ARTICLE 43-12
AUGUST 1960

A MECHANICAL RECORDING PRESSURE TESTER

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THE "PRESSURE TEST" is a common objective measure of attributes of fruits and vegetables. It is widely used for indicating changes in maturation and ripening of apples, peaches, and pears, and as an index of texture in pickles. It is used extensively in experimental work to follow changes in firmness. The USDA (Magness-Taylor) fruit pressure tester[2] as modified and presently manufactured[3] is the standard in the fruit and vegetable industry. Results of experiments carried on in this laboratory indicate that there may be significant differences in the results obtained by different operators using the hand powered Magness-Taylor pressure tester.

This is a report of the development of a mechanically operated recording pressure tester designed to eliminate part of the human element from pressure testing and, at the same time, provide a force-displacement diagram for a better understanding of the behavior of the product during testing.

Construction and Operation

Fig. 1 is a labeled photograph of the mechanical recording pressure tester; the pedestal, including rack and pinion, was formerly part of a spring tester.

The mechanical recording pressure tester operates in a manner similar to the Magness-Taylor pressure tester where a plunger of standard dimensions is forced into the fruit to a fixed distance and the resistance of the fruit to penetration is measured. In the Magness-Taylor pressure tester, the force for penetrating the fruit is supplied by the operator and measured by the displacement of a calibrated spring.

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[2]Magness, J. R. and G. F. Taylor (1925). An improved type of pressure tester for the determination of fruit maturity. USDA Circular No. 350.
[3]Ballauf Mfg. Co. Inc., Washington, D. C.; Model 30A.

Reprinted from the QUARTERLY BULLETIN of the Michigan Agricultural Experiment Station, Michigan State University, East Lansing.
Vol. 43, No. 1, pages 117 to 121, August 1960

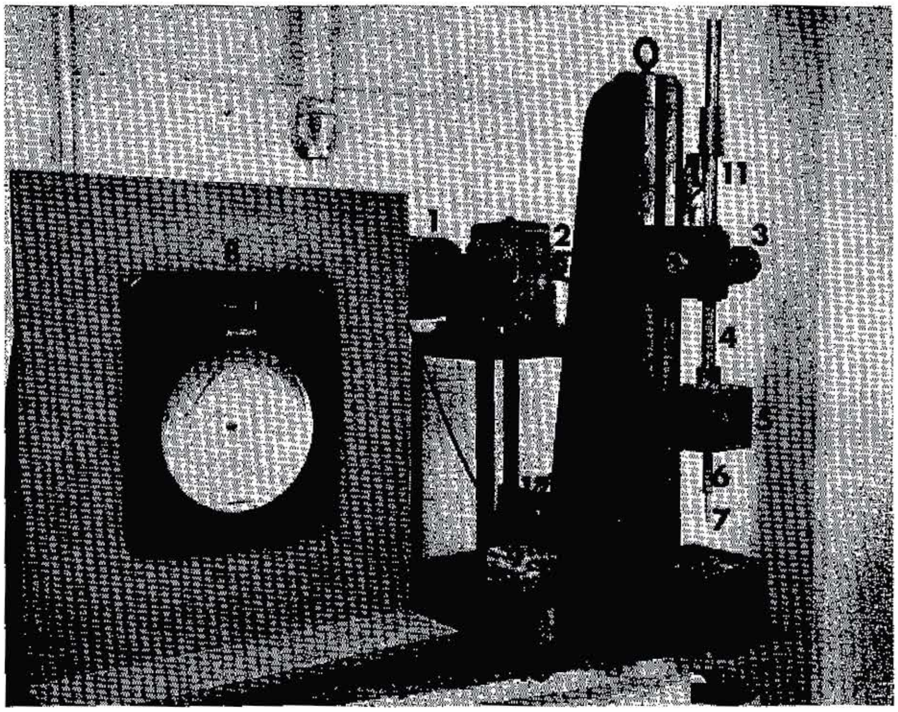

Fig. 1. Mechanical recording pressure tester. 1. Motor, 2. Drive sprocket, 3. Pinion sprocket, 4. Rack shaft, 5. Load cell, 6. Safety sleeve, 7. Plunger and tip, 8. Recorder, 9. Reversing switch, 10. Chart drive switch, 11. Microswitch and sleeve, and 12. Microswitch bypass.

The plunger of the mechanical recording pressure tester is powered by a 1/6-H.P. constant speed reversible electric motor acting through a mechanical power train. The resistance of the fruit to penetration is measured by a Baldwin SR-4 type load cell (50 lb. capacity)—Foxboro Dynalog resistance bridge system. The pressure in pounds is recorded directly on a circular chart that rotates at 1 rpm.

The operator of the mechanical recording pressure tester controls the direction of plunger movement with the electric motor reversing switch. The chart drive motor is powered from the "down" side of the reversing switch so that the chart moves only when the plunger is moving downward. A separate chart drive switch allows the chart drive motor to be disconnected even when the plunger is moving downward. This permits the necessary flexibility if only the maximum force is wanted rather than a force-displacement diagram.

The system is equipped with several safety devices designed to limit the travel of the plunger and to protect the load cell. A microswitch in series with the plunger motor may be adjusted to stop the plunger at any desired point by adjusting the sleeve that actuates the microswitch. The total plunger travel is governed by the length of the microswitch sleeve. A microswitch bypass (which allows the operator to move the plunger when the microswitch is open) is located on the control panel just above the motor reversing switch. A spring safety sleeve is located between the load cell and the plunger; if the force on the plunger exceeds 30 lbs. the plunger will compress the spring and move against a stop rather than transfer the force to the load cell. The plunger drive motor electrical circuit passes through the control section of the Foxboro Dynalog instrument, which provides an additional safety feature to prevent overload of the load cell. The controller is adjusted so that the motor will be turned off when the test force exceeds 30 lbs.

Plunger speed may be varied by changing the drive-sprocket-pinion-sprocket tooth ratio. This operation requires only a few minutes. The speed is governed, in addition, by the drive motor output, 1.91 rpm, the number of teeth on the pinion, 13, and the number of teeth on the rack shaft, 46 teeth/ft. The plunger speed, s, is calculated to be

$$s = \frac{\text{no. drive sprocket teeth}}{\text{no. pinion sprocket teeth}} \times \frac{1.91 \text{ rev.}}{\text{min.}} \times \frac{13 \text{ teeth}}{\text{rev.}} \times \frac{12 \text{ in.}}{46 \text{ teeth}}$$

$$s = \text{tooth ratio} \times 6.48 \text{ in./min.}$$

In the tests described herein, tooth ratios of 12:26, 12:12, and 26:12 were used; the corresponding speeds are, respectively, 3:00, 6.48, and 14.0 in./min.

The instrument was calibrated by placing known weights up to 20 lbs. on the plunger sleeve. The recorder response is linear over the range 0-20 lb. and the force may be estimated to the nearest 0.2 lb. The angular distance on the chart, which is a measure of plunger displacement, is different for each plunger speed; for example, 0.146 in./chart division at a plunger speed of 14.0 in./min.

The data may all be taken in chart divisions, manipulated, and converted to inches at the end or a template may be made for reading the displacements directly in inches. If displacement data are found to be particularly useful, it is recommended that a suitable juggling of chart and plunger speeds be made or that special charts be designed. A strip chart recorder would facilitate the analysis of large amounts of force-displacement data.

The sleeve at the bottom of the Baldwin SR-4 load cell was designed for use with several types of plungers. The plungers are mounted in the lower end of the mounting sleeve and held in place with a set screw. In the original work using this instrument, several different head shapes were used; for comparative work with the Magness-Taylor fruit pressure tester, an adaptor is used so that the plunger tip of the Magness-Taylor fruit pressure tester can be attached to the mechanical pressure tester.

Application

Fig. 2 shows curves for two fruits tested with the recording pressure tester (5/16″ fruit pressure tester tip, plunger speed 6.48 in./min.). These curves have been redrawn from the circular charts for the read-

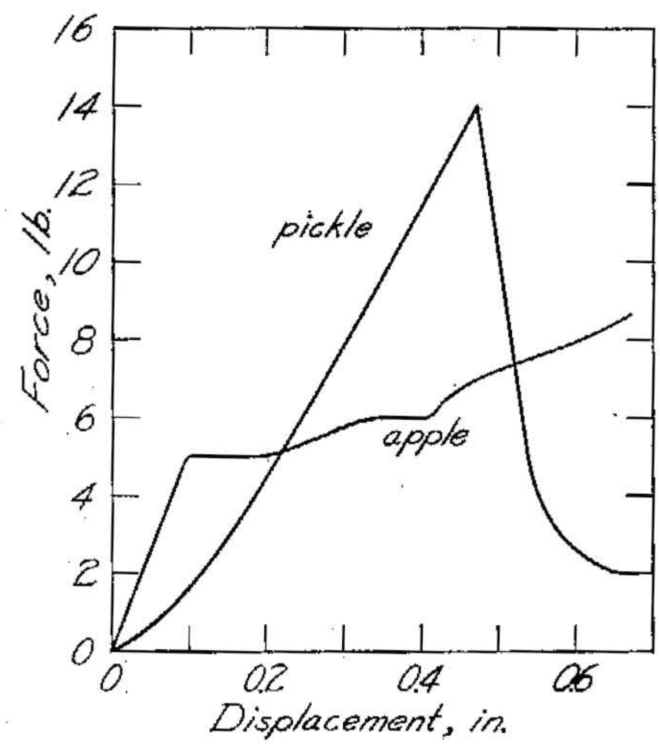

Fig. 2. Force-displacement curves obtained using the mechanical recording pressure tester (plunger speed 6.48 in./min., 5/16 in. tip).

er's convenience. According to recommended procedure,[4] the apple was punched after removing a section of skin; the salt-stock pickle was punched through the skin. The area under the curve is a measure of the energy expended in doing the work of puncturing the fruit.

Table I gives the results of punching salt-stock pickles at three plunger speeds. The variables measured were the force at which the fruit failed under load, the area under the curve (energy) up to the point of failure, and plunger displacement at the point of failure. Displacement is measured from the skin of the fruit toward its center. The standard deviations of the variables at each speed were tested by the F-test and were not significantly different. An analysis of variance of the data showed no significant difference in yield force means or energy means at the three speeds. The displacement means are significantly different among all three speeds. This difference is probably related to the relaxation time for the fruit.

TABLE 1—Characteristics of pickle force-displacement curves obtained with the mechanical recording pressure tester (5/16 in. tip)

Variable	No.	Plunger speed, in./min.			Standard deviation
		3.00	6.48	14.0	
Force, lb.	30	14.8	15.6	15.8	1.9
Energy, in.-lb.	15	3.71	3.33	3.13	0.75
Displacement, in.	15	0.547	0.491	0.443	0.058

The mechanical recording pressure tester was designed as a research tool. Some of its advantages are permanent record of force vs. displacement, and elimination of personal idiosyncrasies. Some of its disadvantages, vis-à-vis, hand pressure testers are higher initial cost, fewer tests per hour (about 100) and it is not portable.

SUMMARY

The construction and operation of a fruit and vegetable pressure tester having a mechanically driven plunger and force vs. displacement recording system is described. Examples of the application of this apparatus are presented.

[4]Haller, M. H. (1941). Fruit pressure testers and their practical application. USDA Circular No. 627.