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Pectin degradation and the firmness of the canned sweet potatoes

Inocencio Martinez

To the Graduate Council:

I am submitting herewith a thesis written by Inocencio Martinez entitled "Pectin degradation and the firmness of the canned sweet potatoes." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Melvin R. Johnston, Major Professor

We have read this thesis and recommend its acceptance:

I. E. McCarty, H. D. Swingle

Accepted for the Council:
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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 26, 1968

To the Graduate Council:

I am submitting herewith a thesis written by Inocencio Martinez entitled "Pectin Degradation and the Firmness of the Canned Sweet Potatoes." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology.

Melvin B. Johnston
Major Professor

We have read this thesis and recommend its acceptance:

Homer D. Swingle

H E McCarty

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

PECTIN DEGRADATION AND THE FIRMNESS OF THE CANNED SWEET POTATOES

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Inocencio Martinez

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ABSTRACT

From a culinary standpoint, firmness is one of the most important attributes of thermally processed sweet potatoes; nevertheless, the consistent production of a canned sweet potato that would hold its shape while being prepared for the table is a problem confronting the sweet potato processors. Although considerable research has been conducted on variables generally associated with the firmness of cooked fruits and vegetables, the firmness of canned sweet potatoes is an attribute which is not fully understood.

This study was undertaken in an attempt to improve the firmness of canned sweet potatoes. The following four major studies were conducted:

1. Effect of four thermal processing treatments on the firmness of the canned product,
2. The relationship between changes in the AIS content during thermal processing and the firmness of the canned product,
3. The relationship between changes in the pectic materials during thermal processing and the firmness of the canned product, and
4. The relationship between the diameter and the firmness of the canned product.

The firmness of the raw and canned sweet potatoes was rated objectively using the ASCO Firmness Meter and subjectively by taste

panel evaluation. The changes in the AIS and in the pectic substances were determined chemically. The results of the pectin analysis were expressed as percentage AGA of the dry AIS.

Under the conditions of this study, several conclusions were indicated:

1. The possibility of favorably influencing the firmness of canned sweet potatoes by thermal processing treatments designed to effect low degrees of cooking was indicated.
2. Thermal processing effected a marked decrease in the AIS content. The two high processing temperature treatments had a greater solubilizing effect on the AIS, regardless of processing time, than the two low processing temperature treatments. There was no relationship between the AIS changes and the firmness of the canned product.
3. Thermal processing effected a marked decrease on the pectic substances. The two low heat penetration ratio treatments effected a lower degree of depolymerization on the total pectin than the two high heat penetration ratio treatments. The changes in the pectic substances were not significantly related to the firmness of the canned product.
4. Storage time was found to be a significant factor in the objective evaluation of firmness and in the chemical analysis for the AIS and pectin content of the canned sweet potatoes.

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CHAPTER I

INTRODUCTION

Kattan and Littrell (24)* stated that firmness was among the most important attributes of quality of canned sweet potatoes, and yet this attribute was possibly the least understood or controlled.

Culpepper and Magoon (12) stated that in the use of canned sweet potatoes for culinary purposes it was sometimes desirable to have a product that was very firm and that would hold its form while being prepared for the table. They found that freshly dug roots were very firm and stated that this fact seemed to suggest a possible solution of the problem of mushy canned sweet potatoes.

Baumgardner (4) stated that, although stored sweet potatoes were normally not utilized for canning, the consistent production of a firm product was a major processing problem. They further stated that it was often necessary to hold the canning stock for a week or more following harvest and that the roots were subjected to a wide range of temperatures during this time, depending upon the season and time of harvest.

Baumgardner and Scott (5) stated that a major problem confronting the processor of small whole sweet potatoes was the consistent production of a firm product. They stated that a certain degree of firmness was required in order to insure the retention of the original shape and

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*The numbers in parentheses represent similarly numbered references in the Literature Cited.

form necessary for commercial acceptance. They found that processing immediately after harvest produced a product of adequate firmness, but the roots were quite soft when processing was delayed. However, they stated that, although this effect was recognized, a holding period of varying lengths continued to be the practice.

With the problem of the canned sweet potato firmness in mind, this study was made in an attempt to:

1. Ascertain the effects of various processing treatments on the firmness of the canned sweet potatoes,
2. Study the relationship between changes in the pectic materials during processing and the firmness of the canned sweet potatoes,
3. Study the relationship between changes in the alcohol insoluble solids (AIS) content during processing and the firmness of the canned sweet potatoes, and
4. Study the relationship between the diameter and the firmness of the canned sweet potatoes.

CHAPTER II

REVIEW OF LITERATURE

I. EFFECT OF VARIOUS PROCESSING TREATMENTS ON THE FIRMNESS OF THE CANNED SWEET POTATOES

Two references were found in the literature which mentioned the relationship of different processing times to firmness changes of processed sweet potatoes. Baumgardner and Scott (5) studied the effect of processing on the firmness of Nemagold variety. Using a temperature of 240°F. and processing times of 20, 40, 50, and 60 minutes, they found that processing caused pronounced changes in the AIS constituents. They also found that processing longer than 20 minutes resulted in pronounced alteration in the pectic constituents. However, the effect of the various cooking times on the chemical changes could not be correlated to the firmness of the sweet potatoes since roots processed 60 minutes were just as firm as those processed 20 minutes.

Twigg and Scott (38) stated that decreasing processing time would not result in increased firmness of the cooked product. Repeated trials of cooks at 240°F. for periods greatly exceeding the recommended processing times showed that increasing the time of processing did not result in a softer product and that decreasing the time of the process did not result in a firmer product. The tests also showed that

greater firmness could only be obtained by undercooking to such an extent that spoilage would be inevitable.

II. PECTIN CHANGES DURING PROCESSING AND THEIR RELATION TO FIRMNESS OF PROCESSED FRUITS AND VEGETABLES

Pectin is generally recognized as being the cementing substance between cells. Kertesz (25) and Bettelheim and Sterling (7) located the pectic substances in the middle lamella between adjoining cells and stated that they were assumed to consist primarily of calcium salts of pectic and pectinic acids. It was believed that the calcium between polygalacturonic acid molecules was responsible for increasing or maintaining the cementing power between adjacent cells (10). This belief was supported by the work of Van Buren (39) who studied the effect of calcium during brining of Winsdor cherries and found that the calcium formed insoluble salts with pectic acid and made possible the growth of large calcium pectate aggregates that served effectively in strengthening cell walls and enhancing intercellular adhesion.

It is generally agreed that there are three pectin fractions in fruit tissue. Van Buren (39) described them as follows:

1. A water soluble fraction which was commonly referred to as pectinic acid. Bettelheim and Sterling (7) added that this fraction was low in calcium content and that it contributed little to any cementing effect.

2. A fraction soluble in Calgon (sodium hexametaphosphate) or other calcium-complexing agent solutions. This fraction was less highly methoxylated and formed insoluble salts with calcium ions. This was called pectic acid. Bettelheim and Sterling (7) added that the relatively high calcium content of this fraction indicated that it was derived partly from the middle lamella, since the middle lamella was rich in calcium; that staining, in conjunction with Calgon application, indicated or appeared to support the view that pectic materials were removed from the middle lamella in the cell wall; and that the low intrinsic viscosity in this fraction was possibly a result of the medianism of the solvent action, that is, since the large metaphosphate polymers of Calgon could not penetrate deeply into the matrix of insoluble polysaccharides only molecules exposed at the surfaces would be brought into solution.
3. The third fraction, whose native state was unknown, was called protopectin. This fraction was brought into solution with dilute acid at elevated temperatures. According to Bettelheim and Sterling (7), the removal of this fraction was effected by solubilizing the calcium and other insoluble salts, breakage of hydrogen bonds, and breakage of primary valence bonds. They found that this depolymerization resulted in decreased intrinsic viscosity. They inferred that, since this value was higher than that of the Calgon-soluble fraction, it was

composed of higher molecular weight molecules. It was generally agreed that this fraction was the parent pectin and that it was primarily responsible for the cementing effect between adjacent cells.

Numerous studies (3, 5, 11, 13, 25, 30) have been made on the transformations which occur in fruit during maturation. They have shown that ripening was accompanied by a decrease in protopectin and an increase in soluble pectin. These changes were similar to those encountered during processing of fruits and were irreversible in nature (1, 7, 26, 30, 34).

Numerous studies have shown that changes in pectic substances are responsible for firmness loss of fruits during ripening and during processing. Kertesz (25) found that the firmness of cherries depended primarily on the natural pectin present, and McCready and McComb (28) added that when this pectin was destroyed the cherries became soft. Jacobs (22) suggested that the pectic substances of tomatoes formed a firm gel around the fibrous tissue of the fruits, their function being to prevent the collapse of the fruit and to aid in keeping it firm. As the pectin components of the tomatoes were converted to less complex units, there was a decrease in firmness and ultimate collapse of the fruit. Van Buren (39) found that during ripening of Winsdor cherries, the proportion of protopectin decreased, resulting in a softer texture of brined cherries with increasing maturity of the fresh material. The protopectin decrease was accompanied by a decrease in the intrinsic

viscosity of the pectic material, indicating a decrease in the molecular weight of the pectic substances.

Simpson and Halliday (34) associated the conversion of protopectin to soluble pectin and a reduction of total pectic substances with the softening of vegetables during cooking. They found that progressive changes occurred in the pectic substances of carrots and parsnips during cooking. In every instance these changes were in the direction of an increase in pectin and pectic acid and a decrease in protopectin and in the total pectic substances. They stated that the changes were similar to those which occurred during the ripening of fruit and vegetable tissue and that in both instances they were related to the softening which took place. Using a staining technique, coupled with microscopic examination, they found that the cell walls revealed that the loss of pectic substances was particularly evident in the region of the primary cell wall and intercellular spaces.

Baumgardner and Scott (5) found that the degree of firmness in the sweet potato was mainly associated with changes in the pectic substances. They found that as firmness values decreased on processing the protopectin contained in the AIS extractable materials also decreased. Processing caused drastic changes in the nature of the pectic substances. Cooking times longer than 20 minutes at 240°F. affected the ethanol-precipitation characteristics of the pectic substances. However, they stated that apparently the change caused by prolonged processing was not related to firmness since there was no difference in firmness between the sweet potatoes cooked 20 minutes and those cooked 60 minutes.

Ahmed and Scott (1) found that the nature and extent of the pectic changes effected by baking or processing were similar to those occurring during the storage of the fresh roots. Studying the effect of pectin changes during curing and during cooking as related to the characteristics of the cooked sweet potato, they found that the intrinsic viscosity values for the water-soluble and oxalate-soluble fractions decreased markedly after curing and continued to decrease at a lesser rate during the storage period. This indicated that depolymerization of the respective molecules occurred during the curing and storage periods, possibly as a result of enzymatic activity. They also found that baking and processing resulted in a reduction in the total anhydrogalacturonic acid content, particularly in the acid-soluble fraction (protopectin). There also occurred a reduction in the degree of esterification and in the intrinsic viscosity values of the extractable polygalacturonides. The authors stated that softness and breakdown of the processed roots, which were particularly evident when stored roots were processed, differed greatly with varieties and could be related to the content and nature of the pectic constituents. They further stated that the lower content of the acid-soluble fraction and the lower viscosities of the water and oxalate-soluble fractions (pectinic and pectic acids, respectively) in the stored roots would substantiate such a relationship.

Roberts and Proctor (32) studied the effects of radiation on the starch-containing cells of the Irish potato. Using microchemical methods, they reported an alteration in the pectic substances of the middle

lamella which resulted in a softening of the tissue. Unlike the action of heat, irradiation had no effect on the cellulose-containing cell structures, and it did not change the form of starch granules. However, from this study one could only infer that the pectic substances were primarily responsible for the firmness loss since no quantitative measure of texture changes or pectic alterations were reported.

McArdle and Nehemias (26) studied the effect of gamma radiation on the pectic constituents of fruits and vegetables. They found a relationship between radiation-induced softening of apple and carrot tissues and the changes which occurred in the pectic substances. This study showed that gamma radiation caused a decrease in the total pectic substances, indicating a breakdown of pectin and pectates to simpler non-pectic materials. The most extensive changes occurred in the protopectin which was almost completely destroyed by the high radiation dose levels. The changes were manifested by decreased viscosities of all three pectic fractions, indicating that depolymerization occurred during irradiation. The authors stated that a destruction of all pectic substances probably took place simultaneously; but protopectin, having the most complex molecular structure, was reduced most rapidly. They concluded that, since insoluble pectic materials maintain cellular adhesion in plant tissues, the destruction of protopectin by ionizing radiation appeared to be the cause of radiation-induced softening of fruits and vegetables. They also concluded that alteration of protopectin in the intercellular areas allowed the tissue to separate and loss of texture occurred.

Bettelheim and Sterling (8) studied the physical attributes of Irish potato texture during cooking. They stated that cell separation was the principal physical attribute of a mealy potato, and the degree of cell separation was a measure of the degree of mealiness. They also stated that certain characteristics of the pectic materials played a role in the development of textural quality. Where the starch tended to cause cell rounding and separation, the main role of the pectic materials was to counterpose an adhesive force tending to prevent the resulting cell separation. This passive role of the pectic materials was also recognized by Whittenberger and Nutting (40) who studied the sloughing of the tissues of the Irish potato during cooking. They stated that cells separated because of failure of the intercellular cement which was made of pectic substances. This failure was brought about either by chemical changes in the pectic substances, by mechanical fracture due to pressure developed in the cells and tissues, or by a combination of the two means. In the potato tissue, pressure within the cells and tissues was due to expansion of the starch as it gelatinized.

Bettelheim and Sterling (7) found that the major effect of cooking on the pectic materials was solubilizing. A constant effect found in all three fractions was a lower methoxyl content in the cooked Irish potato. They stated that this was due to enzymatic activity in the first few minutes of heating, to direct heat-induced deesterification, or to removal of fractions of higher ester content by the cooking water.

They disagreed with other workers in that they found no direct relationship between the characteristics of the pectic materials and potato texture. They assumed that this lack of relationship was due to the inadequacy of the methods of pectin analysis used by earlier workers which did not disclose differences in the chemical nature of the various pectic substances in the middle lamella, and that the relationship could be masked by other factors such as starch.

Studying factors which affected the cooking qualities of Irish potatoes, Sweetman (36) found that cooking resulted in an increase in the solubility of the pectic constituents. He agreed with Bettelheim and Sterling (7) in that he could find no direct relationship between these changes and the mealiness of the cooked product.

III. CHANGES IN ALCOHOL INSOLUBLE SOLIDS IN SWEET POTATO DURING PROCESSING AND THEIR RELATION TO FIRMNESS OF THE PROCESSED PRODUCT

Baumgardner and Scott (5) studied the effects of storage at various temperatures on the pectin and starch components of the sweet potato and related the effects of these changes to the firmness of the processed product. They found that processing caused pronounced changes in the AIS constituents, the most apparent of which was a reduction in the per cent AIS reflecting the hydrolysis of starch into sugars. Chemical analyses showed that differences in pectic substances were closely associated with the degree of firmness and that, compared

to these differences, starch differences were slight and not consistently related to firmness.

Culpepper and Magoon (12) studied the chemical composition of the sweet potato canned immediately after harvest, after storage, and after curing. They related the chemical changes effected by cooking to the difference in plasticity and firmness of different sweet potato varieties. The authors stated that starch was the chief constituent giving firmness to the canned product. They found that during cooking there was always a pronounced increase in the reducing sugars of which maltose was the principal component. This increase in maltose was accompanied by a corresponding decrease in starch. Since maltose resulted from the conversion of starch, this change greatly affected the softness of the canned product. In addition, they also stated that the hydrolyzable polysaccharides of the sweet potato consisted almost entirely of starch and that during cooking large quantities were converted into soluble products, chiefly maltose; but in some varieties considerable quantities were changed to dextrin-like forms. They found that where there was high dextrin content the material was soft in texture.

Jenkins and Gieger (23) reported that the AIS content of the sweet potato was greatest in the raw roots, but that about one-third of this fraction was converted to sugars during the first 30 minutes of baking at 200°F. The conversion of the hydrolyzable part of the AIS into sugars would account for the increase in reducing sugars reported by Culpepper and Magoon (12). This increase, in turn, would indicate a

decrease in the AIS during cooking. Thus, a decrease in the AIS during cooking could be related to firmness loss of the cooked sweet potato.

Kattan and Littrell (24) studied pre- and post-harvest factors affecting the firmness of the canned sweet potato. In various experiments they found that the percentage of AIS in the canned product was positively related to firmness. They found that early September harvest consistently produced a firmer product than the October harvest, and they associated the delay in harvest with a decrease in the AIS. Irrigation was found to increase the AIS percentage and was related to a firmer canned product. Of all the factors studied, post-harvest handling had the greatest effect on firmness of the canned product. They showed that increased duration of storage at room temperature and curing caused a progressive decrease in the firmness of the canned product. This decrease in firmness was associated with a rapid decrease in AIS and starch. In contrast, when the raw product was stored at 35°F. the firmness of the canned product continued to increase. This increase in firmness was associated with increases in the AIS and starch content of the canned product.

IV. DIAMETER OF THE SWEET POTATO AND ITS RELATIONSHIP TO THE FIRMNESS OF THE CANNED PRODUCT

No references could be found in the literature concerning the relationship between sweet potato diameter and the firmness of the canned product. This portion of the study was not included in the

original experimental design. However, since data on the diameter of the raw and canned stocks were gathered, an attempt was made to explore the possibility of such relationship.

CHAPTER III

MATERIALS AND METHODS

I. TREATMENTS

The two sweet potato varieties (Centennial and Goldrush) used in this study were grown on The University of Tennessee Agricultural Experiment Station Farm near Knoxville, Tennessee. They were harvested mechanically at comparable stages of maturity on October 29, 1964.

Beginning the day of harvest, both varieties were stored at 80°F. and 80 per cent relative humidity for ten days. They were then canned in the facilities of the Food Technology Department of The University of Tennessee.

Both varieties were prepared for canning by preheating at 130°F. for 30 minutes. This was followed by peeling by immersing in a 12 per cent concentration of boiling lye. The Centennial variety was immersed for 2 minutes and the Goldrush variety was immersed for 2-1/2 minutes. After peeling, the roots were washed, trimmed, dipped in a 1 per cent solution of citric acid, rinsed in fresh water, and placed in No. 303 cans. Each can was filled with 240 grams of sweet potatoes, plus cold cover syrup to a headspace of 1/2 inch. This was followed by thermal processing. The four processing treatments used are described in Table I. These treatments were triplicated within 24 hours.

TABLE I

HEAT PENETRATION DATA, DEGREE BRIX OF SYRUP, AND THERMAL PROCESSING TREATMENT NUMBERS FOR CANNED SWEET POTATOES

Heat Penetration Factor	Degree Brix of Syrup and Heat Penetration Data			
	Treatment No. 1	Treatment No. 2	Treatment No. 3	Treatment No. 4
	25 brix	40 brix	25 brix	40 brix
RT	240°F.	240°F.	250°F.	250°F.
j	1.03	0.70	1.03	0.70
f_h	12.13	28.70	12.13	28.70
f_2	19.60	55.20	19.60	55.20
x^1_{bh}	16.90	31.70	16.90	31.70
F_o	3.0	3.5	3.0	3.5
IT	160°F.	160°F.	160°F.	160°F.
B_B	24.2 min.	37.0 min.	15.0 min.	24.0 min.

The heat penetration data for the four treatments were calculated using procedures outlined in "Calculation of Processes for Canned Foods" (9), from recommendations in "Processes for Low-Acid Canned Foods in Metal Containers" (31), as well as from recommendations by Gerald R. Bee of the National Canners Association Research Laboratories (6).

After processing the cans were cooled to 100°F. in running water and stored at room temperature for 30 days before starting chemical analyses of their contents. Approximately 30 days elapsed between canning and the opening of the first replication of all four treatments (two varieties). Likewise, approximately 30 days elapsed between analyses of each successive replication (Table II).

The object of using two different processing temperatures, combined with syrup of two different sugar concentrations and four different processing times (Table I) in this study, was to achieve equal of comparable sterilization values and different degrees of cooking during thermal processing. In this manner it was attempted to study the possibility of controlling the firmness of the canned sweet potatoes by means of thermal processing. A higher cooking effect would normally be associated with a higher degree of tissue breakdown and loss of firmness in fruits and vegetables.

TABLE II

VARIETY, REPLICATIONS, TREATMENT NUMBERS, AND APPROXIMATE STORAGE TIME AT ROOM TEMPERATURE FOR CHEMICAL ANALYSES OF CANNED SWEET POTATOES

Variety	Replication	Approximate Storage Time at Room Temperature* Treatment No. 1	Treatment No. 2	Treatment No. 3	Treatment No. 4
Centennial and Goldrush	1	30**	30	30	30
	2	60	60	60	60
	3	90	90	90	90

*Treatment numbers and description are shown in Table I, page 16.

**Number of days.

II. METHODS OF ANALYSIS

Diameter of Raw Sweet Potatoes

Three lye-peeled roots were picked at random for each replication of each treatment (four treatments, three replications, two varieties). The diameter of each root was obtained by measuring the circumference around the thickest section and substituting in the equation "Diameter equals circumference divided by 3.1416." Measurements were taken to the nearest 0.1 centimeters and the diameter was expressed in centimeters.

Diameter of Canned Sweet Potatoes

Three No. 303 cans were opened for each replication of each treatment, and their contents were pooled. Three roots were picked at random from the pooled contents, and their diameter was measured by the procedure used for measuring the diameter of the raw roots.

Firmness of Raw and Canned Sweet Potatoes

Firmness of the raw and canned roots was measured objectively on roots of known diameter. The instrument used was the ASCO Firmness Meter, Model 30 (Agricultural Specialty Company, Hyattsville, Maryland) as suggested by Kattan and Littrell (24). For the raw roots, a pre-stress load of 500 grams and a linear test load of 1,000 grams were applied for 5 seconds. The linear test load was placed on the third position of the wheel. For the canned roots, a pre-stress load of 200 grams and a linear test load of 100 grams were applied for 5 seconds. The linear test load was placed in the first position of the wheel.

The pre-stress and linear load combinations used in the raw and in the canned roots were decided after preliminary examinations of raw and canned commercial stock showed these combinations to give the greatest firmness differences with different diameter sizes.

This method of objective firmness evaluation showed that the lower the numerical firmness value, the firmer the roots.

Firmness of Canned Sweet Potatoes (Sensory Evaluation)

After six months storage at room temperature, samples representing each treatment (four treatments, three replications, two varieties) were evaluated by a test panel for firmness with respect to a standard.

The standard was selected from several brands of canned commercial stock labelled as "yams" that appeared to be of a moist variety and similar in size and shape to the test samples.

The evaluation of firmness was conducted following the method of Fry (17) as modified by Graham (18). The scoring system was as follows:

Plus 3 - much better than control

Plus 2 - better than control

Plus 1 - slightly better than control

Zero - same as control

Minus 1 - slightly worse than control

Minus 2 - worse than control

Minus 3 - much worse than control.

The panel consisted of seven members. Each panelist was instructed to indicate his preference with respect to the control sample for the attribute of firmness.

The procedure for determining the firmness was by using a common table fork and pressing downward with the side of the pronged end. The length of the fork was at an undetermined angle with respect to the longtitudinal axis of the sample and control roots. All treatments within one replication were judged at one sitting, one variety at a time.

Alcohol Insoluble Solids in Raw Sweet Potatoes

Two kilograms of raw roots of various diameters were peeled with a knife, ground to a fine consistency, and mixed into a homogeneous mixture.

The digestion of the roots for the AIS determination was conducted following the method outlined in the Laboratory Manual of the National Canners Association (37). However, the filtering and washing of the insoluble material was conducted following the method of Shewfelt (33) whose procedure was as follows:

When the digestion of the sample was completed, the contents were cooled to room temperature in running water and filtered through a Buchner funnel using No. 2 filter paper with light suction. The insoluble material was washed four times with 100-ml. portions of 95 per cent ethyl alcohol, followed by washing twice with 100-ml. portions of acetone. During each of the washings with 95 per cent ethyl alcohol and

with acetone, the insoluble material was mixed thoroughly with the wash liquids. The moist insoluble material was transferred to a weighing dish and dried overnight at 122°F.

The dry material was weighed to 0.001 grams, and the percentage AIS was calculated on fresh weight basis. The determination was conducted in triplicate for each of the two varieties.

The dry AIS material was stored in a tightly closed glass jar for future determination of the various pectin fractions.

Alcohol Insoluble Solids in Canned Sweet Potatoes

Three No. 303 cans were selected at random. The combined contents of the three cans were drained for 2 minutes on a No. 2 mesh screen. The product was macerated to a smooth consistency and mixed thoroughly into a homogeneous mass. The method of determining the percentage AIS was the same as the one outlined for the AIS determination in the raw roots. The results were expressed as percentage AIS on drained weight basis. The determination was conducted in triplicate for each replication of each treatment (four treatments, three replications, two varieties).

The dry AIS material was stored in a tightly closed glass jar for future determination of the various pectin fractions.

The syrup of the three cans was combined and stored for 2 to 4 hours at 40°F., after which it was used for the determination of gammas of anhydrogalacturonic acid (AGA) per ml. of syrup.

Gammas of Anhydrogalacturonic Acid per Ml. of Syrup

A 1-ml. aliquot was taken from the composite sample of syrup from the three cans opened for AIS determination. The aliquot was diluted to 100 ml. with distilled water, mixed thoroughly, and filtered through No. 1 filter paper. The gammas of AGA per ml. of syrup were determined colorimetrically in this final dilution. The procedure was as follows:

A 2-ml. aliquot of the diluted sample was pipetted into a 50-ml. Erlenmeyer flask. One ml. of 0.1 per cent carbazole was added, followed by the addition of 12.0 ml. of concentrated sulfuric acid. The acid was added slowly to the walls of the flask from a burette with gentle swirling to prevent premature color development.

The flask was stoppered and the color was developed for exactly 15 minutes at room temperature. The optical density of the solution was then observed using a colorimeter (Bausch & Lomb Spectronic-20) at a wavelength of 540 millimicrons (mu.). A blank sample was prepared using water instead of syrup.

This colorimetric determination was based on Dische's (15, 16) carbazole-hexuronic acid-sulfuric acid reaction. The AGA was reacted with sulfuric acid and the intermediate compound of sulfuric acid-galacturonide mixture was developed with carbazole.

The determination was conducted in triplicate from the composite syrup samples of each replication.

Mg. of Anhydrogalacturonic Acid per Ml. of Alcoholic Insoluble Solids Filtrate

The mixture of AIS and alcohol was allowed to settle until cool. A 1-ml. sample was taken from the filtrate of each of the three AIS determinations for each replication of each treatment (four treatments, three replications, two varieties). This sample was diluted to 250 ml. with distilled water and mixed. A 2-ml. aliquot sample was pipetted into a 50-ml. Erlenmeyer flask and the Mg. of AGA per ml. of alcoholic filtrate was determined following the same procedure outlined for the gammas of AGA per ml. of syrup.

Total Pectin

The dry AIS material of the three determinations for each replication (four treatments, three replications, two varieties) were combined and ground in a small Wiley mill using a 60-mesh screen as suggested by Shewfelt (33). The ground material was mixed thoroughly to obtain a uniform mixture. The total pectin extraction on the dry AIS was conducted following the method of McCready and McComb (27, 29) as modified by Shewfelt (33). The extraction procedure was as follows:

A 0.1-g. sample of the ground AIS was weighed into a 100-ml. beaker. Weights were recorded to 0.001 g. The sample was wetted with two or three drops of ethanol. Forty ml. of 0.5 per cent Versene (Nutritional Biochemicals' brand of Ethylene-diamine-tetraacetic acid) was added to sequester the divalent pectin cations (29). The pH was adjusted to 11.5 with 1N NaOH in order to deesterify the extracted pectin and

pectinates (29). The solution was allowed to stand for 30 minutes with occasional stirring. The pH was then adjusted to 5.0-5.5 with 1N acetic acid to extract the acid soluble fraction, and the solution was allowed to stand for 1 hour with occasional stirring. The solution was transferred to a 100-ml. volumetric flask and 5 ml. of 1N NaOH was added to saponify the extracted pectin to sodium galacturonate (14). This solution was diluted to 100 ml. with distilled water and was allowed to stand for 30 minutes, after which it was filtered through No. 1 filter paper. Five ml. of the filtrate was diluted to 50 ml. with distilled water. The percentage total pectin was determined colorimetrically in this final dilution. The procedure was as follows:

A 2-ml. aliquot of the final dilution was pipetted into a 50-ml. Erlenmeyer flask. One ml. of 0.1 per cent carbazole was added. This was followed by the addition of 12.0 ml. of concentrated sulfuric acid. The acid was added slowly to the walls of the flask from a burette with gentle swirling to prevent premature color development.

The flask was stoppered and the color was developed for exactly 15 minutes. The optical density of the solution was observed using a colorimeter (Bausch & Lomb Spectronic-20) at a wavelength of 540 mu. A blank sample was prepared by using distilled water instead of the pectin solution. The results were expressed as percentage AGA on dry AIS basis.

The colorimetric determination was based on Dische's (15, 16) method of the carbazole-hexuronic acid-sulfuric acid reaction, as modified by Dietz (14) and Shewfelt (33).

The determination was conducted in triplicate in each of the combined AIS samples of the three determinations for each replication.

In this method of total extraction and determination, the concentration of AGA in gammas per ml. was the same as the percentage AGA in terms of dry AIS if the specified sample weight and dilutions were used (33).

Water Plus Versene Soluble Pectin

A similar portion of the dry ground AIS used for the extraction of the total pectin was used for the extraction and determination of the water plus versene soluble pectin fraction.

The extraction of this fraction was conducted according to the method of Shewfelt (33). The procedure was as follows:

A 0.1-g. sample of the dry ground AIS material was weighed to 0.001 g. into a 100-ml. beaker. The sample was wetted with two or three drops of ethanol. Forty ml. of 0.5 per cent Versene were added to sequester the divalent pectin cations (29) and the pH was adjusted to 6.0 with 1N acetic acid. The solution was allowed to stand for 1 hour with frequent stirring after which it was transferred to a 100-ml. volumetric flask and the volume was diluted with distilled water. The solution was shaken vigorously and filtered through No. 1 filter paper. Five ml. of filtrate were pipetted into a 50-ml. volumetric flask and 40 ml. of water were added. This was followed by the addition of 2.5 ml. 1N NaOH in order to saponify the extracted pectin to sodium galacturonate (14). The volume was diluted to 50 ml. with distilled water, and the solution was allowed to stand for 30 minutes.

The percentage water plus versene soluble pectin was determined colorimetrically in the final dilution. The procedure was the same as that outlined for the total pectin determination. The results were expressed as percentage AGA on dry AIS weight basis.

The determination was performed in triplicate in each of the combined AIS samples of the three determinations for each replication.

Water Soluble Pectin

A similar portion of the dry ground AIS used for the extraction of the total pectin was used for the extraction and determination of the water soluble pectin fraction.

The extraction of this fraction was conducted following the method of Shewfelt (33). The procedure was as follows:

A 0.1-g. sample of the dry ground AIS was weighed to 0.001 g. into a 100-ml. beaker. Each sample was wetted with two or three drops of ethanol. Forty ml. of distilled water were added, and the solution was allowed to stand for 1 hour with frequent stirrings in order to solubilize the water soluble pectin fraction. The solution was transferred to a 100-ml. volumetric flask and diluted to volume with distilled water. This was followed by shaking and filtering through No. 1 filter paper. Five ml. of the filtrate were transferred to a 50-ml. volumetric flask. Twenty-five ml. of 1N NaOH were added to saponify the extracted pectin to sodium galacturonate (14), and the solution was allowed to stand for 30 minutes. The solution was diluted to 50 ml.

The percentage water soluble pectin was determined colorimetrically in the final dilution. The procedure was the same as that outlined for the total pectin determination. The results were also expressed as percentage AGA on dry AIS weight basis.

The determination was conducted in triplicate in each of the combined AIS of the three determinations for each replication.

Statistical Analysis

The following effects were tested by means of the analysis of variance:

1. Effect of random sampling on the firmness variability of raw sweet potatoes used for each treatment and for each replication.
2. Effect of treatment on the firmness by sensory evaluation of canned Centennial sweet potatoes.
3. Effect of treatment on the firmness by sensory evaluation of canned Goldrush sweet potatoes.
4. Effect of treatment and storage on the firmness by objective evaluation of canned sweet potatoes.
5. Effect of treatment and storage on the percentage AIS of canned sweet potatoes.
6. Effect of treatment and storage on the percentage total pectin of canned sweet potatoes.
7. Effect of treatment and storage on the percentage versene soluble pectin of canned sweet potatoes.

8. Effect of treatment and storage on the percentage water soluble pectin of canned sweet potatoes.
9. Effect of treatment and storage on the gammas of AGA per ml. of syrup of canned sweet potatoes.
10. Effect of treatment and storage on the Mg. of AGA per ml. of alcoholic filtrate from the AIS determination of canned sweet potatoes.

The BMD02V subroutine (21) on the IBM Model 7040 digital computer (The University of Tennessee Computing Center) was used to perform the analysis of variance calculations.

Calculations for Duncan's new multiple range test were performed for the following effects:

1. Differences in variability in firmness by objective evaluation within treatment means of raw sweet potatoes as affected by random selection.
2. Differences in variability in firmness by objective evaluation within replication means of raw sweet potatoes as affected by random selection.
3. Effect of treatment on the firmness by sensory evaluation of canned Centennial sweet potatoes.
4. Effect of treatment on the firmness by sensory evaluation of canned Goldrush sweet potatoes.
5. Effect of firmness ratings by individual panel member on the firmness by sensory evaluation of canned Centennial sweet potatoes.

6. Effect of firmness ratings by individual panel member on the firmness by sensory evaluation of canned Goldrush sweet potatoes.
7. Effect of treatment on the firmness by objective evaluation of canned sweet potatoes.
8. Effect of storage on the firmness by objective evaluation of canned sweet potatoes.
9. Effect of treatment on the percentage AIS of canned sweet potatoes.
10. Effect of storage on the percentage AIS of canned sweet potatoes.
11. Effect of treatment on the total pectin of canned sweet potatoes.
12. Effect of storage on the percentage total pectin of canned sweet potatoes.
13. Effect of treatment on the percentage versene soluble pectin of canned sweet potatoes.
14. Effect of storage on the percentage versene soluble pectin of canned sweet potatoes.
15. Effect of treatment on the percentage water soluble pectin of canned sweet potatoes.
16. Effect of storage on the percentage water soluble pectin of canned sweet potatoes.
17. Effect of treatment on the gammas of AGA per ml. of syrup of canned sweet potatoes.

18. Effect of storage on the gammas of AGA per ml. of syrup of canned sweet potatoes.
19. Effect of treatment on the mg. of AGA per ml. of alcoholic filtrate of the AIS determination of canned sweet potatoes.
20. Effect of storage on the mg. of AGA per ml. of alcoholic filtrate from the AIS determination of canned sweet potatoes.

The following regression analyses were performed:

1. The percentage AIS of canned sweet potatoes was correlated to the firmness by objective evaluation of raw sweet potatoes.
2. The percentage total pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of canned sweet potatoes.
3. The percentage total pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of raw sweet potatoes.
4. The percentage versene soluble pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of canned sweet potatoes.
5. The percentage versene soluble pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of raw sweet potatoes.
6. The percentage water soluble pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of canned sweet potatoes.

7. The percentage water soluble pectin of canned sweet potatoes was correlated to the firmness by objective evaluation of raw sweet potatoes.
8. The gammas of AGA per ml. of syrup of canned sweet potatoes was correlated to the firmness by objective evaluation of canned sweet potatoes.
9. The mg. of AGA per ml. of alcoholic filtrate from the AIS determination of canned sweet potatoes was correlated to the firmness by objective evaluation of raw sweet potatoes.
10. The mg. of AGA per ml. of alcoholic filtrate from the AIS determination of canned sweet potatoes was correlated to the firmness by objective evaluation of canned sweet potatoes.

The BMD02R subroutine (20) on the IBM Model 7040 computer was used for the stepwise multiple regression analysis.

In the analysis of variance and regression analyses, the statistical significance was calculated at the .05 level of probability according to Snedecor (35). In the analysis of variance, the statistical significance at the .01 level of probability is shown where calculations showed this level of significance.

The statistical significance within mean differences in Duncan's new multiple range test was calculated at the .05 level of probability according to the tables in Biometriks (19).

CHAPTER IV

RESULTS AND DISCUSSIONS

I. EFFECT OF DIAMETER AND TREATMENT

Firmness by Objective Evaluation

Raw sweet potatoes. Table III shows the mean diameter values of the raw sweet potatoes used for each treatment. The mean diameter values of the raw sweet potatoes used for each replication are shown in Table IV. Results of the analysis of variance to determine the effect of random selection on the firmness variability of the raw sweet potatoes used for each treatment and for each replication, as determined by objective evaluation (ASCO Firmness Meter), are shown in Table V. Results of Duncan's new multiple range test for the effect of random selection on the variability in firmness by objective evaluation of the raw sweet potatoes used for each treatment are shown in Table VI. Results of Duncan's new multiple range test for the effect of random selection on the variability in firmness by objective evaluation of the raw sweet potatoes used for each replication are shown in Table VII.

Random selection effect on the firmness of the raw sweet potatoes used for each treatment and for each replication was not significant at the .05 level of probability (Table V).

Table III shows little or no variability in the diameter of the raw sweet potatoes used for each treatment. The greatest difference,

TABLE III

MEAN DIAMETER VALUES OF RAW AND CANNED SWEET POTATOES USED FOR EACH TREATMENT

Treatment Number*	Mean Diameters (centimeters)	
	Raw Sweet Potatoes	Canned Sweet Potatoes
1	3.55	3.57
2	3.62	3.33
3	3.57	3.46
4	3.56	3.85

*See Table I, page 16.

TABLE IV

MEAN DIAMETER VALUES OF RAW AND CANNED SWEET POTATOES USED FOR EACH REPLICATION

Replication Number	Mean Diameters (centimeters)	
	Raw Sweet Potatoes	Canned Sweet Potatoes
1	3.49	3.80
2	3.69	3.46
3	3.69	3.41

TABLE V

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE EFFECT OF RANDOM SELECTION ON THE FIRMNESS VARIABILITY BY OBJECTIVE EVALUATION OF RAW SWEET POTATOES USED FOR CANNING

Source	d. f.	Means Square
Replication	2	2.43
Treatment	3	243.05
Variety	1	62.34
Replication x Treatment	6	141.30
Error	48	97.55

TABLE VI

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE DIFFERENCE IN OBJECTIVE FIRMNESS VARIABILITY WITHIN TREATMENT MEANS OF RAW SWEET POTATOES USED FOR CANNING AS AFFECTED BY RANDOM SELECTION

Treatment Number*	Means**
1	48.556a
2	54.833b
3	54.722b
4	48.278a

*See Table I, page 16.

**Means followed by the same letter are not significantly different at the .05 level of probability.

TABLE VII

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE DIFFERENCE IN OBJECTIVE FIRMNESS VARIABILITY WITHIN REPLICATIONS OF RAW SWEET POTATOES USED FOR CANNING AS AFFECTED BY RANDOM SELECTION

Replication Number	Means*
1	51.250a
2	51.667a
3	51.875a

*Means followed by the same letter are not significantly different at the .05 level of probability.

which was 0.07 centimeters, occurred between treatments No. 1 and No. 2. This uniformity of size in the raw sweet potatoes possibly contributed to the lack of significant firmness differences between treatment and between replication means of the raw roots used for canning.

A correlation coefficient of the effect of diameter on the firmness of the sweet potatoes was not calculated due to the uniformity in the diameter of the raw roots. Therefore, this study showed primarily the firmness and diameter uniformity of the raw sweet potatoes randomly selected for this study.

Canned sweet potatoes. Table III shows the mean diameter values of the canned sweet potatoes used for each treatment and the mean diameter values of the canned sweet potatoes used for each replication are shown in Table IV. These tables indicate that the diameter variability was not significant. Results of the analysis of variance to determine the effect of treatment and storage on the firmness by objective evaluation of the canned sweet potatoes are shown in Table VIII. Results of Duncan's new multiple range test for the effect of treatment on the firmness by objective evaluation of the canned sweet potatoes are shown in Table IX. Results of Duncan's new multiple range test for the effect of storage on the firmness by objective evaluation of the canned sweet potatoes are shown in Table X.

The effect of treatment on the firmness of the canned sweet potatoes was significant at the .01 level of probability, and the effect of storage on the firmness of the canned sweet potatoes was significant at the .05 level of probability (Table VIII).

TABLE VIII

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE EFFECT OF TREATMENT AND STORAGE TIME ON THE FIRMNESS BY OBJECTIVE EVALUATION OF CANNED SWEET POTATOES

Source	d. f.	Means Square
Storage	2	430.05*
Treatment	3	804.86**
Variety	1	0.01
Storage x Treatment	6	410.13**
Error	48	128.68

*Statistical significance at the .05 level of probability.

**Statistical significance at the .01 level of probability.

TABLE IX

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF TREATMENT ON THE FIRMNESS BY OBJECTIVE EVALUATION OF CANNED SWEET POTATOES

Treatment Number*	Means**
1	48.944a
2	58.500b
3	47.667a
4	60.944b

*See Table I, page 16.

**Means followed by the same letter are not significantly different at the .05 level of probability.

TABLE X

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF STORAGE TIME ON THE FIRMNESS BY OBJECTIVE EVALUATION OF CANNED SWEET POTATOES

Storage Time*	Means**
30 days	49.542a
60 days	54.542b
90 days	57.958c

*See Table II, page 18.

**Means followed by the same letter are not significantly different at the .05 level of probability.

A correlation coefficient of the effect of diameter on the firmness of the canned sweet potatoes, as determined by objective evaluation, was not calculated due to the uniformity in the diameter of the raw sweet potatoes used in this study. Therefore, this study became an indication of treatment effect on the firmness of the canned sweet potatoes.

Therman processing effected a marked decrease on the firmness of the sweet potatoes. This is a confirmation of a generally recognized effect of thermal processing in fruits and vegetables.

Table IX shows that the firmest sweet potatoes were those subjected to treatments No. 3 (25 degree brix syrup and 250°F. for 15.0 min.) and No. 1 (25 degree brix syrup and 240°F. for 24.2 min.), whose firmness means were not significantly different. The sweet potatoes subjected to treatments No. 2 (40 degree brix syrup and 240°F. for 37.0 min.) and No. 4 (40 degree brix syrup and 250°F. for 24.0 min.), whose firmness means were not significantly different, were significantly softer than those subjected to treatments No. 1 and No. 3.

The significantly higher firmness differences between the sweet potatoes cooked in 25 degree brix syrup (treatments No. 1 and No. 3) and those cooked in 40 degree brix syrup (treatments No. 2 and No. 4) were attributed to the lower degree of cooking of treatments No. 1 and No. 3. The heat penetration data in Table I, page 16, shows that treatments No. 1 and No. 3 (25 degree brix syrup) had an f_h value of 12.3 min. and an f_2 value of 55.2 min. The lower f_h and f_2 values of treatments No. 1 and No. 3 indicated that their heat penetration was higher than that of

treatments No. 2 and No. 4. A higher heat penetration ratio would be associated with a lower degree of cooking. Since the sterilizing value (F_o) was equal for all treatments, the cooking effect of treatments No. 1 and No. 3 (25 degree brix syrup) would be lower than that of treatments No. 2 and No. 4 (40 degree brix syrup).

It is possible that the higher cooking effects of treatments No. 2 and No. 4 (40 degree brix syrup) effected a higher degree of degradation on the tissue constituents responsible for the firmness characteristics of the sweet potatoes. This could have resulted in a greater firmness loss.

This study suggested that the firmness of canned sweet potatoes could be controlled by treatments designed to effect low degrees of cooking, provided the sterilization values attained insured a safe process.

The significant effect of storage (Table X, page 42) could be attributed to the tendency of the contents of the can to reach an equilibrium with increased storage time. Increased storage of the canned sweet potatoes resulted in an increased diffusion of syrup into the tissue of the roots, until an equilibrium was reached by the can contents. The increased storage time possibly allowed a corresponding increase in the moisture content of the canned sweet potatoes. This progressive moisture increase could have caused a corresponding firmness loss with increased storage time since the ASCO Firmness Meter could have had a greater squeezing effect on the roots as the moisture

increased. The sweet potatoes stored for 30 days, which would have had the least amount of syrup diffused into the tissue, would also have been expected to be the firmest. The data in Table X, page 42, appears to substantiate this effect of storage.

Another possibility for the significant firmness differences due to storage time (Table X) could be derived from observations of the differences between firmness means within replications of the raw sweet potatoes (Table VII, page 38). A comparison of the data in Tables VII and X shows an identical pattern in the firmness ratings of the replications of the raw sweet potatoes and the corresponding storage time of each replication. (Table II, page 18, shows the corresponding storage time of each replication.) Even though the firmness means within replications in the raw sweet potatoes were not significantly different at the .05 level of probability, they could have been significant in relation to the firmness of the canned sweet potatoes. These results would suggest that a firmer raw sweet potato would result in a firmer canned product.

Firmness by Sensory Evaluation

Canned Centennial sweet potatoes. Results of the analysis of variance to determine the effect of treatment and panel rating on firmness by sensory evaluation of canned Centennial sweet potatoes are shown in Table XI. Results of Duncan's new multiple range test for the effect of treatment on the firmness as determined by sensory evaluation are shown in Table XII. Results of Duncan's new multiple range test

TABLE XI

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE EFFECT OF TREATMENT AND PANEL RATING ON THE FIRMNESS BY SENSORY EVALUATION OF CANNED CENTENNIAL AND GOLDRUSH SWEET POTATOES

Source	d. f.	Means Square	
		Centennial	Goldrush
Treatment	3	13.38*	6.04*
Panel	6	2.02	7.90*
Panel x Treatment	18	2.06	2.61
Error	56	1.19	1.51

*Statistical significance at the .01 level of probability.

TABLE XII

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF TREATMENT ON THE FIRMNESS BY SENSORY EVALUATION OF CANNED CENTENNIAL AND GOLDRUSH SWEET POTATOES

Treatment Number*	Means**	
	Centennial	Goldrush
1	4.238a	3.143a
2	3.667b	3.667b
3	2.714b	3.381ab
4	4.524a	4.381c

*See Table I, page 16.

**Within columns means followed by the same letter are not significantly different at the .05 level of probability.

for the effect of firmness ratings by individual panel member are shown in Table XIII.

Treatment effect on the firmness of the canned Centennial sweet potatoes, as determined by sensory evaluation, was significant at the .01 level of probability. Firmness ratings as affected by individual panel member were not significant at the .05 level of probability (Table XIII).

The significant effect of treatment on the firmness of the canned Centennial sweet potatoes, as determined by sensory evaluation, could be attributed to a combination of the following factors:

1. Effect of thermal processing on the tissue of the sweet potatoes. Since each of the four treatments was designed to effect different degrees of cooking, each one could have effected different degrees of degradation on the tissue constituents responsible for firmness.
2. Since the canned sweet potatoes were stored for approximately six months prior to the panel evaluation, the different degrees of cooking on the tissue could have influenced the roots to react differently with the cooking medium storage. Table XII shows that treatments No. 1 (25 degree brix syrup and 240°F. for 24.2 min.) and No. 4 (40 degree brix syrup and 250°F. for 24.0 min.) were rated the firmest by the panel. These were followed by treatments No. 2 (40 degree brix syrup and 240°F. for 37.0 min.) and No. 3 (25 degree brix syrup and

TABLE XIII

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF FIRMNESS RATINGS BY INDIVIDUAL PANEL MEMBER ON THE FIRMNESS BY SENSORY EVALUATION OF CANNED CENTENNIAL AND GOLDRUSH SWEET POTATOES

Panel Member Number	Means*	
	Centennial	Goldrush
1	4.333d	4.417a
2	3.583a	4.083a
3	4.167cd	3.083b
4	3.083	2.750b
5	3.667ab	2.583b
6	3.750abc	4.083a
7	3.917bcd	4.500a

*Within columns means followed by the same letter are not significantly different at the .05 level of probability.

250°F. for 15.0 min.), in order of decreasing firmness. This pattern of firmness differences disagreed with the pattern of the ratings by objective evaluation of the canned sweet potatoes (Table IX, page 41) in which the sweet potatoes cooked in 25 degree brix syrup (treatments No. 1 and No. 3) were firmner than those cooked in 40 degree brix syrup (treatments No. 2 and No. 4). These pattern differences were possibly related to a combination of the different degrees of cooking and storage time since the sweet potatoes rated objectively were evaluated after approximately 30, 60, and 90 days of canning (Table II, page 18). These findings would indicate the possibility that prolonged storage became an additional and a critical source of variability in firmness evaluation.

3. An additional source of variability in firmness evaluation could have been introduced by the sweet potatoes used as control, which could have had roots varying considerably in firmness within the lot used.

Canned Goldrush sweet potatoes. Results of the analysis of variance to determine the effect of treatment and panel rating on the firmness by sensory evaluation of the canned Goldrush sweet potatoes are shown in Table XI, page 46. Results of Duncan's new multiple range test for the effect of treatment on the firmness as determined by sensory evaluation are shown in Table XII, page 47. Results of Duncan's new multiple

range test for the effect of firmness ratings by individual panel member are shown in Table XIII, page 49.

Treatment effect was significant at the .01 level of probability (Table XI, page 46). The effect of rating by individual panel member was significant at the .01 level of probability (Table XIII).

The significant effect of treatment on the firmness of the canned Goldrush sweet potatoes could be attributed to a combination of the factors responsible for the significant firmness differences of the canned Centennial sweet potatoes. It could also be attributed to the highly significant variability in the firmness ratings within panel members.

Table XII, page 47, shows the firmness pattern of Goldrush sweet potatoes to be different from that of the Centennial variety as well as from the pattern of firmness by objective evaluation of the canned sweet potatoes (Table IX, page 41). These pattern differences are possibly due to varietal differences.

The firmest sweet potatoes in the Goldrush variety were those subjected to treatment No. 4 (40 degree brix syrup and 250°F. for 24.0 min.). (See Table XII.) Possibly a combination of treatment effect on the tissue, the high sugar concentration, and the prolonged storage allowed some degree of polymerization to occur between the sugar and the tissue constituents responsible for firmness in the canned sweet potatoes. This effect was suggested by Amos (2), who found that the texture of freeze-dried formulated strawberry slices appeared to improve as sugar level increased.

The significant differences in firmness ratings within panel members were possibly due to a combination of variability in the firmness of the canned commercial sweet potatoes used as controls and the various degrees of tissue degradation effected by the different treatments (which possibly caused the roots to react differently during storage).

II. EFFECT OF ALCOHOL INSOLUBLE SOLIDS

Results of the percentage AIS in the raw sweet potatoes are shown in Table XVIII in the Appendix. Results of the analysis of variance to determine the effect of treatment and storage on the percentage AIS of the canned sweet potatoes are shown in Table XIV. Results of Duncan's new multiple range test for the effect of treatment on the percentage AIS of the canned sweet potatoes are shown in Table XV. Results of Duncan's new multiple range test for the effect of storage on the percentage AIS of the canned sweet potatoes are shown in Table XVI. Correlation coefficient of the effect of AIS content on the firmness of canned sweet potatoes is shown in Table XVII.

Treatment effect on the percentage AIS of the canned sweet potatoes was significant at the .05 level of probability (Table XIV). The effect of storage on the percentage AIS in the canned sweet potatoes was significant at the .01 level of probability (Table XIV). Correlation coefficient of the effect of percentage AIS in the canned sweet potato on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = -0.047$).

TABLE XIV

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE EFFECT OF TREATMENT AND STORAGE ON THE CHEMICAL ANALYSIS OF PECTIN FRACTIONS OF CANNED SWEET POTATOES

		Means Square					
Source	d. f.	Alcohol Insoluble Solids	Total Pectin	Versene Soluble Pectin	Water Soluble Pectin	Gammas of AGA per Ml. of Syrup	Mg. of AGA Per Ml. of Alcoholic Filtrate
Storage	2	9.69*	12.98*	8.94*	1.17**	5073.68*	1.71*
Treatment	3	0.38**	3.35*	0.93**	0.45	317.96	0.32
Variety	1	0.00	0.75	0.19	0.08	7775.27*	3.27*
Storage x Treatment	6	1.16*	14.11*	2.46*	0.81**	7336.73*	5.22*
Error	48	0.12	0.58	0.29	0.32	150.29	0.26

*Statistical significance at the .01 level of probability.

**Statistical significance at the .05 level of probability.

TABLE XV

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF TREATMENT ON THE CHEMICAL ANALYSIS OF PECTIN FRACTIONS OF CANNED SWEET POTATOES

Test	Means*			
	Treatment No. 1**	Treatment No. 2	Treatment No. 3	Treatment No. 4
Alcohol Insoluble Solids	8.069b	8.025b	7.768a	7.835a
Total Pectin	11.045b	10.431a	11.211b	10.351a
Versene Soluble Pectin	9.731a	9.476b	9.758a	10.034c
Water Soluble Pectin	7.590a	7.351a	7.210a	7.356a
Gammas of AGA per Ml. of Syrup	122.033ab	130.173c	121.186a	126.699bc
Mg. of AGA per Ml. of Alcoholic Filtrate of AIS determination	6.139ab	6.328b	6.039a	6.284b

*Within rows means followed by the same letter are not significantly different at the .05 level of probability.

**See Table I, page 16.

TABLE XVI

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR THE EFFECT OF STORAGE TIME ON THE CHEMICAL ANALYSIS OF PECTIN FRACTIONS OF CANNED SWEET POTATOES

Test	Storage Time* and Means**		
	30 days	60 days	90 days
Alcohol Insoluble Solids	8.562a	7.920a	7.291a
Total Pectin	11.182a	9.910b	11.186a
Versene Soluble Pectin	9.053b	10.006a	10.190a
Water Soluble Pectin	7.623b	7.197a	7.310a
Gammas of AGA per Ml. of Syrup	111.744a	122.765a	150.559a
Mg. of AGA per Ml. of Alcoholic Filtrate from AIS determination	5.952b	6.379a	6.263a

*See Table II, page 18.

**Within rows means followed by the same letter are not significantly different at the .05 level of probability.

TABLE XVII

CORRELATION COEFFICIENTS OF THE EFFECT OF VARIOUS PECTIN FRACTIONS ON THE FIRMNESS OF RAW AND CANNED SWEET POTATOES

Correlation Analysis	Correlation Coefficients (values of r)
Effect of AIS content in the canned sweet potatoes on the firmness of canned sweet potatoes	-0.047
Effect of water soluble pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes	-0.114
Effect of water soluble pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes	-0.069
Effect of versene soluble pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes	-0.012
Effect of versene soluble pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes	0.104
Effect of total pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes	-0.185
Effect of total pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes	0.018
Effect of gammas of AGA per ml. of syrup on the firmness of the canned sweet potatoes	-0.046
Effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the canned sweet potatoes	0.210
Effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the raw sweet potatoes	0.116

Thermal processing effected a market decrease in the percentage AIS of the sweet potatoes. Table XV shows that the sweet potatoes subjected to treatments No. 3 (cooking at 250°F. for 15.0 min.) and No. 4 (cooking at 250°F. for 24.0 min.), whose means were not significantly different, had a lower AIS percentage than those subjected to treatments No. 1 (cooking at 240°F. for 24.2 min.) and No. 2 (cooking at 240°F. for 37.0 min.). The percentage means between treatments No. 1 and No. 2 were not significantly different. These results indicate that the higher therman processing temperatures had a greater solubilizing effect on the AIS, regardless of processing time, then did the lower temperatures.

The results of AIS decrease with thermal processing agreed with Baumgardner and Scott (5), Jenkins and Gieger (23), and Culpepper and Magoon (12).

The decrease in the percentage AIS with increased storage time of the canned sweet potatoes was attributed to the stabilizing effect between the syrup and the sweet potatoes in the can--the longer the storage time, the greater the amount of liquid that was diffused into the tissue of the roots in the can until an equilibrium was reached. Since the percentage AIS analysis was performed on the drained product, a lower ratio of sweet potato tissue to syrup resulted in a progressive decrease in the percentage AIS with indreasing storage time.

The lack of significant relationship between the AIS content and the firmness of the canned sweet potatoes agreed with Baumgardner and Scott (5) and disagreed with Kattan and Littrell (24).

III. EFFECT OF PECTIC SUBSTANCES

Water Soluble Pectin (Expressed as Percentage AGA in the Dry AIS)

The percentage water soluble pectin in the raw sweet potatoes is shown in Table XVIII in the Appendix. Results of the analysis of variance to determine the effect of treatment and storage on the percentage water soluble pectin of the canned sweet potatoes are shown in Table XIV, page 53. Results of Duncan's new multiple range test for the effect of treatment on the percentage water soluble pectin of the canned sweet potatoes are shown in Table XV, page 54. Results of Duncan's new multiple range test for the effect of storage on the percentage water soluble pectin of the canned sweet potatoes are shown in Table XVI, page 55. Correlation coefficient of the effect of percentage water soluble pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes is shown in Table XVII, page 56. Correlation coefficient of the effect of percentage water soluble pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes is shown in Table XVII.

Treatment effect on the percentage water soluble pectin of the canned sweet potatoes was not significant at the .05 level of probability (Table XIV). Storage effect on the percentage water soluble pectin of the canned sweet potatoes was significant at the .05 level of probability (Table XIV). Correlation coefficient of the effect of percentage water soluble pectin of the canned sweet potatoes on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = -0.114$). Correlation coefficient of the effect of percentage water

soluble pectin of the canned sweet potatoes on the firmness of the raw sweet potatoes was not significant at the .05 level of probability ($r = -0.069$).

Thermal processing effected a marked increase in the percentage water soluble pectin of the canned sweet potatoes. This increase was from a mean of 2.719 per cent in the raw sweet potatoes to a mean of 7.376 per cent in the cooked sweet potatoes, and it represented an overall increase of 200.63 per cent. The increase agreed with Ahmed and Scott (1), Bettelheim and Sterling (7), McArdle and Nehemias (26), Postlmayer et al. (30), and Simpson and Halliday (34).

The increase in the water soluble pectin fraction could be attributed to a combination of the following factors:

1. The action of pectinesterease (PE) enzyme during the first few minutes of processing as suggested by Baumgardner and Scott (5).
2. A greater degree of solubility effected by the high cooking temperatures on all the pectin fractions. This effect was reported by Sweetman (36).
3. Cell fracturing and separation occurring due to the expansion of starch as it gelatinized. This effect was reported by Bettelheim and Sterline (8) and by Whittenberger and Nutting (40), and it could have made possible the water extraction of molecules that were not extracted from the tissue of the raw sweet potatoes.

4. Heat-induced depolymerization into single AGA units of higher molecular weight molecules corresponding to the versene soluble and protopectin fractions. A similar effect was reported by Ahmed and Scott (1) and by McArdle and Nehemias (26).

The depolymerization which occurred with thermal processing in the higher molecular weight molecules was supported by the results of the analysis of the syrup of the canned sweet potatoes and by the analysis of the alcoholic filtrate from the AIS determination of the canned sweet potatoes. These results are discussed later in this report.

The significant effect of storage time on the water soluble pectin of the canned sweet potatoes (Table XVI, page 55) was attributed to the equilibrium reaction within the syrup and the roots in the can. This effect possibly caused the ratio of sweet potato material to syrup per unit mass of drained sample to decrease progressively with increased storage time. In turn, this resulted in a progressive decrease in the percentage AIS per unit mass of drained sweet potatoes, which reflected as an apparent decrease in the percentage AGA of the dry AIS. Table XVI shows that equilibrium was reached between 60 and 90 days of storage since no significant difference at the .05 level was found between the means of these storage time periods. Storage after 30 days, whose mean was significantly higher than those of storages after 60 and 90 days, also showed a higher percentage of AGA in the dry AIS. Since no moisture content determinations of the canned sweet potato were performed, it is also possible that sugar molecules from the syrup diffused into the tissue. This effect could also have contributed to the decrease in the

ratio of sweet potato material to non-sweet potato material per unit mass of drained sample, thus contributing to the apparent decrease in the percentage AGA of the dry AIS. Therefore, the decrease in the water soluble pectin with increased storage was a relative rather than a real decrease as Table XVI, page 55, suggests.

The lack of significance between the percentage water soluble pectin of the canned sweet potato and the firmness of the canned sweet potato was in agreement with the findings of Bettelheim and Sterling (7) and Sweetman (36).

Versene Soluble Pectin (Expressed as Percentage AGA in the Dry AIS)

The percentage versene soluble pectin in the raw sweet potatoes is shown in Table XVIII in the Appendix. Results of the analysis of variance to determine the effect of treatment and storage on the percentage versene soluble pectin of the canned sweet potatoes are shown in Table XIV, page 53. Results of Duncan's new multiple range test for the effect of treatment on the percentage versene soluble pectin of the canned sweet potatoes are shown in Table XV, page 54. Results of Duncan's new multiple range test for the effect of storage on the percentage versene soluble pectin in the canned sweet potatoes are shown in Table XVI. Correlation coefficient of the effect of percentage versene soluble pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes is shown in Table XVII, page 56. Correlation coefficient of the effect of versene soluble pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes is shown in Table XVII.

Treatment effect on the percentage versene soluble pectin of the canned sweet potatoes was significant at the .05 level of probability (Table XIV, page 53). Storage effect on the percentage versene soluble pectin of the canned sweet potatoes was significant at the .01 level of probability (Table XIV). Correlation coefficient of the effect of percentage versene soluble pectin of the canned sweet potatoes on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = -0.012$). Correlation coefficient of the percentage versene soluble pectin of the canned sweet potatoes on the firmness of the raw sweet potatoes was not significant at the .05 level of probability ($r = 0.104$).

Thermal processing effected a 76.25 per cent increase in the versene soluble pectin of the canned sweet potatoes. This increase was attributed to the factors which caused the increase in the percentage water soluble pectin of the canned sweet potatoes.

The data in Table XV, page 54, indicated that treatment No. 2 (40 degree brix and 240°F. for 37.0 min.) had the lowest percentage AGA in the dry AIS. This was followed by treatments No. 1 (25 degree brix syrup and 240°F. for 24.2 min.) and No. 3 (25 degree brix syrup and 250°F. for 15.0 min.), whose means were not significantly different, and by treatment No. 4 (40 degree brix syrup and 250°F. for 24.0 min.), in order of increasing percentage AGA in the dry AIS. These results suggested that a greater depolymerization occurred when the roots were subjected to treatment No. 1 than when subjected to treatment No. 2.

The longer processing times would normally be associated with a greater degree of depolymerization of the pectic substances of fruits and vegetables. Therefore, the percentage versene soluble pectin would have been expected to be lower with the shorter cooking time of treatment No. 1, as the differences between treatments No. 3 and No. 4 indicate. A possible explanation for these results could be that the lower heat penetration rate of treatment No. 2 (f_h = 28.70 and f_2 = 55.20) could have effected a significantly lower degree of depolymerization of the pectic substances. This possible effect of the lower heat penetration rate was also observed on the results of the total pectin which will be discussed later in this report.

The significant effect of storage (Table XVI, page 55) was attributed to the equilibrium reaction within the syrup and the roots in the can, as described in the discussion of the results of the water soluble pectin. It will be shown later that the syrup of the canned sweet potatoes contained AGA units and that it was also possible that it contained high molecular weight molecules similar in chemical characteristics to those of the versene soluble pectin. These molecules could have diffused into the sweet potato tissue with increased storage time until an equilibrium was reached. Table XVI shows that equilibrium was reached between 60 and 90 days of storage since their means were not significantly different. The sweet potatoes stored for 30 days, which would have been expected to have the least amount of syrup diffused into the tissue, showed a significantly lower percentage of versene soluble

pectin than those stored for 60 and 90 days. They also showed the lowest content of versene soluble pectin (AGA) in the dry AIS.

Total Pectin (Expressed as Percentage AGA in the Dry AIS)

Table XVIII in the Appendix shows the percentage total pectin in the raw sweet potatoes. Results of the analysis of variance to determine the effect of treatment and storage on the percentage total pectin of the canned sweet potatoes are shown in Table XIV, page 53. Results of Duncan's new multiple range test for the effect of treatment on the percentage total pectin of the canned sweet potatoes are shown in Table XV page 54. Results of Duncan's new multiple range test for the effect of storage on the percentage total pectin of the canned sweet potatoes are shown in Table XVI, page 55. Correlation coefficient of the effect of percentage total pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes is shown in Table XVII, page 56. Correlation coefficient of the effect of total pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes is shown in Table XVII.

Treatment effect on the percentage total pectin of the canned sweet potatoes was significant at the .01 level of probability (Table XIV). Storage effect on the percentage total pectin of the canned sweet potatoes was significant at the .01 level of probability (Table XIV). Correlation coefficient of the effect of percentage total pectin in the canned sweet potatoes on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = -0.185$). Correlation

coefficient of the effect of percentage total pectin in the canned sweet potatoes on the firmness of the raw sweet potatoes was not significant at the .05 level of probability ($r = 0.018$).

Thermal processing effected a 39.63 per cent increase in the total pectin of the dry AIS of the canned sweet potatoes. This increase was attributed to a combination of the factors which could have caused the increase in the water soluble and versene soluble pectin fractions.

The increase of the total pectin, expressed as percentage AGA of the dry AIS of the canned sweet potato, could also be interpreted as a decrease in the total amount of the three pectin fractions with thermal processing. The heat-induced depolymerization which was largely responsible for the reported increases in the percentages of water soluble and versene soluble pectin fractions, was also responsible for the depolymerization which caused the apparent increase in the total pectin. This increase in all three pectin fractions could be interpreted as a decrease in the total pectin when it is considered that a pectin molecule of high molecular weight will yield a large number of AGA units when depolymerized to such a degree. The analysis of the syrup and of the alcoholic filtrate from the AIS determination, whose results will be discussed later, indicated that depolymerization to single AGA units occurred with thermal processing. Since water soluble and versene soluble pectin fractions (as well as the total pectin) were analyzed as single AGA units, an in crease in their total amounts indicated a decrease in their native content with thermal processing.

The significant differences between treatment means (Table XV, page 54) indicated that the lowest degree of depolymerization was effected by treatments No. 2 (40 degree brix syrup and 240°F. for 37.0 min.) and No. 4 (40 degree brix syrup and 250°F. for 24.0 min.), whose means were not significantly different. These were followed by treatments No. 1 (25 degree brix syrup and 240°F. for 24.2 min.) and No. 3 (25 degree brix syrup and 250°F. for 15.0 min.), whose means were not significantly different. The lower degree of depolymerization of the total pectin by treatments No. 2 and No. 4 was attributed to their lower rate of heat penetration (f_h = 28.70 and f_2 = 55.20) due to the 40 degree brix syrup used in these treatments. The higher heat penetration rate of treatments No. land No. 3 (f_h = 12.13 and f_2 = 19.60) due to the 25 degree brix syrup used in these treatments appeared to have effected a greater degree of depolymerization in the total pectin. Possibly the high sugar concentration of treatments No. 2 and No. 4 (40 degree brix) combined with treatment effect on the tissue and the prolonged storage time to allow some degree of polymerization to occur between the sugar and the cleaved pectin molecules. This resulted in an apparently lower degree of depolymerization by these treatments. A similar effect was suggested in the discussion of the storage effect on the firmness of the canned Goldrush sweet potatoes.

The significant effect of storage (Table XVI, page 55) was possibly due to a combination of the effect of treatment on the tissue of the sweet potatoes and the consequent different behavior of the roots during the equilibrium reaction of the can contents during storage.

Gammas of AGA per Ml. of Syrup of Canned Sweet Potatoes

Results of the analysis of variance to determine the effect of treatment and storage on the gammas of AGA per ml. of syrup of canned sweet potatoes are shown in Table XIV, page 53. Results of Duncan's new multiple range test for the effect of treatment on the gammas of AGA per ml. of syrup of canned sweet potatoes are shown in Table XV, page 54. Results of Duncan's new multiple range test for the effect of storage on the gammas of AGA per ml. of syrup of canned sweet potatoes are shown in Table XVI, page 55. Correlation coefficient of the effect of gammas of AGA per ml. of syrup on the firmness of the canned sweet potatoes is shown in Table XVII, page 56.

Treatment effect on the gammas of AGA per ml. of syrup of canned sweet potatoes was not significant at the .05 level of probability (Table XIV). Storage effect on the gammas of AGA per ml. of syrup of canned sweet potatoes was significant at the .05 level of probability. Correlation coefficient of the effect of gammas of AGA per ml. of syrup (which was an indication of depolymerization of the total pectic substances) on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = -0.046$).

Thermal processing caused extensive depolymerization of the pectic substances as evidenced by the high content of AGA in the syrup which showed a mean of 12.5 per cent AGA per ml. These results were interpreted as an indication of the depolymerization into single AGA units effected by thermal processing on the pectic substances. This

effect possibly occurred to a higher degree in the smaller molecular weight molecules followed by progressively molecules, and it could have contributed to the marked increases in the contents of water soluble pectin, versene soluble pectin, and in the total pectin in order of decreasing depolymerization into single AGA units.

Bettelheim and Sterling (7) found that the cooking medium removed pectin molecules of higher ester content from the tissue of the Irish potato. Since the syrup had a high content of AGA units, it could be inferred that it also contained pectin molecules of high molecular weight which were not detected by this method of assay.

The significant effect of storage was attributed to factors described in the discussions of AIS and of the various pectin fractions of the canned sweet potatoes.

Mg. of AGA per Ml. of Alcoholic Filtrate of the AIS Determination of the Canned Sweet Potatoes

Table XVIII in the Appendix shows the mg. of AGA per ml. of alcoholic filtrate (filtrate) from the AIS determination of the raw sweet potatoes. Results of the analysis of variance to determine the effect of treatment and storage on the mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes are shown in Table XIV, page 53. Results of Duncan's new multiple range test for the effect of treatment on the mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes are shown in Table XV, page 54. Results of Duncan's new multiple range test for the effect of

storage on the mg. of AGA per ml. of filtrate from the AIS determination of canned sweet potatoes are shown in Table XVI, page 55. Correlation coefficient of the effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the canned sweet potatoes is shown in Table XVII, page 56. Correlation coefficient of the effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the raw sweet potatoes is shown in Table XVII.

Treatment effect on the mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes was not significant at the .05 level of probability (Table XIV, page 53). Storage effect on the mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes was significant at the .05 level of probability (Table XIV). Correlation coefficient of the effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the canned sweet potatoes was not significant at the .05 level of probability ($r = 0.210$). Correlation coefficient of the effect of mg. of AGA per ml. of filtrate from the AIS determination of the canned sweet potatoes on the firmness of the raw sweet potatoes was not significant at the .05 level of probability ($r = 0.116$).

The results of the analysis of the filtrate basically agree with those of the analysis of the syrup in that thermal processing caused a depolymerization of the pectic substances into single AGA units, as evidenced by the high content of AGA in the filtrate of the canned sweet

potatoes. Analysis of the filtrate from the AIS determination of the canned sweet potatoes showed that thermal processing caused an overall increase of 256.90 per cent AGA per ml. of alcoholic filtrate.

These results were also interpreted as an indication of the depolymerization into AGA units effected by thermal processing on the pectic substances. The additional heating of the sweet potato samples during the AIS determination possibly caused no further depolymerization of high molecular weight molecules since the temperature was relatively low compared to those of the processing treatments. However, blending of the sample for the AIS determination possibly caused mechanical cell rupturing and separation which allowed the alcohol to remove AGA units entrapped within the tissue of the canned sweet potatoes.

The significant effect of storage was attributed to the tendency of the can contents to reach an equilibrium with progressing storage time.

CHAPTER V

SUMMARY

The objective of this study was an attempt to improve the firmness of thermally processed sweet potatoes. The four major variables studied were as follows:

1. Effect of various processing treatments on the firmness of canned sweet potatoes.
2. The relationship between changes in the AIS content during thermal processing and the firmness of canned sweet potatoes.
3. The relationship between changes in the pectic substances during thermal processing and the firmness of canned sweet potatoes.
4. The relationship between the diameter and the firmness of canned sweet potatoes.

Under the conditions of the study reported in this paper, it was found that:

1. The effect of thermal processing treatment on the firmness by objective evaluation of canned sweet potatoes was significant at the .01 level of probability.
2. The sweet potatoes subjected to treatments with high heat penetration ratios (f_h = 12.13 and f_2 = 19.60) were significantly firmer than the sweet potatoes subjected to treatments with low heat penetration ratios (f_h = 28.70 and f_2 = 55.20).

3. The treatments with high heat penetration ratios were associated with a lower degree of cooking and the treatments with low heat penetration ratios were associated with a higher degree of cooking.
4. This study suggested the possibility of controlling the firmness of canned sweet potatoes by treatments designed to effect a low degree of cooking provided the sterilization values attained a safe process.
5. Analysis of variance showed that storage time was a significant factor (at the .05 level of probability) in the objective evaluation of firmness of canned sweet potatoes.
6. Although the analysis of variance showed that the effect of thermal processing on the AIS content was significant at the .05 level of probability, the AIS content was not significantly related to the firmness of canned sweet potatoes.
7. Duncan's new multiple range test showed that treatments with a high thermal processing temperature (250°F. for 15.0 and 24.0 min.) had a significantly greater solubilizing effect on the AIS, regardless of processing time, than the treatments with a low processing temperature (240°F. for 24.2 and 37.0 min.).
8. Analysis of variance showed that storage time was a highly significant (.01 level of probability) factor on the AIS content of canned sweet potatoes. Duncan's new multiple

range test showed an apparent decrease in the AIS content of the canned sweet potatoes with increasing storage time, until equilibrium was reached.

9. Pectic substances were not significantly related to firmness of the canned sweet potatoes.

10. Analysis of variance showed that treatment effect on the versene soluble pectin was significant at the .05 level of probability. The effect on the total pectin was significant at the .01 level of probability.

11. Duncan's new multiple range test showed that the treatments with low heat penetration ratios (f_h = 28.70 and f_2 = 55.20) effected a lower degree of depolymerization on the total pectin than the treatments with high heat penetration ratios (f_h = 12.13 and f_2 = 19.60).

12. Thermal processing effected the following increases in various pectin fractions analyzed: (a) 200.63 per cent in the water soluble fraction, (b) 76.25 per cent in the versene soluble fraction, (c) 39.63 per cent in the total pectin. Due to the method of analysis used in this study, these increases were interpreted to be representative of decreases in the content of the native pectin fractions.

13. Thermal processing caused extensive depolymerization of the pectic substances into AGA units.

14. The analysis of the syrup of the canned sweet potatoes showed a mean of 12.5 per cent AGA per ml. The analysis of the alcoholic filtrate from the AIS determinations of the raw and the canned sweet potatoes showed an overall increase of 259.60 per cent in the AGA content. The analyses of these two fractions were interpreted as being an index of the depolymerization of the pectic substances into AGA units as a result of thermal processing.

15. Analysis of variance showed that, except in the case of the water soluble pectin, the effect of storage on the percentages of all the pectin fractions analyzed was significant at the .01 level of probability. The effect of storage on the water soluble pectin was significant at the .05 level. The significant effect of storage was attributed to the equilibrium reaction within the contents of the can.

16. Due to the uniformity in the diameter of the roots randomly selected for this study, a correlation analysis for the effect of diameter on the firmness of the canned sweet potatoes was not calculated.

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APPENDIX

TABLE XVIII

RESULTS OF THE CONTENTS OF VARIOUS PECTIN FRACTIONS IN THE RAW SWEET POTATOES

Fraction	Variety	
	Centennial	Goldrush
Percentage AIS	12.645	11.825
	12.600	11.570
	12.610	11.650
Water soluble pectin (as percentage AGA in the dry AIS)	2.813	2.626
	2.626	2.719
	2.626	2.907
Versene soluble pectin (as percentage AGA in the dry AIS)	5.720	5.251
	6.283	5.439
	5.720	4.876
Total pectin (as percentage AGA in the dry AIS)	8.252	6.939
	8.252	7.033
	8.439	7.408
Mg. of AGA per ml. of alcoholic filtrate from the AIS determination	2.461	2.251
	2.532	2.321
	2.579	2.321

TABLE XIX

TREATMENT, REPLICATION, DIAMETER, AND FIRMNESS BY OBJECTIVE EVALUATION OF RAW CENTENNIAL AND GOLDRUSH SWEET POTATOES

Treatment* Number	Replication Number	Centennial		Goldrush	
		Diameter (Centimeters)	Firmness (ASCO Firmness Meter)	Diameter (Centimeters)	Firmness (ASCO Firmness Meter)
1	1	3.5	49	3.3	40
		3.4	48	3.3	44
		3.8	44	3.7	62
1	2	3.7	39	4.0	48
		3.9	54	3.3	66
		3.8	63	3.2	55
1	3	3.4	47	4.0	54
		3.6	40	3.1	78
		3.4	50	3.6	51
2	1	3.4	60	3.6	40
		3.7	44	3.3	60
		3.7	38	3.3	49
2	2	3.7	61	3.5	48
		4.2	78	3.7	44
		4.1	80	3.6	58
2	3	3.6	53	3.1	46
		3.3	59	3.2	46
		4.1	80	3.1	62
3	1	3.3	42	3.2	54
		3.4	48	3.4	42
		3.5	41	3.4	38

TABLE XIX (continued)

Treatment* Number	Replication Number	Centennial		Goldrush	
		Diameter (Centimeters)	Firmness (ASCO Firmness Meter)	Diameter (Centimeters)	Firmness (ASCO Firmness Meter)
3	2	3.5	40	3.3	76
		3.5	43	3.4	52
		3.5	50	2.8	49
3	3	4.1	46	3.8	52
		4.5	40	3.8	50
		3.5	40	4.4	47
4	1	3.8	53	3.7	62
		3.7	52	3.7	40
		3.4	50	3.3	55
4	2	4.1	50	3.0	46
		3.9	66	3.7	58
		3.7	66	3.5	49
4	3	3.7	44	3.1	50
		4.0	52	3.0	60
		4.1	46	2.8	46

*See Table I, p. 16.

TABLE XX

TREATMENT, STORAGE TIME, DIAMETER, AND FIRMNESS BY OBJECTIVE EVALUATION OF CANNED CENTENNIAL AND GOLDRUSH SWEET POTATOES

Treatment* Number	Storage Time** (days)	Centennial		Goldrush	
		Diameter (Centimeters)	Firmness (ASCO Firmness Meter)	Diameter (Centimeters)	Firmness (ASCO Firmness Meter)
1	30	3.7	56	4.0	34
		4.1	47	4.0	63
		4.5	50	3.1	67
1	60	3.5	50	4.9	41
		3.3	35	4.3	33
		3.6	40	3.6	44
1	90	3.3	67	3.2	39
		3.2	36	5.2	26
		4.0	47	3.3	46
2	30	4.0	26	4.0	65
		4.6	61	4.2	44
		4.3	45	4.2	52
2	60	3.6	50	3.8	76
		3.5	39	4.6	44
		3.9	45	4.5	40
2	90	4.0	52	3.7	57
		3.8	31	3.5	52
		4.3	47	4.0	57
3	30	4.1	60	4.0	34
		3.7	67	3.2	64
		3.8	47	4.6	64

TABLE XX (continued)

Treatment* Number	Storage Time** (days)	Centennial		Goldrush	
		Diameter (Centimeters)	Firmness (ASCO Firmness Meter)	Diameter (Centimeters)	Firmness (ASCO Firmness Meter)
3	60	4.7	56	3.6	49
		4.8	64	4.1	73
		4.6	70	4.1	62
3	90	2.6	45	3.9	52
		3.3	73	3.5	99
		3.2	46	4.0	71
4	30	4.7	45	4.2	42
		4.8	99	4.1	73
		4.6	63	4.1	38
4	60	5.0	49	3.9	73
		3.8	59	4.1	69
		4.0	60	4.7	60
4	90	3.4	44	3.6	42
		3.9	67	3.9	70
		2.7	69	3.5	67

*See Table I, p. 16.

**See Table II, p. 18.

TABLE XXI

TREATMENT, REPLICATION, AND FIRMNESS RATING BY INDIVIDUAL PANEL MEMBER OF CANNED CENTENNIAL AND GOLDRUSH SWEET POTATOES STORED APPROXIMATELY 180 DAYS AT ROOM TEMPERATURE

Treatment* Number	Replication Number	Centennial Panel Member Score**							Goldrush Panel Member Score						
		M1	M2	M3	M4	M5	M6	M7	M1	M2	M3	M4	M5	M6	M7
1	1	-1	+3	-2	-1	-2	+1	-1	-1	-2	-1	0	-1	+1	+2
	2	+1	+1	-1	0	-2	0	-1	-1	-1	-1	0	-1	+1	-1
	3	-1	-1	+1	-1	-2	-1	+1	-2	+1	-1	+1	-2	+1	-1
2	1	-2	+1	-1	-1	-1	+2	+1	-2	+2	-3	-1	-3	+2	-2
	2	+2	+2	-1	+1	-2	+1	-1	-1	-1	-1	-1	-2	0	+1
	3	0	0	0	0	-1	0	0	-2	+2	0	0	-1	+2	-3
3	1	+2	+2	-1	-1	-2	+1	+1	-2	+2	-2	+1	-3	+1	-1
	2	+2	-1	0	0	-1	0	+1	-2	-1	-1	+1	-2	+2	-1
	3	+1	-2	-1	-1	-1	+2	-1	-1	+2	+1	-1	-2	+1	+1
4	1	-3	+1	-1	-2	-1	+2	+1	-3	+1	-3	0	-2	+2	+1
	2	+1	+2	-1	-2	-2	+2	-1	-3	0	0	+1	-1	-1	+2
	3	-2	+1	-1	-2	-2	+1	0	-1	+3	-1	+1	+1	+2	0

*See Table I, p. 16.

**For computer programming, the firmness values were computed as follows: -3 = 1, -2 = 2, -1 = 3, 0 = 4, +1 = 5, +2 = 6, +3 = 7.

TABLE XXII

TREATMENT, STORAGE TIME, AND RESULTS OF CHEMICAL ANALYSES OF VARIOUS PECTIN FRACTIONS OF CANNED CENTENNIAL SWEET POTATOES

Treatment* Number	Storage Time** (days)	% AIS on Drained Weight Basis	% Water Soluble Pectin in the Dry AIS	% Versene Soluble Pectin in the Dry AIS	% Total Pectin in the Dry AIS	Gammas AGA per ml. of Syrup	Mg. AGA per ml. of Alcoholic Filtrate from the AIS Determination
1	30	8.630	8.439	10.127	13.128	80.877	5.392
		8.695	7.502	9.846	13.315	80.877	5.275
		8.815	8.439	9.846	13.972	78.533	5.175
1	60	8.780	7.502	8.439	11.252	91.428	6.447
		8.735	7.971	8.439	11.252	101.975	5.439
		8.715	7.314	8.439	11.159	98.460	5.861
1	90	8.010	7.502	8.439	11.185	71.500	4.969
		7.975	7.033	8.627	12.847	64.468	5.040
		8.055	6.752	8.627	11.725	59.780	5.040
2	30	9.070	8.158	9.377	11.440	135.968	6.095
		9.020	7.502	9.377	12.096	140.658	6.587
		8.815	7.971	8.439	11.440	143.000	7.033
2	60	8.295	7.502	8.908	12.003	138.313	7.267
		8.275	7.502	9.471	11.721	145.345	6.916
		8.260	7.314	9.471	12.096	143.000	6.494
2	90	8.435	7.689	9.377	11.628	164.098	6.447
		8.530	8.158	9.096	12.096	152.378	7.033
		8.490	8.158	9.096	11.253	154.723	6.399

TABLE XXII (continued)

Treatment* Number	Storage Time** (days)	% AIS on Drained Weight Basis	% Water Soluble Pectin in the Dry AIS	% Versene Soluble Pectin in the Dry AIS	% Total Pectin in the Dry AIS	Gammas AGA per ml. of Syrup	Mg. AGA per ml. of Alcoholic Filtrate from the AIS Determination
3	30	8.590	7.971	9.377	8.439	107.838	5.469
		8.330	7.502	9.096	8.439	93.770	6.212
		8.380	7.502	9.377	8.908	103.148	5.626
3	60	8.590	7.502	9.189	9.471	107.838	5.744
		8.600	7.502	9.471	8.908	114.870	5.673
		8.555	6.939	8.908	8.271	119.558	6.493
3	90	8.865	7.502	8.252	8.439	110.180	5.275
		8.910	6.564	8.439	8.439	101.975	5.392
		8.860	6.564	8.439	7.971	99.633	5.861
4	30	8.040	7.033	9.283	8.346	152.378	6.799
		8.040	7.033	9.377	9.002	152.378	7.783
		8.275	6.939	9.096	8.346	164.098	7.033
4	60	8.970	8.439	9.377	9.377	164.098	7.197
		8.890	8.252	9.096	8.267	175.820	7.502
		8.960	8.252	9.189	8.908	180.510	7.853
4	90	8.230	7.689	10.127	9.377	159.410	7.267
		8.255	7.595	10.135	8.267	154.723	7.502
		8.190	7.502	9.377	9.189	168.788	7.970

*See Table I, p. 16.

**See Table II, p. 18.

TABLE XXIII

TREATMENT, STORAGE TIME, AND RESULTS OF CHEMICAL ANALYSIS OF VARIOUS PECTIN FRACTIONS OF CANNED GOLDRUSH SWEET POTATOES

Treatment* Number	Storage Time** (days)	% AIS on Drained Weight Basis	% Water Soluble Pectin in the Dry AIS	% Versene Soluble Pectin in the Dry AIS	% Total Pectin in the Dry AIS	Gammas AGA per ml. of Syrup	Mg. AGA per ml. of Alcoholic Filtrate from the AIS Determination
1	30	7.230	6.095	10.127	9.565	60.950	6.142
		7.395	5.626	9.565	9.283	58.608	5.392
		7.240	5.814	9.752	9.377	70.328	5.439
1	60	7.515	7.033	10.409	10.784	79.705	4.009
		7.505	7.502	10.409	11.253	89.083	4.689
		7.510	7.502	10.784	10.315	80.479	4.806
1	90	7.425	6.752	11.253	12.096	92.598	5.087
		7.525	6.752	11.253	12.096	90.255	5.369
		7.550	6.752	11.253	12.003	93.770	5.415
2	30	7.635	7.502	10.784	11.628	164.098	6.916
		7.810	7.971	10.784	12.003	152.378	6.377
		7.710	7.689	10.689	11.346	164.098	6.095
2	60	7.290	8.158	11.346	12.847	140.658	7.549
		7.265	7.595	11.721	12.847	140.658	7.197
		7.230	7.595	11.346	12.284	157.068	7.197
2	90	6.620	7.502	11.253	12.284	131.280	7.385
		6.715	8.158	10.689	12.284	143.000	5.744
		6.655	7.502	10.502	12.096	150.033	6.099

TABLE XXIII (continued)

Treatment* Number	Storage Time** (days)	% AIS on Drained Weight Basis	% Water Soluble Pectin in the Dry AIS	% Versene Soluble Pectin in the Dry AIS	% Total Pectin in the Dry AIS	Gammas AGA per ml. of Syrup	Mg. AGA per ml. of Alcoholic Filtrate from the AIS Determination
3	30	7.290	7.033	9.846	10.877	111.353	5.415
		7.280	7.033	10.033	11.346	99.633	4.993
		7.290	7.971	9.565	11.065	107.838	5.111
3	60	6.825	6.658	10.409	10.315	117.215	5.978
		6.805	6.939	9.846	11.159	121.903	5.861
		6.790	7.033	9.377	11.159	131.280	6.142
3	90	7.155	6.564	9.471	10.315	107.838	5.275
		7.095	6.658	9.939	9.846	113.698	4.876
		7.100	6.658	9.377	10.221	113.698	5.225
4	30	7.645	6.939	9.471	11.065	150.033	6.329
		7.630	7.220	9.846	11.502	140.658	6.564
		7.750	6.939	10.409	10.315	145.345	6.681
4	60	7.610	8.158	10.502	11.253	159.410	7.666
		7.580	8.439	10.409	10.689	164.098	7.853
		7.575	7.877	10.784	11.721	168.788	7.033
4	90	7.400	6.658	9.377	11.253	168.788	7.079
		7.405	7.127	9.846	11.253	168.788	6.799
		7.375	7.033	10.315	11.315	175.820	6.728

*See Table I, p. 16.

**See Table II, p. 18.

VITA

The author was born September 22, 1935, in Rio Verde, S.L.P., Mexico. He was graduated from the Presbyterian Panamerican School, Kingsville, Texas, in 1957. From 1957 to 1962 he attended King College, Bristol, Tennessee, where he received a Bachelor of Arts degree in Chemistry. In September, 1963, he entered The University of Tennessee Graduate School and in 1965 completed the academic work toward a Master of Science degree. In June, 1965, he accepted employment with The Heekin Can Company, Cincinnati, Ohio. Since that time he has been working in absentia on the writing of this thesis in order to complete the requirements for the degree, Master of Science.