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Pre- and Postharvest Factors Affecting Textural Quality of Fresh Asparagus[1]

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Abstract. **Factors determined to have a pronounced effect on shear-press peak-force values of asparagus, *Asparagus officinalis* L. included sample size, spear diameter, length of green, and preharvest temperature. Shear-press values were greater following periods of cold weather in early spring. Larger diameter spears had lower peak-force values than smaller spears, indicating that larger spears are more tender than smaller spears. The number and diameter of spears produced by a particular cultivar, and not differences between cultivars, were the characteristics observed to influence shear-press values. Shear-press max peak-force values correlated well with subjective and objective determinations of asparagus fiber.**

Excessive fiber is an undesirable textural quality in asparagus that can make this plant material unacceptable as a food. Fully 40% of the U.S.D.A. quality grade of canned and frozen asparagus is "character" (refers to the degree of development of the head and bracts and to the tenderness and texture of the unit) in which fiber is an important consideration (11, 12). Fiber content in asparagus increases basipetally increasing very rapidly beyond the "snapping" point of the stalk (6, 9, 10). Differences in fiber content between cultivars has been determined (10). A blender method for rapid determination of the fiber content of asparagus was developed and (3) showed this blender method to be an excellent test. The shear press has been used to measure fiber content in asparagus (6, 7, 14) and results have correlated very well with organoleptical evaluations (7, 14). Variation of spear diam may limit the accuracy of bulk determination of fiber in asparagus (1), but variability within a sample of asparagus could be accurately determined with the shear press (4). Total asparagus spear toughness increases with aging after harvest and this toughness is dependent upon the cutting height at harvest (2). A mathematical prediction model for postharvest toughening in asparagus has been developed and shear test comparisons determined (8).

This study was initiated to determine the relationship of cultivar, sample size, spear diam, length of green, preharvest temp and postharvest storage, with fiber content and textural quality of fresh asparagus.

Materials and Methods

Asparagus for this study was obtained from a planting at the Washington State Irrigated Agriculture Research and Extension Center, Prosser. The planting was 7 years old at the time this 3-year-study began. The cultivars 'Mary Washington', 'U.C. 500', 'U.C. 500-W' and 'U.C. 66' were used. Asparagus was harvested as for commercial processing (17.8-cm spears with a min of 12.7 cm of green) and harvested repeatedly throughout the season (May and June). Spears were sorted for diam at a point 12.7 cm from the tip and each diam group was further sorted for equal length of green in all 3 seasons. During the first season spears were sorted to diam identical to canning sizes 1.0–1.3, 1.3–1.6 and 1.6–2.2 cm (11). In the first season it was determined that very little objectionable fiber existed in the top 10.2-cm portion of the spear. So, spear diam comparable to those for frozen asparagus 1.0–1.6, 1.6–2.2 and 2.2–2.9 cm (12) were used in the second and third years.

Max peak-force measurements were determined with a Food Technology Corporation, Model T-2100, Texture Test System equipped with a single-blade (0.3 cm wide) CA-1 cell. The blade sheared at the rate of 2.5 cm per min. All max peak-force readings were made at 1.3-cm intervals on spear samples beginning 1.3 cm below the junction of white and green, and advancing towards the tip. Max peak-force values are reported in kg-wt of force required to shear 21 spears diam 1.0–1.6 and 11 spears diam 1.6–2.2 cm. A blender method (9) was used to measure fiber content, in sections, starting 1.3 cm below the junction of the white and green and advancing towards the tip. To determine the relationship between objectionable organoleptic fiber and shear-press max peak-force values a sensory panel composed of 10 members (5) was used.

Samples for postharvest storage were prepared by compositing freshly harvested asparagus with a comparable no. of spears of equal diam and lengths of green. These subsamples were divided into 5 lots. One lot was shear tested immediately. A second lot was stored at 16°C with butts in H_2O and shear tested after 48 hr. A third lot was held at 0°, a fourth lot was stored at 16° and the fifth lot was stored at 27°. Replicate samples were taken from the 3 lots at each temp treatment 1, 2, 3, 5, and 7 days after placement in storage. These samples were sheared to obtain max peak-force readings at 11.4, 12.7, and 14.0 cm from the tips. Mean daily temp was recorded by thermograph bulb 121.9 and 15.2 cm above ground, and 15.2 cm in the soil.

Results

Effect of sample size. Sample size has a definite effect on measurement of max peak-force value readings. When limited supplies of asparagus were obtained in the first harvest season it was decided to use partial-cell samples (1/3) of a full cell, or 7 spears diam 1.0–1.6, and 4 spears 1.6–2.2 cm. This resulted in a higher coefficient of variability than a full cell. Therefore, full-cell samples were used in following seasons, or 21 spears diam 1.0–1.6, and 11 spears diam 1.6–2.2 cm.

Shear-press measurements (max peak-force values) using a partial cell (1/3) and a full cell were correlated to fiber content. The linear correlation was 0.85 and 0.91, respectively, for partial- and full-cell samples. The partial cell (1/3), in most cases gave lower values of peak force for the same fiber values. Although the correlation of max peak force with fiber was satisfactory, it was decided to use only full-cell samples after the first season because of the greater variability of smaller samples. Coefficient of variation of partial cells (1/3) averaged 29.3; whereas full-cell samples averaged 20.2 when spears of similar

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Table 1. Effect of cultivar and diam of asparagus spear on max peak force readings in kg.

Cultivar	Max peak force (kg) Length of green (cm) 15.2 Interval from tip cm 14.0	15.2	16.5	14.0 Interval from tip cm 12.7	14.0	15.2	12.7 Interval from tip cm 11.4	12.7	14.0	Total no. spears sheared
				1.0 to 1.6 cm diam						
U.C. 500W	125b[z]	180b	216b	106b	138b	193b	90a	120b	173b	822
Mary Wash.	124b	198b	251b	126b	200c	228b	106a	154b	204b	1266
U.C. 66	114ab	186b	224b	104b	157b	203b	87a	119b	176b	931
				1.6 to 2.2 cm diam						
U.C. 500W	103a	137a	169a	90a	112a	154a	83a	96a	130a	213
Mary Wash.	91a	133a	168a	79a	114a	147a	81a	102a	138a	238
U.C. 66	91a	117a	161a	72a	98a	140a	75a	89a	117a	515

[z]Mean separation in column by Duncan's multiple range test, 1% level.

diam and amounts of green were used.

Organoleptic tests on asparagus showed objectionable fiber to correspond to a full cell max peak-force reading of 87 kg-wt or higher with raw asparagus. The corresponding value in a partial cell (1/3) was 75 kg-wt. This relationship between objectionable organoleptic fiber and full cell max peak-force value with raw asparagus is similar to the findings of Kramer et al., (4) and Wiley (14).

Effect of cultivar. The effect of max peak-force values by cultivar was only dependent on the no. and size distribution of the spears produced (Table 1). When sorted for diam and lengths of green there was no significant difference due to cv. Cultivars tending to produce more smaller diam spears than larger diam spears would have correspondingly higher total max peak-force values. Studies (10) which have found differences in fiber content between cultivars may in fact be measuring other asparagus spear attributes.

Effect of spear diameter. When spears with equal lengths of green were sheared the same distance from the tip the smaller diam spears tended to give higher max peak-force values indicating a higher fiber content in the smaller spears (Tables 1 and 2). A comparison of 1.0–1.6- and 1.6–2.2-cm diam spears gave differences in max peak-force values equivalent to 0.6–1.3 cm more usable green length (readings below 87 kg-wt) on the larger diam spears. As indicated in Table 2, the larger diam spears have a longer usable green length in relation to fiber content than smaller diam spears, indicating less fiber in the larger diam spears. Comparable correlations were found between fiber by the blender method (9) and max peak-force values of 0.93 and 0.89 for 1.0–1.6- and 1.6–2.2-cm diam spears, respectively.

Table 2. Effect of length of green and diam of asparagus spear on max peak-force readings using all cultivars.

Length of green (cm)	Peak-force readings in kg at designated cm intervals from the tip 11.4	12.7	14.0	15.2	16.5	% Usable length of green[z]
			1.0 to 1.6 cm diam			
12.7	78	136	175	–	–	91.6bc[y]
14.0	–	98	169	208	–	89.6ab
15.2	–	67	108	180	230	87.7a
			1.6 to 2.2 cm diam			
12.7	66	98	134	–	–	96.6d
14.0	–	73	114	154	–	95.1cd
15.2	–	60	80	130	179	93.0c

[z]Fiber content was not considered objectionable at shear-press peak-force readings of 87 kg or below.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

Effect of length of green. The length of green has a marked effect on max peak-force values especially on measurements taken near the junction of the white and green, Table 2. Each successive value taken 1.3 cm nearer the tip may be 40–60% less than the previous value. Between the tip and 10.2 cm of green there is very little objectionable fiber as shear-press max peak-force values are less than 87 kg-wt. Values were taken at 1.3-cm intervals between 11.4-12.7-cm spear tip to 1.3 cm below the junction of the white and green or, 12.7–15.2 cm from the tip. As the length of green increases the usable length also increases but the usable percentage decreases. In the lengths of green and spear diam shown in Table 2, this change is 91.6–87.7% for the 1.0–1.6-cm diam and 96.6–93% for the larger diam spears. Conversely, the objectionable fiber progresses further toward the tip in a given length of green for the smaller than the larger diam spear.

Effect of postharvest storage. Postharvest storage appeared to have considerable effect on max peak-force values of asparagus as shown in Table 3. After 2 days' storage the samples at 16°C with spear butts in water elongated an average of about 2.5 cm and had the lowest max peak-force values. As values

Table 3. Shear-press max peak-force values for asparagus stored at various lengths of time and temp using all cultivars.

Post-harvest treatment (°C)	Days before shearing	Max peak-force readings in kg at designated cm intervals from the tip 14.0	12.7	11.4
Control (no storage)	0	75.5	54.8	37.5
0[z]	1	88.0	51.0	39.0
0	2	69.3	39.0	34.0
0	3	73.5	48.0	33.0
0	5	86.0	55.5	37.0
0	7	59.0	44.5	34.0
16[y]	1	100.3	75.0	55.5
16	2	121.3	72.5	45.5
16	3	39.3	52.5	36.5
16	5	132.3	77.0	54.0
16	7	124.0	65.5	50.5
16 Butts in water	2	33.5	28.0	28.0
27[x]	1	134.5	79.3	53.5
27	2	128.5	71.0	41.8
27	3	172.3	98.3	65.8
27	5	125.5	75.5	57.5
27	7		Samples spoiled	

[z]R.H. 85%.

[y]R.H. 60%.

[x]R.H. 40%.

Table 4. Correlation between mean hourly temp, 24 hrs before harvest and mean shear-press peak-force values for 'U.C. 500'.

Length of green (cm)	Distance from the tip in cm	r for air temp at 15.2 cm above ground	r for air temp at 121.9 cm above ground	r for soil temp at 15.2 cm below ground
		Spear diam 1.0–1.6 cm		
12.7	14.0	–.592**	–.406*	–.558*
	12.7	–.548**	–.503**	–.579**
	11.4	–.139	–.125	–.255
14.0	15.2	–.732**	–.683**	–.841**
	14.0	–.681**	–.650**	–.774**
	12.7	–.418**	–.397*	–.642**
15.2	16.5	–.801**	–.719**	–.759**
	15.2	–.671**	–.604**	–.725**
	14.0	–.387*	–.584**	–.599**
	12.7	–.119	–.175	–.376*
		Spear diam 1.6–2.2 cm		
12.7	14 0	–.108	–.052	–.279
	12.7	–.009	+.005	–.140
	11.4	+.144	–.163	–.026
14.0	15.2	–.326*	–.269	–.544**
	14.0	–.279	–.261	–.539**
	12.7	–.003	–.002	–.194
15.2	16.5	–.508**	–.490**	–.486**
	15.2	–.541**	–.513**	–.785**
	14.0	–.138	–.104	–.339*
16.5	17.8	+.216	+.244	–.129
	16.5	–.666*	–.623**	–.587*
	15.2	–.584**	–.689**	–.569*
	14.0	–.101	–.205	–.159

*Saatistically significant, 5% level.
**Statistically significant, 1% level.

were taken at a measured distance from the tip, the elongation resulted in measurements being made in a less fibrous region. Asparagus stored at 0°C gave lower max peak-force readings than that stored at 16° of 27°. Storage temp had a pronounced effect on max peak-force values of asparagus; whereas time in storage after the first day tended to have little or no influence on max peak-force values.

Effect of preharvest temp. The effect of temp on shear-press max peak-force values was significant (Table 4). The effect of season and weather on shear-press values seemed to be dependent on temp during the growing period, particularly 24 hr preceding harvest. During the first season max peak-force values were higher in smaller diam spears (1.0–1.6 cm) following a cold period (0°C or less in the morning) than for samples of the same length of green harvested during a warmer growing period. The cold period had less effect on shear values of larger diam spears (1.6–2.2 cm) than smaller diam spears (1.0–1.6 cm) of 'U.C. 500'. The mean temp for the 24-hr period preceding harvest was correlated with mean peak-force values (Table 4). Correlation between soil temp and mean peak-force values was superior to the correlations determined for air temp and mean peak-force values. Small diam spears gave significant correlations between mean temp and mean peak-force readings taken 1.3 cm below the junction of white and green to 1.3 cm above this point. Exceptions were found with spears of 12.7 and 15.2 cm of green, and 1.3 and 2.5 cm above ground level when mean temp were recorded in the air. The larger diam spear (1.6–2.2 cm) shear value correlated with mean temp taken in the 24-hr period before harvest of the 14.0, 15.2, and 16.5-cm lengths of green at 1.3 cm below ground level and at ground level. The 16.5-cm length of green also gave correlations with values taken 1.3 above ground level. There was no correlation between peak-force values and temp with spears 1.6–2.2-cm diam having 12.8 cm of green. This would indicate larger spears to be less fibrous and less sensitive to low temp during growth.

A similar study was made in the third season with 'U.C. 500-W', relating shear-press reading to temp above and below 12°C as affected by spear diam, length of green and usable length of green (Table 5). The small diam spears (1.0–1.6 cm) are shown to be more sensitive to cold. A mean temp of 12°C was arbitrarily selected for comparisons. The % of usable length decreases with increased lengths of green. The larger spears (1.6–2.2 cm) have a higher % usable green than small spears (1.0–1.6 cm) of similar lengths.

Table 5. Usable amount of green asparagus in relation to length of green, spear diam and temp for 'U.C. 500 W'.

Length of green (cm)	% usable length[z]			
	1.0–1.6-cm spear diam		1.6–2.2-cm spear diam	
	Mean air temp above 12°C	Mean air temp below 12°C	Mean air temp above 12°C	Mean air temp below 12°C
12.7	94.4b[y]	88.0c[y]	97.6d[y]	94.6c[y]
14.0	90.0b	84.7b	92.0c	92.0bc
15.2	87.5ab	84.2b	90.3c	88.3b
16.5	85.4a	82.6ab	87.7b	87.1b
17.8	84.3a	80.0a	87.4b	85.7a
19.1	84.0a	83.7b	84.0a	83.7a
20.3	85.2a	83.1b	86.2ab	89.0b

[z]Usable length of green is that portion of spear with shear-press peak-force values 87 kg or less.
[y]Mean spearation within columns by Duncan's multiple range test, 5% level.

The problem of increased amounts of fiber in processing asparagus harvested during cold weather could be alleviated to some extent by utilization of shorter spear lengths and spears of larger diam for packs of asparagus requiring min amounts of fiber. The longer and smaller diam spears could be used in packs tolerating more fiber.

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