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EFFECTS OF CROSS-HEAD SPEED AND PROBE DIAMETER ON INSTRUMENTAL MEASUREMENT OF TOMATO FIRMNESS

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ABSTRACT

Five textural characteristics, epicarp strength, deformation, firmness, toughness and penetration time were calculated from force/deformation curves obtained by pressure testing tomato fruits. The fruits were harvested at either the mature-green or red maturity stages. The effects of changing the probe diameter and cross-head speed were investigated on force/deformation characteristics of tomatoes. It was confirmed that increasing of cross-head speed and probe diameter highly significantly effected all textural the characteristics mentioned above, except epicarp strength of red tomatoes at 200 mm minute^{-1} cross-head and penetration time of red and green tomatoes after 200 mm minute^{-1} and 100 mm minute^{-1} cross-head speed respectively.

Key Words: Cross-head speed, probe diameter, epicarp strength, firmness, deformation, toughness, penetration time.

INTRODUCTION

One of the main quality factors of fresh tomatoes is their texture which is influenced by flesh firmness and skin toughness (Kader, 1978). Softening during storage, distribution and ripening of tomatoes can be a major problem because it may increase their susceptibility to damage. The degree of fruit firmness, has been used as an indication of fruit quality (Burton, 1982).

Fruit firmness can be determined in several ways. One of them is to determine the force required to deform the tissue by a certain distance or by determining the degree of deformation for a certain applied force (Curd, 1987). This method is non destructive but many kinds of machines have been developed which could measure firmness by destructive methods. These have been used for tomatoes and include the Cornell pressure tester, Allo-Kramer shear press, Magness and Taylor penetrometer and the Instron Universal Testing Machine (Kader et al, 1978). The Shore durameter has also previously been used for testing firmness of some fruit and vegetables (Thomas et al, 1982; Malis-Arad et al, 1983). An automatic penetrometer with 1.016 mm probe was also used (Thorne and Alvarez, 1982 ; Efiuvwevwere and Thorne, 1988). The Instron is commonly used for textural measurements but many different diameters and shapes of probes have been fitted. Some researchers used 6 mm diameter probes (Risse et al, 1985) , some used 1 mm diameter (Adegoroye et al, 1989) and some have used 11.1 mm diameter and different approach speeds (Thai et al, 1989). These variations have produced quite different results.

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The aim of the study was to determine the effect of different sizes of probes and different speed of approach on the measurement of force and deformation values on tomatoes.

MATERIAL AND METHODS

Tomatoes (cultivar, Counter) were obtained from the greenhouses of Silsoe Research Institute. Fruit diameter were between 50-55 mm. Two experiments were carried out to evaluate the differences in firmness of green and red tomatoes by applying a constant weight of 50 N using an Instron universal testing machine. In the first experiment it was fitted with one of six different diameter round stainless steel probes. These were 2, 4, 6, 8, 10 and 12 mm. The amount of force which was required to penetrate through the tomato skin and deformation value were recorded. In the experiment toughness, firmness and penetration time were determined from the force/deformation curve (Figure 1). Tests were carried out at 20 mm minute^{-1} cross-head (approaching) speed.

In the second experiment a 6 mm diameter probe was used and the cross head speed was varied 5, 10, 20, 50, 100, 200 and 500 mm minute^{-1}. In this study each measurement were was taken twice at opposite sides on ten tomatoes on the equator (in the middle).

The analysis of variance was carried out on a complete randomised split plot design. Comparison of means and calculations of least significant difference (LSD) and linear regression were also performed on the data (Steal and Torrie, 1987).

Five textural characteristics were determined from the force deformation curve in Figure 1. Epicarp Strength was the force at the bioyield point. Deformation was the distance travelled by the probe from first contact with the tomato skin to the bioyield point. Firmness was defined as the average slope of the force/deformation curve. Toughness was the total energy absorbed during penetration (Adegoroye et al, 1989). Penetration time was the time between the probe contacting the tomato skin and penetration, or the ratio of pen movement to chart speed on the Instron.

RESULTS AND DISCUSSION

As the size of probe was increased over the range of 2 mm to 6 mm there was a significant ($p=0.001$) increase in all the characteristics measured, but these were not always linear (Table 1). Similar result were shown for both red and green fruit. With cross-head speed the relation was different and less constant (Table 2). These results indicate a relationship where the surface area of fruit which is deformed, increased as the penetration force also increased. This had previously been described by Curd (1987) as: force = stress . area. In red tomatoes the deformation and penetration time increased linearly with increasing probe diameter between 2 mm and 6 mm but the rate of increase reduced over the range of 6 mm to 12 mm. In contrast in green tomatoes the rate of increase with increasing probe diameter was consistent over the whole range of probe diameters.

The measurements of epicarp strength also gave similar rates of increase for both red and green tomatoes over the whole range of probe diameters. Each difference was significant ($p=0.001$) except the penetration times for individual comparison between 6 mm and 12 mm and between 8 mm and 10 mm diameter of probes. The effect of varying the cross head speed of the Instron while keeping probe diameter constant at 6 mm had a significant ($p=0.001$) effect all the measurements of both green and red tomatoes (Table 2). Firmness, epicarp strength and deformation increased while toughness and penetration time decreased with increasing cross-head speed. Toughness and penetration time values dropped sharply between 5 mm minute^{-1} and 50 mm minute^{-1} cross-head speed. The effect of the increasing the cross-head speed on penetration time was not significantly different ($p=0.001$) between 100 mm minute^{-1} and 200 mm minute^{-1} cross-head speeds. Cross-head speed significantly affected fruit toughness. Force deformation was significantly ($p=0.001$) affected by cross-head speed in tomatoes which contrasts with the results of Curd (1987) who showed no significant effect of cross-head speed on force deformation of apples over the range of 1 mm minute^{-1} to 100 mm minute^{-1}.

There were consistent increases were in epicarp strength and firmness values of green tomatoes between 5 mm minute^{-1} and 200 mm minute^{-1} cross-head speeds. Speeds between 200 mm minute^{-1} and 500 mm minute^{-1} showed a reduced rate of increase. There was a gradual increase in the firmness value of red tomatoes over the range of 5 mm minute^{-1} to 500 mm minute^{-1}. Between 50 mm minute^{-1} and 200 mm minute^{-1} there was a gradual increase but between 200 mm minute^{-1} and 500 mm minute^{-1} there was a trend for the data to plateau. The deformation values showed a gradual increase on both green and red tomatoes between 5 mm minute^{-1} and 500 mm minute^{-1} cross-head speeds but the values for red tomatoes were bigger than for green ones. The effect of cross-head speed on firmness were similar from 5 mm minute^{-1} to 20 mm minute^{-1} cross-head speeds. At higher levels there was a dramatic increase in the value for firmness of green tomatoes. The increase was much less with red tomatoes.

CONCLUSIONS

It was found that there were positive correlations with increasing of cross-head speed and diameter of probe on the of epicarp strength, firmness and deformation on both red and green tomatoes. Toughness and penetration time was positively correlated with diameter of probe and they were negatively correlated with cross-head speed. However, relationships were often curvi-linear and varied between green and ripe fruit. This means that it is not always possible to make direct comparisons between papers using different methods of measuring fruit texture.

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Table 1. Effect of diameter of probe on penetration application on force/deformation charactaristics of tomatoes

		Diameter of Probe (mm)						LSD	R^2
	Colour	2	4	6	8	10	12	P=0.001	
EPICARP STRENGTH	Red	4.25	8.87	13.87	17.23	20.69	25.60	0.073	0.82L
(N)	Green	6.75	17.73	30.97	42.57	50.36	66.58	0.063	0.99L
DEFORMATION (mm)	Red	3.40	6.40	9.20	10.00	10.98	11.17	0.305	0.99Q
	Green	2.00	4.40	5.80	7.20	8.00	10.17	0.154	0.92L
FIRMNESS (N/mm)	Red	1.23	1.38	1.51	1.74	1.89	2.23	0.083	0.57L
	Green	3.53	3.97	5.43	5.95	6.33	6.52	0.156	0.67L
TOUGHTNESS (Nmm)	Red	7.36	28.47	64.16	85.29	113.07	143.10	1.251	0.62L
	Green	6.45	39.80	88.26	152.4	200.18	340.09	1.508	0.98Q
PENETRATION TIME	Red	0.17	0.32	0.46	0.50	0.55	0.56	0.063	0.98Q
(min)	Green	0.10	0.23	0.28	0.37	0.40	0.51	0.035	0.99L

L= Linear , Q = Quadratic

Table 2. Effect of cross-head speed on penetration application on force/deformation charactaristics of tomatoes

		Cross-Head (Approaching) Speed (mm/min)							LSD	R^2
	Colour	5	10	20	50	100	200	500	P=0.001	
EPICARP STRENGTH	Red	11.25	11.72	13.63	15.48	16.31	16.71	16.77	0.116	0.99Q
(N)	Green	25.95	26.5	28.7	30.45	32.93	37.25	39.05	0.838	0.98Q
DEFORMATION (mm)	Red	8.75	10.2	11.00	11.50	14.00	16.00	20.00	0.223	0.97Q
	Green	6.15	6.30	6.40	7.50	8.00	10.00	15.00	0.276	0.92L
FIRMNESS (N/mm)	Red	0.32	0.57	1.29	3.42	6.04	12.17	24.32	0.135	0.99L
	Green	1.05	2.27	4.53	10.36	22.21	38.52	56.07	0.132	0.94Q
TOUGHNESS (Nmm)	Red	197.10	119.92	71.97	35.06	22.15	11.41	5.61	0.496	0.87Q
	Green	318.70	154.74	90.94	44.76	24.66	15.24	11.11	1.777	0.97Q
PENETRATION TIME	Red	1.74	1.02	0.55	0.23	0.14	0.08	0.04	0.049	0.87Q
(min)	Green	1.23	0.58	0.32	0.15	0.07	0.05	0.02	0.031	0.98Q

L= Linear , Q = Quadratic

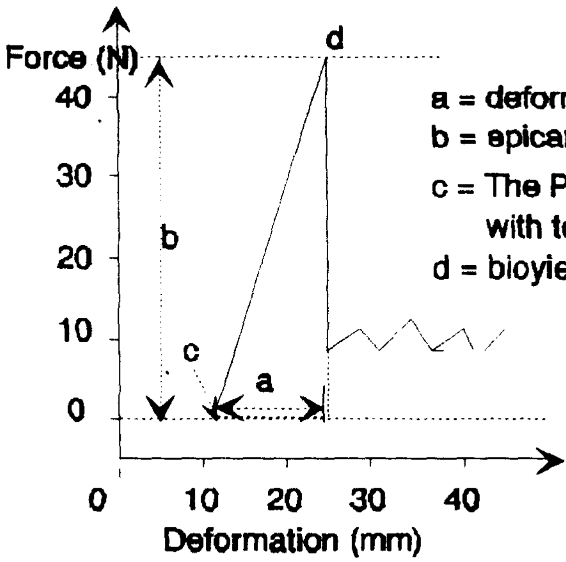

Figure 1. Typical force/deformation curve obtained during penetration of individual tomato.