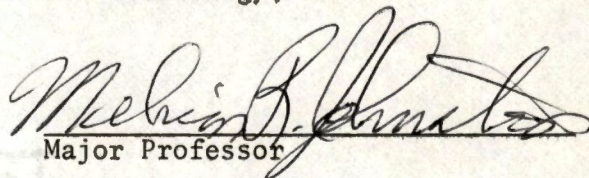


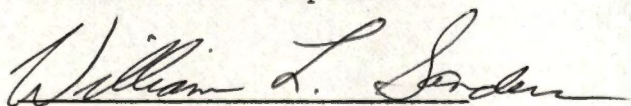
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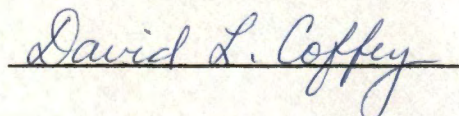
To the Graduate Council:

I am submitting herewith a thesis written by David Wayne Adkins entitled "A Long-Term Storage Study of Canned Red and Green Bell Peppers." 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.

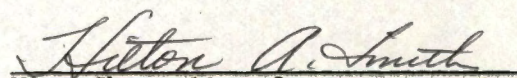

Major Professor

We have read this thesis and
recommend its acceptance:





Accepted for the Council:


Vice Chancellor for
Graduate Studies and Research

A LONG-TERM STORAGE STUDY OF CANNED
RED AND GREEN BELL PEPPERS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
David Wayne Adkins
December 1972

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to his major professor, Dr. Melvin R. Johnston, for his advice and guidance during the preparation of this thesis and throughout the period of graduate study.

Appreciation is extended to Dr. William L. Sanders for his advice and assistance in the statistical analysis of the experimental data as well as serving on the graduate committee, and to Dr. David L. Coffey for serving on the graduate committee and for reviewing the manuscript.

The author also wishes to acknowledge the interest and guidance given by Professor I. E. McCarty and Dr. J. L. Collins throughout the graduate study period.

Recognition is given to Miss Pat Davis for her assistance in the initial phase of the laboratory work.

Sincere appreciation is extended to Moody Dunbar, Incorporated, Limestone, Tennessee, for their support and generous grant which made this research possible.

Finally, a special note of appreciation is expressed to the author's wife, Kristin, for her encouragement and support throughout the graduate study period.

ABSTRACT

This research project was designed to determine the effects of long periods of storage at two temperatures on the composition and quality of canned bell peppers (Capsicum annuum L.).

One lot each of canned red and canned green bell peppers were obtained at the beginning of the 1970 packing season. Two similar lots were obtained at the beginning of the 1971 packing season. Each of these lots were divided into two storage groups. One group was stored at 75°F, and the other group was stored at 100°F.

The stored peppers were analyzed periodically to measure changes in the peppers' quality factors. At the end of the second year of the experiment, a proximate analysis was performed on canned peppers packed during the 1970, 1971, and 1972 canning seasons.

Analysis of variance was performed on all dependent variables related to quality. Regression equations were formulated for the five variables which had been defined as quality factors, and these equations were tested for nonhomogeneity due to temperature.

All variables were classified as either quality factors or storage factors, and these two groups were evaluated by the canonical correlation procedure.

Analysis of variance of the data indicated that the quality of canned red and canned green peppers changed at a different rate when stored under similar conditions. Canonical correlation analysis of the

data indicated that two separate systems were being affected in both canned red and canned green peppers. These two systems were the basis of a proposed method by which canonical variables could be used as independent indices to measure the quality level of the product. It was also proposed that the canonical variables could serve as the basis of a technique to maximize the over-all quality of canned bell peppers.

Drained weight loss occurred at about the same rate in both canned red and canned green peppers. A decrease of about 14 percent occurred over a one-year period in peppers stored at 100°F, and about 2 percent of drained weight was lost for one year of storage at 75°F.

Little variation was found in the proximate composition of canned peppers as a result of storage time or temperature. This was thought to be due to the relatively small amount of materials tested for in a large volume of water. The moisture content of canned bell peppers was found to be over 90 percent.



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CHAPTER I

INTRODUCTION

Canned bell peppers (Capsicum annuum L.) became a commercially important food item as a result of the development of processing methods which increased the product's storage stability. Prior to the use of these new techniques, bell peppers were preserved for short periods by brining and pickling, or by low-temperature (212°F or less) heat processing methods. Attempts to process the bell pepper at temperatures greater than 212°F resulted in a degraded product.

Presently, the canned bell pepper's quality and safety are being preserved by the controlled addition of citric acid to the product. This practice permits the pepper canner to use a low-temperature process designed to render high acid foods (pH less than 4.5) commercially sterile.

Although the canned bell pepper's quality level is not lowered during the canning and processing operations, the problem of long-term stability in this product remains, for the marketing pattern of canned bell peppers may involve storage periods of over one year. A product which has been in storage for a long period would most likely not have the same fresh-like characteristics of the just packed product, and, as a result, would be of less value on the commercial market.

The storage stability of canned foods has been the subject of several scientific investigations. The storage studies of the early

1940's were primarily concerned with vitamin retention, while the more recent studies have given some consideration to quality changes in canned foods. However, to date, very little has been published which deals specifically with the effects of storage on the quality attributes of canned bell peppers.

This research project was performed to determine the effects of long periods of storage at two temperatures on the composition and quality of canned bell pappers. The objective of the study was to provide both the producer and the consumer of canned bell peppers with information which would increase the utility of this product.



CHAPTER II

LITERATURE REVIEW

I. THE HISTORY OF CAPSICUM PEPPERS

Capsicum peppers have been cultivated for centuries as a condiment. Columbus is said to have returned to Spain from the newly discovered South America with a spice the natives called "Uchu", a red powder made by grinding the dried seed pod of a plant of the genus Capsicum. (39).^{*} This condiment was thought to have obtained the name "Pepper" because of Columbus' desire to find Indian spices, one of which was known as pepper (3).

The cultivation of capsicum peppers had spread throughout Europe, Africa, and Asia by 1650. A variety of these peppers grown in Hungary became much milder, larger, and less pungent over time, and came to be known as paprika (39). Paprika spices may be obtained from any one of the many varieties of Capsicum annuum simply by grinding the dried seed pod to a fine, red, nonpungent powder (40).

Capsicum peppers had become an important fresh market item in the United States in the early 1900's. By 1925, 2,326 cars of Ruby King and Chinese Giant cultivars were shipped to market centers. The increased consumption of the fresh pepper was probably due to a period of new developments in seed stock preparation between 1875 and 1900 (48).

^{*} The numbers in parentheses represent similarly numbered references in the bibliography.

There is little recorded in early American history concerning the commercial development of capsicum peppers, for much of the work with this crop was performed by private industry and never publicized (48).

Prior to the development of acidification of bell peppers, the only cultivar sturdy enough to withstand the rigorous treatment of a canning and retorting operation was the "Perfection" or pimiento pepper. This variety was developed in Georgia about 1912, and was the original canned bell pepper (48).

II. THE TAXONOMY OF CAPSICUM PEPPERS

American seedsmen listed between 125 and 150 varietal names for capsicum peppers in 1901. Perhaps only 18 to 20 distinct cultivars really existed (48). This inconsistency was most likely due to two factors: First, the wide range of shapes and sizes of peppers found in any given cultivar might have been the cause of the many different names proposed for bell peppers, and secondly, the seedsmen had been trying to develop new types of bell peppers by selective breeding, and were prone to tag each new crossbreed with a new name (39).

The confusion that existed in both popular and scientific literature with regard to the taxonomical classification of bell peppers may have been due to the general nature of the term "Pepper", as well as the numerous nomenclature systems proposed over the years for the Capsicum genus (39). Most authorities now recognize only five species of Capsicum. They are: C. annuum, C. frutescens, C. chinese, C. pendulum, and C. pubescens (39).

There are two principle types of peppers grown in the United States. One is the very pungent tasting C. frutescens, of which the Tobasco variety is an example. The other type is the sweet, mild tasting group known as bell peppers, sweet peppers, or mangos. All of those in this group are of the C. annuum species (40).

The Capsicum genera are in the family Solanaceae (40), and are not related to the black or white pepper of commerce, Piper nigrum, of the family Piperaceae (43). The capsicum peppers are distantly related to both the tomato and potato, for all are of the family Solanaceae (48).

One additional fact that has resulted in some confusion lies in the common name of the Perfection cultivar of C. annuum, the pimiento or pimento pepper. This fruit is often confused with pimiento spice, also known as allspice, which is derived from the Pimenta officinalis, a type of tree (43).

III. USES OF CANNED BELL PEPPERS

Canned red and green bell peppers have been used in almost any situation calling for a fresh cooked pepper. The bulk of the canned bell peppers are used by commercial food processors to prepare such food items as stuffed olives, pickle packs, processed meat items, and pimento cheese (40).

This utilization pattern is quite apparent in the pack statistics for canned pimientos over several years. While the total amount of pimientos packed from 1962 to 1966 increased by a factor of about 2.3, the number of cases of No. 10 cans of pimientos packed during the same period increased by a factor of about 10.7 (21).

Future uses for canned bell peppers may develop as a result of the very high ascorbic acid and carotene content of the raw pepper (40). However, certain modifications of both processing and storage techniques may be necessary in light of the unstable nature of some nutrients (13).

IV. QUALITY FACTORS OF CANNED BELL PEPPERS

Kramer (25) noted that the quality attributes of a food item must be defined in terms of what the product purchaser wants from the product. In the case of canned bell peppers, food processors expect to get the fresh-like characteristics of bell peppers, for many producers depend upon the bell pepper to supply aroma, texture, and eye-appeal to their product.

Kramer (25) also noted that the amount of usable product per unit pack is of some economic importance, and in terms of large scale commercial operations, should be considered an important quality factor.

The United States Department of Agriculture has published quality standards for the Perfection cultivar of C. annuum, but none have been published for the other cultivars (21). However, acidification of the pack now permits canning and heat processing of several varieties (20, 37). There is little difference in the composition of the different cultivars of C. annuum, and there is little reason to assume that the desired quality attributes differ for the different cultivars.

The USDA grade standards for canned pimiento peppers takes into consideration such factors as size, color, defects, character, and drained weight. Character is defined in terms of texture and firmness.

Drained weight is not a scored factor, but minimum requirements must be met (21). A composite of the quality factors desired by the purchaser and the quality factors listed by USDA for canned pimiento peppers may be assumed to include the more important quality factors for canned red and green bell peppers. Thus, the important quality factors for canned bell peppers are flavor, aroma, color, defects, texture, and drained weight. The makeup of these factors will be considered in the following section.

V. PHYSICAL BASIS OF BELL PEPPER QUALITY FACTORS

The flavor and aroma of bell peppers have been qualitatively analyzed using conventional and capillary gas-liquid chromatography, with characterization by mass, infrared, ultraviolet, and proton magnetic resonance spectra. The characteristic odor of the bell pepper was found to be due to 2-methoxy-3-isobutylpyrazine (5). The same group reported that the odor threshold for this compound was 0.002 parts per billion, while the whole pepper contains from 10 to 20 parts per million.

The colors of canned bell peppers are primarily either green or red, depending upon the maturity of the product. The less mature green peppers, like all higher plants, owe their green color to the presence of chlorophyll A and chlorophyll B (9, 19).

The more mature red peppers have a characteristic red-orange color derived from a mixture of carotenoids containing about 35 percent capsanthin, 10 percent each of β -carotene and violaxanthin, 6 percent each of cryptoxanthin and capsorubin, 4 percent cryptocapsin, and many other carotenoids at levels less than 2 percent (9).

Defects are almost nonexistent in canned bell peppers now. Those defects sometimes detected include grit, sand, silt, seeds, core, stem materials, charred materials, and insect damage (21). These defects occur rarely, and have little significance in over-all quality of the canned pepper pack.

Although texture is a very important quality factor, it may have different meanings to different people, for texture is intimately related to several sensory parameters (26). It has been pointed out that before a quality factor can be evaluated objectively, it must be defined in terms of physical measurements under specified conditions, and on a defined scale (45). More specifically, texture is a sensory property of touch or feel, and is measured in units of mass or force (26).

Drained weight, as was previously pointed out, is a quality factor of economic importance. Drained weight is a function of the permeability of the cell membrane and the concentration of dissolved materials in the packing fluids (45). The amount of fluid given up by the processed material has been used as a gauge to determine the level of degradation occurring in the canned product (7). Minimum drained weight requirements have been set for canned peppers by the USDA (21).

VI. EFFECTS OF TEMPERATURE AND STORAGE ON CANNED FOOD

Several storage studies were performed during the early 1940's to evaluate vitamin retention in canned foods under various storage conditions. One of the first studies was inaugurated in 1942 by the National Canners Association and the Can Manufacturers Institute to establish

quantitative data on the high temperature storage of vitamins in military rations (32).

Similar studies were performed in 1947 and 1948 (4, 34). All of these experiments brought up the fact that thiamine and ascorbic acid were lost as a result of high temperature storage, but carotene, niacin, and riboflavin were completely retained. Every report on vitamins also made note of the fact that there was a high degree of variation in all nutrients due to the variability of the test materials.

Monroe et al. (33) studied the temperatures in 79 warehouses across the United States in 1949, and suggested that the previously performed storage studies in the 100°F range were unnecessary, for the highest yearly average temperature found in the United States was only 80°F. This argument received little support from other workers. It was pointed out by Hearne (17) and Cecil and Woodroof (6) that the information would be of use in certain circumstances.

More recent storage studies have been concerned with the quality changes that occur in foods held for long periods and under extreme storage conditions. A long-term storage study performed by Cecil and Woodroof (6) was designed to evaluate quality changes that occurred in many different military rations stored under both normal and high temperature conditions. They evaluated quality changes by use of sensory panels, moisture content, acidity, rancidity, vacuum, brix, Hunter color measurements, pH, and drained weights. Evaluations were made every six months for four years and then once a year for three years. Tests were made in duplicate, and the results were analyzed statistically. Some of their conclusions were:

1. Each type of food had a different shelf-life potential.
2. A direct relationship exists between product stability and storage temperature.
3. Color loss in tomatoes occurred more rapidly at higher storage temperatures.
4. There was no relationship between drained weight and time or temperature for corn, but there was for tomatoes.

There has been very little reported work concerning the effects of high temperature and long periods of storage on the quality of canned bell peppers. However, some of the quality attributes of bell peppers have been studied with regard to storage time and temperature in similar products.

The effects of temperature and storage time on chlorophyll in "Perfection" peas were reported by Blair and Ayres (2) in 1943. They found that chlorophyll retention was lower at higher temperatures as a result of the pH varying as a function of temperature. They also found that if the pH was held constant, the chlorophyll would still be lost, but at a rate that was entirely dependent upon temperature. Like other workers, Blair and Ayres made note of the wide variations they observed between duplicate samples.

Chichester (7) reported that the fate of the chlorophyll molecule in storage was unresolved, for no large, obviously derived compounds could be found to piece together the step-by-step breakdown of the chlorophyll molecule. He stated that the general occurrence in processing and storage was an oxidative reaction that was affected by heat or enzyme activity.

Both Blair and Ayres (2) and Chichester (7) described the cause of the appearance of a characteristic olive-drab color as being due to the degradation of chlorophyll to pheophytin. This reaction usually occurs in an acidic media in which hydrogen ions displace the magnesium ion in the chlorophyll molecule.

The color pigment of red peppers is called capsicum red. As previously stated, this pigment is made up of a complex set of carotenoids, mostly in the form of esters (9, 27).

Several workers have reported that the carotenoids are fairly stable under high temperature storage conditions (4, 33, 35), but are decomposed by oxidative conditions (7), and are subject to conversion from the trans to the cis form (32). Both oxidation of the carotenoid molecule and its conversion to the cis configuration result in a brightening or lightening of the carotenoid color. The conversion to the cis form is caused by heat, light, or acid (32).

Color changes in tomato products stored for long periods under high temperature conditions have been attributed to temperature, paste concentration, and the presence of reducing sugars (27). The major color pigment of tomato products is the carotenoid lycopene. Since the color pigment of bell peppers is also a carotenoid complex, one would expect that canned bell pepper color changes might also be influenced by the factors mentioned above.

Color changes in both red and green bell peppers in storage are thought to be the result of a complex series of chemical reactions occurring in the dying cell, but little is known about what actually

happens. It is known that upon death, the discrete carotenoid bodies within the plant cell become dispersed in oil droplets (49).

Browning reactions most likely have some influence on the color changes that occur in stored canned bell peppers, particularly when high storage temperatures are involved (17). Although three types of browning may occur in canned bell peppers, the browning due to the reaction of reducing sugars and amino acids, commonly known as the Malliard reaction, takes place so rapidly as to mask the slower oxidation types of browning (17).

Texture is an important quality factor in canned bell peppers, and is known to be influenced by storage (20). Its complex nature has been mentioned previously.

Powers et al. (37) stated that neither texture nor drained weight of canned peppers was affected by changes in acid content. Ten years later, Powers et al. (38) reported that both firmness and drained weight were increased by the addition of acid to canned pimiento peppers.

Hoover (20) reported that texture in canned red and green bell peppers was preserved from loss during heat processing by the addition of calcium compounds. He noted that green peppers responded better than red peppers to this treatment, that calcium hydroxide seemed to give the best results, and that both treated and untreated samples tended to decrease at about the same rate over time.

Drained weight is another important quality factor in canned bell peppers. Sane et al. (41) found that the drained weight of canned bell peppers varied with the amount of acid added to the pack. This was

supported by the work of Powers et al. (38) who also reported that in many cases, processing time was as important a factor on drained weight as acid content. Neither report made reference to the affect of storage time or storage temperature on drained weight.

Sterling (45) reported that drained weight was inversely related to the sugar concentration of the packing fluid for fruits canned in a heavy syrup. He suggested that the drained weight of some processed vegetables showed a significant increase over time because of some hydrophilic swelling of starch and protein components in the cells.

One other factor known to have some influence on the drained weight of canned bell peppers is the presence of intercellular air spaces. Upon death, the permeability of the cellular material changes to the extent that fluids are released into the intercellular air spaces. This has been said to be the cause of a 16 percent drained weight increase observed in processed carrots (49).

VII. DATA EVALUATION IN STORAGE STUDIES

There are many useful techniques available for the evaluation of data obtained from storage studies. The choice of which techniques to use should be based upon such criteria as design of the experiment, procedures used in collecting data, and what types of decisions are to be made from the test statistics (4).

Results of the vitamin retention experiments of the early 1940's were reported in terms of percent difference of vitamin content (35) or conclusions were drawn by simply plotting vitamin content over time and

describing the variations in general terms (29). Other workers have used such techniques as line fitting by the least squares method (24), analysis of variance (46), and Duncan's multiple range test (6).

Simon et al, (44) have suggested that once a specified set of data have been obtained for a given food item, use of the computer would permit storage predictions to be made for a wide range of conditions. His proposed methods involved the calculation of regression equations in terms of time and temperature.



CHAPTER III

MATERIALS AND METHODS

I. MATERIALS

On October 15, 1970, one lot of canned, red, diced bell peppers and one lot of canned, green, diced bell peppers were obtained from Moody Dunbar, Incorporated, Limestone, Tennessee. These two lots were divided into two test groups each. One test group from each lot was placed in storage in a room with an average temperature of 75°F, and the other test group from each lot was placed in a storage room with a controlled temperature of 100°F.

On September 1, 1971, one lot of canned, red, diced bell peppers and one lot of canned, green, diced bell peppers were obtained from Moody Dunbar, Incorporated. These two lots were divided into two test groups each and stored under the same conditions described above.

On September 12, 1972, one case each of red and green bell peppers were obtained from Moody Dunbar, Incorporated, and stored at room temperature for one week before being used in the experiment.

Both red and green canned peppers were packed in number ten cans, and the cans were packed in cardboard cases, six per case. The samples were stored in the cardboard case until they were analyzed.

Moody Dunbar, Incorporated, has canned bell peppers for 25 years. Much of the equipment they use has been developed in their plant at

Limestone, Tennessee. The procedure used in processing the canned bell peppers at this plant has changed very little over the past three packing seasons.

Although the product does not vary much in quality as a result of the processing operation, the wide range of variations known to occur in biological materials as a result of seasonal climatic conditions was a possible source of error in the experiment. It was decided that the peppers placed in storage during the 1970 season would be used to define the parameters of the experiment and to refine the techniques used in measuring quality variations. The data obtained from evaluation of the 1971 season samples were to serve as the basis for conclusions drawn with regard to the quality changes in canned peppers.

A proximate analysis was made on samples obtained during the 1970, 1971, and 1972 packing seasons. This provided information as to the changes occurring in the proximate composition in canned peppers over a period of three growing seasons.

II. METHODS OF SAMPLE EVALUATION

Samples were removed from storage 48 hours prior to analysis and were placed in a laboratory with a temperature range of from 74°F to 76°F, to permit both high-temperature stored and room-temperature stored samples to reach the same temperature. The order of testing the samples was as follows: Red peppers stored at a high temperature, red peppers stored at room temperature, green peppers stored at a high temperature, green peppers stored at room temperature.

There were three cans or replications for each of these four sample blocks. Five determinations were made on each can as it was opened. The five determinations were vacuum, drained weight, brix, pH, and acid content. After these five determinations were made on one can, the next can was opened and the same five determinations made. This was repeated until these five determinations were made on all cans to be tested at the particular test period.

After all cans had been opened and tested for the five factors stated above, all samples' texture was measured. All samples were then tested to determine reflectance color factors. This testing procedure was used for each of the five test periods in which the September, 1971, packed samples were evaluated.

Vacuum

The vacuum was measured for each can with an Ashcroft AMP 6683 vacuum gauge. The gauge reading was recorded as vacuum, expressed as inches of mercury.

The gauge had been adapted to measure can vacuum by having a sharp, hollow, metal probe attached to the vacuum gauge port. The sharp probe was seated in a soft rubber ring so that when enough pressure was applied to the gauge to cause the probe to penetrate a metal can, a seal was formed between the can surface and the gauge port by the compressed rubber ring. Since the test destroyed the vacuum in the can, only one vacuum determination could be made on each can.

Drained Weight

The drained weight of each pack was determined by placing the total contents of the can into a 12-inch diameter sieve, screen size eight, and positioning the sieve about 25 degrees from the horizontal. After two minutes, the weight of the drained solids remaining on the sieve was taken as the drained weight.

Since, in reality, canned peppers are packed by volume and not by weight, it was necessary to weight the fluid that drained off of the peppers, in order to express the weight of the drained peppers in terms of the total weight of the pack. This was called the drained-weight ratio.

Brix

The Brix or sugar level of the packing fluid was determined by means of a Bausch and Lomb Optical Company refractometer with a Brix scale. Although variations of the Brix within the individual cans were very small, duplicate readings were made for each can.

pH

The pH of the packing fluid was measured with a Fisher Scientific Company Model 801 digital pH meter. Prior to each series of pH determinations, the pH meter was calibrated with a buffer solution made from Coleman Certified Buffer Tablets, formula number 10, at the pH level 4.00.

pH readings were made on 100 ml of the fluid drained off the canned product during the drained weight determinations. The fluid was

placed in a 250 ml beaker and stirred at a very slow rate with an electric stirrer until the pH reading became stable.

Acid

The acid content of the packing fluid was determined by titration with 0.100 N sodium hydroxide. A 10 ml sample of the pack fluid was diluted to 100 ml with distilled water and titrated to an estimated end-point of pH 8.0, using a 1 percent alcoholic solution of phenolphthalein as the indicator.

Enough 0.100 N sodium hydroxide solution was prepared at the beginning of the experiment to make all necessary titrations. At the end of the experiment, the normality of the sodium hydroxide was tested and found to be 0.101 N.

Acid content of the packing fluid was taken as the average of two titrations per can, and the acid content was recorded as the number of ml of 0.100 N sodium hydroxide used to titrate the 10 ml sample,

Texture

Texture of the drained peppers was measured on the Allo-Kramer Shear Press. The downstroke of the instrument was adjusted to 20 seconds, and a 1000-pound range test ring was used.

The texture measurement was recorded as pounds of force needed to shear a 100 gram sample held in the standard cell. Two shear measurements were made for each can, and the average of the two was recorded as texture, measured in pounds of shear force,

Color

The color of the drained peppers was evaluated using the Signature Model D-1 Color-Eye, manufactured by Instrument Development Laboratories, Attleboro, Massachusetts. Two sets of determinations were made on each can of peppers. Values were read for the Color-Eye units "X, Y, Z, and x'." The average of the two determinations for each Color-Eye unit was recorded as the Color-Eye color units of the sample.

The samples to be tested were packed in a two-inch diameter sample cup which had an optically designed transparent bottom. The cup was filled to capacity, a flexible plastic sheeting material was folded over the open end of the cup and held in place with an elastic band. The sample was manipulated through the plastic sheeting until all air bubbles were worked away from the surface of the bottom of the cup.

The sample was held against the sensing port of the Color-Eye instrument, and the X, Y, Z, and x' values were read. The values were read in the order stated. Some samples were retested when it was apparent that some discrepancy had occurred.

The Color-Eye values were converted to C. I. E. (32) values by the conversion calculations given in the Color-Eye instruction manual. These calculations were based on the following formulae:

$$X_{CIE} = .783 (X_{Color-Eye}) + .197 (x'_{Color-Eye})$$

$$Y_{CIE} = (Y_{Color-Eye})$$

$$Z_{CIE} = 1.180 (Z_{Color-Eye})$$

Once the C. I. E. color values for the samples had been calculated, the C. I. E. chromaticity coordinates, "x and y" were calculated by these formulae:

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

The C. I. E. chromaticity coordinates were then plotted on a C, I. E. chromaticity diagram. A straight line was drawn from the illuminant point of the diagram, through the coordinant point, to the edge of the diagram. The dominant wavelength of the pepper tissue was read at the periphery of the diagram. The distance from the illuminant point to the coordinate point was divided by the distance from the illuminant point to the periphery of the diagram along the previously constructed line. The derived value was multiplied by 100 to obtain a percent color purity value.

The C. I. E. "Y" color value was used to calculate the lightness or reflectance of the sample. The Lightness value of the sample, often referred to as the "L" value, was derived by multiplying the square root of the "Y" value by 10.

A proximate analysis was performed at the end of the second year of the experiment on samples of canned red and green peppers. One can of each type of pepper was selected from each of the two storage temperatures, for each of the two storage periods. One can of each color type was also selected from the 1972 packing season to be analyzed.

Each sample was tested for moisture content, ash, fat by ether extract, protein by kjeldahl nitrogen, and crude fiber. The carbohydrate content was determined by difference (47).

III. METHODS OF DATA EVALUATION

Several statistical analyses were performed, using the Statistical Analysis System of Barr and Goodnight (42), a "packaged" computer program which permits easy access to many commonly used statistical methods.

Since the factors thought to affect quality were recorded as quantitative values, the analysis of variance procedure was applied to each of these variables to determine how each was affected by time, temperature, and the (time $\times$ temperature) interaction.

Regression equations were formulated for the five quality measuring variables. These equations were of the form:

$$\hat{\text{Variable}} = a + b_1(\text{time}) + b_2(\text{time}^2) + b_3(\text{time}^3)$$

where time, time², and time³ represented the linear, quadratic, and cubic effects of time. The equations were formulated for each variable within temperature classes. They were then tested for homogeneity between the two temperature levels. A nonhomogeneous relationship between the two equations would indicate that when the same variable was measured at different temperatures, different rates of change were found.

Those equations having a significant difference from the average were recorded as two separate equations, while those which were found to be homogeneous were expressed by one equation for both temperatures, and a constant difference factor was reported.

The second approach taken to the evaluation of quality changes in canned peppers involved the use of canonical correlations. This procedure

was first developed to study the relationships between two batteries of psychological tests administered to the same individual (34). The canonical correlation analysis is a multivariate statistical method by which two groups of variables can be tested for interdependence by computing canonical variables from the grouped variables. The degree of interdependence is expressed by the correlation between the canonical variables calculated, and is called the canonical correlation (34).

The degree to which any single variable of a group of variables affects the value of the canonical variable can be estimated by the simple correlation coefficient between the single variable and the canonical variable. The canonical correlation analysis procedure weights each variable within the group in such a manner as to obtain the maximum correlation between the canonical variables of the two groups being compared. The number of canonical variables calculated for two groups of variables is limited to the smallest number of variables in either of the compared groups.

Canonical correlation analysis was used to relate the quality factors wavelength, drained weight ratio, texture, color purity, and reflectance to the storage factors of time, temperature, acid content of the packing fluid, Brix of the packing fluid, and can vacuum.

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CHAPTER IV

RESULTS AND DISCUSSION

The data determined in this experiment appear in Table 5, in the Appendix. An analysis of variance was performed on each dependent variable measured in the course of the experiment to determine the significance of time, temperature, and the (time $\times$ temperature) interaction on the changes in each variable. The determined "F" ratio for each of the variables analyzed appears in Table 1. The significance of each of the values is noted.

From the analysis of variance of the dependent variables, it was noted that canned red peppers and canned green peppers responded differently to temperature and time of storage. Thus, even though both red peppers and green peppers are derived from the same raw materials and differ only in their state of maturity, they should be considered as completely different products when determining their optimum storage conditions.

Regression equations were formulated for the five variables of pepper quality as a means of predicting the level of any one of these values after a specified time in storage. These equations appear in the Appendix on page 50. The graph of each of these equations appears in Figures 1 through 5.

Table 2 is a summary of the homogeneity tests performed on the equations for the regression lines shown in Figures 1 through 5. It was

TABLE 1

A SUMMARY OF THE "F" RATIOS DERIVED BY ANOVA^a OF ALL STORAGE STUDY DEPENDENT VARIABLES

Variable	Red Peppers			Green Peppers		
	Temperature	Time	Interaction	Temperature	Time	Interaction
Acid	15.01**	12.23**	0.82 ^{ns}	1.36 ^{ns}	18.78**	3.43*
Shear	456.30**	10.11**	1.05 ^{ns}	258.15**	6.08**	7.18**
Vacuum	10.66**	3.24*	1.87 ^{ns}	2.40 ^{ns}	1.30 ^{ns}	0.59 ^{ns}
pH	9.96**	1.04 ^{ns}	0.87 ^{ns}	3.51 ^{ns}	4.53**	5.93**
Brix	2.13 ^{ns}	1.47 ^{ns}	0.47 ^{ns}	0.01 ^{ns}	1.61 ^{ns}	5.15**
Weight Ratio	524.76**	20.13**	11.61**	43.90**	12.39**	10.41**
Wavelength	4.48*	3.86*	0.80 ^{ns}	0.18 ^{ns}	0.97 ^{ns}	0.52 ^{ns}
Purity	0.74 ^{ns}	1.54 ^{ns}	3.96*	6.68*	7.27**	3.29*
Lightness	4.52*	7.97**	0.02 ^{ns}	29.08**	7.72**	1.83 ^{ns}

^aAnalysis of Variance.

* Significant at the .05 level of probability.

** Significant at the .01 level of probability.

ns Not significant.

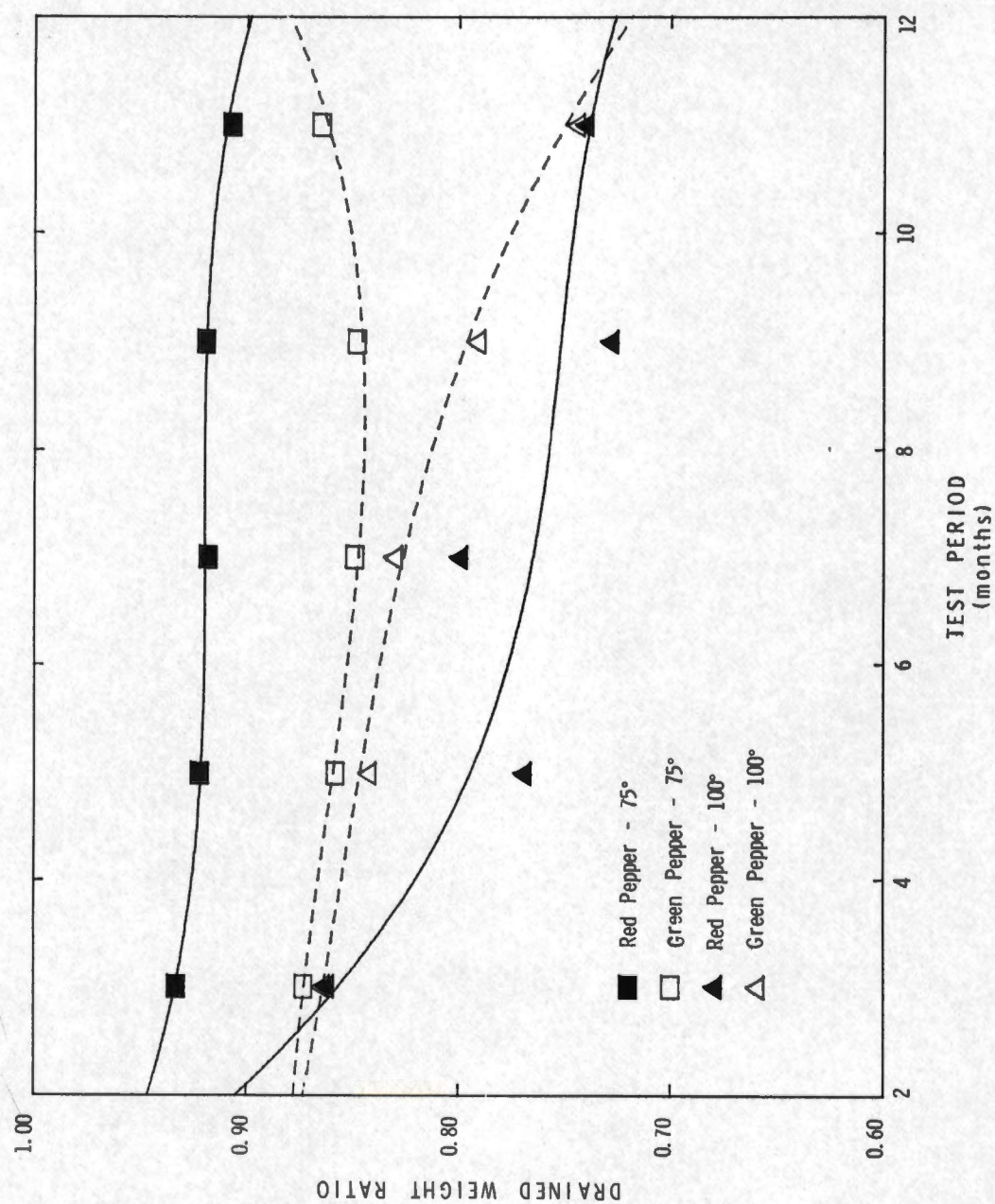


Figure 1. Effects of time and temperature on the drained weight ratio of canned red and green bell peppers.

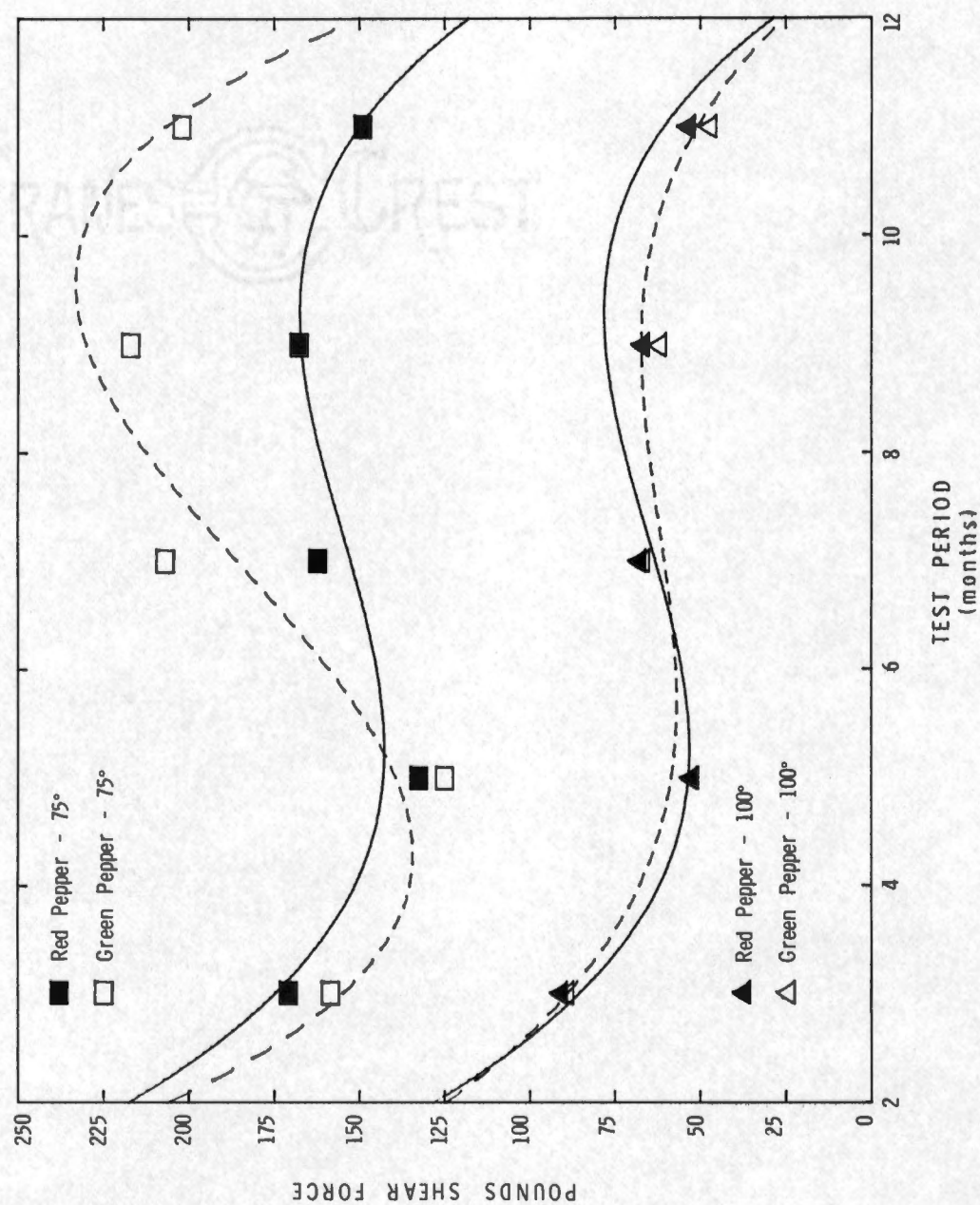


Figure 2. Effects of time and temperature on the texture of canned red and green bell peppers.

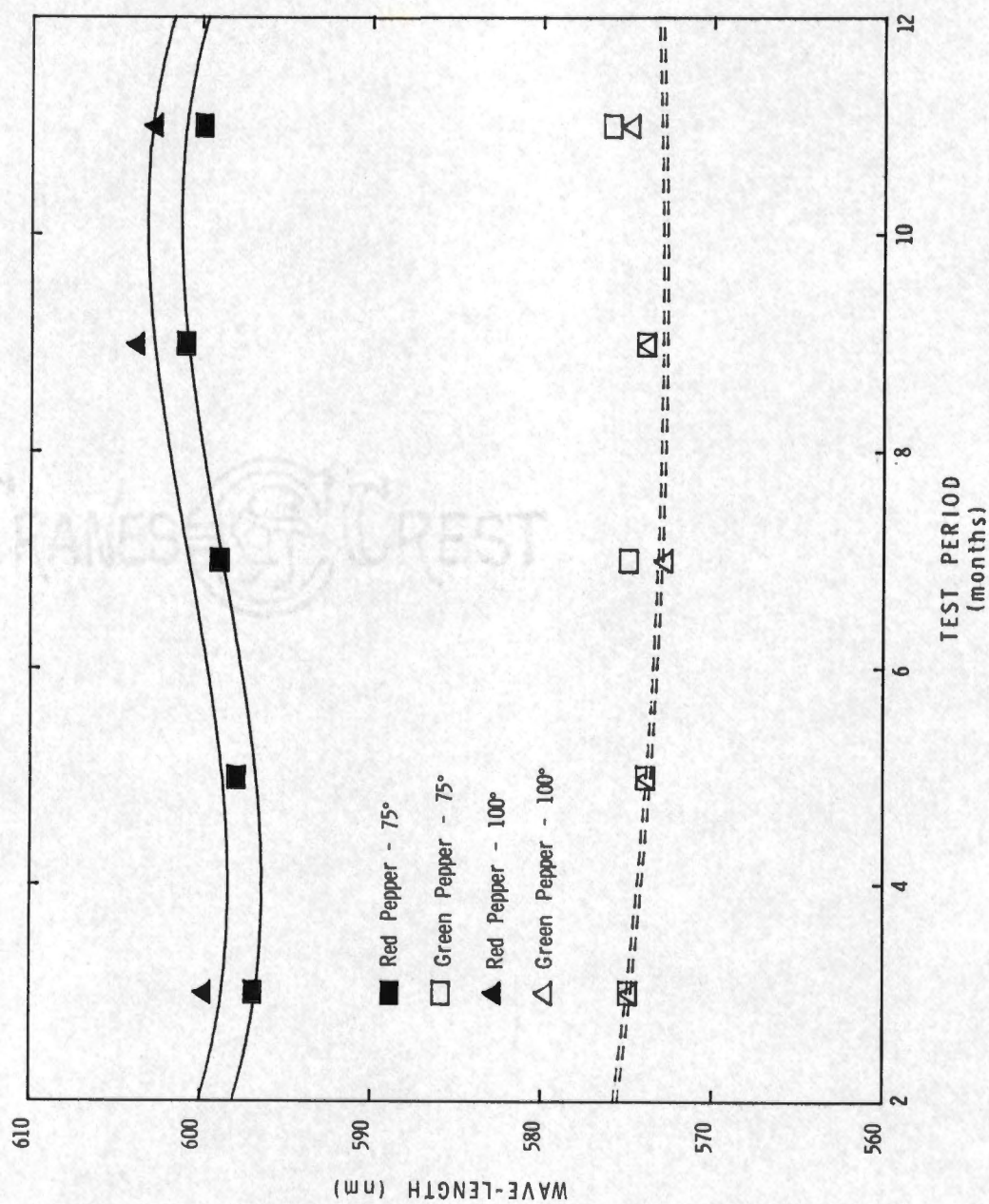


Figure 3. Effects of time and temperature on the wavelength of canned red and green bell peppers.

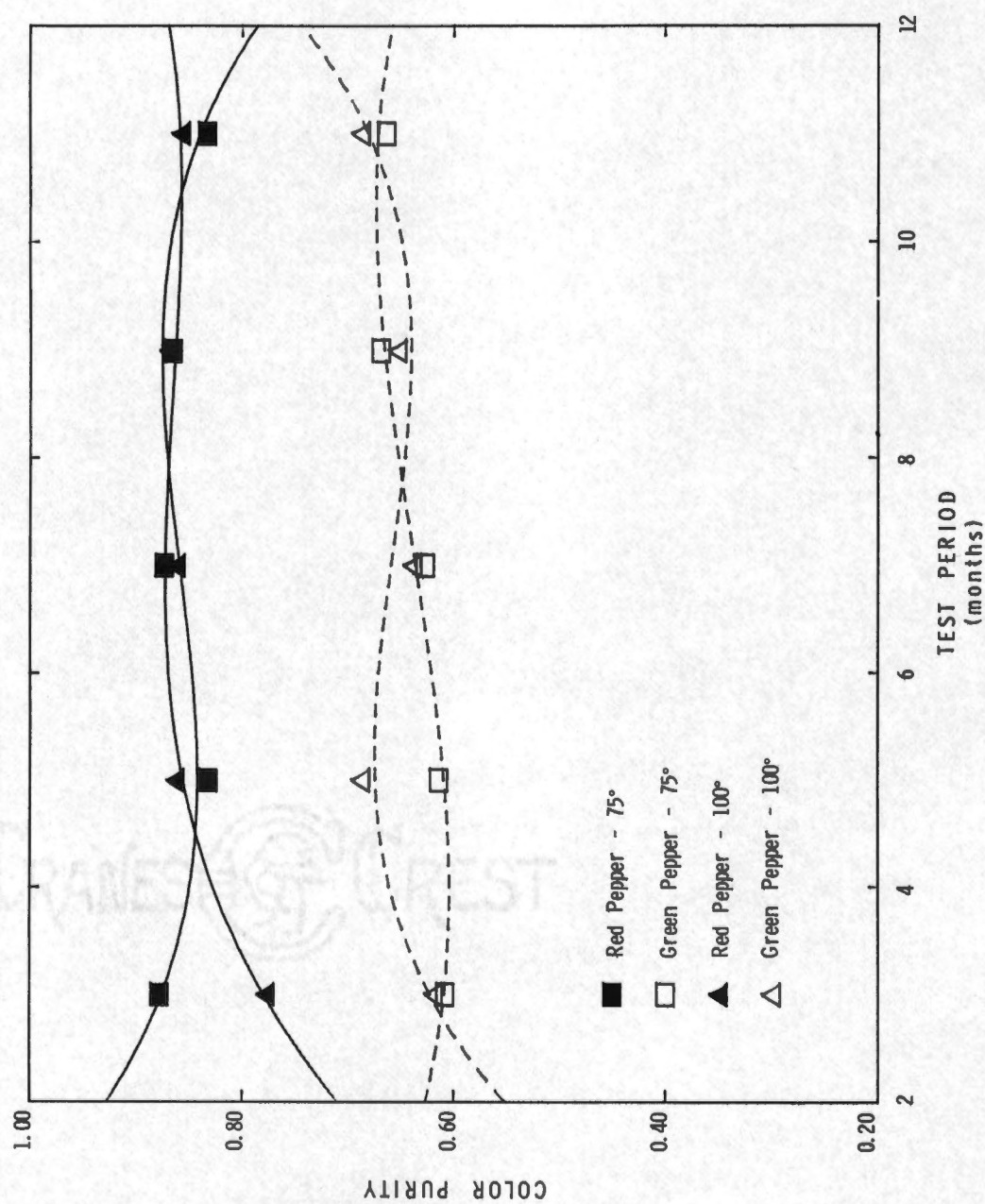


Figure 4. Effects of time and temperature on the color purity of canned red and green bell peppers.

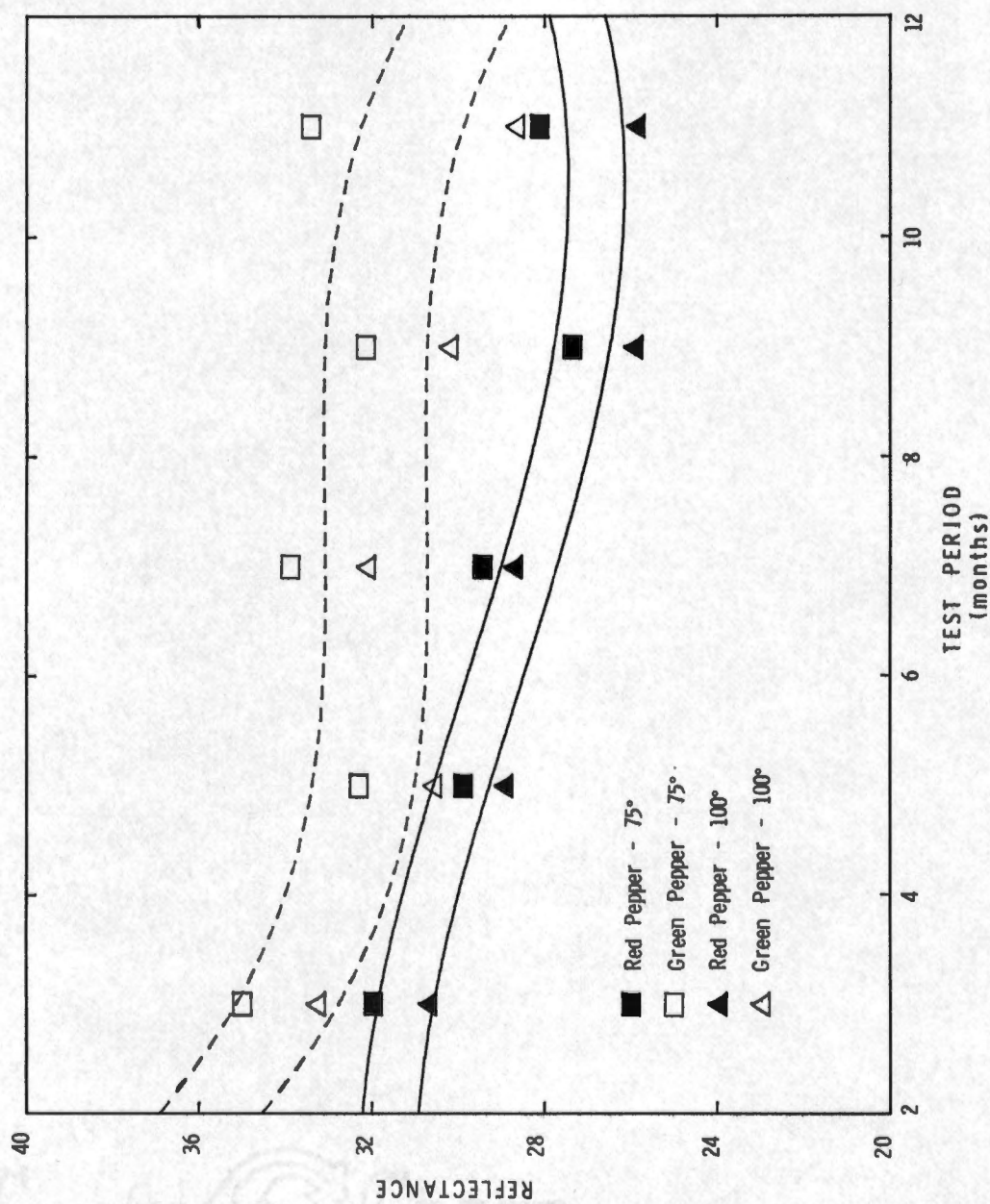


Figure 5. Effects of time and temperature on the reflectance of canned red and green bell peppers.

TABLE 2
SUMMARY OF REGRESSION HOMOGENEITY TESTS

Variable Tested	F-Ratio	
	Red Peppers	Green Peppers
Shear Force (Texture)	1.18 ^{ns}	7.39 ^{**}
Drained Weight Ratio	11.43 ^{**}	14.33 ^{**}
Wavelength	1.10 ^{ns}	0.30 ^{ns}
Color Purity	13.67 ^{**}	3.33 [*]
Reflectance (Lightness)	0.24 ^{ns}	1.77 ^{ns}

^{ns} Not significant.

^{*} Significant at the .05 probability level.

^{**} Significant at the .01 probability level.

found that the drained weight ratio and color purity were affected by temperature in both red and green canned bell peppers, but there was a temperature related variation in texture for the green peppers only.

This difference was thought to be due to physical or chemical differences between the two maturity levels represented by the red and green peppers. Such a situation would explain the initial difference in texture in the two types, and would be in agreement with the work of Hoover (20) which reported higher shear measurements in green peppers than red, and Powers et al. (38) reported that texture varied with acid content.

Canonical correlations were calculated in order to compare the over-all quality of canned bell peppers with the storage conditions thought to affect their quality. Although a maximum of five canonical variables could have been generated for each of the two groups of variables, only the first two were deemed significant in both canned red and green bell peppers.

The canonical correlations for the first two sets of canonical variables for both red and green peppers, and the associated list of correlations between the canonical variables and the individual variables of each group are tabulated in Table 3.

By inspection of Table 3, it can be seen that in order to obtain a maximum correlation between quality and storage conditions for red pepper, the quality factors of texture and drained weight ratio were most heavily weighted, while the storage factors of temperature, can vacuum, and acid content of the pack fluid were weighted more heavily than others.

TABLE 3

CORRELATION COEFFICIENTS CALCULATED BETWEEN CANONICAL
VARIABLES AND THE INDIVIDUAL VARIABLES WITHIN
EACH CANONICAL GROUP

	Red Peppers		Green Peppers	
	Canonical Variable		Canonical Variable	
	1	2	1	2
<u>Quality Factors</u> ^a				
Wavelength	- .42 ^a	0.67	0.06	- .06
Shear Force (Texture)	0.97	0.14	0.84	- .53
Drained Weight Ratio	0.98	- .16	0.86	0.42
Color Purity	0.05	0.27	- .51	- .35
Reflectance (Lightness)	0.41	0.82	0.80	0.18
<u>Canonical Correlation</u> ^b	0.97	0.77	0.90	0.87
<u>Storage Factors</u> ^a				
Time	- .20	0.95	- .38	0.87
Temperature	- .97	- .19	- .89	- .84
Brix	- .24	- .20	- .02	0.01
Vacuum	0.63	- .17	0.44	0.10
Acid	- .51	0.62	- .53	- .79

^aValues listed are simple correlation coefficients between the Canonical Variable and the individual variables within a storage or quality group.

^bCanonical correlation values are the correlation coefficients between the storage factor canonical variables and the quality factors canonical variables.

This could be interpreted to mean that if texture and drained weight ratio were the quality factors for red peppers, then temperature, can vacuum and acid content were the storage factors which control changes in red pepper quality.

The group of correlations between the second canonical variable of red pepper quality and the individual factors of quality indicated that if reflectance and wavelength were important factors in defining the quality of red peppers, then time in storage and the acid content of the packing fluid were the storage factors to consider.

In reality, as has already been pointed out, all of these quality factors are important in defining the over-all quality of red peppers. The real implication of this type of analysis lies in the fact that two independent groups of quality factors have been detected, and that the over-all quality of the red peppers could be defined in terms of these independent factors.

Table 3 also contains the same information for green peppers' quality factors and their relationship to the storage factors. The canonical correlation between canned green peppers' quality and storage factors may also be interpreted in terms of two independent quality indexes. The first canonical variables for quality factors and storage factors have a canonical correlation of 0.91. Within the quality factors group, texture, drained weight, reflectance, and color purity have a relatively high correlation with the canonical variable of that group. Within the storage factors group, storage temperature and acid content have a relatively high correlation with the canonical variable of that

group. This was interpreted to mean that one index of quality in canned green peppers was made up of a combination of texture, drained weight, reflectance, and color purity. This quality index's value varied with variations in storage temperature, and acid content of the pack, while a second index of canned green pepper quality was made up of the quality factor texture, which varied because of a combination of acid, time in storage, and temperature of storage.

One general observation was made with regard to the canonical correlation analysis of both red and green peppers: Both canned red pepper quality and canned green pepper quality were defined by two different sets of chemical and physical conditions which were expressed generally as being related to texture and drained weight, or being related to color purity, reflectance or wavelength, or as a combined index of texture, drained weight, wavelength, color purity, or reflectance.

A method was proposed by which the two independent indexes of quality could be used to predict and control the quality level of canned peppers. Figure 6 illustrates that the two quality indexes could be used to assign a point within an X - Y coordinate system. Such a point could be called an over-all quality point. Although it has not been done in this study, the X - Y plane could be divided into regions of quantified quality values in terms of consumer acceptability, and one numerical value used to represent the pepper's over-all quality.

It can be seen in Figure 6 that if it were possible to control the values for each index of quality, then the over-all quality point could be caused to fall in any one of the four quadrants marked. Thus,

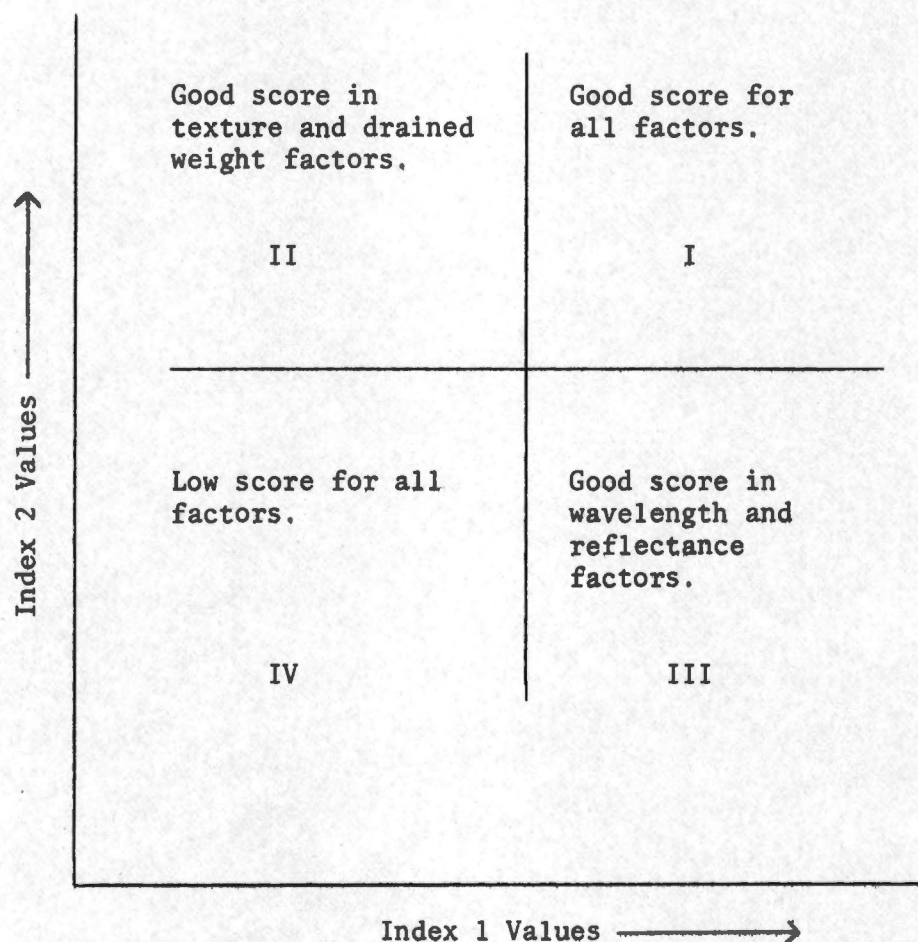


Figure 6. A proposed method to evaluate canned red pepper quality in terms of two indexes generated by use of a canonical correlation analysis.

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if the quality point was located in the "I" quadrant, the over-all quality would be high, for the product would have a high score for all quality factors. If the quality point fell in the "III" quadrant, the over-all quality would be lower due to low drained weight and texture scores.

By reviewing Table 3 (page 33), it can be seen that for canned red peppers, one quality index (canonical variable) was negatively correlated with acid content and temperature of storage, while the second quality index was positively correlated with acid content and time of storage. These data indicated that it might be possible to manipulate the storage factors in such a manner as to obtain a desired quality level at a given time. However, this study did not explore that possibility in more detail.

Very little variation was observed in the proximate analysis data, and no analysis of variance was performed on this data as was previously planned. It was suggested that the reason for so small a change in the drained pepper's composition in light of a large decrease in drained weight over time was due to the fact that the total solids in the pack were so small that changes in them were not detected. The average proximate composition of canned red and green bell peppers is listed in Table 4. All proximate analysis data for storage groups are listed in Table 6, in the Appendix.

The changes which occurred in the quality factors of canned red and canned green peppers over a period of one year as a result of storage in 75°F or 100°F storage generally occurred in the same manner reported in other types of vegetables.

TABLE 4
AVERAGE PROXIMATE ANALYSIS OF CANNED BELL PEPPERS

Test ^a	Pepper Type	
	Green	Red
	(Percent)	
Moisture	94.1	92.7
Fat	0.1	0.2
Protein	0.7	0.8
Crude Fiber	0.9	1.0
Ash	0.3	0.4
Carbohydrate	3.9	5.1

^aEach value is the average of ten determinations.

The observed decrease in reflectance in canned green peppers stored at 100°F was 13.9 percent as compared with a change in reflectance of only 4.6 percent in canned green peppers stored at 75°F. This was in agreement with the work of Blair and Ayres (2), which indicated that temperature had a direct effect on the conversion of chlorophyll to pheophytin, the cause of the so-called olive drab color.

The decrease of reflectance in canned red peppers appeared to be dependent upon the passage of time and high temperature, and both factors were found to be significant. This was in agreement with the work of Chichester (7) who has pointed out that the more mature a product, the less stable it is to conditions of degradation.

Chichester's (7) comments on the more mature product being less stable held true for changes in color purity of canned peppers under normal storage conditions, and under high temperature conditions also. Color purity changed about 10 percent in the 100°F stored red peppers, but there was no change in purity in the green peppers stored at that temperature. This was thought to be due to the different color pigments in the peppers.

Changes in drained weight were about the same for red and green peppers stored at the same temperature. About 14 percent drained weight was lost over one year of storage at 100°F as compared to about 2 percent loss of drained weight at 75°F storage.

There was no relationship detected between the sugar (Brix) level of the pack and the loss or change in color as was found by Luh (29) in tomato ketchup.

CHAPTER V

SUMMARY

This experiment was conducted to determine the effects of long periods of storage and two storage temperatures on the composition and quality of canned, red, diced peppers and canned, green, diced peppers.

Both types of peppers were subjected to storage temperatures of 75°F and 100°F. The effects of these treatments were evaluated over a one-year period for quality changes and over a two-year period for changes in proximate composition.

Quality changes were measured in terms of variations in can vacuum, drained weight ratio, pH of the pack fluid, acid content of the pack fluid, Brix of the pack fluid, texture, dominant wavelength, reflectance of the product and color purity. Determinations made in the proximate analysis were moisture, ash, protein, fat, crude fiber, and carbohydrate by difference.

The data were analyzed with a "packaged" computer program, the statistical analysis system of Barr and Goodnight. Analysis methods included analysis of variance, formulation of prediction equations for the individual quality variables by regression procedures, tests for homogeneity on the regression equations to detect any temperature effect, and canonical correlation analysis.

Based on the results of this study, the following conclusions were made:

1. Canned red and canned green bell peppers underwent quality changes at different rates when stored under similar conditions.

2. High storage temperature caused an increased loss rate of drained weight and color purity in both canned red and canned green peppers, but the loss rate of texture was affected by temperature in canned green peppers only.

3. The rate of drained weight loss was about the same for both canned red and canned green peppers over a one-year period. Both types decreased about 14 percent in drained weight when stored at 100°F for one year, and both types decreased about 2 percent in drained weight when stored at 75°F for the same period.

4. There were two sets of quality variables in canned peppers which were affected by storage time and storage temperature. The quality variables in each set were independent of the variables appearing in the other set of quality variables. It was proposed that the canonical variables representing these sets of variables be used as indices of over-all quality in canned bell peppers.

5. Brix was found to have no effect on the color of canned bell peppers.

6. Little variation was detected in the proximate analysis of canned peppers stored for different periods and under different temperatures because those materials thought to undergo change were present in quantities too small to be measured accurately.



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APPENDIX



TABLE 5

MEANS OF VARIABLES MEASURED IN CANNED BELL PEPPERS
STORED OVER A PERIOD OF ONE YEAR^a

Sample Type	Storage Temp. (°F)	Days in Storage	Shear Force (lbs)	Pack Acid (ml)	Can Vac. (in)	Fluid pH (unit)	Brix of Fluid (unit)	Weight Ratio	Wave-length (nm)	Color Purity (unit)	Lightness Value (unit)
Red	100	93	91.7	11.3	20.5	3.29	6.0	0.8626	600	77.8	30.72
Red	100	155	53.3	10.1	17.3	3.47	5.5	0.7703	598	86.3	28.96
Red	100	217	68.7	13.0	19.3	3.43	6.1	0.8000	599	86.2	28.74
Red	100	280	67.7	14.1	17.5	3.50	5.9	0.7290	604	86.9	25.94
Red	100	347	54.3	12.8	14.7	3.47	5.3	0.7410	603	85.8	25.88
Red	75	93	171.0	9.5	20.5	3.56	6.1	0.9333	597	87.8	31.97
Red	75	155	132.6	9.9	19.7	3.64	5.4	0.9220	598	83.2	29.89
Red	75	217	162.3	11.1	20.0	3.69	5.5	0.9186	599	87.3	29.44
Red	75	280	167.7	12.4	19.7	3.57	5.0	0.9193	601	86.5	27.34
Red	75	347	149.0	11.6	19.7	3.51	5.0	0.9073	600	83.3	28.11

TABLE 5 (continued)

Sample Type	Storage Temp. (°F)	Days in Storage	Shear Force (lbs)	Pack Acid (ml)	Can Vac. (in)	Fluid pH (unit)	Brix of Fluid (unit)	Weight Ratio	Wave-length (nm)	Color Purity (unit)	Lightness Value (unit)
Green	100	93	90.0	4.7	13.8	3.68	3.3	0.8617	575	61.9	33.31
Green	100	155	53.7	4.4	6.8	3.92	3.8	0.8430	574	68.8	30.60
Green	100	217	67.7	5.1	14.0	4.16	3.1	0.8313	573	63.9	32.14
Green	100	280	62.7	6.7	11.5	3.87	3.1	0.7923	574	65.3	30.22
Green	100	347	48.0	7.1	4.4	3.71	3.4	0.7450	575	68.8	28.68
Green	75	93	158.7	4.3	20.7	3.78	3.3	0.8730	575	60.8	35.02
Green	75	155	125.0	5.0	12.1	3.87	3.2	0.8580	574	61.4	32.30
Green	75	217	207.0	5.7	11.0	3.73	4.0	0.8490	575	62.7	33.90
Green	75	280	217.0	5.8	14.0	3.80	3.1	0.8447	574	66.9	32.14
Green	75	347	202.0	6.1	13.2	3.79	3.0	0.8650	576	66.4	33.42

^aEach value listed is the average of three observations.

REGRESSION EQUATIONS TO PREDICT CHANGES IN QUALITY FACTORS IN CANNED RED AND

GREEN BELL PEPPERS DUE TO STORAGE TIME UNDER 75°F AND 100°F CONDITIONS

RED PEPPERS

$$\begin{aligned}
 \text{Drained Weight Ratio}_{75} &= 0.99225600 - 0.03068264 (TP)^a + 0.00429749 (TP^2) - 0.00019949 (TP^3) \\
 \text{Drained Weight Ratio}_{100} &= 1.04771652 - 0.08841489 (TP) + 0.00927140 (TP^2) - 0.00034480 (TP^3) \\
 \text{Shear Force}_{75} &= 380.45535519 - 111.62846251 (TP) + 16.64021927 (TP^2) - 0.76338142 (TP^3) \\
 \text{Shear Force}_{100} &= 291.05535519 - 111.62846251 (TP) + 16.64021927 (TP^2) - 0.76338142 (TP^3) \\
 \text{Wavelength}_{75} &= 604.77787041 - 4.8600060 (TP) + 0.85511797 (TP^2) - 0.04045407 (TP^3) \\
 \text{Wavelength}_{100} &= 606.77787041 - 4.8600060 (TP) + 0.85511797 (TP^2) - 0.04045407 (TP^3) \\
 \text{Reflectance}_{75} &= 31.95154882 + 0.53693313 (TP) - 0.22630047 (TP^2) + 0.01278134 (TP^3) \\
 \text{Reflectance}_{100} &= 30.65377988 + 0.53693313 (TP) - 0.22630047 (TP^2) + 0.01278134 (TP^3) \\
 \text{Color Purity}_{75} &= 1.13476990 - 0.14397248 (TP) + 0.02243765 (TP^2) - 0.00107202 (TP^3) \\
 \text{Color Purity}_{100} &= 0.48410358 + 0.14532800 (TP) - 0.01759855 (TP^2) - 0.00068022 (TP^3)
 \end{aligned}$$

^aTP is the number of days in storage divided by 31.

GREEN PEPPERS

Drained Weight Ratio₇₅ = $0.87891108 + 0.00331271 (TP) - 0.00229870 (TP^2) + 0.00016883 (TP^3)$
 Drained Weight Ratio₁₀₀ = $0.89864277 - 0.01549451 (TP) + 0.00170862 (TP^2) - 0.00013907 (TP^3)$
 Shear Force₇₅ = $436.85579469 - 165.82380396 (TP) + 28.00609774 (TP^2) - 1.34820348 (TP^3)$
 Shear Force₁₀₀ = $255.27846312 - 88.37709739 (TP) + 12.68894061 (TP^2) - 0.57678817 (TP^3)$
 Wavelength₇₅ = $577.43800057 - 1.08229810 (TP) + 0.06883724 (TP^2) + 0.00075178 (TP^3)$
 Wavelength₁₀₀ = $577.70466723 - 1.08229810 (TP) + 0.06883724 (TP^2) + 0.00075178 (TP^3)$
 Reflectance₇₅ = $43.01866761 - 4.02378984 (TP) + 0.53905548 (TP^2) - 0.02384823 (TP^3)$
 Reflectance₁₀₀ = $40.65058315 - 4.02378984 (TP) + 0.53905548 (TP^2) - 0.02384823 (TP^3)$
 Color Purity₇₅ = $0.71446967 - 0.06405530 (TP) + 0.01121489 (TP^2) - 0.00052257 (TP^3)$
 Color Purity₁₀₀ = $0.28020308 + 0.18684920 (TP) - 0.02821246 (TP^2) + 0.00132184 (TP^3)$

TABLE 6

PROXIMATE COMPOSITION OF CANNED RED AND GREEN BELL PEPPERS
FROM THE 1970, 1971, AND 1972 PACKING SEASONS*

Sample Type	Time in Storage	Storage Temperature	Proximate Composition					CHO ^a
			Moisture	Fat	Protein	Fiber	Ash	
(Percent)								
Red	2 yr.	75°F	92.9	0.2	0.8	0.9	0.3	4.9
Red	2 yr.	100°F	92.4	0.2	0.9	1.1	0.3	5.1
Red	1 yr.	75°F	92.7	0.1	0.7	0.8	0.3	5.4
Red	1 yr.	100°F	92.3	0.1	0.8	0.9	0.5	4.3
Red	none	ambient	93.1	0.1	0.7	1.1	0.4	4.9
Green	2 yr.	75°F	94.2	0.1	0.7	1.0	0.2	3.9
Green	2 yr.	100°F	94.0	0.1	0.7	0.8	0.3	4.0
Green	1 yr.	75°F	94.5	0.1	0.6	0.9	0.4	3.5
Green	1 yr.	100°F	94.7	0.1	0.7	1.0	0.3	3.4
Green	none	ambient	93.9	0.1	0.7	0.8	0.3	4.2

* Each value is the average of two determinations.

^aCHO represents the carbohydrate level determined by difference.

VITA

David W. Adkins was born in Harriman, Tennessee, on February 13, 1944. He attended elementary and high school in Knoxville, Tennessee, and graduated from South High School in May, 1962.

He worked for Kern's Bakery, Knoxville, from June, 1962, to June, 1967, and attended classes at The University of Tennessee during this period. In July, 1967, he entered the United States Army, and was released from active duty in February, 1969.

In January, 1970, he resumed attendance at The University of Tennessee, and received the Bachelor of Science degree with a major in Food Technology, in June, 1971. From September, 1971, to November, 1972, he has been working to complete the requirements for the Master of Science degree with a major in Food Technology.

He and his wife, the former Miss Kristin Hartman, were married in June, 1969, and they have one daughter, Leeda Szoon, age three months.