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Application of Work Measurement to the Determination of Fibrousness in Asparagus[a, b]

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PREVIOUS WORK at the University of Maryland has indicated that the shear-press is applicable to the measurement of fibrousness of asparagus *(5)*. As a result of the recent adaptation of shear resistance instruments for electrical indicating and recording, it is now possible to obtain not only the force required to overcome the resistance offered by the food sample at the maximum point, but a complete time-force curve for the entire stroke *(1)*.

This work was therefore undertaken in order to determine what additional information could be obtained from these time-force curves that could not be obtained from maximum force indications alone. Specifically, the following points were investigated in regard to their effects on results obtained in terms of time-force curves as compared to maximum force indications:

1. Sample size.
2. Speed of stroke.
3. Size of asparagus stalks.
4. Sample stratification.
5. Variability in fibrousness within the sample.
6. Extent of correlation with fibrousness.

MATERIALS AND METHODS

Asparagus stalks were harvested daily during the period from April 30 to May 7, 1956, from plots grown on the University of Maryland Plalnt Research Farm. With the exception of one lot which was held for storage studies, each day's harvest was brought to the Beltsville Plant Industry Station where shear-press determinations were obtained within 4 to 8 hours after harvest. After cutting by the blade of the asparagus test cell of the shear-press, the respective portions of each sample were then packed separately in frozen food containers with no further treatment, frozen at −20° F., and stored at 0° F. at the University of Maryland until they were analyzed for fiber content by the Blendor method *(2)*.

The area under each time-force curve was integrated by the use of a planimeter. Since the correlations between percentage fiber and shear-press values exhibited some curvilinearity, rank correlations were calculated for all preliminary results, while for the more definitive results, curves of best fit were obtained by the least squares method *(4)*.

RESULTS AND DISCUSSION

1. Sample size. Since the asparagus test cell consists of one blade which cuts through the sample at one surface *(5)*, sample size is measured in terms of area, rather than volume or weight. Thus, in order to determine the additiveness and linearity of the relation of sample area to shear-press values, several series of samples were prepared consisting of groups of stalks varying in combined area from approximately one to 6.9 square inches, which is the area of the completely filled sample box of the asparagus test cell. For each sample, the total work value as determined by the integration of the area under the time-force curve, was divided by the respective sample area. Thus, all results were reported on a one square inch sample basis. The linear correlation of these values with percentage fiber was 0.87, the rank correlation 0.91, and the correlation of the logarithms of the work values with percentage fiber was 0.93. These results, shown in Figure 1, demonstrate the high correlation between work values and fiber content of asparagus, and the logarithmic nature of this relationship.

Eight series of samples comprising a total of 40 analyses began with completely filled boxes, followed by half filled boxes, etc., as shown in Table 1. It was found that as the sample size is cut in half, the work value is correspondingly cut approximately half; however, the maximum force required to shear is reduced by considerably less than half.

2. Speed of stroke. It has been established previously that the rate of application of force has an effect on maximum force as indicated by a dial gauge *(3)*. In order to secure information on the effect of this factor on registration of work, the shear-press

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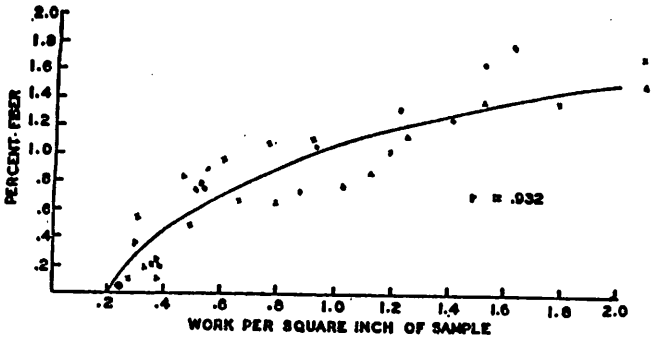

Figure 1. Relation of percent fiber to work per square inch of sample, as influenced by sample size. • indicates samples having a total cutting area of one square inch, x = 2 square inches, △ = 4 square inches, and ◇ = full box.

was set for 6 different speeds, so that the curve was recorded on chart lengths varying from 2.1 to 32.0 inches. The results on 12 samples are presented in Table 2, and show the relation of work and maximum force, to percentage fiber, as affected by the speed of the stroke. These results demonstrate that the speed of stroke greatly influences the area under the curve, and also has a definite effect on the maximum force. Thus, the rank correlation between percentage fiber and the curve area for this series of samples was only 0.37, which for so small a number of comparisons was not even statistically significant. However, when the curve areas were divided by the respective lengths of the chart so that they were all on an equivalent speed basis (Table 2, column 3), the rank correlation between these adjusted work values and per cent fiber rose to the very satisfactory level of 0.96. The correlation between fiber content and maximum force was originally 0.86 and was improved to 0.93 by an arbitrary adjustment of the maximum force values, this adjustment being based on the relationship of maximum force to percentage fiber, when the speed of stroke is held constant.

3. **Size of stalks.** It has been established previously that when individual asparagus stalks of equal fiber content are tested the shearing force increases with increasing stalk diameter *(2)*. This is primarily a sample area effect. It would be of interest to know what effect the stalk diameter has on maximum force and on work when fiber content and total sample area are held constant.

TABLE 1

Relation of sample size to work and maximum force required to shear asparagus stalks
(Each value represents an average of 8 samples)

Sample size		Work value		Maximum point	
Square inches	Percent of full box	Area under curve in square inch	Percent of full box	Percent of scale	Percent of full box
6.9	100	5.3	100	52	100
3.5	51	3.0	55	42	81
1.7	25	1.4	26	33	63
.85	12	.80	15	24	46
.42	6	.35	7	14	27

TABLE 2

Effect of speed of stroke on the relation of work and maximum force required to shear asparagus stalks, to percent fiber

Speed, as inches of chart travel	Work value		Maximum force		Percent fiber
	Area under curve square inch	Per inch of chart	Percent of scale		
			Actually observed	After arbitrary adjustment	
32.0	55.7	1.74	80	62	1.18
32.0	13.4	.42	21	16	.12
12.5	19.3	1.54	76	63	.94
12.5	5.2	.42	22	18	.16
6.6	8.2	1.24	62	56	.68
6.6	2.7	.42	22	20	.18
4.2	5.4	1.32	58	58	1.08
4.2	1.9	.45	20	20	.38
2.8	5.8	2.11	81	90	1.42
2.8	1.4	.51	24	27	.48
2.1	3.7	1.76	66	83	1.63
2.1	1.5	.71	23	29	.30

To determine this point, 3 series of samples comprising a total of 27 determinations were tested in which stalk size was varied and both total sample area and fiber content maintained nearly constant. Although it was not established with statistical certainty, there was an indication that work values were not influenced by stalk size, but that maximum force values tended to increase slightly with decreasing size of stalk for the same fiber content.

4. **Sample stratification.** Lots of asparagus are extremely variable in fibrousness. It was therefore considered important to determine the effect of the method of loading the sample on shear-press results. Thus, in another series of tests, samples were first sorted visually for differences in apparent fibrousness, and the most fibrous units placed on the bottom, middle, or top of the sample box. For these data also, an analysis of variance did not establish the existence of difference with statistical certainty. There were indications, however, that such sample stratification had no effect on the relation of work values to fiber content, but the maximum force values tended to be somewhat higher for the same fiber content, if all the tough units are placed on the top of the sample.

5. **Variability in fibrousness within the sample.** Shear-press values, whether in terms of work as shown by the area under the time-force curve, or in terms of maximum force, may be used to indicate average fibrousness of a lot of asparagus. Such information may be used as a guide for determining whether a lot of asparagus *on the average* will be of sufficient tenderness. The asparagus processor, however, is interested not only in the average fibrousness, but also in the distribution of fibrousness within the lot. Thus for example, if stalk segments at a certain distance from the tip average 1.0% fiber rather uniformly, all of these segments may be discarded; however, if the lot is extremely variable, there may still be a substantial portion of tender material that may be utilized, and only the more fibrous units discarded.

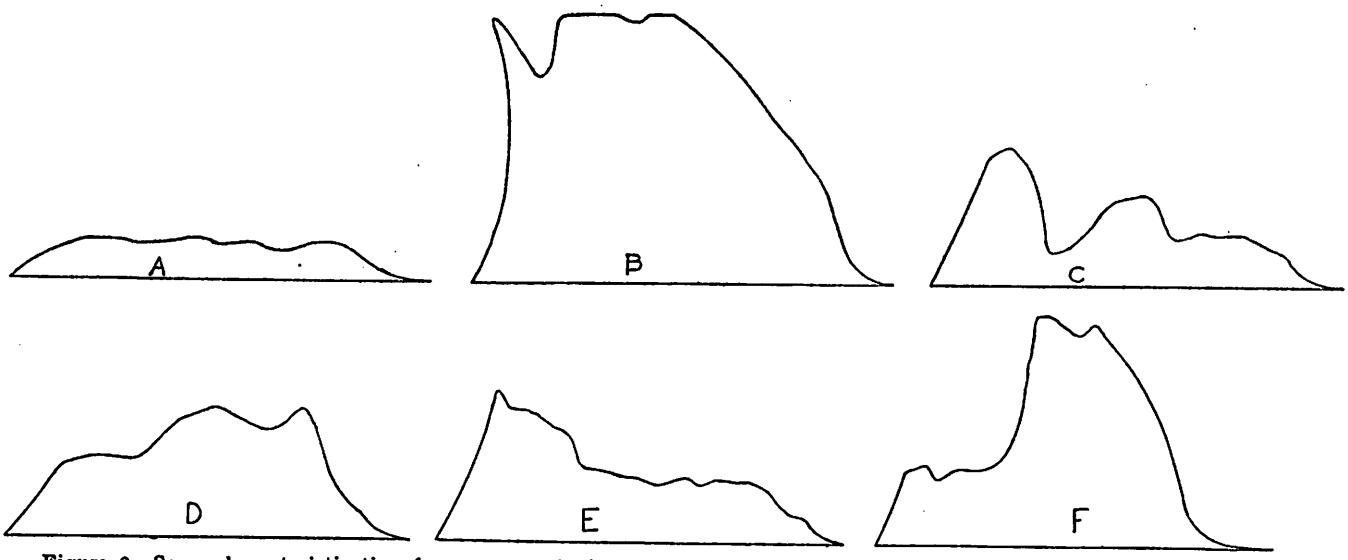

Figure 2. Some characteristic time-force curves obtained with the recording shear-press on asparagus. A = uniformly tender asparagus, B = uniformly tough asparagus, C = one tough stalk at bottom of sample, D = one tough stalk at the top of the sample, E = several increasingly tough stalks at the bottom of the sample, F = several tough stalks at the top of the sample.

An examination of the time-force curve provides the opportunity of estimating the variability within the sample. In Figure 2, examples are shown of a number of types of curves illustrating how such variability may be interpreted. A sharp peak indicates the presence of a single fibrous stalk, whereas a plateau indicates the presence of several stalks of equal fibrousness. A sustained plateau showing only small peaks and dips indicates uniform material, with the height indicating the degree of fibrousness.

It may be feasible to establish some variability ratio from data provided by time-force curves. This will be investigated during the 1957 season, along with procedures for including such measurements in quality control and grading procedures.

6. Correlation with fiber content. In order to determine whether work values provide any better information on the fibrousness of asparagus than dial indications of maximum force, rank correlations were calculated for 6 separate sets involving 114 individual samples. Correlations between work and maximum force ranged from 0.81 to 0.98, indicating that in general, these two types of data provided the same kind of information. Correlations between work values and percentage fiber ranged from 0.79 to 0.96, while those between maximum force and percentage fiber were from 0.67 to 0.93. These somewhat higher correlations with work values may be due to a number of factors, such as those discussed above.

SUMMARY

Time-force curves obtained with an electrical indicating and recording shear-press provided additional and more precise information on fibrousness of asparagus than maximum force indications alone. Average fibrousness may be indicated in terms of work per square inch of sample, at a given speed of stroke. Stalk diameter and sample stratification have some effect on maximum force values, but the effects on work values may not be as great. Variability within the lot may be observed by examination of the work curves. Additional research is needed to establish a variability ratio based on these curves.

LITERATURE CITED

1. Decker, R. W., Yeatman, J. N., Kramer, A., and Sidwell, A. P. Modification of the shear-press for electrical indicating and recording. *Food Technol.*, 11, 343–347 (1957).
2. Kramer, A., Haut, I. C., Scott, L. E., and Ide, L. E. Objective methods for measuring quality factors of raw, canned, and frozen asparagus. *Proc. Am. Soc. Hort. Sci.*, 53, 411–425 (1949).
3. Kramer, A., Burkhardt, G. J., and Rogers, H. P., Jr. The shear-press: a device for measuring food quality. *Canner*, 112 (5), 34–36, 40 (1951).
4. Snedecor, G. W. *Statistical Methods*, 4th Edition. Iowa State College Press, Ames, Iowa.
5. Wiley, R. C., Elehwany, N., Kramer, A., and Hager, F. J. The shear-press: an instrument for measuring the quality of foods. IV. Application to asparagus. *Food Technol.*, 10, 439–443 (1956).

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