AN ABSTRACT OF THE THESIS OF

Akkinapally Venketeshwer Rao for the M.S. in Food Technology
(Name) (Degree) (Major)

Date thesis is presented March 6, 1963

Title EFFECT OF PROCESSING AND STORAGE ON THE TEXTURE OF CANNED BERRIES

Abstract approved [signature]
(Major Professor)

The texture of processed berry fruits changes both during processing and subsequent storage. A study was made of these changes in processed strawberries, raspberries, blackberries, and blueberries, spin-cooked and stored at 100° F. for 28 days in tin and glass containers. Four samples, from each of the two replications of the above four berries, were analyzed immediately after processing and after 3, 7, 14, and 28 days of storage at 100° F. Physical measurement of texture was obtained by the use of Maryland Shear-press. The work diagrams thus obtained were studied in detail. These samples, after being subjected to the Shear-press, were analyzed for percent A.I.S. and total pectin.

The results indicated the following:

1. There was no significant difference in the texture, percent A.I.S. and total pectin, between berries processed and stored in tin and

glass containers over a period of 28 days at 100° F.

2. Highest correlation was obtained between texture as measured by partial work and total pectin in case of strawberries and blueberries and between maximum force and percent A.I.S. in raspberries and blackberries.

3. Maryland Shear-press gave characteristic work diagrams for each of the four berries, which were consistent throughout.

4. A linear relationship was obtained between sample size and texture as measured by the total work.

EFFECT OF PROCESSING AND STORAGE ON THE TEXTURE OF CANNED BERRIES

by

AKKINAPALLY VENKETESHWER RAO

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1963

APPROVED:

Assistant Professor of Food Science and Technology

In Charge of Major

Head of Department of Food Science and Technology

Dean of Graduate School

Date thesis is presented March 6, 1963

Typed by Nancy Kerley

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. James H. Dietz for his helpful suggestions and valuable guidance throughout the entire work and in the preparation of this thesis.

Appreciation is also expressed to Dr. Clifford E. Samuels for his constructive criticism in preparing this thesis and Dr. Reginald A. Gallop for his helpful suggestions in planning this work.

Acknowledgment is also due to Dr. Edwin J. Hughes for his suggestions regarding the statistical analyses.

Lastly, but not the least, the author wishes to express his greatfulness to his family who made it possible for him to come to the United States of America for graduate work.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

EFFECT OF PROCESSING AND STORAGE ON THE TEXTURE OF CANNED BERRIES

INTRODUCTION

The fruit processing industry, which includes various operations from the time of harvest to the time of consumption, occupies an important position in the food industry. A significant amount of the fruit being processed goes into canning. Thus every year a variety of fruits like peaches, pears and small fruits, including berries, are canned. During the year 1961 in the United States, the total production of peaches was 77,895,000 bushels, of which 43.18 percent went into canning. Similarly 58.83 percent of the total production of pears were canned.

To evaluate the quality of the canned fruit many factors are considered. One of the major factors is texture. In the United States Department of Agriculture standard for grades of canned berries, out of a possible 100 points, 30 points are assigned for the texture, indicating its importance (65, p. 7; 66, p. 6; 67, p. 6). Unfortunately, an absolute definition of texture of a fruit is very difficult to give. However, texture of a fruit is closely related to its structural make-up. It includes such qualities as tenderness, toughness, stringiness, crispness, firmness and slicing quality.

Variation in the texture may have a great influence on the acceptability of the product. Thus, it is important to have a desired texture in the berries after processing. A suitable or desired texture in a fruit is determined by the consumer himself, and depends to a great extent on a subjective interpretation resulting from complex psychological and physiological reactions. These reactions vary from individual to individual. Thus it is important to have a quantitative, objective determination of the texture in controlling the quality of the canned berries. For this purpose various instruments have been used, for example, the tenderometer, for measuring the tenderness of peas (43, p. 110), puncturometer, for measuring the firmness of pears (33, p. 160) and so on. But these instruments were limited in their use, that is they were designed to measure a specific quality in a specific food. Thus, a need was felt for an instrument which could have "multi-purpose" use; one which would consist of a basic unit applicable to all measurements of pressure, cutting, shearing and penetrating for a variety of foods. As a result, considerable work was done at the University of Maryland and in 1950 an instrument called the Shear-Press was introduced (32, p. 34-40). Since then it has been used on various products ranging from marshmallows to meat and has undergone many modifications.

Realizing the importance of texture in the quality evaluation of canned berries, this study was undertaken for the following purposes:

1. To determine the effect of spin processing and storage on the texture of canned berries in tin and glass containers.

2. To determine the possibility of using Maryland Shear-Press as an instrument to determine the texture of processed berries.

3. To determine the effect of sample size on the texture measurements of the different berries.

4. To study in detail various parts of the force diagrams and evaluate the best way of measuring texture of berries.

LITERATURE REVIEW

The preservation of foods in hermetically sealed containers through the agency of sterilization by heat is called canning (24, p. 1858). The majority of the canning is in "tin cans", which are made of tin-coated steel, or in glass containers. It is a well-known fact that all the succulent foods normally carry various types of organisms some of which cause spoilage, if not properly checked. Thus, the fundamental principle upon which the use of hermetically sealed containers is based is the destruction of such undesirable, spoilage causing micro-organisms and further preventing the re-entry of micro-organisms.

The canning industry dates back to 1810 when a French confectioner and baker, Nicolas Appert (2, p. 7-8), first demonstrated that by the use of heat, foods can be preserved in hermetically sealed containers. Since then a tremendous improvement in canning technology has been achieved. As a result canned food of extremely high quality is available, and has become an integral part of the industrialized community of today.

Effect of Processing on Texture

Texture of a fruit, whether raw or processed, is intimately associated with its structural makeup. The bulk of the edible portion of most of the fruits is parenchyma tissue. Crafts (8, p. 443) described these cells as relatively unspecialized and ranging in shape from spherical to elongated. They have prominent intercellular spaces which occupy an appreciable portion of the total space. In case of berries, which are fleshy fruits in which some or all of the ovary wall becomes enlarged to form the fruit, usually the whole fruit is consumed. Two important classifications of berries are (20, p. 73-81): (1) Brambles - the fruit which is commonly referred to as "berries." Botanically speaking these are aggregates of druplets which are firmly or loosely attached to the receptacle. This group includes berries like raspberry and blackberry. (2) Berries other than Brambles. This group includes such commercially important berries as the blueberry, the fruit of which is a many seeded berry, and strawberry, which is a receptacle (which is a stem structure), with the real fruits called the achenes imbedded on the surface of this succulent receptacle.

Apart from the parenchyma cells, which are often separated by air spaces and held together by cementing substances which are mostly composed of pectic compounds, other types of plant cells like conducting cells and the protective cells are also important in the texture of fruits. Thus, a number of factors affect the texture of fruits and these differ from fresh material to cooked or processed material, owing to the differences in the osmotic and turgor pressure of the cells. Isherwood (23, p. 136-143) described these factors as morphological and chemical. He further divides chemical composition into cell wall constituents and non-cell wall constituents. However, as the various constituents of the cell are in dynamic equilibrium with each other, the changes in texture are not a result of one factor but due to the interrelation of many.

Comparatively more work has been done on the cell wall constituents as it is the cell wall which gives the rigidity to the fruit. In the edible portion of fruit the cell wall consists mainly of polysaccharides like cellulose, xylans, araban, galactan, polygalactronic acid (pectic acid) and mannan, and it is the changes in amounts and properties of these polysaccharides of the cell wall that are related to the textural changes of fruits during ripening, maturation and processing (23, p. 137).

Apart from the changes in the cell wall constituents, another important histological change induced by processing is the change in cellular adhesion which determines the final texture of a product.

Some cells have a single-layer cell wall, whereas in others upon cell division three different layers are formed. Meyer (45, p. 261) described them as primary wall, secondary wall and middle lamella which is shared with adjacent cells. This middle lamella consists mainly of insoluble pectin substances, probably as calcium pectates (45, p. 262), which act as the cementing material in holding adjacent cells together. In addition to the middle lamella, pectic substances are also found in the primary walls of many cells and in the cell sap (48, p. 604). However, Revee (52, p. 20) has shown that the nature of the pectic substances in the middle lamella changes not only between different varieties of peas but also during different stages of maturity of the same variety.

The changes that take place in the texture of fruits and vegetables, during ripening and storage, has been shown to be related to the changes in the pectic substances by many workers (58, p. 189; 53, p. 592; 49, p. 7; 1, p. 6; 60, p. 120; 30, p. 34). Simpson and Halliday (58, p. 190), Woodruff, Dewey and Sell (64, p. 393) and Carre (5, p. 705) indicate that as ripening progresses protopectin, which is an insoluble pectin, is converted to soluble pectin. They further show that there is a decrease in total pectin substances with over maturity. Along with these changes, a cell wall thinning occurs and as the cementing substances between cells is changed, the cells separate, resulting in a softer fruit. The changes in pectic material during the ripening stage of fruits is accomplished mainly by enzymes, but even in canning where the enzymes are essentially inactivated by means of heat, histological changes leading to softening of the fruits take place. The essential factors affecting the cellular adhesion in processing then are heat and chemical treatments (63, p. 310). Postlmayer (51, p. 621) working with peaches showed that the protopectin content of clingstone peaches decreased at the time of heat processing and some of it was converted to water-soluble pectin. Along with the conversion he also demonstrated a slight decrease in total pectin substances. Rendle (54, p. 72) showed that the total pectic substances of fresh raspberry dropped from 0.92 percent to 0.34 percent in six days when stored at 18 - 24° C (65 - 75° F). Conrad (7, p. 101) showed a slight decrease in the total pectic substances of ripe, fresh strawberries when held at 30° C (86° F) for 47 hours and an insignificant increase in the soluble fraction. Morris (47, p. 157) obtained a complete destruction of pectin in frozen raspberries stored for six months at -10° C (14° F).

With regards to changes in pectic substances during ripening, storage and processing, the role of enzymes cannot be over emphasized. Of the many enzymes found in fruits, the major ones responsible for the changes in texture are the pectic enzymes. McCready (44, p. 535) working with Elberta peaches concluded that pectic enzymes come in contact with the pectic substances and hydrolyze them, and the firm structure of the fruit is lost. The important pectic enzymes involved are:

Protopectinase: This enzyme hydrolyzes protopectin, rendering it more soluble, which results in the separation of the tissue cells from each other (29, p. 334) and thus, softening of the fruit occurs.

The optimum pH range for the action of protopectinase has been shown by workers (27, p. 90-91; 39, p. 280) to be different, ranging from 3.5-5. However, many other factors,like rate of diffusion of the enzyme into the tissue, extent of esterification of the pectic acid component, etc., will effect the pH optimum of the enzyme.

Pectin-polygalacturonase: It has now been shown that polygalacturonases consists of several groups of enzymes (28, p. 58). Denel and Stuntz (11, p. 361) classify polygalacturonases into three groups.

a. Those which hydrolyze the 1,4-glycosidic linkages.

b. Those which preferentially attack pectins of high degrees of esterification.

c. Those which hydrolyze pectins only from one end of the chain molecule, probably the reducing end.

Polygalacturonases have been found in molds and higher plants. The pH optimum as indicated in the literature varies from 3.0-5.0, depending on the source (27, p. 90-91; 39, p. 280).

Pectin-Methylesterase: This enzyme hydrolyzes the methyl ester groups naturally occurring in pectinic acids and pectin.

Pectin-Methylesterase is found in the roots, stems, leaves and fruits of many higher plants. It is usually strongly absorbed on the water-soluble cellular components.

The possible synthetic action of pectin-methylesterase is not well understood.

Measurement of Texture

The methods mentioned in the literature and the instruments described for practical uses lay emphasis on such fruits as apples, pears and peaches, whose structural makeup and edible portions vary greatly from that of berries. The edible portion of fruits like apple, peaches and pears is the paranchyma tissue, whereas in case of berries the whole fruit including seeds and other components are consumed. Thus, the difficulty in using such methods and instruments is obvious.

The measurement of texture in case of berries, can be divided into two groups for convenience: (1) chemical methods and (2) instrumental methods.

Chemical Methods of Measuring Texture

The chemical methods of measuring texture, though time consuming as compared to the instrumental methods, are quite frequently used because of the high degree of precision.

The most commonly used method is the determination of the moisture content which gives a measure of the total solids present. Caldwell (4, p. 7) working with sweet corn showed that the solid materials increased as corn approached maturity, becoming more starchy, tough and undesirable. It was suggested that a moisture determination would be useful in the textural measurement of foods. Haller, Harding and Dean (15, p. 330) argued that the amount of dry matter in ripe strawberries, though low, varies considerably and since this dry matter forms the structure of berries, it would be largely responsible for their firmness. Similarly a relatively high moisture content would tend to dilute these solids resulting in a softer berry. Thus moisture determination would be a good indication of firmness. Moisture determination is used as an index for measuring the maturity of fruit and firmness. Haller, Harding and Dean (15, p. 334) working with strawberries have shown a direct correlation between the dry weight and the firmness. Shutak, Hindle and Christopher (56, p. 179) determined the moisture content of the Highbush blueberry at three different stages of maturity, which they refer to as green, half-ripe (red) and fully ripe (blue) berries, and showed direct relationship between moisture content and softening of the berries.

For products to which other soluble compounds like sugars and salts are added, a total solids determination does not give the true picture. Thus, in 1935 Kertesz (26, p. 5) introduced a method of determining the Alcohol Insoluble Solids (A. I. S.). Here the samples are extracted with 70 to 80 percent alcohol, filtered, washed and dried. This dried residue gives a measure of the alcohol insoluble starches, cellulose, pectins, proteins and fiber which are mainly responsible for the texture of a product. Weckel (62, p. 26) working with Alaska and Perfection peas obtained a correlation of 0.9 between Shear press and Tenderometer readings and the quality as measured by the Alcohol Insoluble Solids Test.

Hamson's (17, p. 377) work with tomatoes indicated that firmness and pectinesterase activity of tomato fruits might be related, thus an enzyme assay for pectinesterase could be an indication of texture. However, Hall (14, p. 631) working with the same fruits found no significant correlation between firmness and pectinesterase activity.

Instrumental Methods of Measuring Texture

The texture of fruits can be measured by some means of application of force. This force as described by Kramer and Twigg (33, p. 212) can be applied by one or more of the following methods: compression, shearing, cutting and tensile strength.

The resistance of a fruit to pressure of the thumb is an age-old method of evaluating the texture of fruits. However, the first reference to the use of mechanical instruments for measuring the resistance of fruit to applied pressure dates back to 1917 when a simple method was devised by Morris (46, p. 8). He used a marble partially embedded in paraffin and resting on a spring scale. The test was made by pressing the fruit against the marble until the marble penetrated the fruit as far as the paraffin. The pressure was read in pounds from the scale. Later Lewis, Murneek and Cate (38, p. 17) and Magness and Taylor (42, p. 3), using the same principle, developed more elaborate instruments. Such instruments have been used commercially to measure picking maturity and ripeness of various fruits, and along with other types, have been used extensively to measure the firmness of various fruits under experimental conditions.

Clark (6, p. 229) described a pressure tester used for measuring the texture of strawberries. The pressure tester is known as the "New Jersey Type Pressure Tester." The principle parts, as described, are a polished metal tube, a spring, and plunger which works inside the tube. A pointer is attached to the plunger and works through a slit in the tube. It moves along a scale graduated in grams. A ratchet device holds the plunger and pointer at the maximum pressure attained until a reading can be made.

Geo (12, p. 231) described two types of pressure testers which were used on strawberries. These were the Galloway tester and the Chatillon tester. Both of these testers are based on the pressure required to force a blunt plunger into the berries to a depth of 1/8 of an inch. The pressure is read on a dial in units on the Galloway tester and on a scale of grams on the Chatillon tester. Overholser and Claypool (50, p. 222) also used a similar pressure tester for strawberries. They expressed the firmness of strawberries in grams of pressure necessary to force a 1/8 inch diameter plunger through the flesh to a depth of 3/10 inch. Similar pressure testers were also used by Culpepper, Caldwell and Moon (9, p. 648); Rose, Haller and Harding (55, p. 429); Haller, Harding and Dean (15, p. 333); Haut, Welester, and Cochran (19, p. 405); Greve and Shoemaker (13, p. 183) and Hall and Dennison (14, p. 629) for measuring the firmness of strawberries. Bouyoucos and Marshall (3, p. 211-213) describe a pressure tester more suitable for small fruits like strawberries and cherries. Hamson (18, p. 427), working on the measurement of firmness of tomatoes, described another pressure tester called the "Magness-Taylor Pressure Tester." It consists of a movable specimen platform, a movable indicating platform to which plungers of various sizes may be attached, a calibrated scale for indicating the degree of firmness of the fruit as measured by compression of the fruit and a calibrated scale for indicating the diameter of the fruit. This tester is also known as "Cornell Firmness Meter."

Kattan (25, p. 380) used another instrument called the "Firm-o-meter" for measuring the firmness of tomatoes. The Firm-o-meter is designed to determine firmness by measuring the constriction of a fruit by a given force. In operation the fruit is placed in position and encircled by a chain which is in close contact with the fruit. A known test weight is then attached and the compression of the fruit is measured on a scale graduated from 0 - 10. The values obtained are inversely related to firmness. The measurements made with the Firm-o-meter correlated highly with readings obtained by the Cornell Pressure Tester.

Kramer, Burkhart and Rodgers (32, p. 34-40) described another instrument called the Shear press. (The description of the shear press will appear in a later chapter.) It was developed with the idea that it could be used for several purposes, like measurement of shearing, cutting, pressing and penetrating for a variety of foods, both cooked and raw. It utilizes some of the principles of the tenderometer and texturometer, at the same time is more versatile, accurate and portable. In describing the possible uses of the shear press, Kramer (34, p. 2-3) mentioned the following:

a. Determining the optimum time of harvesting

b. In purchasing of raw materials

c. To standardize the texture measuring instruments

d. In in-plant use

e. To measure the quality of finished products.

The original model has undergone modifications since 1951. Initially, mechanical dials were used which were hard to read. Also in penetrating the product variations in texture frequently caused the needle to change so fast that it is impossible for the human eye to follow its action. This makes accurate texture recordings difficult to obtain. Thus, in the more recent models the mechanical energy of shearing is transformed into electrical energy, which gives shear resistance readings on a separate graph paper. Supporting the use of such curves, Sidwell and Decker (57, p. 11) mentioned that the curves plotted are good indications of tenderness and fibrousness, and also that each product had its own particular curve. However, Kramer (34, p. 22) stated that in most instances as good results, if not better, were secured by using the peak values only, instead of the area under the curve. But he further stated that the added information obtained from the curves is useful. Decker, Yeatman, Kramer and Sidwell (10, p. 343-347) described the modification of the shear press for electrical indicating and recording.

Though the shear press has been used for measuring the texture of peas (36, p. 417-423), lima beans (31, p. 112-113, 187) and corn (21, p. 6), no detailed reports have appeared in the literature regarding the use of the recording shear press for measuring the textural properties of berries, either raw or processed. Decker, Yeatman, Kramer and Sidwell (10, p. 347) and Sidwell and Decker (57, p. 10) showed the force diagrams obtained with strawberries. Sidwell and Decker (57, p. 10) reported that the curves obtained from testing strawberries showed definite differences between varieties.

Those which have tough skins and core tissue had curves with relatively sharp peaks and those with uniform texture showed a more even curve. No reference to the use of shear press for the measurement of texture in raspberries, blackberries and blueberries was obtained. Talburt, Nimmo and Powers (61, p. 16, 19) working with raspberries used a visual grading method.

DESCRIPTION OF THE SHEAR PRESS

The shear press as received from the manufacturer was made up of the following eight parts:

1. A test cell box and grid, which is made up of a series of plunger plates, designed for a given product or products.

2. A test cylinder with a floating piston attached to the plunger plates to transmit the force applied to the product to a 1/2 inch round rod which actuates the tenderness guage which is atop the test cylinder.

3. A power cylinder to provide the actuating force.

4. A valve to control the travel of the test cylinder.

5. A flow control valve to vary the speed of travel of the test cylinder.

6. A hydraulic pump unit.

7. A reservoir for the oil.

8. An 1/2 horse power electric motor to drive the hydraulic pump.

Modifications Made on the Shear Press

At the time the shear press was used for this study the following equipment was attached to the original model:

a. Daytronic Model 102 A-120 Differential Transformer-

Transducer which is mounted just behind the hydraulic piston assembly and fitted to operate against an inclined plane surface. The function of this unit is to serve as the sensing element for transmitting a signal to the X axis of the X-Y recorder indicating the position of the hydraulic piston.

b. The Daytronic Exciter Demodulator, Model 200. This unit consists of a span control, a zero control, a sensitivity control and an on and off switch. It amplifies the signal from the transducer and converts this signal from alternating current to direct current and supplies this variable direct current signal to the X axis of the X-Y recorder.

c. Daytronic Series 140 Force Transducer. It is a differential transformer-transducer combined with a proving ring. The deflection of the ring is linear with load on the shear press piston assembly and the deflection is picked up by the differential transformer transducer, which in turn produces a linear signal with displacement.

d. Daytronic Model 300 A Differential Transformer Indicator. It receives the signal form the Series 140 Force Transducer and amplifies it and converts it to a variable direct current signal. This unit also has five attenuation steps, which can be used to give more or less sensitivity to the X-Y recorder in picking up load signals from the shear press cell.

e. Model 3 Mosely Autograph X-Y Recorder. It receives the signals from the Model 200 A Exciter Demodulator and the Model 300 A Differential Transformer Indicator and plots these signals in the form of a linear curve on rectangular coordinates. It has attenuation steps for various degrees of sensitivity on both the X axis and the Y axis. Steps in between the fixed attentuation steps can be attained by a variable attenuation switch provided on each axis. The recording is accomplished with an ink pen supported in a dual axis carriage.

With these attachments to the shear press (Figure 1) the texture measurements of the berries were made.

Operation of the Shear Press

The shear press is turned on about 30 minutes before using it. Before running any of the samples the shear press was standardized by zero adjusting the Model 300 A Differential Transformer Indicator. After calibration, the attenuator knob was then turned downward through the various settings, making necessary transducer zero adjustments until the needle remained in zero position. The attenuator control button was then left on 0.0025 setting for strawberries, raspberries, and blackberries; and 0.01 for blueberries.

A standard white paper of 8-1/2 x 11 inches dimensions was positioned in the X-Y recorder. Then, it was adjusted to bring the pen on the scale at the desired point,after turning the servo switch on.

Figure 1. Modified Lee-Kramer Shear Press.

It was found necessary to cool the X-Y recorder with the help of an electric fan to obtain the peaks of the curves.

The test cell box and the plates were wetted thoroughly before putting any sample in it to minimize the frictional resistance. Then, a known amount of sample was placed in the test cell taking care to see that the sample was spread evenly. After placing the sample in the box, the top grid plate was placed on the box and the entire assembly slid into the machine.

The electric motor which operates the hydraulic pump was then turned on. With the servo switch on the the marking pen down, the lever was pressed down gently to lower the power piston. The plunger plates enter the slots in the top plates and pass through the berry sample and through the slots in the bottom plate.

Resistance of the berries to the passage of the plunger plates was continuously recorded on the X-Y recorder.

After every sample, the sample cell and the plunger plates were washed thoroughly to remove any berry sample left in the cell from the previous run, before introducing the next sample.

MATERIALS AND METHODS

Raw Material

The purpose of this study was to investigate the effect of processing and subsequent storage at 100° F on the texture of strawberries, raspberries, blackberries and blueberries, as studied by physical measurement by Kramer Shear-Press and chemical analysis.

For this, the Northwest strawberry, Willamette raspberry, Marion blackberry and Jersey blueberry were used. These berries were obtained from the University farm. They were selected to have normal physical properties as used in commercial packs. The berries were precooled overnight at 35° F prior to processing.

The berries were then mixed, washed and sorted to remove dirt and damaged berries on a "McLauchlan Vibratory Washer." They were then drained on eight-mesh stainless steel trays to remove excess water, before hand filling into cans and jars.

Containers

For the canning of these berries two types of containers were used. One was fruit enamel cans of 303 x 406 dimensions and the other Duraglass 303 jars. The berries used in each replication for both cans and jars were taken from a common lot to avoid variations.

Preparation of the Berries for Processing

Cans and jars were weighed individually and 300 grams of washed, sorted berries and 182 grams of 60° Brix syrup at 170° F were filled in the containers.

Before syruping the containers were subjected to a vacuum of 25 inches of one minute in a manually operated vacuum closing machine. The vacuum was then released by filling the containers with syrup at 170° F. The cans were then steam-flow sealed at 20 inches vacuum and the jars sealed with a steam sealer giving a vacuum of 20 inches.

Procedures for Heat Processing of the Berries

The sealed cans were spin-processed in a modified Roll-Thru machine. The cans and jars were spun with coaxial rotation. A can speed of 100 r.p.m. and processing time of five minutes were given to the cans. The spin cooker was preheated for one minute before the cans were introduced. The f_h and j values obtained for blueberries in ten and glass were 1.84, 0.86; 6.08 and 0.87, respectively. The jars were also given a similar processing with the exception of blueberries. In case of blueberries an excessive pressure was built up in the jars, which resulted in blowing off the lids. Thus, the cooking time was reduced to four minutes. The cans and jars after processing were cooled in the same Roll-Thru machine with 55° F water sprays. They were then stored at 100° F.

Product Examination Methods

Two replications of four samples for each one of the four berries used, and for each of the two different containers, were made. The samples were analyzed immediately after processing and after storage times of 3, 7, 14, and 28 days at 100° F. The samples were measured for the following: vacuum, head space, drained weight, Kramer Shear-Press texture measurements, total pectin and alcohol insoluble solids (A. I. S.).

Vacuum measurements were taken on both cans and jars with a U. S. Gauge puncture gauge, after the cans were at room temperature.

The head space measurement was made with a six-inch ruler as the distance between the top of the product and top of the can.

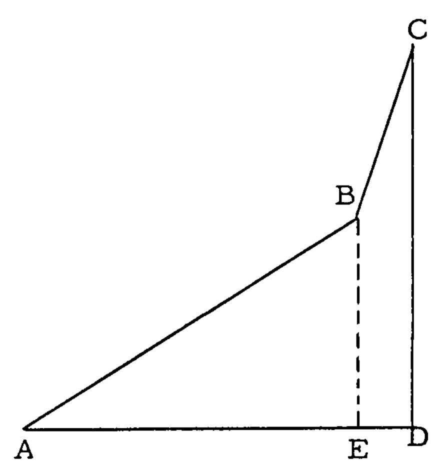
The procedure used for the determination of the drained weights was the U. S. D. A. -A. M. S. method for canned foods as described in the Almanac of the Canning Industries edited by E. E. Judge, 1960 ed. (p. 148-149).

The texture study of the processed berries was carried out by the use of Maryland Shear-Press.

Shear-Press Measurements

Resistance to shear was measured with Kramer Shear-Press made by Bridge Food Machinery Company, Philadelphia, Pennsylvania, with an electronically operated X-Y Recorder attachment made by F. L. Moseley Company, Pasadena, California. The whole drained-weight sample taken from the cans or jars was used for this measurement. The sample was carefully placed in the cup. A thousand pound ring with a transducer value of 0.0025 was used in case of strawberries, raspberries and blackberries; whereas in case of blueberries the same ring with a transducer value of 0.01 was used. The cup was washed with water after every sample.

Figure 2. Diagramatic Representation of Work Diagrams.



The work diagrams obtained, which is diagramatically represented in Figure 2, were later measured for the following measurements: maximum force, total work (area under ACD), partial work area under ABE, angle of BAE and the length of AE. The area under the curve was measured with a planimeter. The work diagrams obtained, using the Kramer Shear-Press, were first converted to pounds force and then calculated on the basis of 100 grams fresh weight and 100 grams drained weight. It was observed that in both cases similar results were obtained. However, the results when based on fresh weight did not show the degree of variation as the ones calculated on the drained weight basis. All calculations were based on 100 grams of drained weight, as it is a common practice in industry to base their texture measurements on drained weights, rather than the fresh weight. The samples obtained after passing through the Shear-Press were carefully collected into separate containers, which were then sealed and frozen at -18^{o} F and held until analysis.

The same procedure was followed in studying the effect of sample size on the texture measurement with the exception that instead of using the whole drained weight, 50, 100, 150 and 200 grams of fresh berries were used in case of strawberries, raspberries and blueberries and 50, 100, 150 grams for blackberries.

Analytical Procedure

All the analytical determinations were made on the samples collected after the Shear-Press measurements. The four samples of each berry, each storage treatment and of the same replications were mixed together thoroughly with a wooden spoon.

1. Alcohol Insoluble Solids:

The method as described by Sistrunk (50, p. 37) formed a basis for this analysis. A few modifications, which appeared to be necessary for the berries, were made in the procedure. After preliminary tests, the following procedure was adopted.

The hand mixed samples were placed in a Waring Blender and blended for one minue. Two-gram samples of this blended material were weighed to the nearest 0.01 gram in a 50 ml. beaker. This was then transferred into a 50 ml., round-bottom centrifuge tubes with 40 ml. of hot 95 percent ethyl alcohol. The tubes were then heated in a water bath at 80^{o} C for ten minutes. They were then centrifuged at 2000 r.p.m. for ten minutes, the supernatent was decanted and discarded. This procedure was repeated twice with hot 70 percent alcohol and once with cold 70 percent alcohol with no heating. The sediment was stirred up each time before heating. The final decanted alcohol was almost colorless. The final residue was then transferred into weighed aluminum cups, which were dried in a vacuum oven under a vacuum of 30 inches at 60° C for 16 hours. They were then cooled in a desiccator and weighed.

2. Total Pectin:

The method of Luh et al. (40) formed the basis for the analysis of pectins. After preliminary tests, this method was adopted with few modifications which maintained the precision and at the same time minimized the time needed. Two hundred grams of the hand mixed samples were blended in a Waring Blender. The blended sample was then transferred to a one liter pyrex flask and covered with 600 ml of 80 percent ethyl alcohol, mixed well and boiled in water bath for ten minutes. After cooling down to room temperature, they were once again blended in a Waring Blender. The blended sample was then filtered through No. 30 Wattman filter paper under vacuum and washed with hot 80 percent ethyl alcohol until the filtrate was colorless. The residue was dried at room temperature first and then under 30 inches of vacuum at 60° C for 16 hours.

The alcohol insoluble solids were then ground up with a F. No. 4, Quaker City Corn Mill grinder and stored in bottles for pectin analysis.

Before analysis, the samples were once again vacuum dried under 30 inches of vacuum at 60° C for four hours. A 0.2 gram sample of this was carefully weighed to the nearest 0.01 gram and transferred into 50 ml., graduated, conical centrifuge tubes. Ten ml. of hot water were added and the sample heated in a water bath at 100° C for five minutes with occasional stirring. To this, 30 ml. of 0.5 M hot acid alcohol (37-1/2 ml. 95 percent ethyl alcohol: 2-1/2 ml. Conc. HCl) was added and held in water bath at 80° C for five minutes. The mixture was then stirred, allowed to cool and centrifuged at 2100 rpm for ten minutes. The supernatent was decanted and discarded. This procedure was repeated once more with hot acid alcohol and twice with hot 70 percent ethyl alcohol. Then the residue was washed twice with cold 70 percent ethyl alcohol without heating in the water bath. Every time the residue was stirred thoroughly. At this stage it was tested with carbazol to see that all the sugars were washed out.

To the residue, 25 ml. of water and 10 ml. of two percent Versene were added, stirred and adjusted to a pH of 11.5 with 1 N sodium hydroxide. It was allowed to sequester for 60 minutes at room temperature, with occasional stirring.

At the end of the sequestering period, the samples were centrifuged and the liquid decanted into a 100 ml. volumetric flask. The residue was washed with 40 ml. of water, which was once again centrifuged at 2000 rpm for ten minutes. The supernatent was collected in the same 100 ml. volumetric flask. The extract was then made up to 100 ml. with water.

Five tenths ml. of this extract and .5 ml. of water were pipetted into six-inch, pyrex test tubes. Six ml. concentrated sulfuric acid was added and stirred thoroughly. They were then heated in boiling water bath for ten minutes. After cooling to room temperature, 0.5 ml. of 0.15 percent alcoholic carbazole solution was added and color allowed to develop for 30 minutes. The tubes were read for percent transmittance on a Spectronic 20 photometer, at a wave length of 520 mμ. A blank with 0.5 ml. of water instead of extract was used.

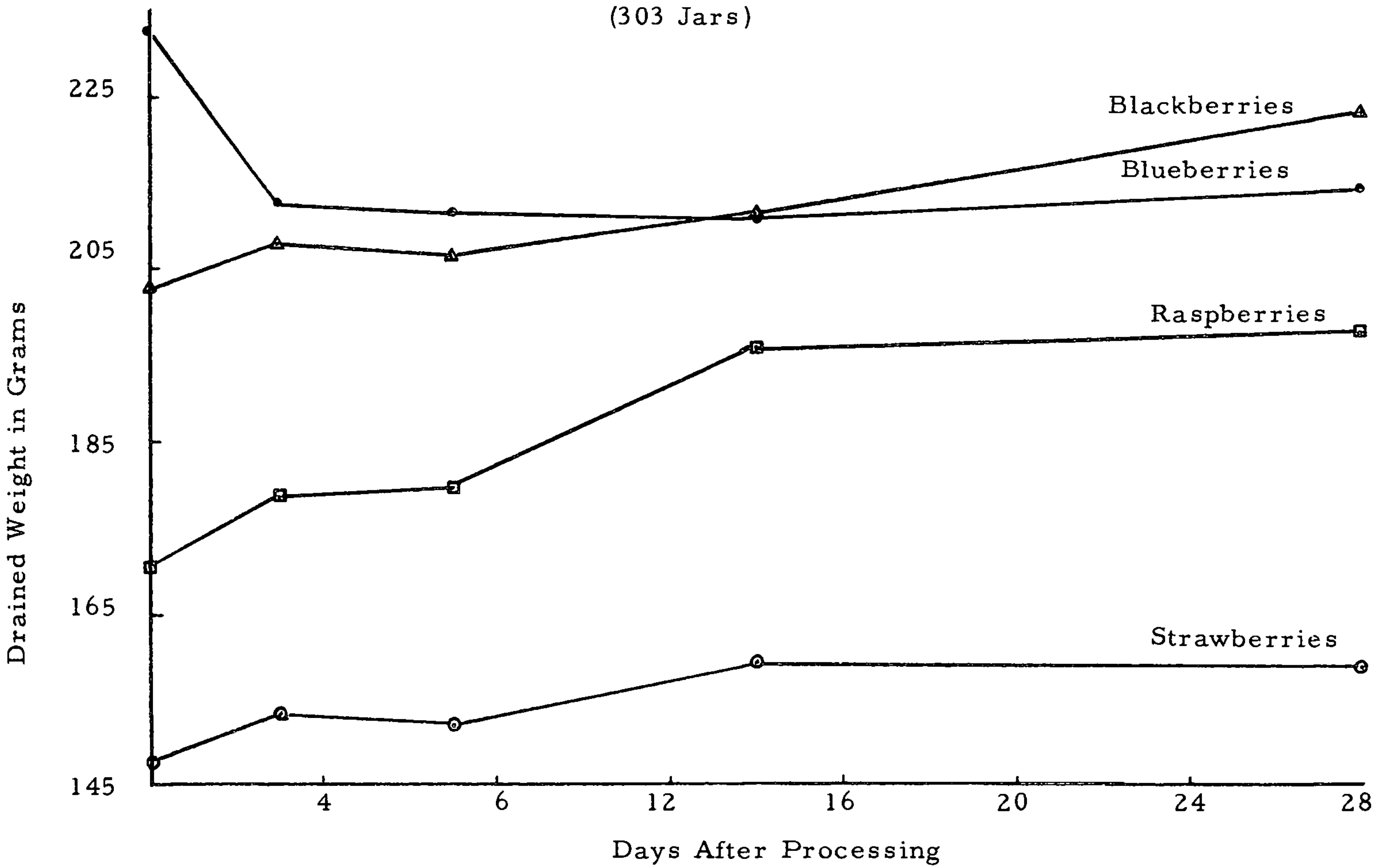
The percent transmittance readings were then transferred to the amount of galacturonic acid with the use of a standard curve.

RESULTS AND DISCUSSION

For the analysis of the berry fruits, processed and stored both in tin and glass containers, the methods described in the previous section were used. The results obtained with regards to vacuum, head space and drained weight were as follows: The average vacuum in the cans was 15 inches with a range of two inches, and in the jars 21 inches with a range of 1.5 inches. The average head space in the cans and jars was 12/16 inches with a range of 4/16 inches. In case of strawberries, raspberries and blackberries the drained weight increased with the storage where as in case of blueberries there was a slight decrease. This is illustrated in Figure 3 which shows the drained weight behavior of the four berries canned in glass jars. The average percent drained weight increase for strawberries for the 28 days of storage was 8.5 percent, for raspberries, 7.7 percent, and for blackberries, 10 percent over the zero storage time. In case of blueberries the decrease was 15 percent for the first replication and two percent for the second replication.

With regards to texture, A.I.S. and total pectins the following results were obtained.

Figure 3. Drained Weight Patterns of Processed Berries.
(303 Jars)

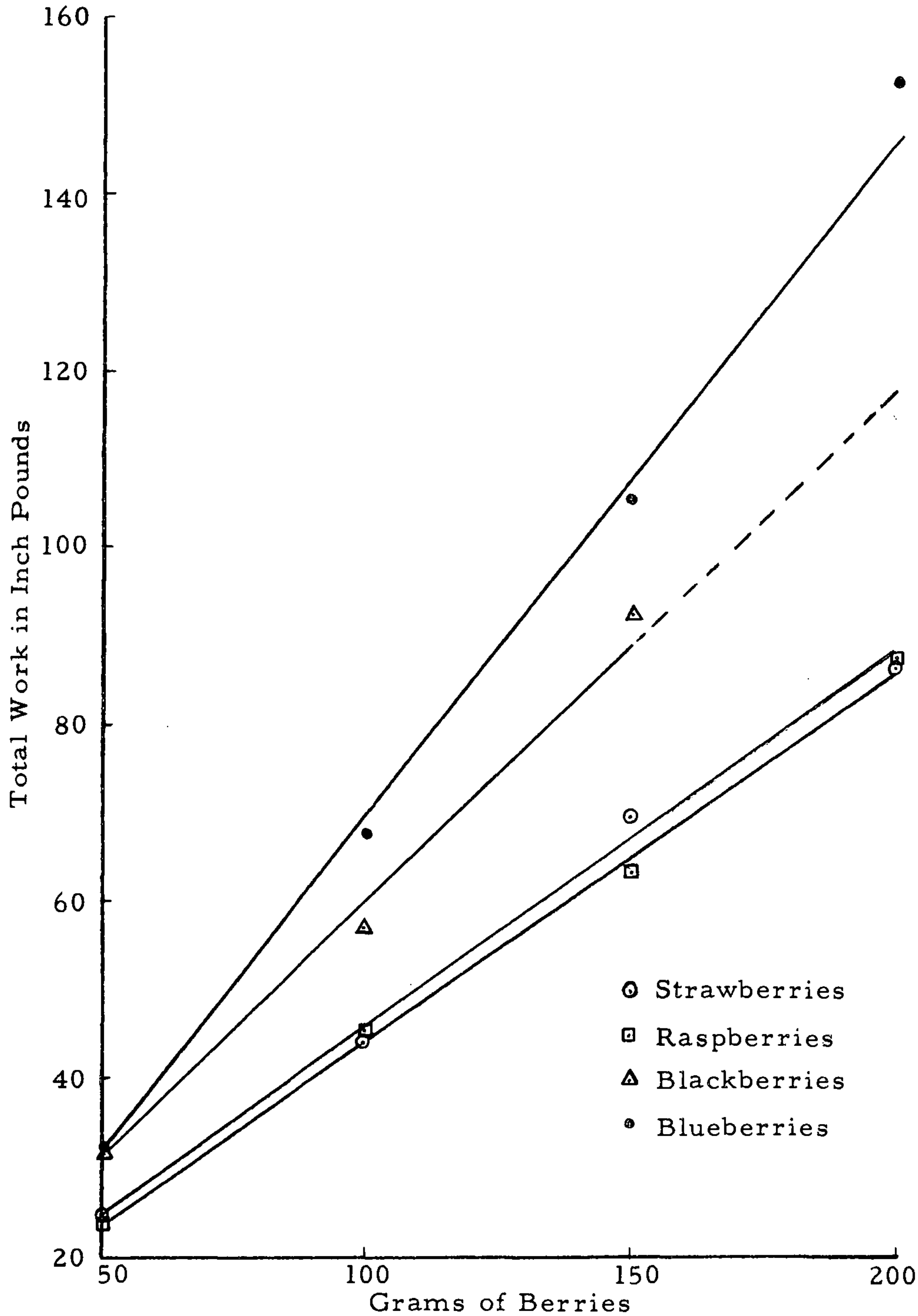


Effect of Sample Size on Texture Measurement

For the measurement of texture the Kramer Shear-press was used. Here, instead of the whole drained weight 50, 100, 150 and 200 grams of fresh berries were taken in the case of strawberries, raspberries and blueberries; whereas in case of blackberries 50, 100 and 150 grams were used. The transducer value used was 0.0025 for strawberries, raspberries and blackberries and 0.01 for blueberries. The work diagrams were then measured for maximum force and total work. The results obtained are shown in Figure 4.

A linear relation was obtained between the sample size and the texture, as measured by the total work, in all the four berries. When maximum force was used for measuring texture, the relationship with sample size was more variable. There was a tendency for the maximum force peaks to level off as they reached the larger sample sizes. With an increase in the sample size the volume occupied by the berries in the test cell box is larger and as a consequence the plates which are moving down through the sample come in contact with the berries sooner, giving an increased area for the work diagram. But as the plates shear through the sample and reach the bottom of the test cell, the amount of fruit material that it finally shears is not appreciably different with different sample sizes and thus, there will not be a proportional increase in the maximum force,

Figure 4. Effect of Sample Size on Texture Measurement.



as is the case with total work.

1. Northwest Strawberries

Shear-press Measurements

The whole drained weight samples were used for the measurement of texture. A thousand pound ring with a transducer value of 0.0025 was used. The work diagrams obtained on the X-Y recorder were then measured for maximum force, total work (total area under ACD) and partial work (area under ABE). Also, the distance of AE and the angle BAE were measured. The readings obtained were first converted to pounds force and then calculated on the basis of 100 grams of drained weight. An average of four samples of each treatment of the same replication was then obtained. The work diagrams of all the samples were of similar shape. They consisted of a gradual rise from the base line in the beginning, followed by a sharp rise to a peak, and then an almost vertical return to the base line. A characteristic work diagram for strawberries is shown in Figure 5. The means of the texture measurements, as calculated on the basis of four samples of 100 grams of drained weight, are tabulated in Table 1.

The texture measurement of fresh fruit were taken by carefully weighing 100 gram samples. The measurements obtained for the fresh fruit of the first replication was 45.95 pounds force as

Figure 5. Characteristic Work Diagrams of Processed Berries.

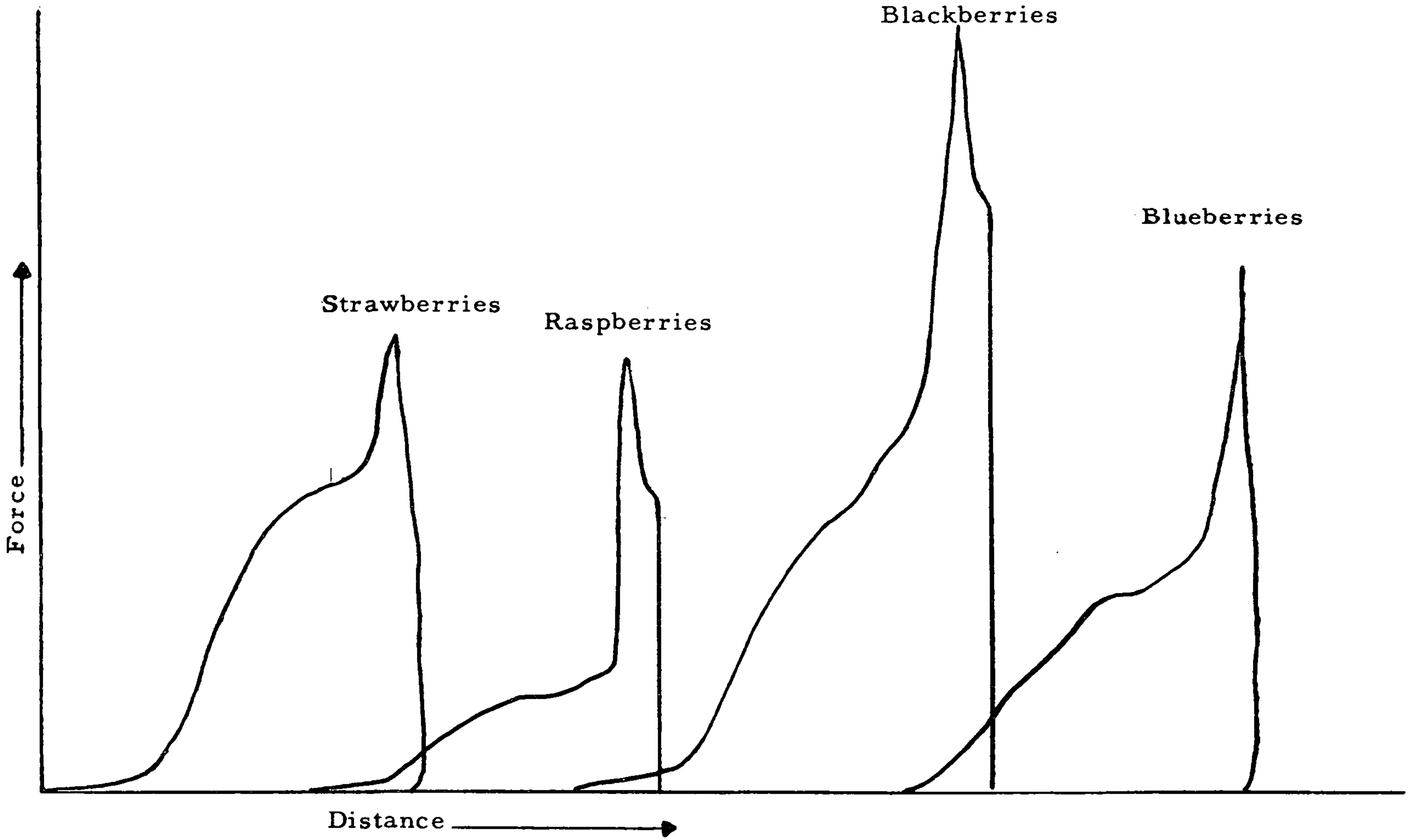


Table 1. TEXTURE MEASUREMENTS ON STRAWBERRIES

Texture Measurement*	Days after Processing	Cans Replication I	Cans Replication II	Jars Replication I	Jars Replication II
		Inches+			
Maximum Force	0	31.32	25.98	35.38	33.19
	3	33.88	27.86	35.22	32.24
	7	26.98	30.36	35.61	35.42
	14	28.50	28.77	33.12	31.19
	28	25.56	25.92	32.37	30.01
		Square Inches#			
Total Work (Area under ACD)	0	30.46	25.35	32.73	28.32
	3	34.30	27.47	32.46	28.22
	7	28.07	29.64	31.87	31.89
	14	27.29	28.09	31.69	28.83
	28	23.97	23.09	29.87	26.78
		Square Inches#			
Partial Work (Area under ABE)	0	22.47	19.08	23.81	18.95
	3	24.82	21.83	23.65	18.44
	7	21.59	21.86	23.10	23.71
	14	20.39	21.70	23.04	21.39
	28	16.85	16.28	20.78	19.98

* All samples on 100 g drained weight basis.

\+ Converted to pounds force by multiplying with 20.

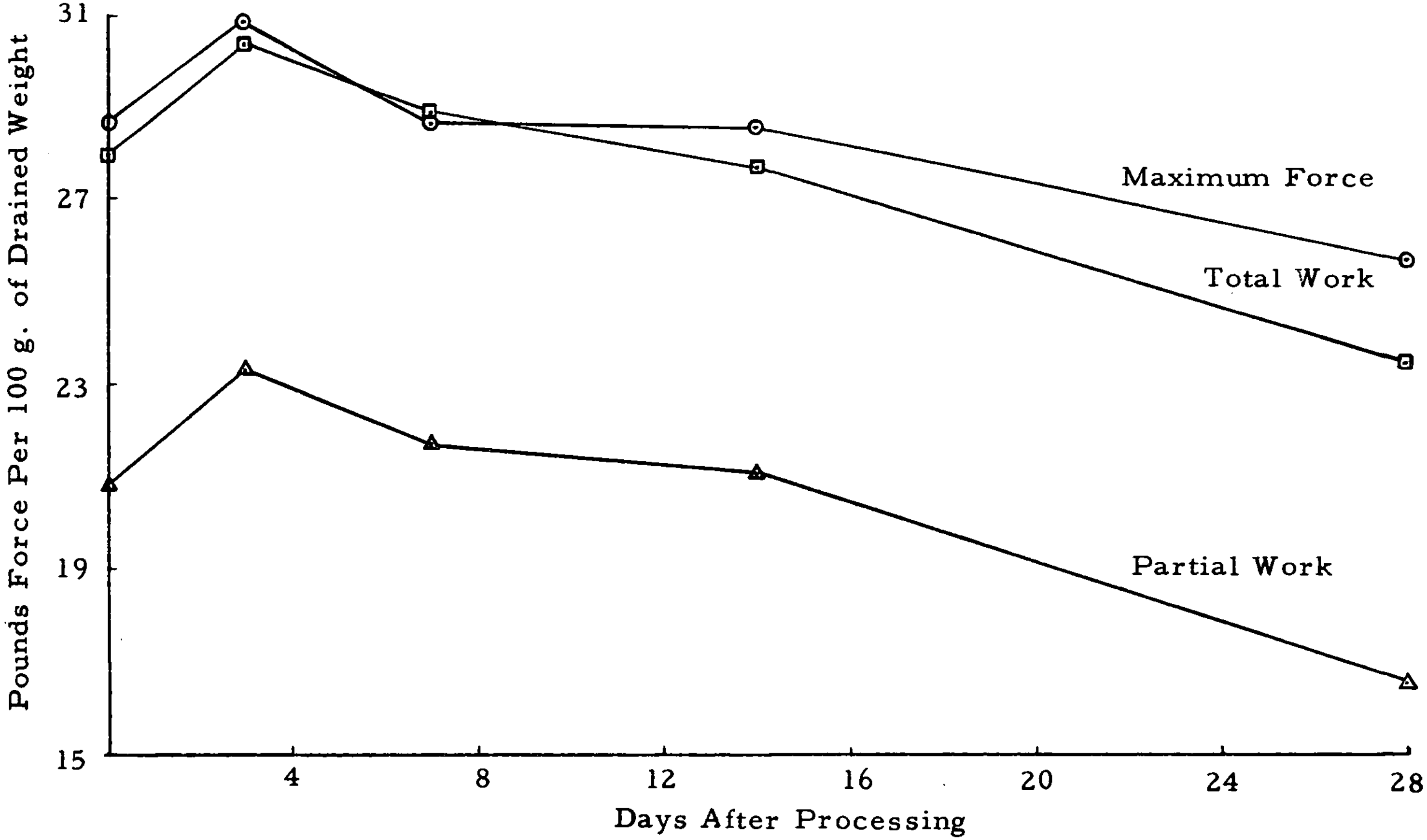
\# Converted to inch pounds by multiplying with 20.

maximum force, 41.90 inch pounds as total work and 31.95 inch pounds as partial work. Similarly, the measurements obtained for the second replication were 36.45 pounds force, 30.05 and 22.35 inch pounds respectively. The measurement of the length AE and the angle BAE did not have any pattern, indicating that they can not be used as an indication for the measurement of texture.

The data tabulated in Table 1 shows that the texture, as measured by the three methods, decreased with processing and storage (Figure 6) with the exception of partial work in case of jars for the second replication of strawberries, where there was an increase after seven days of storage followed by a gradual decrease on further storage up to 28 days. The softening of strawberries at the end of 28 days, as compared to zero storage, was due to the changes in A.I.S. fraction and the total pectin content, as there was an increase of 8.5 percent in the drained weight. Thus, the samples at the end of 28 days had more water and soluble solids content than the ones at zero days storage, resulting in the dilution of the A.I.S. Also, upon storage there was a gradual softening of the fruit and the rate of softening depends upon the storage temperature. During this period the protopectin is broken down into smaller chain length moieties and a loss of methyl groups occurs. As a consequence, there was an increase in the soluble pectin and a softening of the fruit.

Using statistical analysis, the effect of tin and glass, as well as

Figure 6. Texture Measurements of Processed Strawberries.
(303 Cans)



that of storage, on the texture of strawberries was determined. The F values for the difference between tin and glass, as measured by the maximum force, total work and partial work were 5.22, 2.05 and 0.50, respectively, with one and nine degrees of freedom. The five percent critical region was beyond 5.12. The F values for the hypothesis that there was no difference in the texture with storage time were 0.44, 0.92 and 1.05, respectively, for the three methods with four and nine degrees of freedom and the five percent critical region was beyond 3.63. Thus there was no significant change in the texture of strawberries as a consequence of 28 days of storage at 100° F.

Percent Alcohol Insoluble Solids

Two gram samples of the drained weight material were used for the determination of percent A.I.S. The data obtained is tabulated in Table 2. The F value for the difference between tin and glass was 0.14 with one and nine degrees of freedom. The five percent critical region was beyond 5.12. No significant difference was observed in the percent A.I.S. with different storage times as indicated by an F value of 1.07 with four and nine degrees of freedom, with the critical region being beyond 3.63.

The correlation coefficients between A.I.S. and texture, as measured by maximum force, total work and partial work, were 0.61,

Table 2. PERCENT A. I. S. IN PROCESSED BERRIES

Type of Berry	Days after Processing	Percent A. I. S.* Cans Replication I	Cans Replication II	Jars Replication I	Jars Replication II
Strawberry	0	3.69	3.36	3.83	3.74
	3	3.83	3.78	3.75	3.49
	7	3.17	4.37	3.92	4.23
	14	3.24	3.93	3.58	3.26
	28	2.82	3.19	3.46	3.07
Raspberry	0	8.01	8.23	7.59	8.46
	3	6.94	6.89	7.54	7.93
	7	7.48	6.54	7.40	7.62
	14	7.15	6.46	7.21	7.73
	28	7.03	6.28	7.43	6.32
Blackberry	0	7.02	7.48	8.79	7.48
	3	7.26	7.53	8.14	6.87
	7	6.83	7.29	7.86	7.26
	14	6.76	7.84	7.20	6.69
	28	6.18	6.87	7.05	6.43
Blueberry	0	5.67	5.11	5.95	5.34
	3	6.47	4.95	7.09	6.11
	7	5.15	4.15	5.63	5.94
	14	6.75	5.49	7.28	7.17
	28	7.04	5.21	4.49	6.41

* All samples on 100 g drained weight basis.

0.66 and 0.51, respectively.

When the shear press measurements are made on berries, the berries in the sample cell are initially compressed and towards the end, skin and seeds are sheared. This accounts for the sharp rise to a peak of the work diagrams as seen in Figure 5. Thus, it can be assumed that upto the point B in the work diagram the flesh of the berries is being compressed and that the distance from B to C measures the resistance of seeds and skin to shearing. In measuring the texture by maximum force, seeds and skin influence to a great extent the distance between C and D, that is the distance between maximum point and base line. In case of total work, the total area under the curve is measured, thus here there is a total effect of flesh, skin and seeds on the texture. When partial work is used as a criteria of texture, the effect of seeds and skin is essentially eliminated. The A.I.S. fraction of the cell is mostly made up of polysaccharides like cellulose, xylans, araban, galactan, polygalactronic acid (pectic acid), mannan and to a certain extent proteins (23, p. 137; 62, p. 26). Seeds and skins are relatively high in some of these constituents. Thus, when this fraction is eliminated the correlation between A.I.S. and texture is affected as indicated by a correlation of only 0.51 between A.I.S. and partial work.

Total Pectin

Two-tenths gram samples of dried and ground A. I. S. were used for the determination of total pectins. The samples were washed twice with 30 ml. of 0.5 M hot acid alcohol, twice with hot 70 percent ethyl alcohol and twice with cold 70 percent ethyl alcohol to remove all the interfering sugars other than pectins. They were then treated with 10 ml. of two percent Versene and the pH adjusted to 11.5 with 1 N sodium hydroxide. It was then allowed to sequester for 60 minutes. The color was developed with carbazole and read at 520 mμ. The results obtained are tabulated in Table 3.

No significant differences were observed between tin and glass and storage time, as indicated by F values of 0.002 and 1.22, respectively, with the five percent critical region being beyond 5.12 with one and nine degrees of freedom and 3.63 with four and nine degrees of freedom, respectively.

The correlation coefficients between total pectin expressed on the dry weight basis and the three methods of texture measurement, that is maximum force, total work and partial work, were 0.54, 0.78 and 0.83.

Here, the correlation between partial work and total pectin is higher than the other two. Partial work, as mentioned in discussing A. I. S., eliminates the effect of seeds and skins and measures the

Table 3

TOTAL PECTIN CONTENT OF PROCESSED STRAWBERRIES

Basis	Days after Processing	Total Pectin Material			
		Cans		Jars	
		Replication		Replication	
		I	II	I	II
		%	%	%	%
Dry Weight	0	9.26	8.45	9.46	8.64
	3	9.82	8.87	9.23	8.47
	7	8.89	9.12	8.62	9.13
	14	8.37	8.96	8.48	8.86
	28	8.17	7.68	8.25	8.29
Fresh Weight	0	0.188	0.147	0.179	0.158
	3	0.206	0.185	0.175	0.153
	7	0.162	0.218	0.173	0.193
	14	0.156	0.198	0.163	0.151
	28	0.136	0.139	0.151	0.135

texture of flesh which is composed of large number of cells cemented together by means of pectic substances, thus a better correlation was obtained.

2. Willamette Raspberries

Shear-press Measurements

As in the case of strawberries, whole drained weight samples were used to measure texture. Here also, a transducer value of 0.0025 was used with a 1000 pound ring. The three methods of measuring texture, that is maximum force, total work and partial work, that were mentioned previously, were used.

The work diagrams of all the samples were similar in shape. They consisted of a gradual rise from the base line initially, followed by an almost vertical rise to a peak. On the return, a break point was formed about quarter way from the peak to the base line. A characteristic work diagram for raspberries is shown in Figure 5.

The means of the texture measurements, calculated on the basis of four samples of 100 grams of drained weight, are tabulated in Table 4.

The texture measurement of fresh fruit, as determined in the case of strawberries, was 54.50 pounds force as maximum force, 37.60 inch pounds as total work and 24.40 inch pounds as partial work for the first replication. The values for the second replication

Table 4. TEXTURE MEASUREMENTS ON RASPBERRIES

Texture Measurement*	Days after Processing	Cans Replication I	Cans Replication II	Jars Replication I	Jars Replication II
		Inches+			
Maximum Force	0	25.54	26.61	27.45	29.60
	3	23.64	20.58	27.09	27.79
	7	24.11	18.90	24.29	24.00
	14	18.53	17.68	21.46	24.58
	28	20.19	16.45	21.93	20.82
		Square Inches#			
Total Work (Area under ACD)	0	11.76	11.52	12.70	11.14
	3	10.33	9.64	12.74	11.36
	7	9.58	9.27	11.80	10.56
	14	8.21	7.93	10.93	11.23
	28	8.62	7.88	9.99	9.05
		Square Inches#			
Partial Work (Area under ABE)	0	6.04	5.40	7.09	4.96
	3	5.21	5.12	7.27	4.76
	7	5.03	5.01	6.34	5.20
	14	3.55	4.29	6.30	5.61
	28	4.27	4.42	5.58	3.97

* All samples on 100 g drained weight basis.
+ Converted to pounds force by multiplying with 20.
# Converted to inch pounds by multiplying with 20.

were 57. 15 pounds force, 42. 10 and 26. 05 inch pounds, respectively.

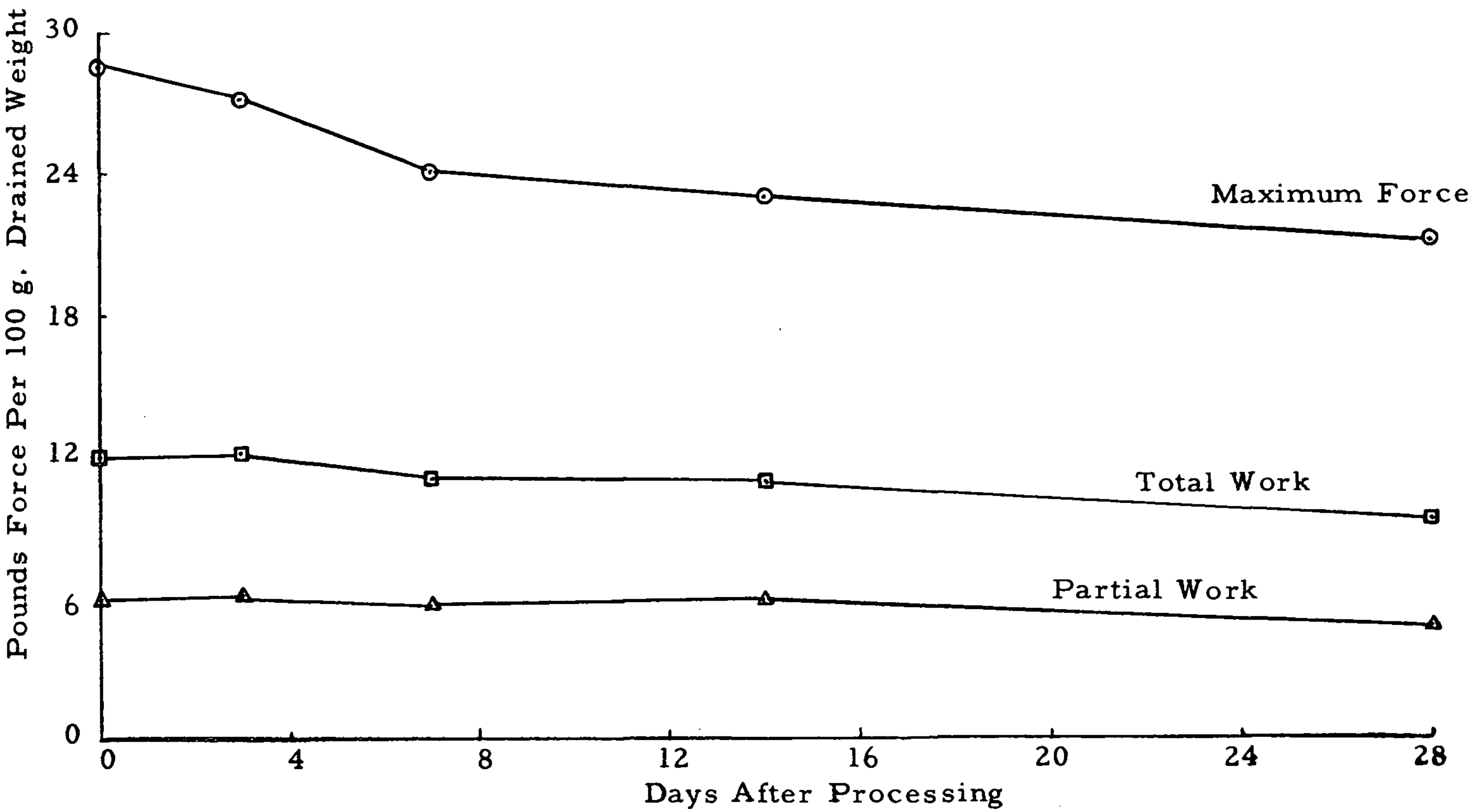
No particular pattern of the length AE and the angle BAE was obtained, hence these measurements could not serve as a means of measuring texture of processed raspberries.

The data tabulated in Table 4 shows a decrease in the texture in every case with a 28 day storage. This softening of raspberries is accompanied by a decrease in the percent A. I. S. and total pectin. According to the argument of Haller, Harding and Dean (15, p. 330) and Isherwood (23, p. 137), the changes in and the amounts of these fractions effects the texture of a fruit, as they form part of the structure components. Thus, a degradation of A. I. S. and total pectin will result in a softer fruit. The F values calculated for maximum force, total work and partial work for the difference between tin and glass were 2. 37, 3. 12 and 2. 29, respectively, with one and nine degrees of freedom. The five percent critical region being beyond 5. 12.

The F values for the hypothesis that there is no difference in the texture with storage time were 1. 32, 1. 16 and 0. 66, respectively, with four and nine degrees of freedom, with the five percent critical region being beyond 3. 63.

The texture measurements of raspberries in jars is shown in Figure 7.

Figure 7. Texture Measurement of Processed Raspberries.
(303 Jars)



Percent Alcohol Insoluble Solids

The method of determining the percent A.I.S. consisted of taking two gram samples weighed to the nearest 0.01 gram. These samples were washed once with hot 95 percent ethyl alcohol, twice with hot 70 percent ethyl alcohol and once with cold 70 percent ethyl alcohol. The sediment was then dried in vacuum oven. The data obtained for raspberries is tabulated in Table 2. The calculated F values for the difference between tin and glass and with different storage time were 1.11 with one and nine degrees of freedom and 1.14 with four and nine degrees of freedom. The five percent ciritcal regions being beyond 5.12 and 3.63 respectively. Hence, there was no significant difference in the percent A.I.S.

The correlation coefficients obtained between percent A.I.S. and maximum force, total work and partial work were 0.88, 0.73 and 0.43, respectively. Hence as in the case of strawberries, a better correlation was obtained between percent A.I.S. and texture when the effect of seeds and skin was included.

Total Pectin

The procedure as described for strawberries was followed for the determination of total pectin content of the processed raspberries. The results obtained are tabulated in Table 5. There was a decrease in the amount of total pectin in every case upon 28 days of storage.

Table 5.

TOTAL PECTIN CONTENT OF PROCESSED RASPBERRIES

		Total Pectin			
		Cans		Jars	
	Days After	Replication		Replication	
Basis	Processing	I	II	I	II
		%	%	%	%
Dry Weight	0	6.00	6.96	5.87	6.70
	3	5.97	6.87	6.26	6.04
	7	5.63	4.55	5.78	6.84
	14	5.48	5.80	5.38	6.95
	28	5.20	6.04	5.20	5.05
Fresh Weight	0	0.302	0.332	0.259	0.313
	3	0.275	0.321	0.295	0.270
	7	0.278	0.205	0.261	0.304
	14	0.269	0.265	0.257	0.344
	28	0.247	0.272	0.251	0.206

The F values calculated for the effect of container and storage are 0.15 and 0.82 with one and nine and four and nine degrees of freedom, respectively, with the five percent critical regions being beyond 5.12 and 3.63, respectively. Thus, there was no significant difference in the amount of total pectin.

The correlation coefficient between total pectin and maximum force, total work and partial work were 0.49, 0.41 and 0.22. Here, unlike the case of strawberries, a lower correlation was obtained between total pectin and texture when the effect of seeds and skin was eliminated. This is because of the structural make-up of raspberries. They have a hollow center with many seeds, held together by the flesh. The parenchyma tissue surrounding the seeds does not form an appreciable portion of the fruit. This can be seen in Figure 5, where the travel through the flesh is short and ends in an abrupt rise to a peak due to the shearing of seeds.

3. Marion Blackberries

<u>Shear-press Measurements</u>

The same method was used for the determination of texture. A transducer value of 0.0025 with a 1000 pound ring was used. The work diagrams of all the samples were identical in shape. They were similar to the work diagrams of raspberries, but were of larger magnitude. A characteristic work diagram for the blackberries is shown in Figure 5. The means of the texture measurements, calculated on the basis of four samples of 100 grams of drained weight, are tabulated in Table 6.

The texture measurements of the fresh blackberries, measured by the three methods: maximum force, total work and partial work for the two replications were 102.48 pounds force, 63.36 and 40.68 inch pounds; 92.60 pounds force, 57.27 and 35.47 inch pounds, respectively.

As in the case of strawberries and raspberries, no particular pattern was observed for the length AE and the angle BAE. Thus they could not be used as a criteria for measuring the texture of processed blackberries.

Upon 28 days of storage at 100° F, a decrease in the texture was observed. However, this difference in the texture on storage was not significant at the five percent level. The effect of the container on the texture was also not significant at the five percent level.

The texture measurement for blackberries in glass container is shown in Figure 8.

Percent Alcohol Insoluble Solids

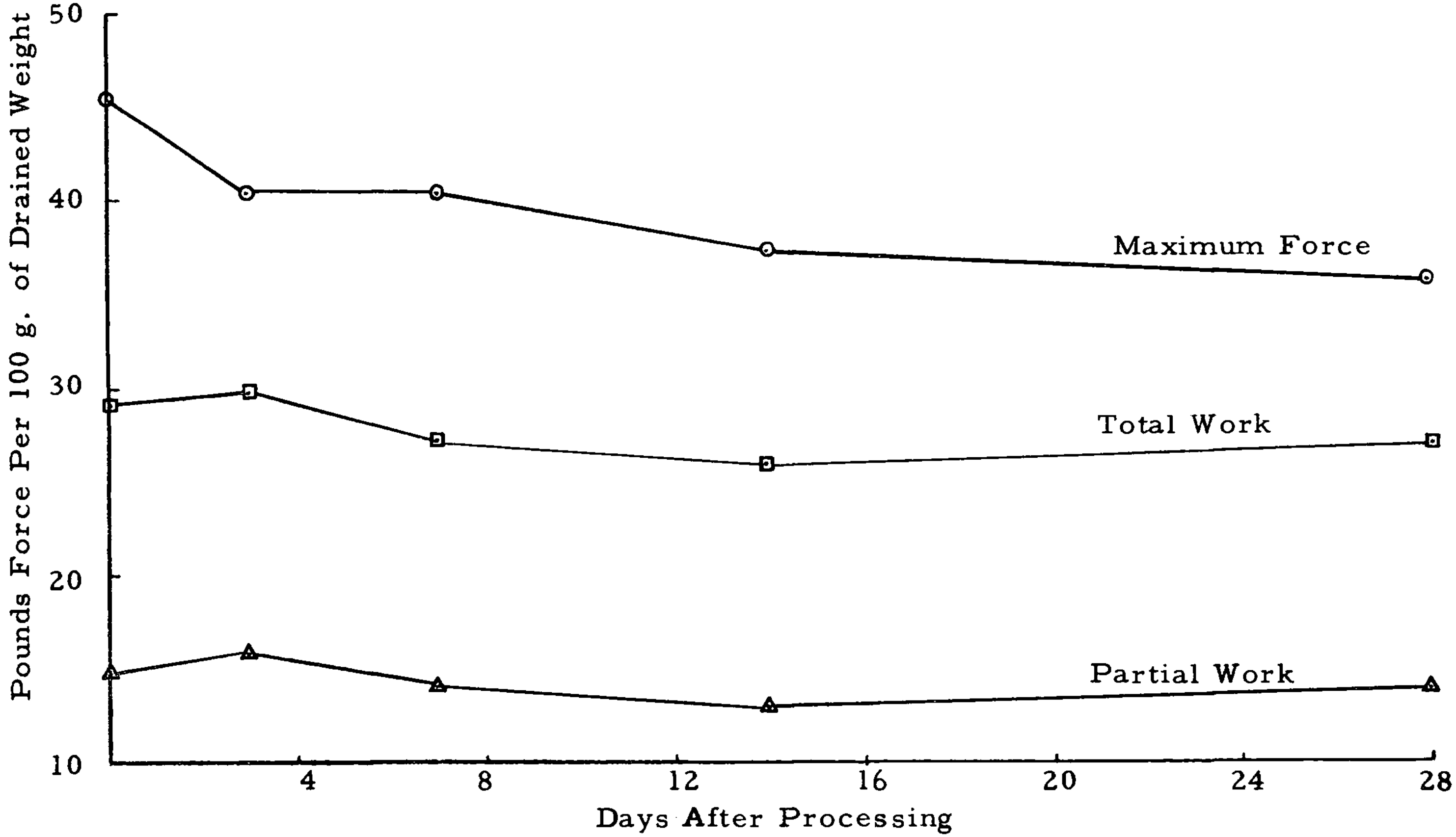
The same technique was used for the determination of percent A.I.S. in blackberries. The data obtained is tabulated in Table 2. A decrease in the amount of A.I.S. was observed upon a 28 day storage

Table 6. TEXTURE MEASUREMENTS ON BLACKBERRIES

Texture Measurement*	Days After Processing	Cans Replication I	Cans Replication II	Jars Replication I	Jars Replication II
		Inches+			
Maximum Force	0	40.93	29.69	53.78	37.05
	3	47.12	30.09	47.78	33.23
	7	38.84	28.28	47.05	34.24
	14	37.76	31.82	42.36	32.03
	28	34.37	25.33	42.10	28.96
		Square Inches#			
Total Work (Area under ACD)	0	31.76	19.01	31.56	26.83
	3	32.58	19.82	35.65	23.66
	7	29.75	19.88	31.71	22.42
	14	26.71	20.32	28.40	23.33
	28	27.48	20.17	32.08	21.35
		Square Inches#			
Partial Work (Area under ABE)	0	17.84	9.86	14.78	14.57
	3	17.07	10.91	18.75	12.76
	7	16.04	10.83	15.49	12.50
	14	12.86	11.86	13.98	11.69
	28	14.14	11.49	16.64	11.65

* All samples on a 100 g drained weight basis.
\+ Converted to pounds force by multiplying with 20.
\# Converted to inch pounds by multiplying with 20.

Figure 8. Texture Measurements of Processed Blackberries. (303 Jars)



at 100° F but the difference was not significant at the five percent level. The container did not have a significant effect on the percent A.I.S. in blackberries.

The correlation coefficients between percent A.I.S. and maximum force, total work and partial work were 0.55, 0.27 and 0.21. The correlations, though lower, are similar in nature to that of strawberries and raspberries.

Total Pectin

Similar techniques were utilized in determining the amount of total pectin in the processed blackberries. The data obtained is tabulated in Table 7.

At the end of 28 days of storage at 100° F, an increase in the amount of total pectin was observed for the second replication in cans and first replication in jars. However, there was no significant difference in the total pectin between containers and also storage time.

The correlation coefficients between total pectin and maximum force, total work and partial work were very low indicating that no relationship existed between these two factors.

4. Jersey Blueberries

Shear-press Measurements

The method used for the measurement of shear of

Table 7.

TOTAL PECTIN CONTENT OF PROCESSED BLACKBERRIES

		Total Pectin			
		Cans		Jars	
	Days After	Replication		Replication	
Basis	Processing	I	II	I	II
		%	%	%	%
Dry Weight	0	7.75	6.95	6.66	9.62
	3	7.01	8.13	8.26	8.00
	7	6.80	7.30	7.29	7.30
	14	5.00	8.48	6.11	6.12
	28	6.68	8.27	8.00	4.92
Fresh Weight	0	0.381	0.373	0.387	0.495
	3	0.375	0.448	0.458	0.388
	7	0.346	0.396	0.391	0.366
	14	0.258	0.517	0.309	0.290
	28	0.321	0.452	0.429	0.230

processed blueberries was similar to the ones used in case of strawberries, raspberries and blackberries with the exception that, here, a transducer value of 0.01 was used instead of 0.0025, with a 1000 pound ring. When a transducer value of 0.0025 was used, the work diagrams were falling outside the scale and hence could not be measured. The texture measurements of 100 grams of fresh blueberries for both the replications were 168.00 and 163.48 pounds force as maximum force, 139.20 and 135.62 inch pounds, as total work and 116.80 and 112.90 inch pounds, as partial work.

The work diagrams of all the samples were similar in nature. They consisted of a gradual, but wavy rise, from the base line in the beginning followed by a sharp rise to a peak, and then an almost vertical return to the base line. A characteristic work diagram for processed blueberries is shown in Figure 5.

A measurement of the length AE and the angle BAE did not show any significant pattern and were, hence, disregarded as a criteria for measuring the texture of processed blueberries.

The means of the texture measurement, as calculated on the basis of four samples of 100 grams of drained weight, are tabulated in Table 8 and shown in Figure 9.

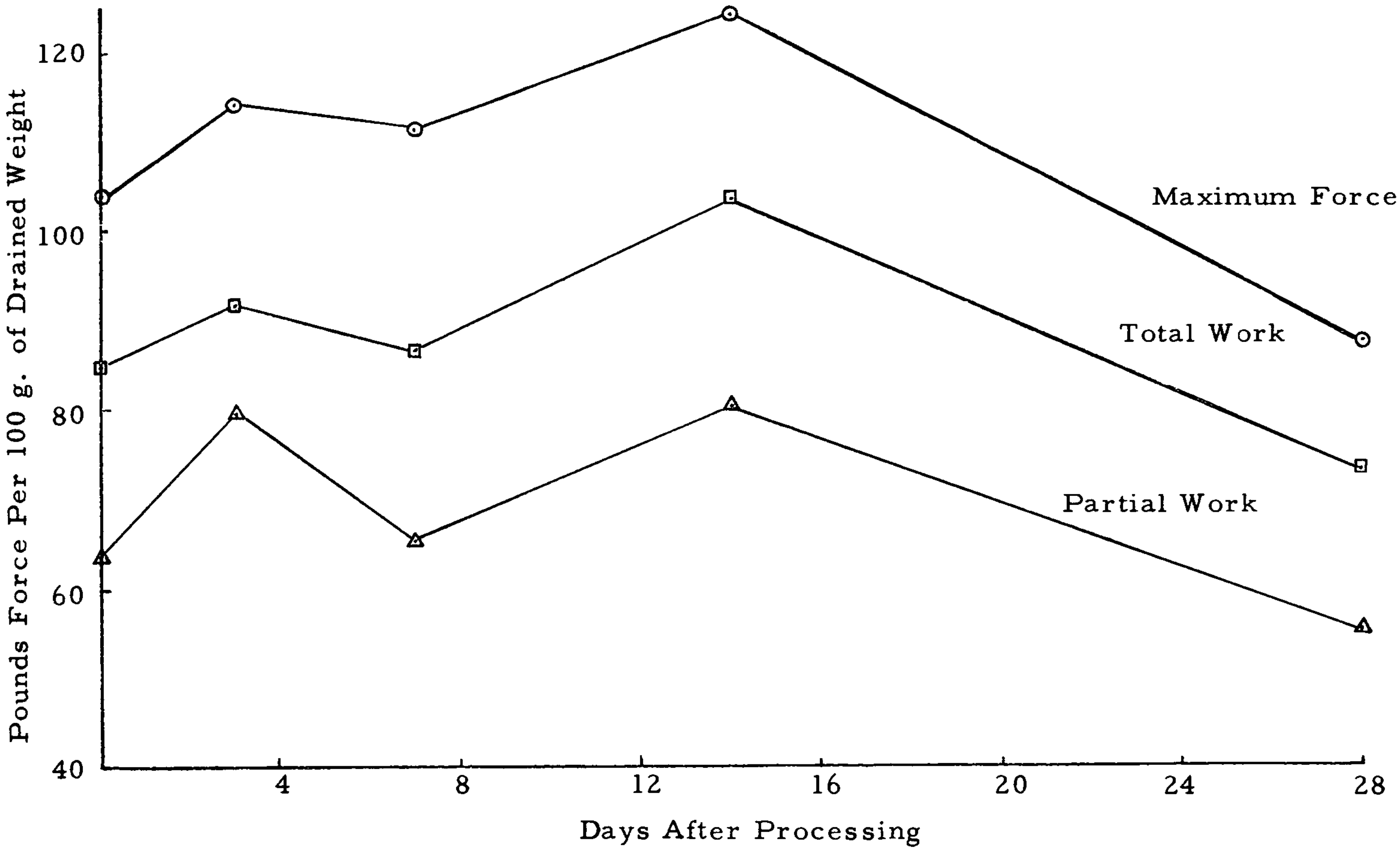
At the end of 28 days of storage at 100° F, an increase in the texture of the processed and stored blueberries was observed, with the exception of first replication in case of jars. Upon storage there

Table 8. TEXTURE MEASUREMENTS ON BLUEBERRIES

Texture Measurement*	Days After Processing	Cans Replication I	Cans Replication II	Jars Replication I	Jars Replication II
		Inches+			
Maximum Force	0	92.85	83.27	102.73	104.58
	3	89.54	81.56	126.60	101.72
	7	88.50	78.88	123.74	99.02
	14	98.01	92.97	133.19	115.14
	28	108.52	91.41	64.44	111.14
		Square Inches#			
Total Work (Area under ACD)	0	72.31	66.32	85.81	83.30
	3	70.20	63.36	93.86	89.19
	7	68.05	62.48	87.86	85.78
	14	74.99	70.45	99.98	106.94
	28	81.10	71.34	49.28	97.56
		Square Inches#			
Partial Work (Area under ABE)	0	54.03	52.50	62.55	64.79
	3	55.10	48.86	70.85	68.75
	7	50.90	46.61	61.50	68.54
	14	58.12	55.13	75.33	85.13
	28	63.70	54.95	36.00	74.54

* All samples on 100 g drained weight basis.
+ Converted to pounds force by multiplying with 80.
# Converted to inch pounds by multiplying with 80.

Figure 9. Texture Measurements of Processed Blueberries
(303 Jars)



was a loss of water from the berries into the surrounding syrup. This gave a rigid structure to the skin, which in turn effected the texture. Thus there was an increase in the texture at the end of 28 days of storage.

The difference in texture between tin and glass was not significant at five percent level, nor was the effect of storage.

Percent Alcohol Insoluble Solids

The method as mentioned for the previous berries was followed. The data obtained are tabulated in Table 2. There was no significant change in the percent A. I. S. between the two containers, nor with storage.

The correlation coefficients between percent A. I. S. and maximum force, total work and partial work were 0.78, 0.78 and 0.80, respectively. Here, unlike the previous three berries, a better correlation was obtained between percent A. I. S. and partial work.

Total Pectin

The technique used for determination of total pectin in blueberries was similar to the one used in case of strawberries, raspberries and blackberries. The data obtained are tabulated in Table 9.

An increase in the amount of total pectin was observed in every case except the first replication of jars, at the end of 28 days

Table 9.

TOTAL PECTIN CONTENT OF PROCESSED BLUEBERRIES

		Total Pectin			
		Cans		Jars	
	Days After	Replication		Replication	
Basis	Processing	I	II	I	II
		%	%	%	%
Dry Weight	0	5.98	5.95	6.37	6.54
	3	5.63	5.76	6.52	6.28
	7	5.57	5.63	6.23	5.97
	14	6.32	6.13	6.85	7.25
	28	6.65	6.06	4.28	6.81
Fresh Weight	0	0.278	0.218	0.324	0.242
	3	0.277	0.205	0.333	0.267
	7	0.202	0.161	0.248	0.250
	14	0.299	0.231	0.353	0.364
	28	0.317	0.221	0.139	0.308

of storage at 100° F. However, the difference was not significant at five percent level. The effect of container was also not significant at this level.

The correlation coefficients between total pectin and maximum force, total work and partial work were 0.83, 0.89 and 0.90, respectively. Hence, a close correlation was observed in all the three cases with partial work being the best.

SUMMARY AND CONCLUSIONS

In this thesis a study was made on the effect of processing and storage on the texture of canned strawberries, raspberries, blackberries and blueberries. These berries were subject to spin-cooking and were subsequently stored at 100° F for a period of 28 days.

The results indicated the following conclusions:

1. There was a slight decrease in the firmness of all the berries except blueberries, where an increase was obtained.

2. A linear relationship existed between sample size and texture, as measured by the total work.

3. Berries, processed and stored in tin and glass containers for a storage time of 28 days at a temperature of 100° F, showed no significant difference in the texture as measured by the Kramer Shear-press.

4. Percent A. I. S. and total pectin content between berries packed in tin and glass containers and also a storage time of 28 days at 100° F showed no significant difference.

5. Strawberries and blueberries gave a maximum correlation between texture, as measured by partial work, and total pectin. In case of raspberries and blackberries, the correlation was best between maximum force and A. I. S.

6. Maryland Shear-press gave consistant, characteristic work diagrams for all four berries.

BIBLIOGRAPHY

1. Appleman, C. O. and C. M. Concord. Pectic constituents of peaches and their relation to softening of fruit. College Park, Maryland, 1926. 8 p. (Maryland. Agricultural Experiment Station. Bulletin No. 283)

2. Appert, Nicholas. L'art de conserver. Paris, Patrie et Gie, 1810. Translated by K. G. Bitting. The book for all households on the art of preserving animal and vegetable substances for many years. Chicago, Glass Container Association of America, 1920. 113 p.

3. Bouyoucos, G. J. and R. E. Marshall. A pressure tester for small fruits and vegetable tissues. Proceedings of the American Society of Horticultural Science 57:211-213. 1951.

4. Caldwell, J. S. Factors influencing quality of sweet corn. Canning Trade 61:7-8. 1939.

5. Carre, M. H. An investigation of the changes which occur in the pectic constituents of stored fruit. Biochemical Journal 16: 704-712. 1922.

6. Clark, J. H. Pressure tests of strawberries. New Jersey, 1928. p. 227-228. (New Jersey. Agricultural Experimental Station. Annual report for the year 1928)

7. Conard, C. M. A furfural yielding substance as a splitting product of protopectin during the ripening of fruits. Plant Physiology 5:93-103. 1930.

8. Crafts, A. S. Cellular changes in certain fruits and vegetables during blanching and dehydration. Food Research 9:442-452. 1944.

9. Culpepper, C. W., J. S. Caldwell and H. H. Moon. A physiological study of development and ripening in the strawberry. Journal of Agricultural Research 50:645-696. 1935.

10. Decker, R. W. et al. Modification of the Shear press. Food Technology 11:343-347. 1957.

11. Denel, H. and E. Stuntz. Pectic substances and pectic enzymes. Advances in Enzymology 20:341-382. 1958.

12. Geo, M. D. Effect of fertilizers on firmness and flavor of strawberries in North Carolina. Proceedings of the American Society of Horticultural Science 28:231-235. 1931.

13. Greve, E. W. and J. S. Shoemaker. Reaction of nitrogen fertilizer to the firmness and composition of strawberries. Proceedings of the American Society of Horticultural Science 27:183. 1930.

14. Hall, C. B. and R. A. Dennison. The relationship of firmness and pectinestrase activity of tomato fruits. Proceedings of the American Society of Horticultural Science 75:629-631. 1960.

15. Haller, M. H., P. L. Harding and H. R. Dean. The interrelation of firmness, dry weight and resipation in strawberries. Proceedings of the American Society of Horticultural Science 29:330-334. 1932.

16. Haller, M. H. Fruit pressure tester and their practical applications. 1941. 21 p. (U. S. Dept. of Agriculture. Circular No. 627)

17. Hamson, A. R. Factors which condition firmness in tomatoes. Food Research 17:370-379. 1952.

18. Hamson, A. R. Measuring firmness of tomatoes in a breeding program. Proceedings of the American Society of Horticultural Science 60:425-437. 1952.

19. Haut, I. C., J. E. Welester and G. W. Cochran. The influence of commercial fertilizers upon the firmness and chemical composition of strawberries and tomatoes. Proceedings of the American Society of Horticultural Science 33:405-410. 1935.

20. Hedrick, V. P. Systematic pomology. New York, Macmillan, 1925. 88 p.

21. Helgason, J. H. Application of the Maryland Shear press in determining the texture of canned whole kernel corn. M. S. thesis. Corvallis, Oregon State College, 1953. 58 numbered leaves.

22. Horner, G. Notes on the texture of canned fruits and vegetables. In: Annual Report of Fruit and Vegetable Preservation Research Station, Campden, England, for the year 1933-34. p. 44-49.

23. Isherwood, F. A. Some factors involved in the texture of plant tissues. London Society of Chemical Industry, Monograph No. 7:135-143. 1960.

24. Jacobs, M. B. Chemistry and technology of food and food products. Vol. 3. New York, Interscience, 1951. p. 1773-2580.

25. Kattan, A. A. Changes in color and firmness during ripening of detached tomatoes and the use of a new instrument for measuring firmness. Proceedings of the American Society of Horticultural Science 70:379-384. 1957.

26. Kertesz, Z. I. The chemical determination of the quality of canned green peas. Geneva, 1935. 26 p. (New York. State Agricultural Experiment Station. Technical Bulletin No. 233)

27. Kertesz, Z. I. and R. J. McCollock. Enzymes acting on pectic substances. Advances in Carbohydrate Chemistry 5:79-102. 1950.

28. Kertesz, Z. I. Enzymes of polysaccharide synthesis and degradation. Food Enzymes 49-63. Edited by H. W. Schultz. Starrs, Connecticut, Avi. 1960. 144 p.

29. Kertesz, Z. I. The pectic substances. New York, Interscience, 1951. 628 p.

30. Knight, L. D. M. A contribution to the chemistry of Raspberry varieties with special reference to its bearing on canning quality. Bristol, Ireland, 1932. p. 32-46. (Bristol University. Agriculture Horticulture Research Station. Annual Report for the year 1932)

31. Kramer, A. New Shear press predicts quality of canned limas. Food Engineering 23:112-113, 187. 1951.

32. Kramer, A. The shear press: A device for measuring food quality. The Canner 112:34-40. 1951.

33. Kramer, A. and B. A. Twigg. Principles and instrumentation for the physical measurement of food quality with special reference to fruit and vegetable products. Advances in Food Research 9:153-220. 1959.

34. Kramer, A. The economics of the shear press. In: Summaries of the First Regional Shear Press Symposium. Washington, D. C. Laboratory of Electronic Engineering Inc., 1960. p. 27.

35. Kramer, A. The shear press, a basic tool for the food technologist. The Food Scientist 5:7-16. 1961.

36. Kramer, A. and K. Aamlid. The shear press, an instrument for measuring the quality of foods. III. Application to peas. Proceedings of the American Society of Horticultural Science 61:417-423. 1953.

37. Lappin, W. Processed fruits and vegetables and mandatory or permissive standards. In: Summaries of the First Regional Shear Press Symposium. Washington, D. C. Laboratory of Electronic Engineering Inc. 1960. p. 27.

38. Lewis, C. I., A. E. Murneek and C. C. Cate. Pear harvesting and storage investigations in Rogue River Valley (Second report). Corvallis, 1919. 39 p. (Oregon. Agricultural Experiment Station. Bulletin No. 162)

39. Lineweaver, H. and E. F. Jansen. Pectic enzymes. Advances in Enzymology 11:267-295. 1951.

40. Luh, B. S. et al. Effect of ripeness level on consistency of canned tomato juice. Food Technology 14:635-639. 1960.

41. Mackey, A. O. Discernment of primary tastes in the presence of different food textures. Food Technology 10:238-240. 1956.

42. Magness, J. R. and G. F. Taylor. An improved type of pressure tester for the determination of fruit maturity. 1925. 8 p. (U. S. Dept. of Agriculture. Departmental Circular 350)

43. Martin, W. M. Apparatus for evaluating tenderness in peas. Canner 84:108-112. 1937.

44. McCready, R. M. and E. A. McComb. Pectic constituents in ripe and unripe fruit. Food Research 19:530-535. 1954.

45. Meyer, L. H. Food chemistry. New York, Reinhold, 1960. 385 p.

46. Morris, O. M. Studies in apple storage. Pullman, 1925. 44 p. (Washington. Agricultural Experiment Station. Bulletin 193)

47. Morris, T. N. Changes in the pectic substances of fruit during storage, 1934. p. 155-161. (Department of Science and Industrial Research. Report of the Food Investigation Board for the year 1933)

48. Naji, D. R. and A. G. Norman. Studies on pectin. II. The estimation of the individual pectic substances in nature. Biochemical Journal 22:596-604. 1928.

49. Nightingale, G. T., R. M. Addoms and M. A. Blake. Development and ripening of peaches as correlated with physical characteristic, chemical composition and histological structure of the fruit flesh. (Histology and Microchemistry II) New Brunswick, New Jersey, 1930. 16 p. (New Jersey. Agricultural Experiment Station. Bulletin 507)

50. Overhoser, E. L. and L. L. Claypool. The retention of fertilizers to respiration and certain physical properties of strawberry. Proceedings of the American Society of Horticultural Science 28:220-224. 1931.

51. Postlmayer, H. L., B. S. Luh and S. J. Leonard. Characterization of pectin changes in freestone and clingstone peaches during ripening and processing. Food Technology 10:618-625. 1956.

52. Reeve, R. M. Relation of histological characteristics to texture of seed coat of peas. Food Research 12:10-23. 1947.

53. Reeve, R. M. and L. B. Leinback. Histological investigations of texture in apples. I. Composition and influence of heat on structure. Food Research 18:592-603. 1953.

54. Rendle, T. Observations on changes in raspberries after picking. Analyst 58:69-77. 1933.

55. Rose, D. H., M. H. Haller and P. L. Harding. Relations of temperature of fruit to firmness in strawberries. Proceedings of the American Society of Horticultural Science 32:429-433. 1934.

56. Shutak, V. G., R. Hindle and E. P. Christopher. Factors associated with ripening of Highbush blueberry fruits. Proceedings of the American Society of Horticultural Science 68: 178-183. 1956.

57. Sidwell, A. P. and R. W. Decker. Shear test indicates tenderness. Agricultural Marketing 4:10-11. 1959.

58. Simpson, J. I. and E. G. Halliday. Chemical and histological studies of the disintegration of cell membrane material in vegetables during cooking. Food Research 6:189-206. 1941.

59. Sistrunk, W. A. Effect of certain field and processing factors on the texture of Blue Lake green beans. Ph. D. thesis. Corvallis, Oregon State College, 1959. 144 numbered leaves.

60. Smithies, R. H. Effect of chemical constitution on texture of peas. London Society of Chemical Industry, Monograph No. 7: 119-127. 1960.

61. Talburt, W. F., C. C. Nimmo and M. J. Powers. Texture problems in raspberry canning. Western Canner and Packer 42:16-19. 1950.

62. Weckel, K. G. Tenderometer, Shear press and A.I.S. values of Alaska and perfection peas. Food Packer 35:24-26. 1954.

63. Weir, T. E. and C. R. Stocking. Histological changes induced in fruits and vegetables by processing. Advances in Food Research 2:297-342. 1949.

64. Woodruff, R. E., D. H. Dewey and H. M. Sell. Chemical changes of Jersey and Rubel blueberry fruit associated with ripening and deterioration. American Society of Horticultural Science 75:387-401. 1960.

65. U. S. Department of Agriculture. United States standards for grades of canned blueberries. Washington, 1951. 8 p.

66. U. S. Department of Agriculture. United States standards for grade of canned blackberries and other similar berries. Washington, 1956. 6 p.

67. U. S. Department of Agriculture. United States standards for grades of canned raspberries. Washington, 1958. 6 p.