

S105

E24

no. 123

cop. 2

**Measuring Textural  
Characteristics of  
Fresh Fruit  
and Vegetables—  
Apples, Carrots,  
and Cantaloupes**

**A Manual of Selected  
Procedures**



**Technical Bulletin 123**



**AGRICULTURAL  
EXPERIMENT  
STATION**  
Oregon State  
University  
Corvallis, Oregon

*January 1973*



# Contents

Introduction .....	3
Recommended Procedures .....	5
Storage Conditions .....	5
Sampling .....	5
Physical Tests .....	7
Chemical Tests .....	22
Sensory Tests .....	32
References Cited .....	38

**AUTHORS:** Andrea C. Mackey, Department of Home Economics Research, Oregon Agricultural Experiment Station, Oregon State University, Corvallis, Oregon; Margaret M. Hard, Department of Home Economics, Washington Agricultural Research Center, Washington State University, Pullman, Washington; Mary V. Zaehring, Department of Home Economics Research, Idaho Agricultural Experiment Station, University of Idaho, Moscow, Idaho.

**COOPERATING AGENCIES:** The Agricultural Experiment Stations of California, Colorado, Idaho, Nevada, Oregon, and Washington, and the Cooperative State Research Service, United States Department of Agriculture.

Under the procedure of cooperative publications, this regional bulletin becomes, in effect, an identical publication of each of the cooperating agencies, and of each of the Experiment Stations in the Western Region, and is mailed under the frank and indicia of each.

**ACKNOWLEDGMENTS:** The cooperation of laboratory technicians and other personnel in each state is greatly appreciated.

# MEASURING TEXTURAL CHARACTERISTICS OF FRESH FRUITS AND VEGETABLES— APPLES, CARROTS, CANTALOUPE

## A Manual of Selected Procedures

ANDREA C. MACKAY, MARGARET M. HARD, and  
MARY V. ZAEHRINGER

### ABSTRACT

This manual brings together methods found useful for measuring various aspects of texture of fresh fruits and vegetables. Apples, carrots, and cantaloupes were used as test materials for evaluating the methods. The manual presents procedures recommended by the Technical Committee of Project WM-55, "Methods of Measuring Textural Qualities of Fruits and Vegetables."

*Key words:* Methods, texture, fruit, vegetables, apples, carrots, cantaloupe.

### INTRODUCTION

Texture is the sum total of kinaesthetic sensations derived from eating a food. It encompasses the mouthfeel, the masticatory properties, the residual properties, and the sound.

According to Szczesniak (1963), textural characteristics can be classified under three main groups: mechanical, geometric, and others. By concentrating on such factors as hardness, springiness, adhesiveness, and chewiness, a taste panel can analyze food texture and describe a texture profile.

The textural characteristics of fruits and vegetables are often referred to as "crispness," "juiciness," "hardness," "toughness," "mealiness," and "fibrousness." These characteristics must be associated with plant tissue, composition and structure of cell wall constituents and intercellular binding tissue, and the water relationships of the tissues.

Examples of desirable texture are crispness of apples, juiciness of oranges, and moderate softness of bananas. In contrast, examples of undesirable texture are mealiness of apples, excessive softness of strawberries, and fibrousness in melons.

The texture of fruits and vegetables is considered of major importance in bringing about their acceptance or rejection. In a consumer survey of 5,171 households in the West, food buyers stated that "freshness," "firmness," and "ripeness" were important factors in their selection of fresh fruits and vegetables (Hard and others, 1963). These characteristics are directly related to texture. Certain nutrient deficiencies have been found in our population, specifically low levels of vitamins A and C, which could be corrected by increased use of fruits and vegetables. Market offerings of fruits and vegetables having desirable textural characteristics will certainly influence consumer acceptance of these products.

Under a western regional project, "Methods of Measuring Textural Quality of Fruits and Vegetables," the physical and chemical attributes of certain fruits and vegetables were studied with emphasis on instrumental and chemical methods which assess the structural characteristics and hence the texture of the plant tissue. The measurements were correlated with sensory evaluations of tissue texture. Methods used included shear, shear compression, penetration, and determinations of pH, pectin, lignin, soluble solids, alcohol-insoluble solids, turgor, moisture, press juice, and specific gravity. Apples, carrots, and cantaloupes were selected for testing the applicability of the methods for texture evaluation.

Although some of the methods used have been referred to in other reports, few details were included. The objectives of this manual are:

1. To present a compilation of selected methods for evaluating texture.
2. To present standardized methods in sufficient detail so that a laboratory technician may carry out the determination.
3. To describe the application of various methods to products differing in textural quality.

Methods were standardized within research laboratories and between research laboratories. Correlations were determined among the methods, and the efficiencies of each method were assessed by reference to coefficients of variation. Data from objective methods were highly correlated with sensory panel evaluations of one or more textural attributes of the plant tissue. These results are published elsewhere. The material presented in this manual represents the recommended procedures based on the results of research of several laboratories in the western region engaged in this project.

## RECOMMENDED PROCEDURES

### Storage Conditions

#### APPLES

To minimize textural changes over several months of storage, a temperature of 31 to 32° F is recommended (Rouse and Atkins, 1955). To accelerate changes in texture, storage at 45° F is advised. During the period required for analysis, further changes can be controlled by maintaining the samples at 31 to 32° F.

Golden Delicious apples are best stored in polyethylene bags with holes. Red Delicious and Winesap apples can be stored in the cartons in which they are shipped. Prior to analysis, samples should be taken from cold storage, removed from the bags, and allowed to come to room temperature.

#### CARROTS

Carrots should be stored in plastic bags at 32° F. Prior to analysis, samples should be taken from cold storage, removed from the bags, and allowed to come to room temperature.

#### MELONS

Melons should be stored at 60 to 65° F for not more than three days, or at 32° F for not more than seven days. They may be stored in open boxes. Prior to use they should be removed from storage and kept at room temperature overnight.

#### Sampling

#### GENERAL

The sample selected for analysis should be as representative as possible of the entire lot of food. The variability in fruits and vegetables is due to many factors, including genetic constitution, soil and climatic conditions during plant growth, maturity at harvest, and storage conditions prior to use. In addition, different parts of the same plant differ in composition.

It is customary to reduce variability in the population to be sampled by limiting the genetic constitution to one variety and one strain. It is also customary to use plant material from a common source, since this reduces the variability due to climate and soil conditions and imposes some control on the maturity. If samples must be shipped to the point of analysis, shipments should be made under refrigerated conditions to arrive on a work day so that facilities will be available for immediate care.

In sampling foods sufficient material must be taken to compensate for the variability involved. Replicate samples should be analyzed in order to provide a measure of variability. This measure is used in statistical analysis to determine whether differences are significant among varieties, storage conditions, or other imposed variables.

## APPLES

The exact number of apples used by a laboratory is dictated by the number of tests to be performed and by the reproducibility of results between replications. For tests in which replications prove to be very much alike, a few replications will yield results having statistical significance. When the variability due to material or method is unknown, it is advisable to begin with a large number of replications.

To illustrate, the planning of one laboratory for the first season's work is described here. Eight apples of each variety and size were needed for each series of tests, and 10 replications were planned. The eight apples for each replication were divided as follows:

- Two apples for the Succulometer
- Two apples for the Texturepress
- Two apples for testing moisture, alcohol-insoluble solids, and soluble solids
- One apple for the Magness Probe
- One apple for sensory evaluation by the panel

Following statistical analysis of this season's work, which demonstrated reproducibility within each method, the number of replications was reduced to five.

## CARROTS

Variation from carrot to carrot may be high. Therefore it is recommended that each carrot be tested individually. Use a portion of each sliced carrot for judging by a sensory panel, and the remainder for one or more of the following: Texturepress, turgor pressure, lignin content, or other chemical tests. Whole carrots may be judged for flexibility and compressibility by the panel and then be submitted to further chemical or physical analyses.

## MELONS

At least 10 melons should be used, each melon comprising one replication. Some tests require more replications than others. For example, melon-to-melon variation will be greater for pectic substances than for moisture or sugars. Each melon may be judged by a sensory panel and other analyses may be made on the remainder of the melon. Prepare representative portions by cutting the melons into quarters and using al-

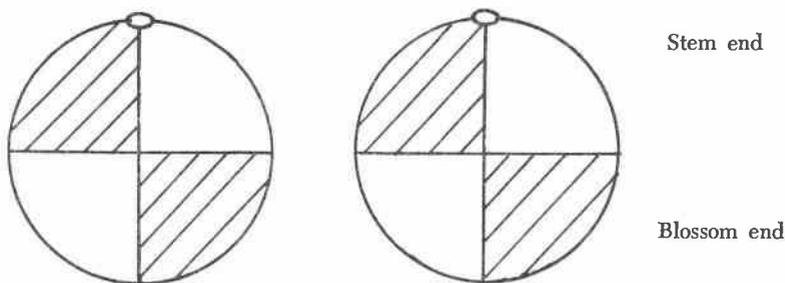


Figure 1. Diagram of method of sampling muskmelons.

ternate sections for the tests. Cut each melon in half from the stem to the blossom end, and quarter these halves (Figure 1).

Use the shaded portions (Figure 1) for sensory analyses and the unshaded portions for objective tests. As can be seen, each group (shaded and unshaded) of eighths comprises portions of the top, bottom, and both ends of the melon. Remove and discard the rind with approximately 1 cm thickness of flesh.

## Physical Tests

### SPECIFIC GRAVITY

#### APPLES

For determining specific gravity, it is necessary to obtain the weight of the apple in air and when submerged in water. Either of the following methods yields satisfactory results.

#### Method 1

##### Equipment

1. Wire basket with a lid.
2. Large container nearly full of distilled water (plastic wastebasket can be used).
3. Toledo scale,<sup>1</sup> capacity 5 kg.

##### Directions

1. Mark a bar of wood approximately 1 inch x ½ inch x 18 inches with red lines about 2½ inches from the end. Place it on the right-hand weighing pan of the Toledo scale, securing it under the metal piece at the side.

<sup>1</sup> Toledo Scale, Toledo, Ohio.

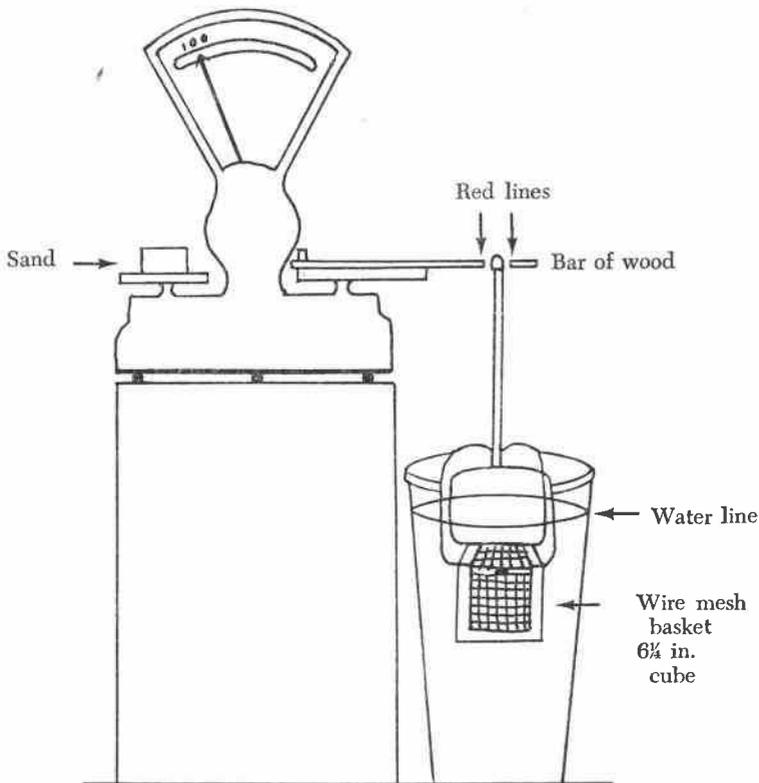


Figure 2. Equipment for determining specific gravity (Method 1).

2. Place the chain of the wire mesh basket between the red lines and suspend the wire basket freely in the container of distilled water, taking care to eliminate air bubbles. A rubber policeman may be used to rub away air bubbles. Leave the basket in water during all weighings.

3. Place a box on the left-hand weighing pan and put sufficient sand in it to bring the pointer exactly to the 100-g mark on the scale.

4. Place the apple on the right-hand weighing pan. Record the scale reading for the weight in air.

5. Place the apple in the submerged basket, taking care to eliminate air bubbles around the apple and under edges of the lid. Record scale reading for weight in water.

$$\text{Specific gravity} = \frac{a - 100}{a - b}$$

a = scale reading for weight in air

b = scale reading for weight in water

## Method 2

### Equipment

1. Metal plunger made of stainless steel wire. Mark a red line on the plunger 9 cm from the bottom.
2. Tin can 22 cm high with a diameter of 17.5 cm; mark a red line inside the can 15.5 cm from the bottom.
3. Toledo scale.

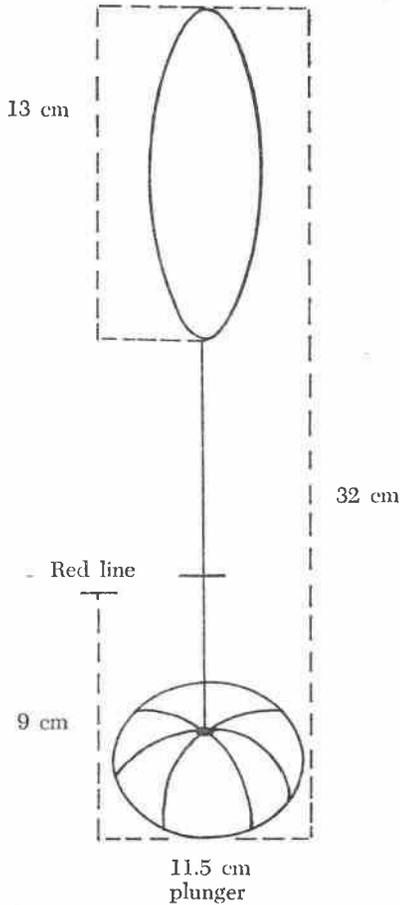


Figure 3. Equipment for determining specific gravity (Method 2).

### Directions

1. Weigh the apple in air.
2. Fill the can to the red line with water at room temperature.
3. Place the can with water and plunger on the scale and weigh.

4. Place each apple with blossom and stem ends horizontal to water level. Place the plunger over the apple, pushing it under water until the red line of the plunger is in line with the red line on the can. Record the weight.

5. The following formula is used:

$$\text{Specific gravity} = \frac{\text{weight of apple in air}}{\text{volume}}$$

Volume = weight of apple + buoyancy

Buoyancy = (container wt. + water + apple wt. + push of plunger) - (container wt. + water)

## MELONS

Weigh the melons in air to 0.1 g precision. Submerge in 2500 ml water at 22° C, and measure the water displaced by each melon. Take two measurements on each melon.

$$\text{Specific gravity} = \frac{\text{Mass (weight in g)}}{\text{Volume (ml water displaced)}}$$

## MAGNESS PROBE

### APPLES

The Magness Probe<sup>2</sup> is suitable for measuring resistance to penetration (Magness and Taylor, 1925; Szczesniak, 1963). Fit a rubber stopper with a hole in the center over the probe so that only ¼ inch will penetrate the apple. Hold the apple firmly against the rear wall of the counter.

#### *Test for skin toughness*

1. Push the probe, 7/16 inch diameter, firmly against the apple at its largest circumference.

2. Make two tests on opposite sides of each apple and record the readings to the first decimal place.

#### *Test of flesh*

1. Remove small circles of skin approximately ½ inch in diameter at opposite sides of the same apple near the largest circumference.

2. Push the 7/16 inch diameter probe firmly into the flesh and record the reading.

<sup>2</sup> D. Ballauf Company Inc., Washington, D.C.

## SHEAR COMPRESSION TESTS

The following directions are offered to simplify and facilitate the operation of the instruments used in the determination of shear compression.

### APPLES

#### *The Instron Universal Testing Machine*

A table model Instron Universal Testing Machine (TM-M)<sup>3</sup> with a CDM compression load cell (capacity 0-500 kg) is used. The gears in the Instron are set so that the crosshead and the recorder move at the same rate of speed, 2 cm per minute. The full scale load (FSL) is set at 10 (100 kg) for Golden Delicious and Red Delicious apples and at 20 (200 kg) for Winesap variety. Apples become softer after storage, so it may not always be necessary to use 200 kg for Winesap.

The Instron is fitted with an adapter to accommodate the Allo C-1 standard compression test cell.

Rinse all parts of the shear compression test cell with distilled water and dry before the first use so that the same amount of moisture is present each time it is used.

#### *Calibration*

The Instron is calibrated as follows:

1. Turn on main power switch. Allow to warm up 30 minutes.
2. Turn on pen motor switch.
3. Set full scale load switch on 20.
4. Depress "zero" switch. Turn "zero knob," while holding zero switch down, until the pen is on the zero line on the chart.
5. Release zero switch and lock knob in place. Adjust the "balance" knob until the pen is on zero.
6. Set FSL on 10, 5, 2, and 1, repeating steps 4 and 5 for each position.
7. With FSL in position 1, load 10 kg on load cell platform. Adjust the pen to 10 on the chart, using the "calibration" knob. Remove weights.
8. Place testing cell on platform. Adjust pen back to zero, using the "balance" knob.

#### *Operation*

The Instron is operated as follows:

1. Set FSL at 10 or 20 as needed.
2. Turn on crosshead power switch. Turn off pen switch.

<sup>3</sup> Instron Corporation, 10831 Bloomfield Avenue, Los Alamitos, California 90720.

3. Set dials to allow crosshead to descend a total of 10 cm. Run crosshead down until blades of shear unit can be aligned with grids of testing cell (about 1¼ cm).

4. Turn on chart switch and pen switch. Depress "down" button at "A" speed. Run crosshead down until blades emerge from bottom of the test cell (about 8¼ cm). Depress "up" button at "B" speed. Run crosshead up until blades are free of the grid. Remove blades and rinse in hot water and distilled water. Remove testing cell and collect samples for alcohol-insoluble solids, if desired. Rinse and dry testing cell.

### *Preparation of sample*

Remove two apples from the refrigerator and allow to come to room temperature. Balance each on the stem end and cut into quarters from the blossom to the stem end. Pare each quarter thinly, core, and cut longitudinally into ¼-inch slices, discarding wedge-shaped pieces. Cut the slices in half crosswise, place in a bowl, and mix well with the hands, stirring and tossing the apples over at least 10 times to obtain a homogeneous sample.

### *Determination of shear compression*

It is convenient to weigh out three 80-g aliquots of apple slices and wrap them in Saran wrap. The first aliquot is used as a "dummy" or "test" run to determine whether a full scale load of 100 kg or 200 kg is needed. A sample size of 80 g of apple was selected in order to stay within the capacity of the Instron compression load cell used with the table model machine.

Arrange the 80 g of apple slices in even layers, alternating directions, in the bottom of the test cell box. Assemble the test cell, set in place, and carry out the shear compression test.

Since the Instron has a metric scale and the planimeter reads in inches, the formulas for a full scale load of 100 kg are:

$$\begin{aligned}\text{Full scale, 10 divisions} &= 100 \text{ kg} \\ \text{Each division} &= 10 \text{ kg}\end{aligned}$$

### *Calculations*

1. **MAXIMUM FORCE.** Number of divisions at highest peak on curve x 10 x 2.2046 = maximum force in pounds.<sup>4</sup>

2. **WORK TO SHEAR.** Each division = 1.056 inches. At full scale load of 10, force per inch in pounds = 10.56 x 2.2046 = 23.281 pounds. Area under the curve in square inches x 23.281 = work to shear in pound-inches.

<sup>4</sup> 1 kg = 2.2046 pounds.

## Texturepress

Shear compression may also be determined with this instrument. In this cooperative research, the Allo-Kramer Shear Press,<sup>5</sup> model S-2HE, and Recorder Indicator, model E-2EZ, were used on three varieties of apples—Red Delicious, Golden Delicious, and Winesap. The recorder chart advanced 2.725 inches for each full stroke of the power ram. The ram speed was 3.475 inches for 60 seconds after 16 to 18 warm-up strokes at room temperature of 72 to 74° F. Other individual instruments or models may differ somewhat, but these factors should be known.

The 5000-pound proving ring at range 10 was used for all varieties except Golden Delicious, which were very tender, or for apples that had been stored at 45° F, in which case a 500-pound proving ring at range 50 was used. Two hundred pounds pressure was used on the 5000-pound ring, and 50 pounds on the 500-pound ring was set at values to accommodate the 60-second stroke of the ram. The test cell was the C-1S standard shear compression cell which consisted of a sample holder, slotted lid, and 10 movable blades each  $\frac{1}{8}$  inch thick.

### Operation

1. Turn function switch of the texture recorder to "Standby" position and allow a 30-minute warm-up period. Power switch *on*. Chart speed *low*.

2. Rinse texture recorder pen with warm water. Fill with just enough ink to cover the bottom of the reservoir.

3. Establish the descent rate and pressure on the ram of the Texturepress. Release the locking nut on the pressure relief valve.

Put the direction control in the *down* position. Turn the power switch to *on* and the direction control valve to *down*. The pressure gauge will register. If the reading is too high for the ring being used, *immediately* turn the pressure control valve *counterclockwise*. Then slowly turn clockwise to the desired pressure setting and lock this setting in by turning the inner black knob clockwise. The 5000-pound ring should not exceed 420 pounds of pressure, and the 500-pound ring should not exceed 50 pounds pressure.

Return the ram to its upper position by turning the direction control valve to *up*. Set the direction control valve to the center position when the ram is fully retracted.

Adjust the ram descent speed by rotating the flow control valve. Turn the bottom silver-colored valve clockwise to decrease the speed or counterclockwise to increase the speed. When ram speed is achieved, lock the flow control valve by tightening the small knurled green knob on top.

4. Turn the function switch of the recorder indicator to *operate*.

<sup>5</sup> Now manufactured by Food Technology Corporation, 11425 Isaac Newton Sq. S., Reston, Virginia 22070.

5. Raise and lower the ram 15 to 20 strokes or until the descent time is one minute.

### *Calibration*

Install the proving ring and test head. Check the transducer carriage so that it is securely in place. Tighten the locking thumb screw.

#### CALIBRATE RECORDER INDICATOR:

1. Turn the recorder zero adjust knob one quarter turn clockwise.
2. Turn the range selector knob to the 1% position on the range dial.
3. Adjust the zero adjust stud on the proving ring so that the pen on the recorder travels to the center of the chart paper.
4. Turn the range selector knob to 100% position and rotate the zero adjust knob on the recorder to zero on the chart paper.
5. Turn the range selector knob to the 1% position and adjust the zero adjust stud on the proving ring until the pen rests on the chart paper zero. At this time the range selector knob should be turned quickly from 1% to 100%, with the pen continuing on zero. If this is not possible, repeat the steps for calibrating the recorder indicator.

#### CALIBRATE PROVING RING:

1. The range selector knob must be on 100% and the recorder indicator pen on zero.
2. Place the gauge block for the designated proving ring between the zero adjust stud and the transducer pickup (number area must be to the front).
3. Push down lightly on the edge of the gauge block to tilt it upwards so that the pen deflects upward five divisions. Remove finger; the recorder indicator pen should return to the position which corresponds to the three-digit number etched on the gauge block.
4. A fine adjustment may be made by adjusting the calibration control on the recorder indicator.
5. A greater adjustment is made by again calibrating the recorder indicator.
6. Slight changes in the zero position may be observed on the more sensitive range settings.
7. Wipe the gauge block with light oil and return it to the container for storage.

### *Determination*

1. Use an 80-g sample of  $\frac{1}{4}$  inch slices of apple. Interlace crosswise over the bars of the shear compression cell.
2. Wet blades before shearing the first sample.
3. Align the blades over the shear cell. If the ram is slightly twisted so the blade element and cell cover do not mesh properly, remove the

cell. Straighten by easing the ram down  $\frac{1}{4}$  inch; then grasp the whole assembly and rotate slightly. Raise the ram and insert the cell.

4. Place drip pan below the shear compression cell.

### Calculations

*Formula for calculation of force:*

Maximum force = maximum height reading in inches x pound equivalent per chart division (according to proving ring size and sensitivity range)

Factors for pound equivalent per recorder chart division

Range	Factor based on ring capacity	
	500 lb.	5000 lb.
100	5	50
50	2.5	25
20	1	10
10	0.5	5

*Formula for calculation of work:*

Area is obtained with the use of the Compensating Polar Planimeter, K & E 620000.<sup>6</sup>

Work in pound-inches = force per inch x area under the curve in square inches x F

$$F \text{ (factor)} = \frac{\text{movement of ram}}{\text{chart speed}} \text{ or } \frac{3.475^7}{2.725} = 1.275$$

Ring	Range	Force per inch	Area (sq. in.)	F
5000	100	1000	A	1.275
5000	50	500	A	1.275
5000	20	200	A	1.275
5000	10	100	A	1.275
500	100	100	A	1.275
500	50	50	A	1.275

<sup>6</sup> Compensating Polar Planimeter, Keuffel & Esser Co., 1963, Seattle, Wash.

<sup>7</sup> Chart speed and ram speed are described on pages 13-14.

## CARROTS

A Texturepress may be used to determine the force and work required to shear carrot samples. Arrange 50 g of sliced carrot in the shear cell. Set the instrument to a full scale of 2400 pounds. During shearing, the time-force curve is recorded as peaks on a graph. Measure the area under the peak in square inches using a Compensating Polar Planimeter, and ascertain the maximum height of the curve in inches by measuring. The full scale of 5 inches is equal to 2500 pounds. The following formulas apply (F is explained under determination for apples, page 15):

$$\begin{aligned}\text{Maximum force} &= \text{maximum height in inches} \times 2500 \text{ pounds} \\ \text{Work in pound-inches per inch} &= \text{force per inch} \times \text{area} \\ &\quad \text{under the curve in square inches} \times F\end{aligned}$$

Compression strength of carrots may be determined with the Instron Universal Testing Machine (Howard and Heinz, 1970). It is recommended that carrots be measured at a point of uniform diameter, since greater force is required to compress material of greater diameter.

## PRESS JUICE

### APPLES

Peel and core apples using a stainless steel corer and knife.

*Method for succulometer cell attached to the Instron*

1. Place a 50-g sample of apple slices cut less than  $\frac{1}{8}$  inch thick in the succulometer cell, arranging them so the curved edges of the slices are toward the curved edges of the succulometer. Keep the slices level and away from the juice funnel.
2. Place a previously weighed beaker under the spout to collect the juice.
3. Bring the crosshead down until the piston is close to the sample.
4. Set the dials to allow the crosshead to descend 8 cm.
5. Using a pressure of 500 kg (FSL at 50), allow the piston to press the slices down about 7 cm or until a lag-stop is heard; turn the machine off.
6. Allow the piston to rest on the sample for 3 minutes.
7. Run the piston down again until a lag-stop is heard; turn off the machine and allow the piston to rest on the sample for an additional 3 minutes.
8. Remove the test cell and allow any remaining juice to drain into the beaker.
9. Weigh the beaker. Weight of beaker + juice - weight of beaker = weight of juice.

### *Method for succulometer cell attached to the Texturepress*

1. Adjust the screw on the Texturepress located at the back of the cell so that all gauges will be correctly aligned.
2. Insert 5000-pound test ring.
3. Adjust the flow control valve for a 60-second stroke. Calibrate, using a range of 100. Adjust the range to 50.
4. Select a representative sample of apple that has been pared, cut in eighths, and sliced into  $\frac{1}{4}$ -inch slices. Weigh 50 g and place the pieces in the cell at random. Push apple away from the spout area.
5. Place a circle ( $2\frac{1}{2}$  inches in diameter) of No. 2 Whatman filter paper over apple slices in the cell area. Attach the cell piston. Install the sample cup in the hydraulic press with the spout facing forward. Place a funnel in a weighed 400-ml beaker below the spout to collect the juice.
6. Turn the exterior part of the pressure adjust knob fully counter-clockwise. Place the direction control valve in the down position.
7. Allow the piston to contact the apple sample in the cup. Slowly turn the exterior part of the pressure control knob clockwise to increase the pressure to 300 pounds or until foam instead of juice appears.
8. Maintain this force until the peak has been reached on the texturegram.
9. Raise the power ram.
10. Remove the test cell and drain the remaining juice into the beaker. Weigh.  $\text{Weight of beaker} + \text{juice} - \text{weight of beaker} = \text{weight of juice collected}$ .
11. Rinse and dry the test cell after each sample is processed.

*Note:* While learning this technique, it is best to use two operators—one to operate the pressure gauge, the second to collect the juice and watch the pen on the texturegram until the procedure is under control. The texturecorder is used simply to check that the pressure is raised gradually and does not register beyond 95.

## CARROTS

A hydraulic laboratory press<sup>8</sup> may be used to press juice from carrots. Using approximately 10 to 12 g of carrot slices, wrap closely in Saran wrap to prevent moisture loss, and freeze overnight. Thaw the sample and subject to a pressure of 15,000 pounds per square inch. The expressed juice may be frozen immediately in dry ice and used later for freezing point determination or other analysis.

## TURGOR PRESSURE

The determination of turgor pressure is a two-step process. The formula is:

<sup>8</sup> Carver Laboratory Press.

TP = DPD - OP  
 TP = turgor pressure  
 DPD = diffusion pressure deficit  
 OP = osmotic pressure.

The figure for DPD, obtained as described in the following pages, is converted to atmospheres for use in calculating turgor pressure. The formula follows.

$$\text{DPD} = \frac{22.4 \times M \times 273}{T}$$

M = Molality of sucrose solution, determined from plot of data

T = Laboratory temperature, °K

(Example: 25° C + 273° C = 298° K).

The figure for osmotic pressure is calculated from the freezing point depression, described in the following pages. The formula follows.

$$\text{OP} = \frac{\Delta}{1.86} \times 22.4$$

Δ = Temperature, in degrees centigrade, at which the juice froze.

### *Diffusion Pressure Deficit*

#### APPLES

1. To obtain the figure for DPD, make up a series of sucrose solutions, from 0.1 to 1.0 molar, each solution differing by 0.1 M.
2. Measure 25 ml of each solution into small screw-cap vials. Each series should include a vial containing 25 ml of distilled water.
3. Use five apples. Each apple constitutes one replication.
4. Using a No. 2, stainless steel, sharp cork borer, cut small cylinders of apple flesh. Weigh 3 g quickly, and place in one of the vials. Continue until apple pieces have been placed in each of the vials. By boring close together, enough cylinders can be obtained from one apple.
5. Use the remaining apple pulp for freezing point determination. Blend in a Semi-Micro Blendor<sup>9</sup> for 1 or 2 minutes. Centrifuge at high speed and filter the juice through Whatman No. 4 filter paper. Use 10 ml for freezing point determination, page 21. This can be done while the apple cylinders equilibrate with the sugar solutions.
6. Allow the apple cylinders to remain in the sugar solutions until the moisture has equilibrated (18 to 24 hours).

<sup>9</sup> Semi-Micro Capacity Blendor, 360 ml, Van Waters and Rogers, Cat. no. 58983-004.

7. The Abbe refractometer has a scale showing percent solids as sucrose. Read the percent solids of the sugar solutions. Read the percent solids of the solutions in which the apple tissue is immersed.

8. Subtract, to find the difference in percent solids. When the percent of solids is found to be higher in the apple-bathing solutions, it indicates that the apple tissue absorbed moisture from the bathing solution. A lower percent of solids in the apple-bathing medium indicates that moisture diffused from the apple, thus diluting the solution.

9. If these data are plotted, a parabolic curve results, from which it is difficult to read the molarity of the sugar solution at which no change would take place. The point at which the percent solids of the bathing solution would show zero change is found by calculating a best-fitting line. This line is plotted, using the molarity of the sugar solutions as the abscissa and the change in percent solids as the ordinate.

10. That concentration of sucrose at which no change in percent solids takes place is the diffusion pressure deficit.

11. The figure for diffusion pressure deficit is converted to atmospheres in order to calculate turgor pressure (page 18).

## CARROTS

1. To obtain the figure for DPD, remove a core through the diameter at the center of the carrot, using a sharp, stainless steel cork borer, No. 2 size.

2. Slice the core as thinly as possible with a razor blade.

3. Blot the slices gently, combine five or six and weigh quickly.

4. Place each group of slices in sucrose solutions ranging from 0.1 to 0.6 molar. Each series should include a vial containing distilled water.

5. Allow to equilibrate for 24 hours.

6. Remove the slices from the solutions.

7. As each set of slices is removed from a vial, blot lightly to remove excess liquid, and weigh. The difference between the initial weight and the final weight = weight change.

8. Calculate best-fitting lines.

9. Plot the lines, using molarity of the sucrose solutions as the abscissa and the change in weight as the ordinate.

10. That concentration of sucrose at which no weight change takes place is the diffusion pressure deficit. This is converted to atmospheres in order to calculate turgor pressure, page 18.

11. Osmotic pressure is calculated from the freezing point of the carrot juice. Obtain the juice as described under Press Juice, page 17.

12. Thaw the frozen juice until just liquid, about 10 minutes, so that the thermocouples of a recording potentiometer or a thermistor may be inserted.

13. Determine freezing point as described (page 21).

## MELONS

1. To obtain a figure for DPD, take 10 cores, approximately 4 cm long, using a stainless steel cork borer, No. 5.
2. Blot all surfaces very lightly with absorbent paper.
3. Weigh each core quickly and place in one of several vials containing sucrose solutions ranging in concentration from 0.1 to 0.7 molar. Each series should include a vial containing distilled water.
4. Close the vials and allow to equilibrate.
5. Remove the cores, blot lightly to remove excess liquid, and weigh quickly.
6. The difference between the initial weight and the final weight = weight change.
7. Calculate best-fitting lines.
8. Plot the lines, using the molarity of the sugar solutions as the abscissa and the change in weight as the ordinate.
9. The concentration of sugar at which water neither enters nor leaves the tissue, as indicated by zero change in weight, is the DPD. This figure is converted to atmospheres for use in the formula for calculating turgor pressure.
10. Osmotic pressure is determined from the freezing point depression of the melon juice. Obtain the juice from melon slurry, page 23.
11. Thaw approximately 20 g of the frozen slurry at room temperature for about 10 minutes.
12. Centrifuge at high speed (4500 rpm) and filter through Whatman No. 4 filter paper.
13. Use 10 ml of the filtered juice for determining the freezing point, (page 21).

### *Freezing Point*

A recording potentiometer or an apparatus employing a thermistor and a moisture ohmeter<sup>10</sup> may be used for noting the freezing point (see Figure 4).

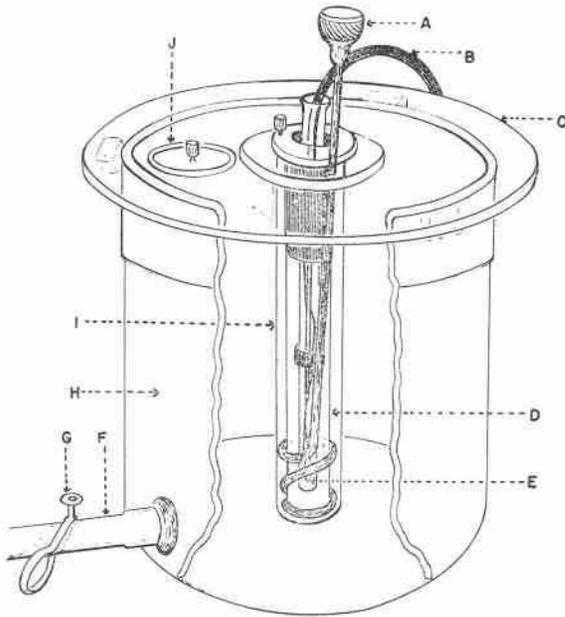
### *Freezer*

The temperature at which freezing of the fruit or vegetable juice takes place can be determined by placing the juice with the inserted thermocouples into a freezer. The freezing point is indicated by a plateau in the temperature readings.

### *Thermistor and moisture ohmeter*

1. Construct a calibration curve, using glycerol solutions maintained at different temperatures in ice, salt and water baths. Insert the thermistor

<sup>10</sup> Beckman Soil Ohmeter, Model 300.



- A. Metallic brine stirrer
- B. Thermistor and cord to ohmeter
- C. Transparent plastic cover
- D. Tube containing juice
- E. Tube containing thermistor
- F. Rubber clamp for water drainage
- G. Clamp
- H. Earthenware crock
- I. Tube with 60% glycerol solution
- J. Opening for ice packing

Figure 4. Thermistor and moisture ohmeter (Beckman Soil Ohmeter, Model 300).

and a thermometer into the glycerol solution and obtain microampere readings and temperature readings simultaneously.

2. To find the freezing point of the juice, insert the thermistor into the juice.

3. Place this assembly in a container of ice and salt, 8 to 10 parts ice to 1 part salt.

4. Stir the liquid surrounding the test tube of juice during cooling.

5. Take readings of electric current in microamperes at zero and at 15-second intervals until a constant reading equal to the freezing point is obtained.

6. Determine the temperature of freezing by reference to the calibration curve relating microampere readings to temperature.

## Chemical Tests

### REAGENTS

#### *Purified ethyl alcohol*

Reflux 1 liter of 95% reagent grade ethanol with 4 g zinc dust and 4 ml of 1:1 sulfuric acid/water for 24 hours. Distill, using all glass apparatus. Add 4 g zinc dust and 4 g KOH to distilled alcohol and redistill.

#### *Versene solution*

Make 6 g sodium tetra ethylenediamine tetracetate (Versene) up to 1 liter with distilled water.

#### *Sodium hydroxide solutions*

*1 N NaOH solution:* Make 40 g NaOH up to 1 liter with distilled water. When using 97.5% NaOH pellets, use 41.03 g and make up to 1 liter using distilled water.

*0.05 N NaOH solution:* Make 2.0 g NaOH up to 1 liter with distilled water. When using 97.5% pellets, make 2.05 g up to 1 liter with distilled water.

#### *Acetic acid solutions*

*1 N acetic acid:* Make 57 ml glacial acetic acid up to 1 liter with distilled water.

#### *Pectic enzyme solution*

Make 5 g of Rohm and Hass Pectinol R-10 up to 50 ml and filter.

#### *Alcohol solutions*

Using 95% alcohol, make a 1% solution by volume by weighing 8.5 g or measuring 10.5 ml and diluting with distilled water to 1 liter (Association of Official Analytical Chemists, 1970). Other concentrations may be arrived at by multiplying these figures by the desired percentage.

*Example:* Strength desired, 60%. Multiply  $8.526 \text{ g} \times 60 = 511.56 \text{ g}$  and dilute to 1 liter with distilled water; or, multiply  $10.53 \text{ ml} \times 60 = 631.8 \text{ ml}$  and dilute to 1 liter with distilled water.

The desired alcohol percentage also can be made by taking the number of ml of 95% alcohol equal to the desired strength and diluting to 95 ml.

*Example:* To prepare a solution of 80% alcohol, use 80 ml of 95% alcohol and dilute to 95 ml.

#### *Carbazole solution*

Dissolve 0.150 g of carbazole in 100 ml of purified alcohol.

## PREPARATION OF SLURRIES

### APPLES

Dice 200 g of apple flesh and homogenize in a blender at high speed for 1 to 1½ minutes until chunks of apple are no longer visible. Push the apple pieces from the sides to the bottom of the blender with a rubber spatula. The exact time needed to achieve a homogeneous blend varies with variety.

### CARROTS

Prepare the slurry with a weighed sample of carrot (approximately 20 g) and twice as much water. Blend at high speed in a Waring blender. The ratio of carrot weight to slurry weight should be 1:3.

### MELONS

Blend 150 g of mixed diced melon in a blender for 1½ minutes until a fine puree is formed. If necessary, freeze the slurry immediately in a precooled petri dish in dry ice to use for testing later.

## ALCOHOL-INSOLUBLE SOLIDS

### APPLES

Weighed filter paper is needed for this analysis.

1. Dry and weigh Whatman No. 1 filter paper, 12½ cm diameter.
2. Prepare a funnel ahead of time by placing a weighed disc in a Buchner funnel, 10½ cm diameter. The filter paper should fit snugly with about ¼ inch rise around the sides of the funnel.

Tissue for determination of alcohol-insoluble solids (AIS) may be obtained either from the slurry or from the tissue extruded from the Texturepress or Instron.

1. Empty the latter material into the catch pan of the press and mix 10 times with a spatula.
2. Weigh two aliquots of 6.25 g and add each to 16 ml 95% alcohol in a 50-ml beaker.
3. Cover with parafilm and refrigerate until needed.
4. Heat the beaker of 95% alcohol plus apple tissue to boiling.
5. Blend in a Semi-Micro Blender for two minutes.
6. Transfer this blendate by washing with 80% ethyl alcohol into a 100-ml centrifuge tube and centrifuge for five minutes at 2500 rpm.
7. Decant the supernatant from the centrifuge tube through the previously weighed filter paper.
8. Wash through the filter paper into the centrifuge tubes containing the residue, using 15 ml 80% ethyl alcohol.
9. Stir the contents while heating in a water bath at 85° C until boiling (approximately 10 minutes).

10. Centrifuge.
11. Decant the supernatant through the same filter paper and add to the first collection.
12. Add 12 to 13 ml 80% ethyl alcohol to the residue by washing the filter paper into the centrifuge tube.
13. Stir the contents again and heat in a water bath to 80° C.
14. Transfer the contents of the centrifuge tube to the filter paper by washing with 95% alcohol.
15. Air-dry the paper plus residue at 75° C in an oven overnight.
16. Transfer to the vacuum oven and dry at 60° C under 26 to 28 inches of vacuum for five hours. Cool in a desiccator and weigh.

## CARROTS

1. Add 20 g of carrot slices to 95 ml of boiling 95% ethyl alcohol in a blender, and blend at high speed for 30 seconds.
2. Transfer the slurry to centrifuge tubes, using 80% ethanol to wash the blender container.
3. Hold in a water bath at 80° C for 15 minutes.
4. Centrifuge at high speed (4500 rpm) for 10 minutes.
5. Decant the sugar-containing supernatant into a beaker.
6. Resuspend the residue in 40 ml of 80% ethanol.
7. Centrifuge 10 minutes.
8. Decant the supernatant and add to that formerly collected.
9. Again suspend the residue in 40 ml of 80% ethanol.
10. Centrifuge 10 minutes.
11. Decant the supernatant and add to that formerly collected.
12. Transfer the alcohol-insoluble solids to a tared watch glass, using 95% alcohol to wash the tubes.
13. Dry the solids for 16 hours at 50° C under 26 to 28 inches of vacuum.
14. Cool in a desiccator and weigh.

## MELONS

1. Weigh 30 g of mixed melon dice and add to 140 ml boiling 95% ethanol in a blender.
2. Blend at high speed for 30 seconds.
3. Transfer the slurry to centrifuge tubes, using 80% alcohol to wash the blender container.
4. Hold the tubes at 80° C in a water bath for 15 minutes.
5. Centrifuge for 10 minutes at high speed (4500 rpm).
6. Decant the supernatant and save for other analyses.
7. Add 60 ml of 80% room-temperature ethanol to the residue.
8. Stir to disperse the residue.
9. Centrifuge again for 10 minutes.

10. Decant the supernatant and add this to the other collection.
11. Again add 60 ml of 80% ethanol to the residue.
12. Stir, centrifuge, and decant the supernatant. Add this to the other collection.
13. Transfer the alcohol-insoluble solids to a tared watch glass.
14. Dry for 16 hours at 50° C under 26 to 28 inches of vacuum.
15. Cool in a desiccator, then weigh.

## pH VALUES

### APPLES, CARROTS, MELONS

Determine pH values directly on the slurried sample, page 23.

## SOLUBLE SOLIDS

### APPLES

Instruments which can be used include a Bausch and Lomb Juice Refractometer 0-25%, hand model, and a Bausch and Lomb Abbe-3L Refractometer. Take duplicate readings at room temperature, 23 to 24° C, on small portions of the freshly prepared apple slurry. Transfer a drop of the slurry to the refractometer, taking care not to touch the prism. Try to avoid including any pulp. For the hand model, a microscope spotlight may be used as a light source.

## MOISTURE

### APPLES

#### *Flesh*

1. Weigh approximately 5 g apple slurry into each of two predried, preweighed moisture pans.
2. Add 3 to 4 g of reagent-grade sea sand if desired. The sand aids in washing the pans.
3. Dry overnight in an air convection oven at 50° C.
4. Continue drying at 70° C under 26 to 28 inches of vacuum until consecutive weighing made at intervals of two hours do not vary by more than 3 mg.
5. Cool the pans in a desiccator for 40 minutes before each weighing. The samples are usually dry after six to eight hours. Percent moisture is computed as follows:

$$\% \text{ moisture} = \frac{(a - b) \times 100}{a - c}$$

a = weight of sample + pan + sand before drying

b = weight of pan + sample + sand after drying

c = weight of tared pan + sand

## Skin

1. Scrape the apple skin with a stainless steel spatula to remove adhering flesh.
2. Weigh approximately 5 g of chopped or sliced skin into each of two dried and weighed moisture pans.
3. Dry overnight at 50° C in a convection oven and then transfer to a vacuum oven.
4. Continue drying under 26 to 28 inches of vacuum at a temperature of 70° C for six to eight hours.
5. Cool the pans in a desiccator and weigh.

## CARROTS

1. Weigh two 20-g samples of carrot-plus-water slurry into dried and weighed aluminum cups.
2. Dry for 24 hours at 50° C under 26 to 28 inches of vacuum.
3. Cool in a desiccator, then weigh. Percent moisture is computed as follows:

$$\% \text{ moisture} = \frac{(I - F) \times 100}{F}$$

I = initial weight of carrot in slurry

F = final dry weight

## MELONS

1. Weigh two 20-g samples of melon slurry into dried and weighed aluminum cups.
2. Dry for 24 hours at 50° C under 26 to 28 inches of vacuum.
3. Cool in a desiccator, then weigh. Percent moisture is computed as follows:

$$\% \text{ moisture} = \frac{(I - F) \times 100}{F}$$

I = initial weight

F = final dry weight

## PECTIC SUBSTANCES

Most technicians use fractional extraction processes to determine changes in pectic substances; for example, during maturation of the plant. This is not completely definitive, since pectic substances overlap somewhat in their solubility characteristics. However, useful information can be obtained by extracting different fractions. In the following paragraphs, extractions of total pectin and protopectin are described for

apples, while stepwise procedures for successively extracting pectic substances of differing solubility are described for carrots and melons.

## APPLES

Alcohol-insoluble solids may be used without drying for the determination of pectic substances. Transfer the alcohol-insoluble solids while still moist after the last filtering step to a 400-ml beaker.

### *Extraction of pectic substances*

The calcium-sequestering agent (Versene) and pectinase are used to extract *total pectic substances* from apple.

1. Add 300 ml of 0.5% Versene solution, page 22. Use part of the 300 ml to rinse the funnel.
2. Adjust the pH to 11.5 with 1 N NaOH.
3. Allow to stand for 30 minutes to de-esterify the pectins and pectinates.
4. Acidify to pH 5.0 with 1 N acetic acid.
5. Add 4 ml of 10% freshly prepared pectic enzyme solution, page 22, and 10 drops of toluene to the mixture. Stir.
6. Allow the mixture to stand overnight at room temperature. Filter.
7. Make the pectin solution up to 500 ml with distilled water.
8. Make 4 ml of this solution to 50 ml with distilled water.
9. Use 2-ml aliquots for pectin determination, using the colorimetric carbazole method, page 30.

The *protopectin* fraction consists of the pectic substances which are insoluble in water at room temperature.

1. Prepare a Whatman No. 2 filter paper in a Buchner funnel by pouring over it a mixture of 1 g Celite blended with water. Remove the water with suction.
2. Mix the alcohol-insoluble solids from 25 g of peeled, cored apple with 300 ml of distilled water.
3. Add 10 drops of toluene and allow the mixture to stand 17 hours.
4. Filter the mixture through the prepared filter paper.
5. Extract the residue again with 600 ml distilled water and filter. Discard the filtrate.
6. Transfer the residue to a 400-ml beaker.
7. Add 300 ml of 0.5% Versene solution.
8. Adjust the solution to pH 11.5 with 1 N sodium hydroxide solution.
9. Allow to stand at room temperature for two hours.
10. Acidify the solution to pH 5.0 with 1 N acetic acid.
11. Add 2 ml of freshly prepared 10% Pectinol solution.
12. Add 10 drops of toluene.
13. Allow the solution to stand for eight hours at room temperature.

14. Filter through a Whatman No. 2 filter paper using suction. Save the filtrate in this and the succeeding steps.
15. Extract the residue with 300 ml of distilled water.
16. Filter.
17. Combine these filtrates and dilute to 1000 ml with distilled water.
18. Use 2-ml aliquots of the combined filtrates for the colorimetric carbazole reaction, page 30.

## CARROTS

*Water-soluble pectic substances* having 8 to 11% methoxyl content are extracted in the first step.

1. Grind the dried alcohol-insoluble solids, using a mortar and pestle and sand.
2. Add 40 ml of distilled water and, to aid precipitation, about  $\frac{1}{8}$  teaspoon Hyflo-Supercel to the finely ground AIS in a centrifuge tube.
3. Stir until the mixture is evenly dispersed.
4. Allow the mixture to stand 10 minutes and stir again.
5. Centrifuge 10 minutes at high speed (4500 rpm).
6. Decant the supernatant into a 100-ml volumetric flask.
7. Repeat the water extraction, using 40 ml distilled water.
8. Centrifuge and decant the supernatant into the same volumetric flask. Save the residue.
9. Add 5 ml of 1 N sodium hydroxide solution to the water extract.
10. Add water to bring the solution up to 100 ml volume.
11. Use 2 ml of this solution for the colorimetric determination of pectic substances, page 30.

In the second step, *low methoxy pectinates* of calcium and magnesium are extracted with sodium hexametaphosphate. This reagent complexes with divalent cations.

1. Add 40 ml of 0.4% sodium hexametaphosphate solution to the residue in the centrifuge tube (step 8 in preceding extraction).
2. Stir the solution and allow it to stand 10 minutes at room temperature.
3. Centrifuge 10 minutes at high speed (4500 rpm).
4. Decant the supernatant into a 100-ml volumetric flask.
5. Repeat the addition of sodium hexametaphosphate. Stir and let stand 10 minutes, centrifuge, and decant the supernatant into the same volumetric flask. Save the residue.
6. Add 5 ml of 1 N NaOH solution to the flask, and distilled water to bring the volume up to 100 ml.
7. Use 2-ml aliquots for the colorimetric determination of pectic substances.

*Protopectin* and any remaining calcium and magnesium pectates are extracted in the third step. Some of the latter compounds are very insoluble and are not removed in step 2.

1. Add to the residue remaining in the centrifuge tube (step 5 in the preceding extraction), 40 ml of 0.05 N sodium hydroxide solution.

2. Allow to stand with occasional stirring for 15 minutes at room temperature.

3. Centrifuge for 10 minutes at high speed (4500 rpm).

4. Decant the supernatant into a 100-ml volumetric flask.

5. Make up to 100 ml with distilled water.

6. Allow to stand 15 minutes before continuing with the colorimetric determinations, page 30.

7. Use 2-ml aliquots for the colorimetric determination of pectic substances.

## MELONS

*Water-soluble pectic substances* are extracted as follows:

1. Grind the dried alcohol-insoluble solids, using a mortar and pestle and sand.

2. Transfer to a centrifuge tube.

3. Add 40 ml of distilled water and about  $\frac{1}{8}$  teaspoon Hyflo Supercel to aid precipitation.

4. Stir, and allow to stand 10 minutes.

5. Centrifuge 10 minutes at high speed (4500 rpm).

6. Decant the supernatant liquid into a 100-ml volumetric flask.

7. Repeat the water extraction, as described above.

8. Decant the supernatant liquid into the same volumetric flask.

9. Add 5 ml of 1 N Na OH solution to the flask, and dilute to volume.

10. Mix, and let stand at least 15 minutes before beginning the colorimetric procedure.

11. Use 1-ml aliquots, or a suitable dilution, for the colorimetric determination of pectic substances.

To extract *low methoxy pectinates*, use the following procedure:

1. To the residue in the centrifuge tube, add 40 ml of 0.4% sodium hexametaphosphate solution.

2. Stir, and let stand 10 minutes.

3. Centrifuge 10 minutes at high speed.

4. Decant the supernatant liquid into a 100-ml volumetric flask.

5. Repeat the extraction with the sodium hexametaphosphate solution.

6. Decant the supernatant liquid into the same volumetric flask.

7. Add 5 ml of 1 N sodium hydroxide solution, and dilute to volume with distilled water.

8. Let stand at least 15 minutes before beginning colorimetric procedure.

9. Use 1-ml aliquots, or a suitable dilution, for the colorimetric determination of pectic substances, page 30.

*Protopectin* is extracted as follows:

1. Add to the residue remaining in the centrifuge tube 40 ml of 0.05 N sodium hydroxide solution.

2. Allow to stand 15 minutes at room temperature, with occasional stirring.

3. Centrifuge 10 minutes at high speed.

4. Decant the supernatant liquid into a 100-ml volumetric flask.

5. Dilute to volume with distilled water, and mix.

6. Allow to stand at least 15 minutes.

7. Use 1-ml aliquots, or a suitable dilution, for the colorimetric determination of pectic substances, page 30.

#### *Colorimetric determination of pectic substances*

A standard curve is used to obtain the concentration of anhydrogalacturonic acid in the samples. Prepare the curve as described below, using anhydrogalacturonic acid over a range of 10 to 120 micrograms.

1. Use three test tubes for each sample. Prepare one to be used for the blank, with pectin extract, purified ethyl alcohol, and concentrated sulfuric acid in the same proportions as used for the color reaction. In place of the carbazole solution, add purified alcohol. Use the blank to adjust the slit of the spectrophotometer.

2. Using a repipette,<sup>11</sup> measure 12 ml of concentrated sulfuric acid into each of three 24 x 200 mm pyrex test tubes (one is to be used for the blank).

3. Place them in an ice water bath until the temperature drops to 3° C.

4. Add a 2-ml aliquot of the pectin solution to each tube.

5. Cover the tubes by inserting a 5-ml beaker into the mouth.

6. Mix the contents thoroughly.

7. Return the tubes to the ice bath and cool to below 5° C.

8. Heat for 10 minutes by plunging the tubes into a boiling water bath.

9. Return tubes immediately to the ice bath and cool to 20° C.

10. Add 1 ml of 0.15% carbazole solution to each of two duplicate tubes and 1 ml purified alcohol to the tube which is to be used as the blank.

11. Shake the contents thoroughly.

12. After  $24 \pm 5$  minutes at room temperature, determine the percent transmittance in an electrophotometer using light of wave length 525 mu.

<sup>11</sup> Repipetter, or automatic pipette. Labindustries, Berkeley, California.

13. Analyze the samples in sequence to keep time and temperature after the addition of carbazole as reproducible as possible.

14. Express the results as percentage of anhydrogalacturonic acid on the fresh basis.

## LIGNIN

### CARROTS

1. Remove a section from the center of the carrot, cutting across the diameter.

2. Grate 11 g and dry in a convection oven at 45° C for 24 hours.

3. Weigh.

4. Place 1 g of the dried material in an extraction thimble and extract with ethanol-benzene (1 part alcohol and 2 parts benzene) for four hours in a Soxhlet extractor.

5. Remove the carrot from the extraction thimble and place in a fritted crucible.

6. Wash with two small portions of ethanol and then with two small portions of ether.

7. Dry at 45° C for 24 hours.

8. Place the dried, extracted material in a 250-ml Erlenmeyer flask containing 40 ml of a freshly prepared 1% pepsin solution in 0.1 N HCl.

9. Allow the mixture to incubate overnight at 40° C.

10. Filter the contents of the flask through a 15-ml fritted glass crucible, using hot distilled water to transfer the contents. Use suction at this point.

11. Wash the carrot residue with 20 to 30 ml hot water, then with 7 to 8 ml of 5% (Wt/Wt) sulfuric acid.

12. Reflux the residue with 150 ml 5% (Wt/Wt) sulfuric acid for one hour and then filter through the fritted glass crucible.

13. Wash the residue with three 20 to 30 ml portions of hot water, twice with 15 to 20 ml portions of ethanol, and twice with 15-ml portions of ether. Leave suction on for a few minutes to dry the residue. Dry overnight at 45° C.

14. Treat the dried sample with 20 ml of 72% (Wt/Wt) sulfuric acid for two hours at 20° C with occasional stirring.

15. Add 125 ml water.

16. Filter the carrot residue through the fritted glass crucible and wash with 20 ml hot water.

17. Reflux for two hours, using 150 ml 3% (Wt/Wt) sulfuric acid.

18. Filter the residue through a dried and weighed Gooch crucible containing an asbestos pad.

19. Wash with hot water and dry at 105° C.

20. Cool in a desiccator, then weigh.

21. Ignite at 600° C and cool in a desiccator.

22. Weigh again.

23. The loss in weight represents the lignin in the 1-g sample of dried carrot. Formula:

Percent lignin in total weight of dried carrot =  $W \times L$

L = Weight of lignin in 1 g dry carrot

W = Total weight of dried carrot sample

## Sensory Tests

### APPLES

The panel for sensory evaluation of apples should consist of at least eight persons, trained and experienced in judging apples. The tasters are seated in individual booths. The booths should be well lighted by 60-watt red bulbs or two 20-watt 23-inch cool, white fluorescent lamps.<sup>12</sup> For each panel member, provide a white rectangular tray with a glass of distilled water, a napkin, a pencil, and the score cards. As many as six samples may be judged at each session.

#### *Procedure*

1. Using a stainless steel corer and knife, peel and core each apple.
2. Cut into eight wedges, using an apple-wedge cutter.
3. Fold the skins from the wedges and place on a tray or plate.
4. Cover both flesh and skin samples with Saran wrap until distributed.
5. Assign both flesh and skin samples to judges' trays, according to a prearranged system of random numbers.
6. Instruct the judges to evaluate each sample without comparison with other samples.

Texture evaluation of apples involves separate testing of flesh and skin. In the evaluation of the flesh, consider the following characteristics: crispness, juiciness, and tenderness. Score these characteristics on a five-point scale, with 5 as high and 1 as low. Evaluation of the skin samples involves judgments of tenderness (score card, page 34).

### CARROTS

Carrot samples should be judged by a trained panel, usually consisting of five members. The judges are seated in individual booths or at separate tables facing a wall. Each space should be well lighted with cool, white fluorescent lamps. Each space should be set up ahead of time with a napkin, a glass of water, a pencil, and the score cards. During the training sessions, judges should be provided with slices of carrots

<sup>12</sup> Available from Westinghouse.

which have been treated in different ways to influence the texture: left at room temperature, soaked in ice water, or frozen overnight and then thawed. All carrots should be at room temperature when served. Each carrot should be judged individually. Three or four carrots may be judged at each session.

### *Procedure*

1. Scrape each carrot to be sliced immediately prior to being judged.
2. Slice each carrot to a uniform thickness and mix the slices. A slicing machine is a valuable aid.
3. Reserve a portion of the sliced carrot, sufficient for the chemical or physical tests planned.
4. Wrap reserved portion closely in Saran wrap and refrigerate at 40° F until needed.
5. Use the remaining slices for sensory testing.
6. Instruct the judges to score the carrot slices for flexibility, hardness of cortex, hardness of core, crispness, and fibrousness. These characteristics are scored on a five-point scale, with 5 as high and 1 as low (score card, page 35).

Flexibility and compressibility also may be judged on the whole carrot, using a panel of five to eight trained judges. Evaluate the carrots manually for compressibility and flexibility, using a nine-point rating scale (score card, page 36).

1. Determine compressibility by pressing the middle portion of the carrot.
2. Determine flexibility by gently bending the carrot with both hands.

## MELONS

Judging of melon samples should be carried out by a trained panel usually consisting of five persons. The judges should be trained in two or more sessions to familiarize them with the goals, criteria, and terminology of the score card.

Each melon should be judged individually, with not more than four at each judging session. Each judge should be seated in an individual booth or at a separate table facing a wall. Each space should be well lighted with cool, white fluorescent lamps. Each space should be set up ahead of time with a napkin, a glass of water, a pencil, and the score cards. The sampling procedure for melons is illustrated under "Sampling," page 6. Use four pieces, each being one-eighth of the melon.

### *Procedure*

1. Peel and dice.
2. Mix diced pieces.

3. Distribute portions of the mix to the judges.

4. Instruct the judges to score the melon dice for tenderness, firmness, crispness, juiciness, and fibrousness. These characteristics are scored on a five-point scale, with 5 as high and 1 as low (score card, page 37).

### SCORE CARD FOR TEXTURE OF APPLES

JUDGE \_\_\_\_\_

DATE \_\_\_\_\_

SAMPLE NUMBER \_\_\_\_\_

#### TEXTURE

##### *Tenderness* (Flesh)

Resistance to biting through

\_\_\_\_\_ Very tender

\_\_\_\_\_ Tender

\_\_\_\_\_ Slightly tender

\_\_\_\_\_ Slightly hard

\_\_\_\_\_ Hard

##### *Juiciness* (Flesh)

\_\_\_\_\_ Very juicy

\_\_\_\_\_ Juicy

\_\_\_\_\_ Slightly juicy

\_\_\_\_\_ Slightly dry

\_\_\_\_\_ Dry

##### *Crispness* (Flesh)

\_\_\_\_\_ Very crisp

\_\_\_\_\_ Crisp

\_\_\_\_\_ Slightly crisp

\_\_\_\_\_ Slightly mealy or soft

\_\_\_\_\_ Mealy or soft

##### *Tenderness* (Skin)

\_\_\_\_\_ Tender

\_\_\_\_\_ Slightly tender

\_\_\_\_\_ Slightly tough

\_\_\_\_\_ Tough

\_\_\_\_\_ Very tough

Comments:

## SCORE CARD FOR TEXTURE OF CARROT SLICES

JUDGE \_\_\_\_\_

DATE \_\_\_\_\_

CARROT NUMBER \_\_\_\_\_

Score *Flexibility* (bend with the fingers)

- (5) ..... very flexible
- (4) ..... quite flexible
- (3) ..... fairly flexible
- (2) ..... somewhat firm
- (1) ..... firm and inflexible

*Hardness* (press with fingernail and bite)

- (5) ..... very hard
- (4) ..... quite hard
- (3) ..... somewhat hard
- (2) ..... fairly soft
- (1) ..... very soft

*Hardness of core* (press with fingernail and bite)

- (5) ..... very hard
- (4) ..... quite hard
- (3) ..... somewhat hard
- (2) ..... fairly soft
- (1) ..... very soft

*Crispness* (how easily teeth bite into the carrot)

- (5) ..... very crisp
- (4) ..... quite crisp
- (3) ..... fairly crisp
- (2) ..... somewhat rubbery
- (1) ..... rubbery

*Fibrousness* (residue or feel of fibers on tongue)

- (5) ..... very fibrous
- (4) ..... quite fibrous
- (3) ..... fairly fibrous
- (2) ..... somewhat fibrous
- (1) ..... slightly fibrous

Comments:

## SCORE CARD FOR TEXTURE OF WHOLE CARROTS

JUDGE \_\_\_\_\_ DATE \_\_\_\_\_

TIME \_\_\_\_\_

A. *Hardness* of whole carrot (press with fingers)

Carrot no.	_____	_____	_____	_____	_____	_____
Very hard	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
Medium	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
Very soft	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____

B. *Flexibility* of whole carrot (bend with fingers)

Carrot no.	_____	_____	_____	_____	_____	_____
Firm and inflexible	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
Medium	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
Very flexible	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____	_____

Comments:

SCORE CARD FOR TEXTURE OF MELONS

JUDGE \_\_\_\_\_ MELON \_\_\_\_\_

DATE \_\_\_\_\_ NUMBER \_\_\_\_\_

*Tenderness* (resistance to cutting and biting through)

- \_\_\_\_\_ very tender
- \_\_\_\_\_ quite tender
- \_\_\_\_\_ fairly tender
- \_\_\_\_\_ somewhat tough
- \_\_\_\_\_ very tough

*Crispness* (yield to first entrance of spoon and teeth)

- \_\_\_\_\_ very crisp
- \_\_\_\_\_ quite crisp
- \_\_\_\_\_ fairly crisp
- \_\_\_\_\_ somewhat leathery
- \_\_\_\_\_ leathery

*Firmness* (press chunk with tongue against roof of mouth)

- \_\_\_\_\_ very easy to crush
- \_\_\_\_\_ quite easy to crush
- \_\_\_\_\_ fairly easy to crush
- \_\_\_\_\_ somewhat resistant to crushing
- \_\_\_\_\_ resistant to crushing

*Fibrousness* (after chewing)

- \_\_\_\_\_ quite "melty"
- \_\_\_\_\_ fairly "melty"
- \_\_\_\_\_ slightly fibrous
- \_\_\_\_\_ somewhat more fibrous
- \_\_\_\_\_ fibrous residue

*Sweetness*

- \_\_\_\_\_ pleasingly sweet
- \_\_\_\_\_ slightly undersweet
- \_\_\_\_\_ moderately undersweet
- \_\_\_\_\_ undersweet
- \_\_\_\_\_ very undersweet

Comments:

## REFERENCES CITED

- Association of Official Analytical Chemists. 1970. *Official Methods of Analysis*. Assn. of Official Analytical Chemists, Washington, D.C.
- Dinus, Linda Ann. 1967. Chemical attributes of muskmelons related to texture. M. S. thesis, Oregon State University, Corvallis.
- Gizis, E. J. 1963. The isolation and characterization of the pectic substances of the Northwest strawberry. Ph.D. thesis, Oregon State University, Corvallis.
- Hard, M. M. Unpublished data.
- Hard, Margaret M., Ferne Bowman, Marilyn Dunsing, and Andrea C. Mackey. 1963. Use of fruits and vegetables by western families. Preferences and practices. Wash. Agric. Expt. Sta. Bull. No. 646.
- Howard, P. L., and D. E. Heinz. 1970. Texture of carrots. *J. Texture Studies*, 1:185-195.
- Hulme, A. C. 1970. *The Biochemistry of Fruits and Their Products*, Vol. 1. Academic Press, N. Y.
- Joslyn, Maynard A. 1970. *Methods in Food Analysis*. Academic Press, N.Y.
- Kirkpatrick, Mary E., Andrea O. Mackey, Ruby R. Little, Ruth H. Matthews, and Claire E. Falatko. 1959. Quality of apples for household use. Home Economics Research Report No. 8, U.S. Govt. Printing Office, Washington, D.C.
- Luh, B.S., and K. D. Dastur. 1966. Texture and pectin changes in apricots. *J. Food Sci.*, 31:178-183.
- McCready, R. M., and E. A. McComb. 1952. Extraction and determination of total pectic materials in fruit. *Anal. Chem.*, 24:1968-1988.
- Magness, J. R., and G. F. Taylor. 1925. An improved type of pressure tester for the determination of fruit maturity. USDA Circ. No. 350.
- Postlmayr, H. L., B. S. Luh, and S. J. Leonard. 1956. Characterization of pectin changes in freestone and clingstone peaches during ripening and processing. *Food Technol.*, 10:618-625.
- Rouse, A. H., and C. D. Atkins. 1955. Pectin esterase and pectin in commercial citrus juices. Univ. Florida Agric. Expt. Sta. Bull. 570.
- Szczesniak, Alina Surmacka. 1963. Classification of textural characteristics. *J. Food Sci.*, 28:385-389.

## **Administrative and Research Personnel**

### **CALIFORNIA AGRICULTURAL EXPERIMENT STATION**

B. E. Day, Director, Davis, California  
Elizabeth M. Elbert, WM-55 Committeeman, Davis, California  
Duane D. Heinz, WM-55 Committeeman, Davis, California  
Howard C. Schutz, WM-55 Committeeman, Davis, California

### **COLORADO AGRICULTURAL EXPERIMENT STATION**

D. F. Hervey, Director, Fort Collins, Colorado  
Ferne Bowman, WM-55 Committeeman, Fort Collins, Colorado  
Samuel Angel, WM-55 Committeeman, Fort Collins, Colorado  
Joseph A. Maga, WM-55 Committeeman, Fort Collins, Colorado

### **IDAHO AGRICULTURAL EXPERIMENT STATION**

J. E. Kraus, Director, Moscow, Idaho  
Mary V. Zaehring, WM-55 Committeeman, Moscow, Idaho  
Rosalita de la Mar, WM-55 Committeeman, Moscow, Idaho

### **NEVADA AGRICULTURAL EXPERIMENT STATION**

D. W. Bohmont, Director, Reno, Nevada  
Antoinette Betschart, WM-55 Committeeman, Reno, Nevada  
Ann Chapman Cattelain, WM-55 Committeeman, Reno, Nevada

### **OREGON AGRICULTURAL EXPERIMENT STATION**

G. B. Wood, Director, Corvallis, Oregon  
R. M. Alexander, Administrative Advisor, Corvallis, Oregon  
Andrea C. Mackey, WM-55 Committeeman, Corvallis, Oregon

### **WASHINGTON AGRICULTURAL EXPERIMENT STATION**

J. M. Nielson, Director, Pullman, Washington  
D. Oldenstadt, WM-55 Administrative Advisor, Pullman, Washington  
Margaret M. Hard, WM-55 Committeeman, Pullman, Washington

### **UNITED STATES DEPARTMENT OF AGRICULTURE**

Gladys W. Royal, Cooperative State Research Service, Washington,  
D. C.