged from 0.75 for 'T-3624' to 0.96 for 'T-3585'. Thus, using changes in pectic substances as a criteria for softening, the P-L Meter was effective in measuring firmness.

Literature Cited

1. Atkins, C. D. and A. H. Rouse. 1953. The effect of different methods of juice extraction on the pectic content of Valencia orange juice. *Proc. Fla. State Hort. Soc.* 66:289-292.
2. Dische, Z. 1947. A new specific color reaction of hexuronic acids. *J. Biol. Chem.* 167:189-198.
3. Garrett, A. W., N. W. Desrosier, G. D. Kuhn and M. L. Fields. 1960. Evaluation of instruments to measure firmness of tomatoes. *Food Tech.* 14:562-564.
4. Hamson, A. R. 1952. Measuring firmness of tomatoes in a breeding program. *Proc. Amer. Soc. Hort. Sci.* 60:425-433.
5. Kattan, A. A. 1957. Changes in color and firmness during ripening of detached tomatoes, and the use of a new instrument for measuring firmness. *Proc. Amer. Soc. Hort. Sci.* 70:374-384.
6. Kertesz, Z. I., G. L. Baker, G. H. Joseph, H. H. Mattern and Aksel G. Olsen. 1944. Report of the Committee for the revision of nomenclature of pectic substances. *Chem. Eng. News* 22:105-106.
7. Lampe, C., and Alley E. Watada. 1971. Post harvest quality of high pigment and crimson tomato fruit. *Proc. Amer. Soc. Hort. Sci.* 96:534-535.
8. Mohsenin, N. N. and H. Goelich. 1962. Technique for determination of mechanical properties of fruits and vegetables as related to design and processing machinery. *J. Agr. Eng. Res.* 7:300-315.
9. Ourecky, D. K. and M. C. Bourne. 1968. Measurement of strawberry texture with an Instron Machine. *Proc. Amer. Soc. Hort. Sci.* 93:317-325.
10. Parker, R. E., J. H. Levin and R. T. Whittenberger. 1966. An instrument for measuring firmness of red tart cherries. *Mich. Agr. Expt. Sta. Quart. Bul.* 48:471-482.
11. Rouse, A. H. and C. D. Atkins. 1955. Pectinesterase and pectin in commercial citrus juices as determined by methods used at the citrus experiment station. *Fla. Agr. Expt. Sta. Bul.* 570.
12. Workman, M., H. K. Pratt and L. L. Morris. 1957. Studies on the physiology of tomato fruit. I. Respiration and ripening behavior at 20 degrees C. as related to date of harvest. *Proc. Amer. Soc. Hort. Sci.* 69:352-365.