AN ABSTRACT OF THE THESIS OF

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in Food Science and Technology presented on July 2, 1980

Title: EFFECT OF THE MATURITY ON THE PHYSICAL, CHEMICAL AND SENSORY PROPERTIES OF FROZEN PEAS

Abstract approved: ______________________
Dr. Morris W. Montgomery

Peas (Pisum sativum) are an important constituent in the diet of many people. Peas may be cooked and eaten as green peas shortly after harvest, stored for short periods in the pods, or, after suitable treatment, stored for long periods before consumption. Many factors influence the yield and quality of frozen peas but maturity requires careful consideration because of the relation of maturity to color, flavor, and texture.

The objectives of this thesis were to determine the effect of the maturity stage on the quality of the frozen peas during processing and storage and to correlate the interactions between the sensory evaluation panel with the physical and chemical quality factors measured.

Venus pea variety grown under commercial conditions at the Sublimity area east of Salem, Oregon, were used in this study. The trials were randomized for three stages of maturity with three replications per each stage of maturity. Each of the three maturity stages

was harvested; vined; blanched by steaming at 98.8°C (210°F) for 30 sec for the immature peas, 60 sec for the mature peas, and 90 sec for the overmature peas; frozen at -37.2°C (-35°F) for 24 hr in an air blast freezer and stored at -23.3°C (-10°F) for 4 and 8 month. During processing and storage the following factors were determined: tenderometer value, total solids, alcohol insoluble solids, peroxidase activity, ascorbic acid, total sugars and sensory evaluation. In the sensory evaluation analysis starchiness, sweetness and tenderness intensity, as well as texture, flavor and overall desirability were measured. Analysis of variance and least significant difference were used to compare the effect of pea maturity during processing and storage on the different quality factors measured. Correlation coefficients were used to determine the relationship between these factors.

Immature peas had lower tenderometer value than overmature peas. Tenderometer value of peas decreased during processing. The highest total solids content was observed in the overmature peas and the lowest total solids content in the immature peas. This behavior was also observed in the alcohol insoluble solids content.

Raw peas in the three maturity stages had the same initial peroxidase activity and the significant effect of the maturity level found in the residual peroxidase was affected by the different blanching time applied at each maturity stage. The ascorbic acid content was significantly affected by the maturity level and was reduced during the blanching treatment. Total soluble sugar content was higher in immature peas and lower in overmature peas.

All the sensory evaluation parameters measured were affected by the maturity. In general, the taste panel found higher flavor desirability on the mature peas but when texture and overall desirability were measured immature and mature peas were equally preferred.

Significant correlations were found between physical, chemical, and sensory parameters analyzed, some of them are tenderometer value and alcohol insoluble solids; total solids and alcohol insoluble solids; alcohol insoluble solids and overall desirability.

# Effect of Maturity on the Physical, Chemical and Sensory Properties of Frozen Peas

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed July 1980

Commencement June 1981

APPROVED:

Associate Professor of Food Science and Technology
in charge of major

Head of Department of Food Science and Technology

Dean of Graduate School

Date thesis is presented July 2, 1980

Typed by Opal Grossnicklaus for Jose A. Olaeta-Coscorroza

To Nancy, Carolina and Gonzalo

also to My Parents and Sister

## ACKNOWLEDGEMENTS

I want to express my appreciation to my major professor, Dr. Morris W. Montgomery, for his guidance during the development of this thesis with so much concern and dedication. To Dr. Robert F. Cain for his great help and constructive criticism during the preparation of this thesis. To Mrs. Lois McGill for her help in the sensory evaluation analysis.

I wish to express my thanks to Seabrook Foods, Inc., especially to Mr. Bryan Behrman, manager of the field department, for his cooperation in supplying the peas for this study.

Acknowledgement is also made to all the faculty and staff members of the Food Science and Technology Department for their cooperation. Thanks are extended to Mr. David Niess for his help concerning the statistical analysis.

I wish to express my thanks to Dr. Robert Mac Vicar, President of Oregon State University, and Mr. Matias Valenzuela, Rector Universidad Catolica de Valparaiso for making these graduate studies possible.

TABLE OF CONTENTS

## LIST OF FIGURES

LIST OF TABLES

# EFFECT OF MATURITY ON THE PHYSICAL, CHEMICAL AND SENSORY PROPERTIES OF FROZEN PEAS

## INTRODUCTION

Peas (Pisum sativum) are widespread and important constituents in the diet of many people. Peas are readily accepted and have a high dietetic value since they are a major source of protein and carbohydrate and because they make a useful contribution to the requirement for accessory food substances. They may be cooked and eaten as green peas shortly after harvest, stored for short periods in the pods, or, after suitable treatment stored for long periods before consumption.

Production and consumption of frozen peas have increased at a rapid rate in recent years. Both demand and supply influences have been responsible for this growth. Technological advances in the processing and freezing of peas and the improvement of refrigerated transportation, storage, and distribution facilities have contributed to the growth and expansion of the industry. Development at the farm level as well as in storing and preserving frozen product in the home also have been important.

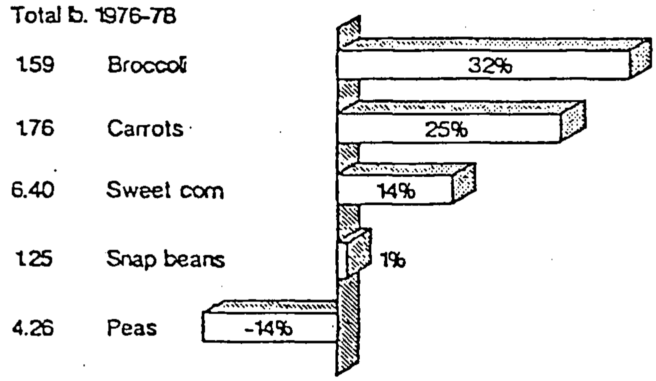
Frozen peas accounted for approximately 5.5% of all frozen vegetables consumed in 1978, after potato products with 61.8% and corn with 6.5%. Expressed in terms of per capita consumption for the ten-year period 1968-1978, frozen pea has decreased about 25%

of the 1968 level of per capita consumption (U.S. Agricultural Mark. Service, August 1979), and 14% between 1970-72 and 1976-78 period (Figure 1).

Raw production of peas for freezing in 1979 (239, 850 tons) was 16% larger than the year before. The pack of frozen green peas, at 406.6 million pounds, was 37% larger than the 1978-79 pack, resulting in a total supply of nearly 490 million pounds for the 1979-80 marketing year, an 8% increase over a year earlier (U.S. Agricultural Mark. Services, Feb. 1980). A comparison of peas with other vegetables packed in the United States since 1966 is shown in Figure 2. The western states contributed about 37% of the total United States green peas for processing supply in 1979, and the Pacific Northwest states account for almost all of the total western production with 183, 000 tons (U.S.D.A. Crop Reporting Board, Dec. 1979).

The Northwest pea industry is unique with respect to both production and markets. Production is a large scale operation often consisting of several hundred acres of peas per farm. Peas from the Northwest are marketed nationally, therefore, must be shipped a greater distance to market than those from some of the competing areas. The industry faces higher transportation costs than other competing areas, and Northwestern wage rates also are higher than those of Eastern competitors. In spite of these cost disadvantages, the Northwest pea industry has expanded and has provided a large

Figure 1. Changes in Frozen Vegetable Consumption Per Capita Between 1970-72 and 1976-78*

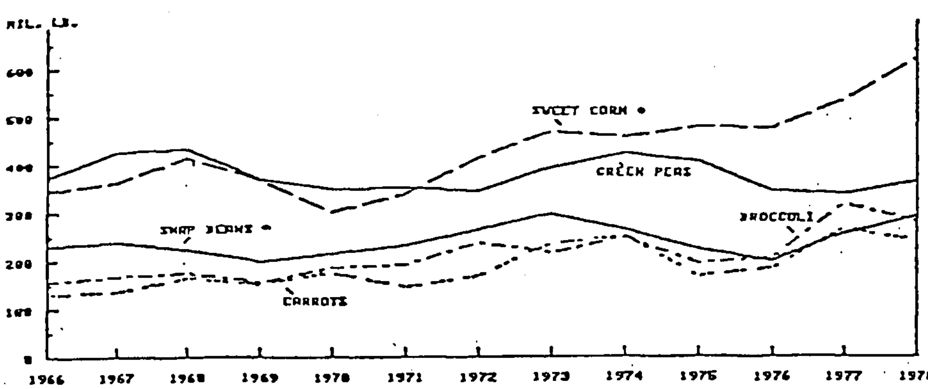



* Fresh weight basis.

USDA
U.S. Agricultural Marketing Service

Neg. ESCS 8874-79 (7)
TVS-213, August 1979

Figure 2. SELECTED FROZEN VEGETABLES - ANNUAL PACKS




• CUT CORN AND CORN-ON-COB. ^ INCLUDES FRENCH, ITALIAN GREEN BEANS AND WAX BEANS.
SOURCE: AMERICAN FROZEN FOOD INSTITUTE.

USDA
U.S. Agricultural Marketing Service

NEG. ESCS 2443-79 (4)
TVS-212, May 1979

portion of the national supply of frozen peas.

There are many factors influencing the yield and quality of frozen peas. Maturity is one of the most important factors because it relates to color, flavor and texture of the product. As Pollard et al. (1947) stated,

> Both growers and processors are definitely interested in knowing the stage of maturity at which peas should be harvested for the greatest yield of acceptable quality. Peas harvested and processed at that stage should give both growers and processors the maximum return if grading methods are satisfactory and price schedules equitable.

This statement is important for peas harvested for freezing.

The objectives of the present work were:

1. To determine the effect of the maturity on the quality of the frozen peas during processing and storage;
2. To correlate the interactions between the sensory evaluation panel with the physical and chemical quality factors measured.

# LITERATURE REVIEW

During development of peas several physiological changes occur in living cells, that are related to chemical and enzymatic composition and structural changes brought about in the cell walls. The physiological and histological changes are influenced by external conditions of growth such as climate, soil type, fertilizers, handling conditions, length of delay after harvest, pretreatment and processing conditions (Smith, 1930; Martin and Brotherton, 1933; Campbell and Diehl, 1937; Anthistle, 1961; Weckel *et al.*, 1964; Casimir *et al.*, 1967; Mitchell *et al.*, 1969; Mitchell and Casimir, 1969; Holdsworth, 1970).

## Chemical and Enzymatic Composition of Pea at Different Stages of Growth

In general, a relationship exists between the chemical composition of pea and the fresh weight, dry weight, carbohydrates, proteins, vitamins (with special reference to ascorbic acid) and other compounds. The level of these substances are, in turn, dependent upon enzymatic composition.

### Fresh Weight and Dry Weight

McKee *et al.* (1955) and Anthistle (1961) found that the fresh weight of the seed increased consistently until 29 days from blossom;

followed by no consistent change for 40 days. This cessation of water accumulation by the seed did not effect the regular increase in dry weight, which was approximately linear between 20 and 40 days. After 40 days there was a rapid increase due to the loss of water accompanying ripening (Bisson and Jones, 1932; McKee et al., 1955; Anthistle, 1961).

Carbohydrates

Changes in carbohydrates during growth have been studied by several authors since 1932, all of them showing similar results. The soluble carbohydrates per seed started at 3.6% and rose steadily to a 6.6% until about 25 days from flowering. The initial starch content in the seed was about 1.4% but after 20 days from flowering began a rapid accumulation and, although sucrose was probably still being synthesized at approximately the same rate, starch synthesis was so intense that the level of sucrose decreased to 2%. These trends continued until 30 days after flowering, after which time there was little increase in starch content of the seed, remaining at 10% (Bisson and Jones, 1932; McKee et al., 1955; Turner and Turner, 1957; Turner et al., 1957; Anthistle, 1961).

McKee et al. (1955) showed that the pectin content per pea seed increased steadily for 23 days after flowering.

Protein (N x 6.25)

Bisson and Jones (1932) and McKee et al. (1955) showed a gradual increase in absolute weight of a total nitrogen from the 12th to the 44th day. However, the percentage of nitrogen gradual decreased during this period from 5.16% to 3.93%. This decrease in the percentage of total nitrogen may be attributed to the fact that the rate of increase in the weight of dry matter was many times greater than the rate of increase in absolute weight of nitrogen.

Ascorbic Acid

Reduction in ascorbic acid content from 0.056% to 0.030% during the development of peas was found by Selman and Rolfe (1979). Their results are in agreement with the previous work of Mack et al. (1936), Kramer et al. (1950) and Morrison (1974). McKee et al. (1955) and Anthistle (1961) reported that the ascorbic acid content of the seed per unit fresh weight rose steadily from 14 to 20 days and then decreased steadily until 40 days from blossom, but when ascorbic acid was expressed in absolute content per seed, it rose steeply until 28 days from flowering and then showed only minor fluctuation to about 35 days, and decreased slightly until 40 days. The ascorbic acid content is also affected by cultivar, sieve size, growth conditions and other factors (Mack et al., 1936; Todhunter and Robbins, 1941; Pollard et al., 1947; Wilcox andMorrel, 1948;

Selman and Rolfe, 1979).

## Other Compounds: Total Phosphorus, Inorganic Phosphate

McKee et al. (1955) reported that total phosphorus increased steadily in seeds over the whole period from 14 to 40 days from flowering. Inorganic phosphate, which had been increasing at a lower rate than the total phosphorus, actually decreased between 20 and 23 days and then increased again.

Rowan and Turner (1957) found that the ratio of inorganic phosphate to hexose monophosphate decreased some days before the rate of synthesis of starch increased to a maximum at 25 days from flowering.

## Enzymatic Composition

Several enzymes are present in peas, including starch phosphorilase, phosphatase, peroxidase, lipoxygenase, and lipase. Turner and Turner (1957) reported that over most of the period of development of the pea there was a linear relationship between the rate of starch formation and the starch phosphorylase activity. Phosphatase activity, as reported by Anthistle (1961), rose up to 23 days after flowering and then fell off to a low level.

Peroxidase is also present in pea and the activity is more pronounced in the skin than in the cotyledons (Anthistle, 1961). Joslyn

(1946) reported that peroxidase activity was closely related with enzymes involved in off-flavor formation after the peas were picked. These results were corroborated later by Wagenknecht and Lee (1958), and Tappel (1962), who reported that peroxidase, like most heme pigments, catalyzes the peroxidative degradation of unsaturated fatty acids, yielding volatile and flavorful carbonyl compounds which contribute to oxidation of flavor. Lipase and lipoxygenase are also involved in off-flavor formation (Wagenknecht and Lee, 1956; 1958; Buckle and Edwards, 1970).

## Structural Changes

The structural changes in the peas are related basically with textural changes that occur in processing peas. Boggs et al. (1942) reported that calcium and magnesium increase the skin toughness of peas and Reeve (1947) found that the major cause of textural change in the seed coats of peas and other legumes during the maturation was the formation of a highly specialized, epidermal structure composed of macrosclereid cells. Anthistle (1961) showed that the texture in peas was influenced by chemical and histological factors. Chemical factors which by Anthistle (1961) were phytic acid inorganic orthophosphate, pectin, calcium and magnesium. These substances were reported to be normally present in the pea and formed insoluble salts which were responsible for textural changes. Histological factors which were reported to affect texture of peas were thickened cell walls that were highly resistant to common extracting agents, indicating the deposition of cellulose in the wall structure.

These chemicals, enzymatic and structural changes affect the quality factors of peas. In general, the quality factors are yield, tenderness, flavor and color (Anthistle, 1961). Greenleaf (1936) and Pollard et al. (1944; 1947) found that there was an increase in total yield of ungraded peas as peas advance in stages of development. Pollard et al. (1947) and Makower (1950) reported that as peas ripened skins toughen and cotyledons become more firm and the peas become more dry. This was reflected in less tenderness. Kramer et al. (1950) showed that the state of development has an important effect on the organoleptic values for flavor and color, but the values for color varied much less than similar values for tenderness and flavor.

## Maturity

Yield and quality of peas are influenced by maturity. As peas mature an optimum quality for processing is reached and beyond this optimum peas continue to grow in size and yields increase but quality decreases (Pollard et al., 1944; 1947; Kramer, 1947; 1964; Makower, 1950; Sayre, 1952). Campbell and Diehl (1940) and Nielsen et al. (1947a) reported that numerous factors affect the quality of frozen peas, but maturity requires a careful consideration because of its relation to color, flavor and texture. During the maturity of peas there is a stage when the eating quality of the vegetable is optimal; at that point flavor and texture is best (Makower, 1950). Mitchell and Lynch (1954) defined the optimal harvest time as the in crop development which coincided with greatest yield of first quality peas. Kramer (1947; 1964) reported that in general the immature or less mature peas are more desirable.

Since an early period of research on peas, there have been many more investigations directed with the purpose of determining the proper level of maturity at harvest for processing peas.

According to Pratt (1939), a test for maturity applicable to the processing requirements must be simple, quick and reasonably accurate. The broad classification of test for maturity are subjective and objective. The subjective tests are usually fast and simple, but since the personal element enters into judging various factors the accuracy cannot be assured. Objective tests are chemical and physical in nature, and have the advantage that they eliminate much of the personal factor and provide data that can be expressed in numbers, suitable to repeats using the same method.

Organoleptic appraisal by panels of human judges has been practiced for many years (Kertesz, 1935; Boggs et al., 1942; Makower et al., 1953; Angel et al., 1965) on cooked peas. The maturity of either the whole peas or the skins and cotyledons were evaluated separately by this same subjective method. As peas ripen, skin toughens, cotyledons become more firm, and flavor and color change (Kramer et al., 1950). Makower (1950) and Anthistle (1961) reported that maturity in peas was essentially a subjective quality, which can be measured directly only by a panel of human judges, that was the method of organoleptic appraisal. Any objective method for measuring maturity must necessarily depend on comparison with the basic subjective method. Nevertheless this method requires basic research in methodology and standardization of techniques (Makower, 1950).

Objective tests for maturity of peas are becoming more important. Previous studies (Makower et al., 1953; Kramer et al., 1950; and Casimir et al., 1971) have shown that objective tests can replace subjective methods, and that they are suitable for commercial use in production scheduling and quality determination of peas. The methods are used to establish relationships between maturity and such factors as heat units, total solids, insoluble solids, starch, sugar, and toughness.

## Heat Units

Sayre (1949; 1953) drew attention to the fact that the maturity of the peas was related to the heat units to which the crop was exposed during growth. The purpose was to schedule planting to produce a harvesting period over a predictable time span to facilitate delivery to the processors. Anthistle (1961) defined heat unit as one degree of temperature above the base growing point of any crop; for peas this is 40°F. The effective heat units per day are defined as the mean dry temperature minus 40; peas require 30,000-35,000 heat units. Heat units are not an accurate maturity index for a specific plot of peas and the method has not been adopted for grading.

Total Solids

Total solids were suggested as an objective index of frozen pea maturity by Pyke (1945), Nielsen et al. (1947b) and Malcom et al. (1956). Kramer (1954) considered this method somewhat inferior to alcohol insoluble solids. Several authors have correlated moisture with organoleptic determinations. Lee (1941) found that the determination of total solids of blanched peas gave results that correlate reasonably well with the organoleptic test, but the total solids values obtained for the raw vegetable gave rather unsatisfactory correlation with the tenderometer reading. Kertesz (1935), Kramer (1954) and Malcom et al. (1956) reported correlations coefficient moisture v/s organoleptic test values between -0.779 to -0.90. Nevertheless the use of this method has not become widespread (Voisey and Nonnecke, 1973).

Alcohol Insoluble Solids

Alcohol insoluble solids is a measure of pea quality for raw and processed peas. Kertesz (1934) proposed a method for determining alcohol insoluble solids and demonstrated that during ripening the chemical changes taking place in peas transform soluble components into less soluble ones; one year later (Kertesz, 1935) reported that it is possible to use total solids, alcohol insoluble solids and water insoluble solids for determination of maturity but the alcohol insoluble solids of the pea appears to be the best suited for the evaluation of maturity and quality; these results were corroborated later by Greenleaf (1936), Makower et al. (1953), Lee et al. (1954), Kramer et al. (1956) and Anthistle (1961). Kertesz (1935) reported that the best quality of canned peas was those which an alcohol insoluble solids index of 10.7%, and Mitchell and Lynch (1954) reported that in frozen Thomas Laxton variety, the best quality was obtained in alcohol insoluble solids 14.5%. Several authors (Kertesz, 1935; Kramer et al., 1954; Malcom et al., 1956; Angel et al., 1965) found correlation between alcohol insoluble solids and maturity score from -0.890 to -0.937. Kramer et al. (1950), Weckel et al. (1954) and Lee and Hicks (1965) found a high correlation between alcohol insoluble solids of canned and frozen peas and tenderometer value of raw peas. Other authors also found high correlation between alcohol insoluble solids and specific gravity (Lee and Hick, 1965) and between alcohol insoluble solids and viscosity (Elehwany and Kramer, 1956; Wiley, 1959).

## Starch

The increase of the starch in peas during ripening of the seed has been studied by many authors (Bisson and Jones, 1932; McKee et al., 1955; Turner et al., 1957; Turner and Turner, 1957). Pollard et al. (1957), Nielsen et al. (1947a), Makower (1950) and Anthistle (1961) reported that starch gave a good indication of maturity because it gave good correlation with cotyledon texture. Lynch and Mitchell (1950) reported that it was not possible to demonstrate the relation between development of starch and advancing maturity. Pyke (1945) found a correlation of 0.93 between starch and tenderometer. Nevertheless, starch content has not been used because the available methods for starch determination have been time consuming and are influenced by the peculiar physical and chemical properties of pea starch (Nielsen, 1947a; Anthistle, 1961).

## Sugars

Bisson and Jones (1932), McKee et al. (1955) and Turner et al. (1957) found that the sugar content of the seed increased in the early stages of development but decreased during the phase of rapid starch synthesis. Pyke (1945) reported that the correlation between sugar and tenderometer reading was not good. Nielsen et al. (1947a) and Makower (1950) suggested the tendency for total sugar content to rise and fall with maturity was one reason why total sugar was a poor indice of maturity in frozen products; another was the loss of sugars through respiration between harvest and processing. Anthistle (1961) found that starch/sugar ratio was probably a somewhat better indication of maturity.

Toughness

Toughness in peas, which is the converse of tenderness, may be defined as that property of the peas which resists shearing or grinding in the mastication process (Martin, 1937). Makower et al. (1953) reported that the cotyledon texture scores were taken as primary standard of textural quality as it might appear to the consumer. Several instruments have been developed for measurement of this property but the pea tenderometer introduced by Martin (1937) was the first widely adopted texture instrument. The tenderometer was developed for peas to determine crop maturity and for grading (Martin, 1937; Campbell and Diehl, 1940; Kramer et al., 1950; Voisey and Nonnecke, 1973). The tenderometer consists of a grid of shearing blades rotated at a constant speed through a second grid which is suspended in such a manner that any force on this grid is interbalanced by a pendulum. As the peas are sheared by the blades, the maximum force is indicated by the angular movement of the pendulum displayed by a pointer moving over a graduated scale (Voisey and Nonnecke, 1973). Numerous studies have been carried out which correlate the tenderometer value on raw peas with other measurements of maturity, such as, the subjective scores (Campbell and Diehl, 1940; Lee, 1941; Makower et al., 1953; Kramer, 1954), alcohol insoluble solids (Kramer et al., 1950; Weckel et al., 1954; Lee and Hicks, 1965), and total solids (Lee, 1941). All these correlations appeared to be relatively good, especially when uniform material from one locality and a single tenderometer had been used throughout a study. Lee (1941) reported that the use of tenderometer was satisfactory for predicting the grades of canned or frozen peas from raw vegetables. Lee (1939), Campbell (1942), Makower and Burr (1954), Varseveld (1967), Varseveld and Olson (1968; 1969) and Voisey and Nonnecke (1971) identified a number of variables associated with the performance of the tenderometer, such as, pea variety, sample temperature, sampling, and relation to commercial grades. Kramer (1964) and Voisey (1974) observed that the instrument was not completely reliable. Voisey and Nonnecke (1971) indicated that the differences between some tenderometers were serious and that interchangeability between machines may be difficult to achieve.

Among other mechanical methods for measuring the texture of peas, the following can be used. Maturometer (Lynch and Mitchell, 1950; and Mitchell and Lynch, 1954) and single puncture maturometer (Casimir and Moyer, 1968; Casimir et al., 1971) have been found to give satisfactory correlation with alcohol insoluble solids. Proctor et al. (1956) and Davison et al. (1959) found that pea testing on the denture tenderometer yielded results which showed a high degree of correlation with the subjective results obtained with taste panels and the results obtained with the Canco tenderometer. Weckel et al. (1954) and Angel et al. (1965) observed that "shear press" was highly correlated with taste panel scores and with alcohol insoluble solids. Voisey and Nonnecke (1972) reported high correlation between five mechanical methods for measuring the texture of peas and tenderometer. These authors selected the wire extrusion cell method for possible replacement of the tenderometer.

Other Objective Methods

Martin and Brotherton (1933) measured the refractive index, freezing point and electrical conductivity of pea sap and found them unsuitable as indices of maturity. Wiley (1959) reported that viscosity measurement in a pea slurry has satisfactory method to determine the maturity of raw, blanched and canned peas. He found high correlation between viscosimeter reading and alcohol insoluble solids.

In summary, the tenderometer can probably be considered the best means of determining the maturity of raw peas, but it does not reveal the effects of handling and processing after harvesting. For processed peas, the alcohol insoluble solids test is probably the most reliable objective measure of the organoleptic quality known as maturity (Makower, 1950).

## Effect of Holding before Processing

Gorrel (1936), Boggs et al. (1942), and Anthistle (1961) reported that peas of all sizes became tougher day after day when left in the field. The rate of toughening increased as temperature was increased. Harvest delays of a few days in warm weather may result in tough and greatly overmature peas. The skin texture of peas was influenced by various conditions of treatment after harvest; one of these was a delay between vining and processing.

Peas with tougher skins were characterized by an increased calcium content (Gorrel, 1936; Makower, 1950; Anthistle, 1961).

Kertesz (1930, 1933), and Holdsworth (1970) found that as holding times and temperatures were increased after harvest the sugar was changed to starch, rendering the product tougher, and resulted in off-flavors and lower quality.

Casimir et al. (1967) reported that the pea yield is affected by the harvest method. Hand shelling resulted in greater yield than was obtained by vining, while a small huller operating at high beater speed gave a still lower yield.

## Processing and Storage

### Blanching

The necessity of blanching vegetables to preserve by freezing has been recognized by several authors since the early 1930's. Blanching is essentially a pre-cook and as such causes a softening of the tissues, renders the product more tender and inactivation of enzymes causing "off-flavor" which develop in raw or underblanched vegetables during frozen storage (Wiegand, 1936; Joslyn, 1946; Mergentine and Wiegand, 1946; Cain, 1950; Dietrich et al., 1955; Lopez et al., 1959; Last and Shipton, 1966; Krotov et al., 1971). Several authors (Joslyn and Marsh, 1938; Joslyn, 1946; Rossoff and Cruess, 1949; Dietrich et al., 1955; Lopez et al., 1959; Last and Shipton, 1966) reported that the adequacy of blanching was determined by assay for residual activity of the enzymes, catalase and peroxidase. Joslyn (1946) and Rossoff and Cruess (1949) found that peroxidase activity was more closely parallel enzyme involved in off-flavor formation than catalase. Masure et al. (1953) reported that catalase gradually disappears in samples during frozen storage. For this reason absence of catalase in frozen material does not necessarily indicate adequate blanching. If the blanching treatment was not sufficient to inactivate peroxidase enzyme, the frozen vegetable developed an "off-flavor."

Several methods have been used to measure the residual peroxidase and catalase activity. Among these are gasometric method (Jeffrey and Cruess, 1933), colorimetric method using guaiacol, hydrogen peroxide and citrate buffer, pH 4.5 (Masure and Campbell, 1944), purpurogallic procedures and titrimetric $H_2O_2$ procedures (Joslyn, 1949), indophenol and o-phenylenediamine methods (Wood and Lopez, 1963).

Lee and Wagenknecht (1951), Wagenknecht and Lee (1956), Whitfield and Shipton (1966) and Buckle and Edwards (1970) found that the rancidity of the lipid material, principally oleic acid, was the cause of the development of off-flavor in unblanched peas, and the enzymes responsible may be lipase and lipoxidase. Bengtsson and Bosund (1964), Whitfield and Shipton (1966), Bengtsson *et al*. (1967) and Grosch (1968) reported that volatiles from stored unblanched frozen peas were shown to contain 12 carbonyl compounds: ethanal, propanal, hexanal, nonanal and others, which contributed markedly to off flavors in peas. Bengtsson and Bosound (1964) reported that the same acetaldehyde, ethanal and hexanal which were formed slowly at freezing temperatures were also characteristic of post harvest changes at room temperature. Whitfield and Shipton (1966) found that lipoxidase was present in peas and catalyzed the oxidation of linoleic and linolenic acids to hydroperoxides. Decomposition of these hydroperoxides in peas would be expected to yield aldehydes.

Aldehydes of the same kind as those isolated from unblanched frozen peas are stated to be responsible for off-flavor in frozen peas.

It has long been known that most vegetables prior to freezing require blanching in hot water (Cain, 1950; Last and Shipton, 1966) or steam (Joslyn and Neumann, 1963). Hard and Ross (1956) reported negative peroxidase activity using dielectric scalding of spinach. Lamb et al. (1948) found that young peas require less severe blanching than the more mature peas. Last and Shipton (1966) blanched peas in boiling water for 15, 30 and 60 sec before freezing and storing at -17.7°C (0°F) during 0, 4, 8, 16 and 24 months. These workers found that the only significant effect of blanching time was the development of "off-flavor" and slight color deterioration in the samples blanched for 15 sec. The results indicate that when boiling water was used, a blanching time of 30 sec was adequate for the retention of quality in frozen peas during storage at -17.7°C (0°F). Blanching time was extended to 60 sec without adverse effect. Mitchell et al. (1969) found that blanching times of 3 min or more were excessive and should be reduced in the interest of quality and economy.

The blanching involves several detrimental factors, such as, leaching out soluble constituents from the peas, which resulted in a loss of weight and decrease in specific gravity (Mitchell et al., 1969); a cooking or softening effect and a rapid fall in tenderometer and maturometer readings (Cain, 1950; Mitchell et al., 1969); destruction of chlorophyll; change in flavor (Legault et al., 1950); and loss of nutritive value, specifically ascorbic acid (Guerrant and O'Hara, 1953; Cain, 1967; Morrison, 1974; Clegg, 1974). The retention of ascorbic acid has been taken as an index to the retention of original nutritive and quality values (Cain, 1967).

Several authors (Moyer et al., 1949; Jurics, 1969; Morrison, 1974) reported that blanching or scalding had the most detrimental effect on the ascorbic acid content during the processing of peas. Feaster et al. (1949) and Lynch et al. (1959) found that during blanching, retention of ascorbic acid decreased progressively with increased time and temperature of the blanch. Heberlein et al. (1950) reported that high temperature and short time were found to be beneficial to increased ascorbic acid retention. Holmquist et al. (1954), Lynch et al. (1959) and Cain (1967) found that steam blanching generally resulted in less ascorbic acid loss than water blanching. This is logical since leaching will be minimal in steam blanching.

Wilcox and Morrel (1948) reported the increase in percent retention of ascorbic acid with increasing maturity of the peas and also revealed that the stage of maturity had less influence on the ascorbic acid content on the frozen and canned peas than on the fresh peas. Lynch et al. (1959) found that the immature peas lost more ascorbic acid during blanching. Morrison (1974) reported that the overall retention of ascorbic acid in the frozen peas was above the 75% level recommended for good commercial practice of freezing vegetables.

Hartzler and Guerrant (1952) found that not only overblanching but also underblanching may cause excessive losses of ascorbic acid. In fact, the largest losses of ascorbic acid observed in their study occurred as the result of under-blanching samples.

Freezing

Wiegand (1936; 1937) reported that temperatures of -20.5°C (-5°F) are satisfactory for freezing. Lee et al. (1947) and Guerrant et al. (1953) found that taste panels were unable to detect any difference in appearance and flavor of peas frozen at different rates and at different temperatures. Lynch et al. (1959) reported that rapid freezing was thought to be an important factor in quality retention due partly to the formation of small ice crystals.

Hucker and Clarke (1961), Cain (1967) and Jurics (1969) found that freezing per se did not injure vitamins--it was the mishandling both before and after freezing which lowered the vitamin content compared to that of the raw material. Kramer (1979) reported that ascorbic acid destruction during storage was influenced by the rate of freezing. In general, rapid freezing was thought to be an important factor in quality retention due partly to the formation of small ice crystals.

## Storage

Storage temperature has special significance for frozen foods. Several authors (Wiegand, 1937; Lindquist *et al.*, 1950; Guerrant *et al.*, 1953; Kramer, 1979; McBride and Richardson, 1979) found the temperatures below -17.7°C (0°F) provide good protection against nutrient and quality loss. At such temperatures, microbial growth was completely arrested. However, even at such low temperature certain enzymatic and non-enzymatic changes continue, but at a much slower rate, to limit storage life of frozen foods (Kramer, 1979; McBride and Richardson, 1979). Davis (1956) and Dorse and Teply (1959) reported that the best means to retain vitamins in frozen foods was to store such foods at below -17.7°C (0°F). All of the vegetables stored at plus -12.2°C (10°F) sustained measureable decreases in ascorbic acid by the end of 4 months. Boggs *et al.* (1960) found the loss of ascorbic acid more than doubled for each 2.7°C (5°F) increase in temperature between -17.7 and -3.8°C (0 and 25°F). Hucker and Clarke (1961) and Cain (1967) reported that alternation of freezing and thawing during storage was particularly destructive. Kramer (1979) observed that ascorbic acid destruction during storage was influenced by the type of packaging and time-temperature conditions of storage. Whatever losses did occur were a function more of time than temperature.

# MATERIAL AND METHODS

## Material

Venus variety peas, provided by Seabrook Foods, Inc., were grown under commercial conditions on the IOKA farm, property of Mr. John Duerst and Dave Doerfler located at the Sublimity area east of Salem, Oregon. Out of a 40 hectar pea field, an area 2,500 $m^2$ was chosen randomly. Samples from this area were also selected at random. During the development of the peas, several inspections were made to check the maturity progress. The trials were randomized for three stages of maturity with three replications each stage.

The stages of maturity were determined by tenderometer value (T.V.) of "immature" (T.V. about 75), "mature" (T.V. about 90) and "overmature" (T.V. about 125). These values were taken according to the optimum harvest time of the variety for freezing (T.V. =90).

The peas were harvested during a period of 8 days, beginning June 21 and ending June 28. The individual harvest dates were as follows:

immature sample on June 21, 1979

mature samples on June 25, 1979

overmature samples on June 28, 1979.

The immature and overmature samples were hand picked with vine at 7 am, keeping the three replications separate in cloth grain sacks.

During the morning, at the Seabrook Foods, Inc. plant in Albany, the peas were vined in a mini viner machine, and small peas and pods were removed on a shaker machine.

Mature samples were harvested with a mobile viner machine and the sample taken, in the same selected area, directly from the machine. After being vined, tenderometer value was taken on the three maturity samples with a Canco Tenderometer at the Seabrook Foods, Inc. plant in Albany, Oregon. Peas were immediately brought to the Food Science and Technology pilot plant for processing and freezing.

In the pilot plant the samples of peas were washed with running water to remove earth and undesirable materials. The peas were blanched in steam at 98.8°C (210°F) in a steam box for 30 sec for the immature samples, 60 sec for the mature samples, and 90 sec for the overmature samples. All peas were cooled with running water. The adequacy of blanching was based upon the semiquantitative estimation of peroxidase activity (Masure and Campbell, 1944). No color was developed in 3.5 min in each sample (minimum time for a negative peroxidase test). Longer incubation time showed some brown development in the immature and mature samples. In immature samples a 30 sec blanching time was necessary to prevent softening of the peas.

After blanching, the 200 g of peas were packed in polyethylene bags, frozen at -37.2°C (-35°F) for 24 hr in an air blast freezer, and transferred to -23.3°C (-10°F) for 4 and 8 months of storage. This procedure was followed for each of the three replications on each harvest date.

The samples of raw and blanched peas were taken for analysis after washing and before freezing, respectively, placed separately in plastic bags and covered with ice until analyzed. Time from harvest to analysis was 6-8 hr. Frozen samples with zero storage time were analyzed during the harvest week and frozen samples stored at 4 and 8 months were analyzed after the storage time was completed (October, 1979 and February, 1980).

Analysis performed on each of the three stages of maturity are presented in Table 1.

Table 1. Analysis measured in each maturity stage.

| Raw | Blanched | Stored Sample |
|---|---|---|
| Tenderometer Value | -- | Tenderometer Value[a] |
| Total Solids | Total Solids | Total Solids |
| Alc. Ins. Solids | Alc. Ins. Solids | Alc. Ins. Solids |
| Peroxidase Activ. | Peroxidase Activ. | Peroxidase Activ. |
| Ascorbic Acid | Ascorbic Acid | Ascorbic Acid |
| Total Sugars | Total Sugars | Total Sugars |
| -- | -- | Sensory Evaluation |

[a] Tenderometer value in the frozen product was measured with a Canco Tenderometer at the Seabrook Foods, Inc. plant in Albany. The samples were prepared in the same manner as those presented for the sensory evaluation panel, and the tenderometer measurements were made on the same day as the sensory evaluations.

## Methods

### Tenderometer

Tenderometer values were obtained by operation of the Canco tenderometer as described by Martin (1937). The cup of the tenderometer was filled with the sample at room temperature. The control lever was pulled and a grid of shearing blades rotated at a constant speed through a second grid which was suspended in such a manner that any force on this grid was interbalanced by a pendulum. As the peas were sheared by the blades, the maximum force was indicated by the angular movement of the pendulum displayed by a pointer moving over the graduated scale No. 2 which is used for peas. The maximum force was recorded as the tenderometer value.

### Total Solids

The percentage of total solids of the samples was determined according to the method described by the Association of Official Analytical Chemists (A.O.A.C., 1975). Approximately 5 gr of sample, previously blended in a Waring Blendor and reduced to smooth, uniform puree, was weighed to an accuracy of 0.001 g in aluminum dishes and dried until constant weight (approximately 8 hr) in a 105°C oven. This oven had mechanical air circulation and vents to allow for an interchange of air to remove moisture. After cooling in a desiccator, the samples were weighed and the total solids of the sample were calculated.

## Peroxidase Activity

The semiquantitative and quantitative estimation of peroxidase activity was determined according to the method described by Masure and Campbell (1944).

Semiquantitative estimation of blanching. Twenty g of sample and 60 ml of distilled water were placed in the Waring Blendor, blended for approximately 1 min and filtered through cotton milk filter. Two ml of this filtrate were added to 20 ml of distilled water in a test tube and, without mixing, 1 ml of 0.5% guaicol solution and 1 ml of 0.08% hydrogen peroxide were added. The contents were mixed thoroughly by inverting and the development of a brown color indicated a positive test. If no color developed in 3.5 min, the test was considered negative.

Quantitative estimation. Fifty g of peas, with 150 ml of pH 4.5 citrate (0.6 M) buffer, were placed in a Waring Blendor. Nitrogen gas was bubbled under the liquid for 1 min and the space above the liquid was purged while sample was blended for 2 min. The extract was filtered through cotton milk fibers and the first 10 ml of filtrate were discarded. The filtrate was collected in an Erlenmeyer flask, the air space flooded with nitrogen and the flask was stoppered. Filtrate

(0.5 ml) was added to 19.5 ml of distilled water in stoppered test tube and just before the starting of the reaction, 1 ml of 0.5% guaiacol in 50% ethanol solution and 1 ml of 0.085% hydrogen peroxide were added. The tube was sealed, inverted quickly two or three time to mix, and a portion of the contents were immediately placed in a Beckman Model DB Spectrophotometer (420 nm) previously zeroed with a blank. The blank had been prepared the same as the sample but without the guaiacol and hydrogen peroxide solutions. Change in absorbance was recorded as the peroxidase activity.

Ascorbic Acid

Ascorbic acid determination was made according to the method described by Loeffer and Ponting (1942). Fifty g of sample previously chopped in a Waring Blendor was weighed and placed in a semi-microblendor jar with 100 ml of 1% metaphosphoric acid and blended at full speed for 1.5 min. The solution was filtreated through Whatman No. 4 paper. An aliquot of known volume of the filtrate was taken and diluted to a known volume in a volumetric flask with 1% metaphosphoric acid.

The determination of ascorbic acid was made in a Spectronic 20 spectrophotometer at 525 nm, as follows:

a) Dye factor (Ld): The instrument was calibrated to zero on absorbance scale with 1% metaphosphoric acid. Next, the absorbance × 100 of the 2, 6-dichlorophenol-indophenol solution (dye solution) was determined by measuring 9 ml of dye solution and 1 ml of 1% metaphosphoric acid into a test tube. The solution was mixed and a portion of the solution was placed into a spectronic 20 cuvette. Absorbance × 100 was recorded as $G_d$. This solution was decolorized by adding a few crystals of ascorbic acid, mixed, and absorbance × 100 was recorded as $G_{dn}$. Dye factor was $Ld = G_d - G_{dn}$.

b) Sample reading ($L_s$): In a test tube 9 ml of dye solution and a ml of sample solution were mixed and a portion was placed in a spectronic 20 cuvette. Absorbance × 100 was recorded as $G_s$. This dye-sample solution was decolorized by the addition of crystals, mixed again, and absorbance × 100 was recorded as $G_r$. Sample reading was $L_s = G_s - G_r$.

The standard curve was prepared using standard solutions of ascorbic acid in 1% metaphosphoric acid and treated as described above. From this standard curve was calculated the constant K value, which was the mg of ascorbic acid per change of one absorbance unit on the scale ($L_d$-$L_s$).

c) Calculation: Ascorbic acid content of the sample was determined by the following formula:

$$\text{Ascorbic acid (mg/100 g sample)} = \frac{K(L_d - L_s) \times 100}{D} \quad \text{where}$$

D was the dilution factor (g original sample/ml of final test sample).

## Alcohol Insoluble Solids

The percent of alcohol insoluble solids was determined according to the method described by A.O.A.C. (1975). A known amount of sample previously blended to a smooth homogenous paste in a Waring Blendor, was weighed into a 600 ml beaker and 300 ml of 80% ethyl alcohol added. This mixture was brought to a boil and simmered for 30 min.

After filtering the mixture through a Buchner funnel using weighed Whatman No. 2 filter paper, the residue on the filter paper was washed with 80% alcohol until the washings became clear and colorless. The filtrate was measured in a graduate cylinder and stored for later determination of total soluble sugars. The filter paper and alcohol insoluble solids were transferred to a previously weighed petri dish, and dried with the cover off at 40°C until constant weight. The cover was replaced, the dish cooled in a desiccator, and weighed. The weight of the recovered alcohol insoluble solids related to 100 g of sample was the percent of alcohol insoluble solids.

Total Soluble Sugars

Total soluble sugars were expressed in reducing sugars and were determined by phenol-sulfuric acid colorimetric method described by Whistler and Wolfram (1962).

Alcohol was evaporated in a Büchi rotary evaporator model "R" from a known aliquot of the alcoholic solution saved from the determination of alcohol insoluble solids. The soluble sugars were transferred in an aqueous solution to an Erlenmeyer flask and clarified with saturated, neutralized lead acetate solution. This solution was filtered, treated with a saturated sodium oxalate solution and filtered again. The sugar solution was diluted with water to a known volume, containing between 10 and 70 μg of sugar/ml.

One ml of the aqueous solution and one ml of 5% phenol solution were mixed in a test tube. From a fast-flowing pipet, 5 ml of 96% sulfuric acid was added to the tube. The test tube was agitated during the acid addition before being placed at room temperature for 10 min, re-shaken again and placed in a water bath at 25-30°C for 20 min. The absorbance at 490 nm of this solution was determined in a Beckman DB spectrophotometer. A blank was prepared using 1 ml of water in place of the sugar solution. The amount of sugar in 1 ml of sugar solution was determined by reference to a standard curve previously prepared using glucose as a standard and relating this to the initial amount of sample used in the alcohol insoluble solids determination.

## Sensory Evaluation

Sensory evaluation was made only with the frozen peas. Samples were subjected to a taste test panel for judging starchiness, sweetness, tenderness, intensity and texture, flavor and overall desirability. For each of the three frozen samples (after 4 and 8 month storage), three maturity stages and three replications in each maturity level were used for the test. The panel members were asked to rank the samples according to preference. The samples were ranked from one to nine by the panel members with the level in starchiness of one equal to extremely starchy and nine equal to little or none; in sweetness one equal to extremely sweet and nine equal to little or none; and in tenderness one equal to extremely hard/tough and nine equal to extremely tender. In the desirability measurements the variables texture, flavor and overall were ranked one equal to extremely undesirable and nine equal to extremely desirable.

The samples were prepared by boiling 1000 g of frozen peas for 5 min in 175 ml of water without salt. Timing was started from resumption of the boil. There were twenty-three members on the panel and the panel compared the same replication of each maturity stage at one time. The three treatments were tasted using the same panel members each time.

## Statistical Methods

The results of the various analyses were analyzed by statistical methods. Analysis of variance and least significant difference (LSD) were used to compare the effect of the pea maturity on the factors analyzed during blanching, freezing and storage (Cochrane and Cox, 1957).

Correlation coefficients were calculated to determine the relationships between the different quality factors analyzed in this thesis (Cochrane and Cox, 1957).

# RESULTS AND DISCUSSION

## Physical Analysis

### Tenderometer Value

Results of the analysis of green peas indicate that there was a significant effect of both maturity level and processing and storage on the tenderometer value. The maturity level times processing and storage interaction[1] was significant (Table 2 and Figure 3). The tenderometer value increased with the maturity level with less mature peas having lower tenderometer values than the more mature ones. Makower (1950) also described this effect of the maturity on the change in tenderness of peas. This change in tenderness was shown directly in the tenderometer value.

The tenderometer value (Table 2 and Figure 3) decreased dramatically during processing, effected principally by the blanching treatment. This decrease in tenderometer value was greater in the overmature peas, compared with the other maturity levels probably due to the longer blanching time given these peas. Tenderometer values did not change during frozen storage for 8 months. The decrease of the tenderometer value at the fourth month of storage

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[1] Hereinafter the maturity level times processing and storage interaction will be referred to as interaction.

Table 2. The effect of the maturity, processing and storage on tenderometer value of green peas.

| Maturity | Means of the individual treatments[a] Raw | Storage Months 0 | 4 | 8 | Maturity levels Means |
|---|---|---|---|---|---|
| Immature | 74.50 | 43.00 | 35.00 | 44.00 | 49.00 |
| Mature | 92.00 | 58.00 | 40.00 | 56.00 | 61.00 |
| Overmature | 126.00 | 69.50 | 44.00 | 65.50 | 76.00 |
| Processing and Storage Mean | 97.00 | 57.00 | 39.50 | 55.00 | |

Effect of Maturity L.S.D.: (0.05) = 3.85[b]
(0.01) = 6.39

Interaction: L.S.D.: (0.05) = 3.43
(0.01) = 4.69

Effect of Processing and Storage L.S.D.: (0.05) = 1.98
(0.01) = 2.71

[a] Tenderometer values are expressed in $lb/in^2$ of grid surface

[b] Least significant difference (0.05) = 5% significance; (0.01) = 1% significance

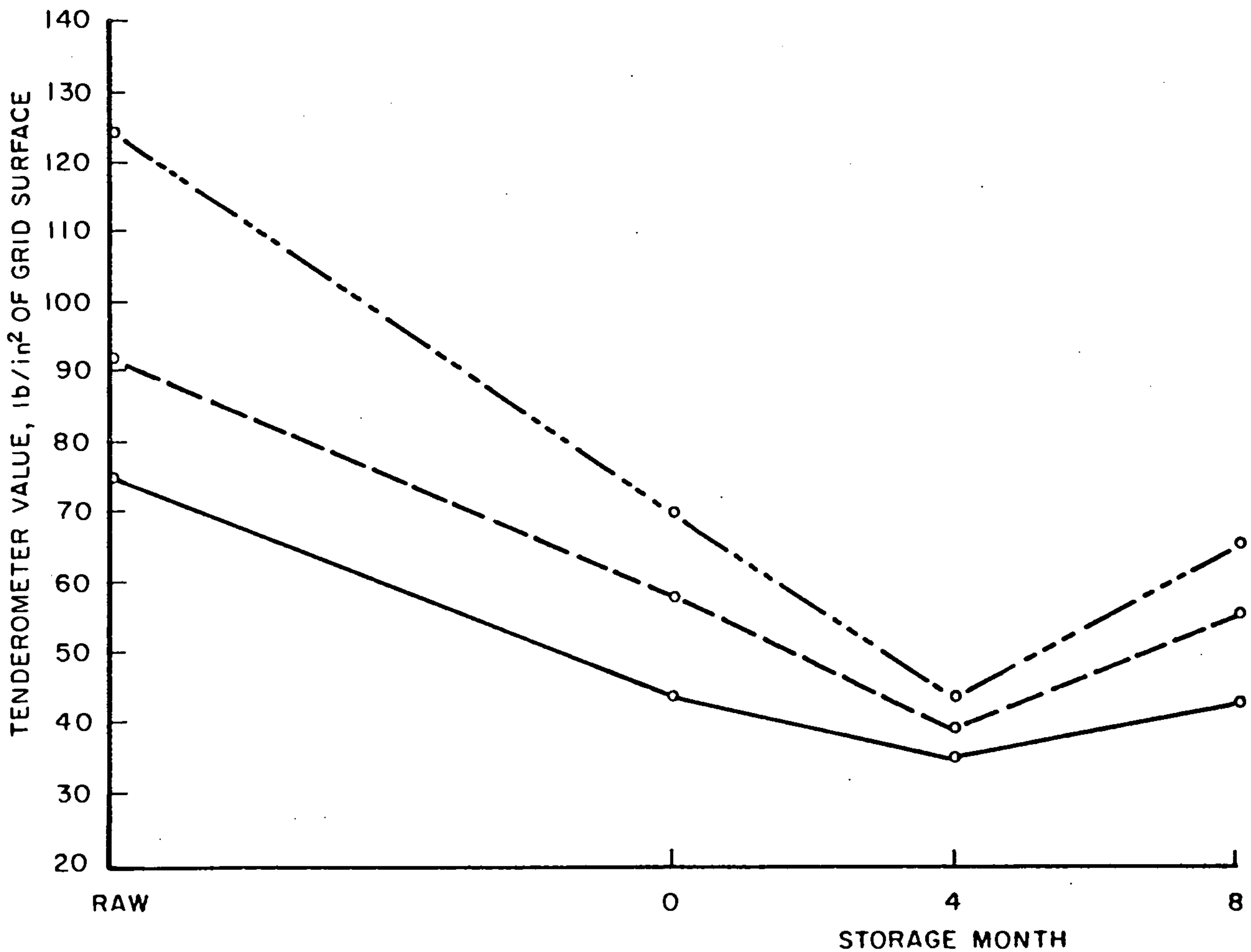


Figure 3. Effect of processing and storage on tenderometer value of Immature (————), Mature (– – – –), and Overmature (— - - —) peas. Each point represents the mean of three replications.

was attributed to lack of calibration of the Canco tenderometer because the instrument had not been used for several months.

## Chemical Analysis

### Total Solids

Maturity level and the interaction showed a significant effect on the total solids content (Table 3, Figure 4). Higher total solids content was detected in the overmature peas and lower total solids content in the immature peas. Anthistle (1961) reported that green peas increase in total solids content during the growing period.

In general, during processing total solids on immature peas decreased significantly and remained constant on mature and overmature peas (Table 3). Lynch et al. (1959) also demonstrated that solids were leached out and lost during blanching of immature peas. During frozen storage the amount of total solids content remained constant in the three maturity levels. The processing and storage did not affect the means of total solids.

### Alcohol Insoluble Solids

The alcohol insoluble solids content of green peas was significantly affected by maturity level, processing and storage and by the interaction (Table 4, Figure 5). The lowest alcohol insoluble solids

Table 3. The effect of the maturity, processing and storage on total solids content of green peas.

| Maturity | Means of the individual treatments[a] | | | | | Maturity levels Mean |
|---|---|---|---|---|---|---|
| | | | Storage Month | | | |
| | Raw | Blanched | 0 | 4 | 8 | |
| Immature | 19.669 | 18.189 | 16.428 | 16.935 | 16.677 | 17.579 |
| Mature | 19.849 | 19.780 | 20.336 | 19.932 | 19.139 | 19.807 |
| Overmature | 22.160 | 22.066 | 22.874 | 23.337 | 23.607 | 22.809 |
| Processing and Storage Mean | 20.559 | 20.012 | 19.879 | 20.068 | 19.808 | |

Effect of Maturity L.S.D. (0.05) = 1.492
(0.01) = 2.475

Interaction L.S.D. (0.05) = 0.995
(0.01) = 1.349

Effect of Processing and Storage L.S.D. (0.05) = N.S.[b]
(0.01) = N.S.

[a]Total solids values expressed in g/100 g samples

[b]N.S. = No significant difference

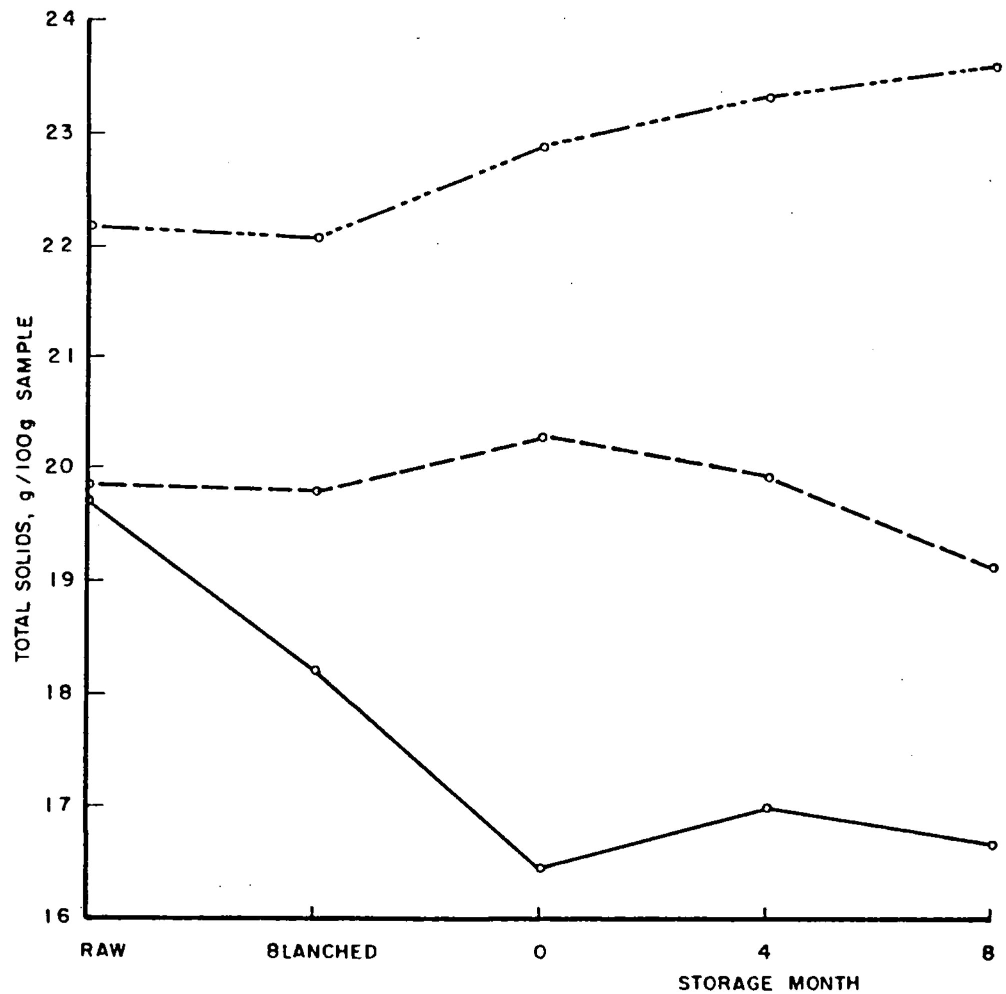


Figure 4. Effect of processing and storage on total solids content of Immature (————), Mature (– – – – –), and Overmature (—··—··) peas. Each point represents the mean of three replications.

Table 4. The effect of the maturity, processing and storage on alcohol insoluble solids content of green peas.

| | Means of the individual treatments[a] | | | | | Maturity levels Mean |
|---|---|---|---|---|---|---|
| | | | Storage Month | | | |
| Maturity | Raw | Blanched | 0 | 4 | 8 | |
| Immature | 8.450 | 8.657 | 8.617 | 7.993 | 8.097 | 8.363 |
| Mature | 11.430 | 11.717 | 11.150 | 11.963 | 11.513 | 11.555 |
| Overmature | 16.073 | 15.107 | 13.417 | 15.900 | 16.080 | 15.315 |
| Processing and Storage Mean | 11.984 | 11.827 | 11.061 | 11.952 | 11.897 | |

Effect of Maturity L.S.D. (0.05) = 0.621
(0.01) = 1.030

Interaction L.S.D. (0.05) = 0.670
(0.01) = 0.908

Effect of Processing and Storage L.S.D. (0.05) = 0.387
(0.01) = 0.546

[a]Values expressed as g/100g sample

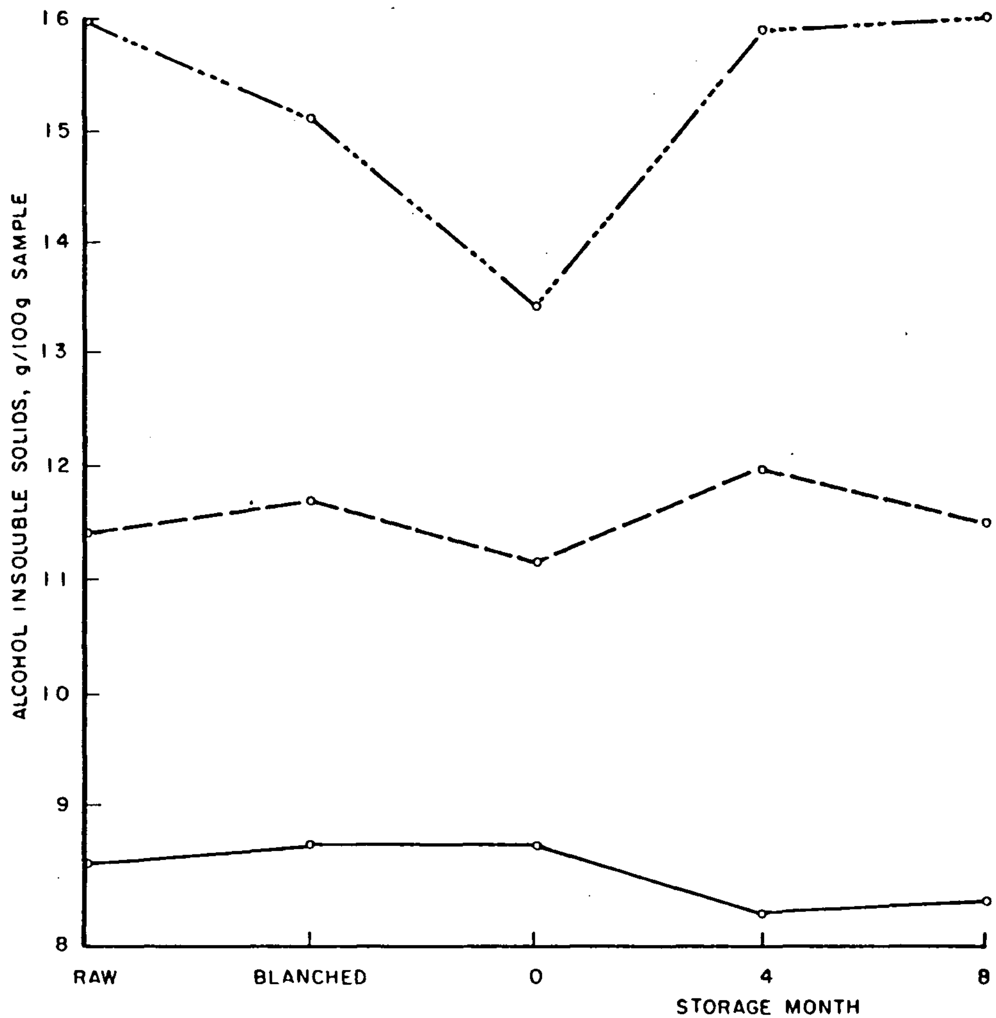


Figure 5. Effect of processing and storage on alcohol insoluble solids content of Immature (————), Mature (– – – – –), and Overmature (—··—··—) peas. Each point represents the mean of three replications.

content was found in the immature peas and the highest content was found in the overmature peas. Similar results were obtained by Lee et al. (1954). During storage a significant decrease in alcohol insoluble solids content was found in the overmature peas at zero month, but the immature and mature peas were not affected. These results can be explained on the basis of possible hydrolysis of starch occurring after blanching. Since starch was part of the alcohol insoluble solids this may be the principal component that was changed.

## Peroxidase Activity

Data presented in Table 5, Figure 6, show a significant difference between the means of peroxidase activity of the maturity levels and processing and storage. However, since the immature peas were blanched for 30 sec, mature peas for 60 sec and the overmature peas for 90 sec, and since there were no differences in peroxidase activity in the raw peas at the different maturity levels, the differences in peroxidase activity were most probably due to differences in blanching times. During processing, the blanching treatment, caused a significant decrease on the peroxidase activity, while, during freezing and storage the peroxidase activity remained constant. Similar results were reported by Pinset (1962).

Table 5. The effect of the maturity, processing and storage on peroxidase activity of green peas.

| Maturity | Means of the individual treatments[a] | | | | | Maturity levels Mean |
|---|---|---|---|---|---|---|
| | | | Storage Month | | | |
| | Raw | Blanched | 0 | 4 | 8 | |
| Immature | 72.83 | 41.50 | 48.42 | 34.67 | 35.67 | 46.62 |
| Mature | 79.00 | 8.17 | 4.25 | 9.00 | 11.83 | 22.45 |
| Overmature | 74.67 | 0.92 | 0.75 | 0.11 | 0.00 | 15.29 |
| Processing and Storage Mean | 75.50 | 16.86 | 17.80 | 14.59 | 15.83 | |

Effect of Maturity L.S.D. (0.05) = 10.74
(0.01) = 17.81

Interaction L.S.D. (0.05) = 13.46
(0.01) = 18.24

Effect of Processing and Storage L.S.D. (0.05) = 7.77
().01) = 10.53

[a]Values expressed in change absorbance at nm/min.

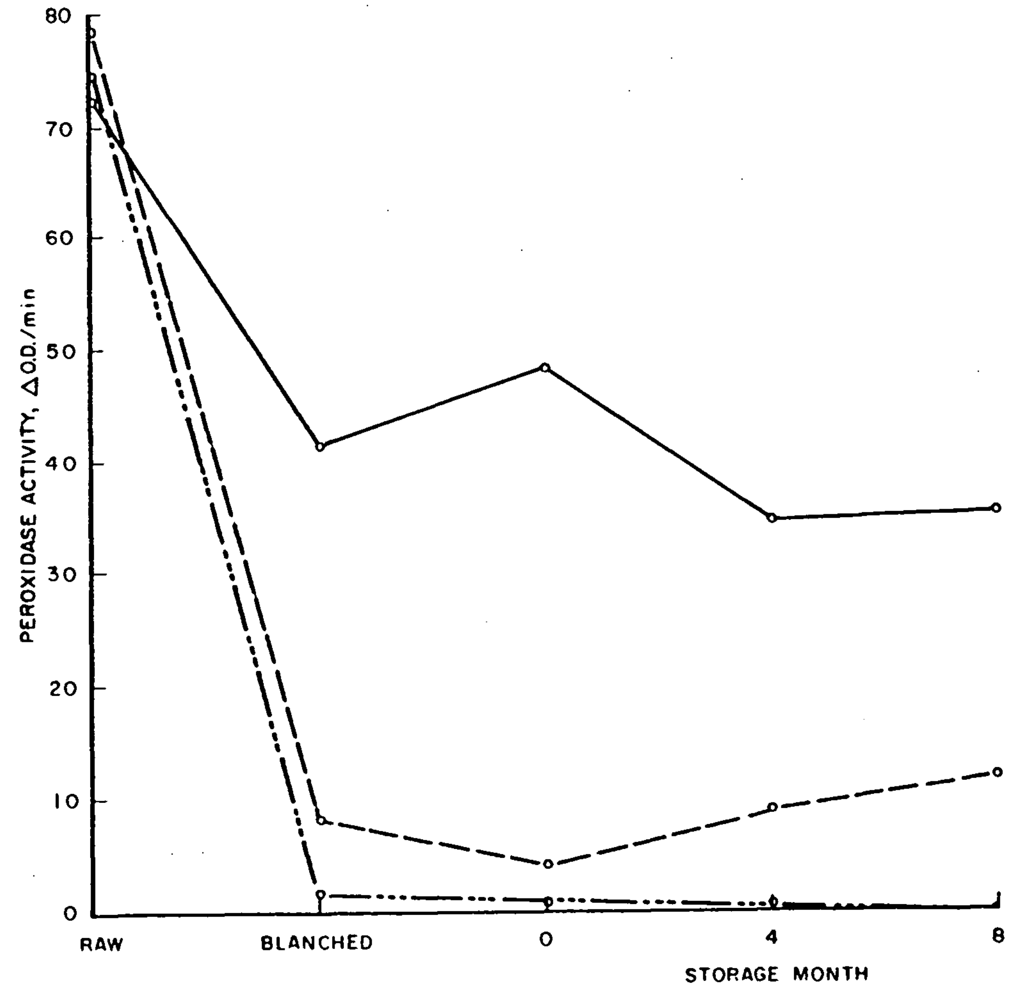


Figure 6. Effect of processing and storage on peroxidase activity of Immature (————), Mature (– – – – –), and Overmature (–·–·–·–) peas. Blanched for 30 seconds, 60 seconds and 90 seconds, respectively. Each point represents the mean of three replications.

## Ascorbic Acid

Significant effect of maturity level, processing and interaction on the ascorbic acid content of the peas are shown in Table 6 and Figure 7. The immature and mature peas had significantly higher ascorbic acid content compared with the overmature peas. These results concur with those of Selman and Rolfe (1979). During processing ascorbic acid content was significantly decreased by the blanching treatment, but was not affected during freezing and storage. Clegg (1974) reported that ascorbic acid in peas was one of the most vulnerable nutrients and was affected considerably by the heat treatment. Cain (1967) and McBride and Richardson (1979) reported that freezing and good storage conditions do not affect ascorbic acid content of peas. The significant interaction indicates that the ascorbic acid content in mature and immature peas was significantly decreased by the blanching treatment, but the ascorbic acid content in the overmature peas was not affected. These results agree with Wilcox and Morrel (1948), who reported the increase in percent retention of ascorbic acid with increasing maturity in peas.

## Total Soluble Sugars

There was significant effect of both maturity level or processing and storage on the means of total soluble sugars content, and the

Table 6. The effect of the maturity, processing and storage on ascorbic acid content of green peas.

| Maturity | Means of the individual treatments[a] | | | | | Maturity levels Mean |
|---|---|---|---|---|---|---|
| | | | Storage Month | | | |
| | Raw | Blanched | 0 | 4 | 8 | |
| Immature | 24.590 | 14.760 | 14.768 | 14.092 | 13.985 | 16.439 |
| Mature | 19.635 | 14.253 | 14.125 | 13.768 | 13.595 | 15.075 |
| Overmature | 14.687 | 13.245 | 12.848 | 12.042 | 11.725 | 12.909 |
| Processing and Storage Mean | 19.637 | 14.086 | 13.914 | 13.301 | 13.102 | |

Effect of Maturity levels L.S.D. (0.05) = 0.951
(0.01) = 1.578

Interaction L.S.D. (0.05) = 2.376
(0.01) = 3.220

Effect of Processing and Storage
L.S.D. (0.05) = 1.372
(0.01) = 1.859

[a]Values are expressed in mg/100g sample

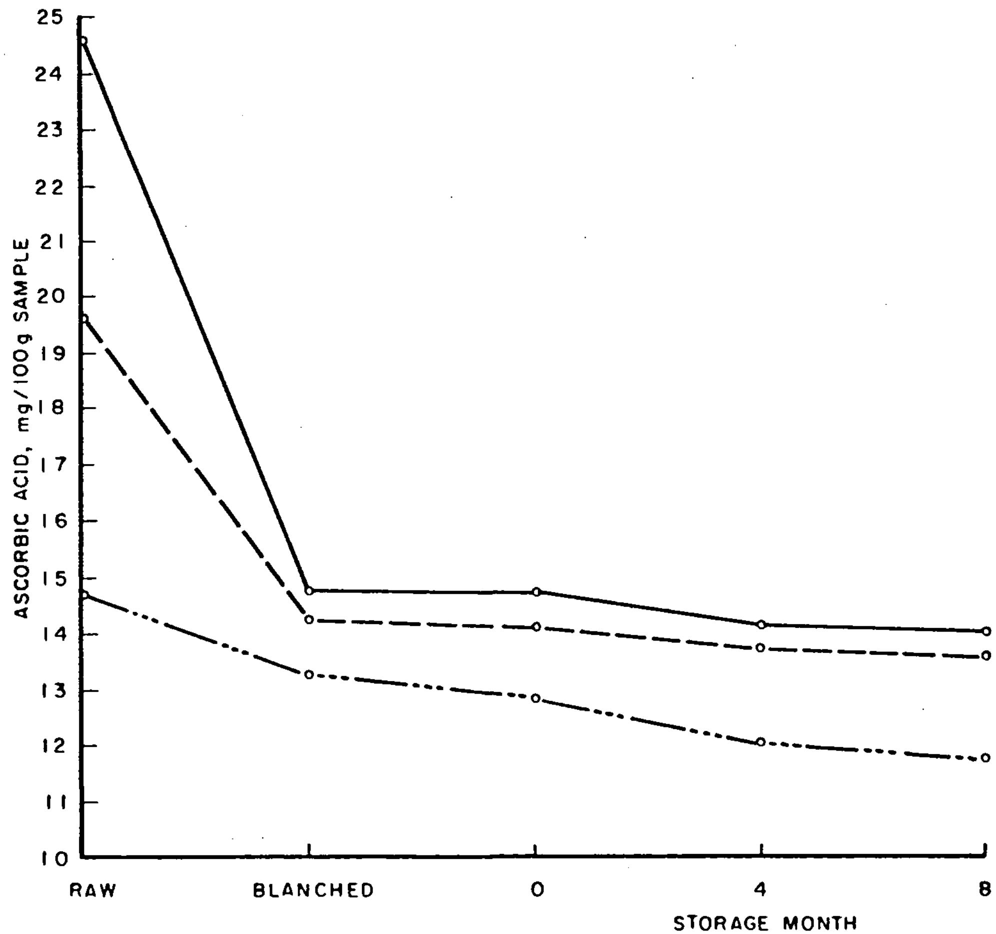


Figure 7. Effect of processing and storage on ascorbic acid content of Immature (————), Mature (– – – – –), and Overmature (–··–··–) peas. Each point represents the mean of three replications.

interaction was also significant (Table 7, Figure 8). Immature peas had the highest and the overmature peas had the lowest total soluble sugar content. Turner et al. (1957) also found that the sugar contents of the seed increased in the early stages of development but decreased during the phase of rapid starch synthesis.

The processing had no effect on the means of the total soluble sugar content, however high sugar contents were noted after frozen storage. This can be explained on the basis of the enzyme hydrolysis of starch. Kramer (1979) reported that certain enzymatic and non-enzymatic changes continue during storage. These results can be related with the higher sweetness detected by the sensory evaluation panel at 4 months of storage (Table 9). This behavior was not found after 8 months of storage.

## Sensory Evaluation

### Starchiness Intensity

The means of the starchiness intensity were significantly affected by the maturity level (Table 8 and Figure 9). The immature peas scored 6.88 indicating the least starchiness intensity. The lowest score or the high starchiness intensity was found in the overmature sample. Turner et al. (1957) reported an increase of the amount of starch in peas during ripening. Neither the storage time nor the

Table 7. The effect of the maturity, processing and storage on total soluble sugars content of green peas.

| | Means of the individual treatments[a] | | | | | Maturity level Means |
|---|---|---|---|---|---|---|
| | | | Storage Month | | | |
| Maturity | Raw | Blanched | 0 | 4 | 8 | |
| Immature | 3.977 | 3.877 | 4.263 | 5.157 | 4.323 | 4.319 |
| Mature | 3.680 | 3.497 | 3 817 | 3.817 | 4.103 | 3.783 |
| Overmature | 3.063 | 2.970 | 3.120 | 3.987 | 3.297 | 3.287 |
| Processing and Storage Mean | 3.573 | 3.448 | 3.733 | 4.320 | 3.908 | |

Effect of Maturity L.S.D. (0.05) = 0.383
(0.01) = 0.635

Interaction L.S.D. (0.05) = 0.325
(0.01) = 0.440

Effect of Processing and Storage L.S.D. (0.05) = 0.187
(0.01) = 0.239

[a]Values expressed in g/100g of sample

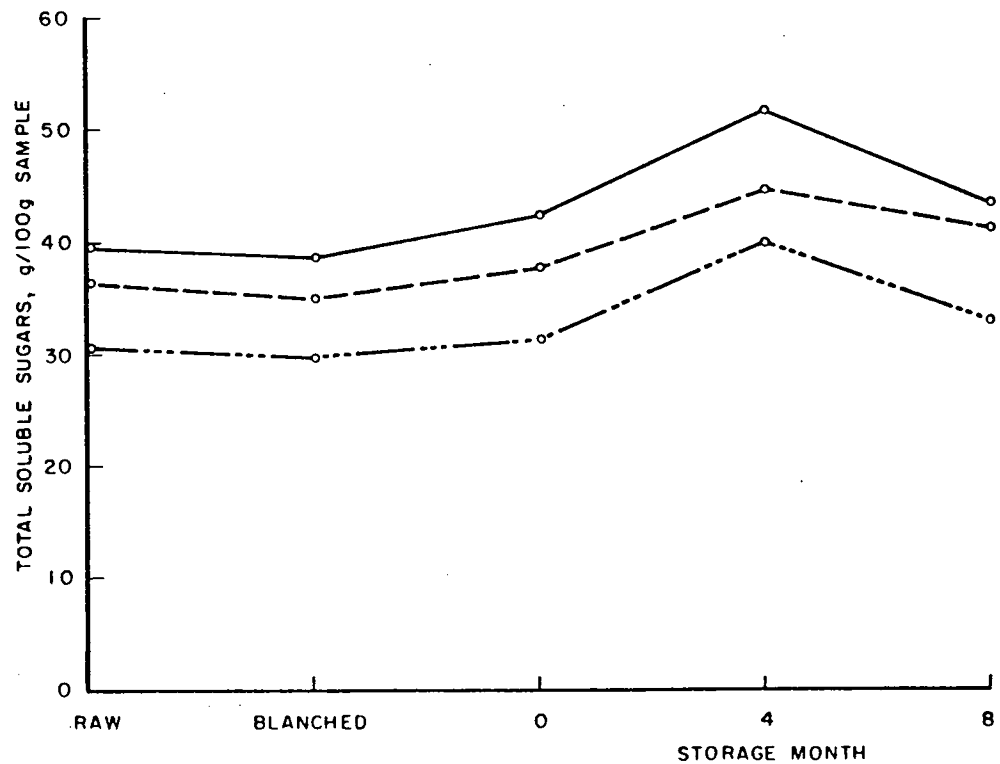


Figure 8. Effect of processing and storage on total soluble sugars content of Immature (————), Mature (— — — —), and Overmature (— ··— ··—) peas. Each point represents the mean of three replications.

Table 8. The effect of the maturity and storage time on starchiness intensity of frozen peas as measured by sensory evaluation panel.

| Maturity | Means of the individual treatments[a] Storage Month 0 | 4 | 8 | Means of Maturity levels |
|---|---|---|---|---|
| Immature | 6.67 | 7.07 | 6.90 | 6.88 |
| Mature | 6.19 | 6.19 | 5.70 | 6.03 |
| Overmature | 3.75 | 3.59 | 3.06 | 3.47 |
| Storage Time Mean | 5.54 | 5.62 | 5.22 | |

Effect of Maturity L.S.D. (0.05) = 0.32
(0.01) = 0.53

Interaction L.S.D. (0.05) = N.S.
(0.01) = N.S.

Effect of Storage L.S.D. (0.05) = N.S.
(0.01) = N.S.

[a]A value of 1 was extremely starchy and a value of 9 was little or no starchy

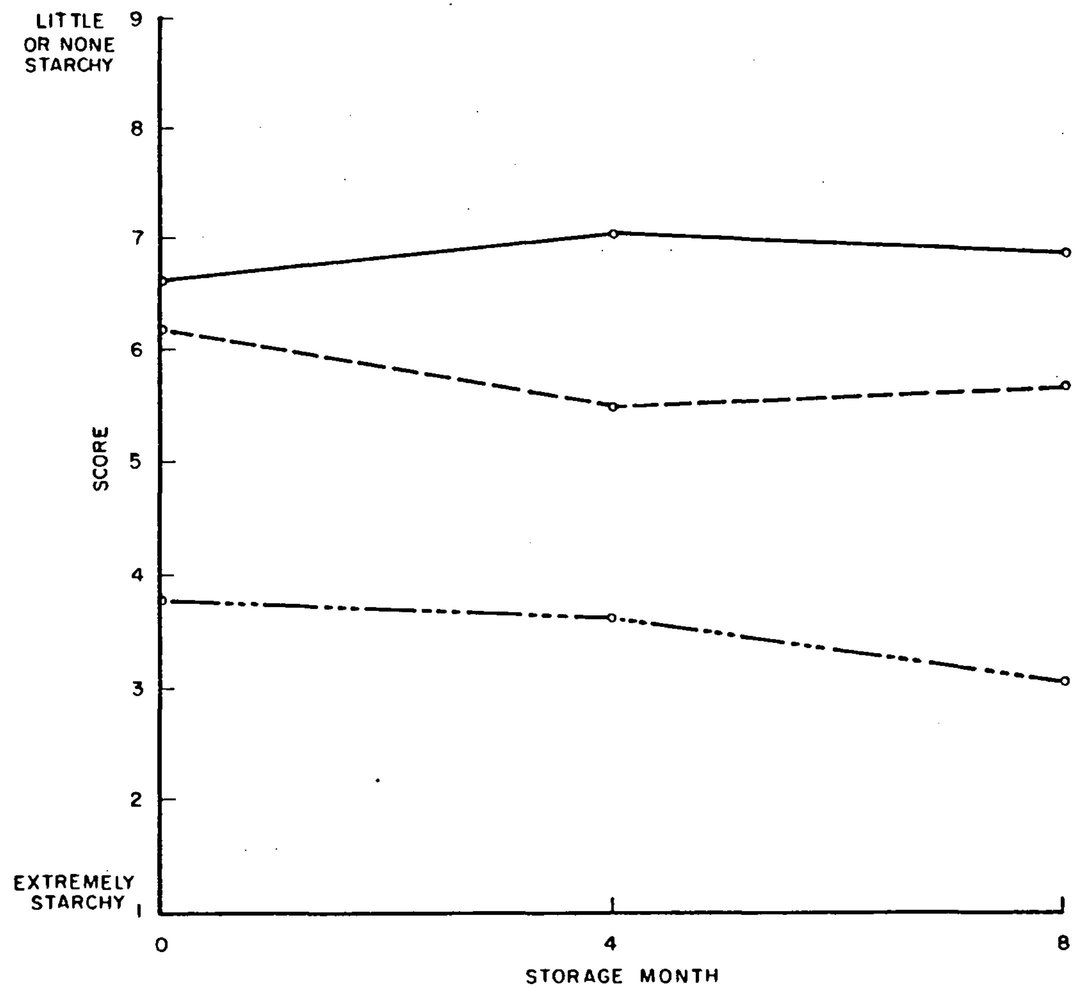


Figure 9. Effect of the storage time on starchiness intensity of Immature (————), Mature (– – – – –), and Overmature (–···——····) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

maturity level times storage interaction[2] affected the starchiness intensity.

Sweetness Intensity

Both maturity level and storage time significantly affected the means of the sweetness intensity of the frozen peas, and the significant interaction indicated an influence of both factors (Table 9, Figure 10). The lowest score or the highest sweetness was found in the immature and mature samples. The overmature peas scored 6.68 indicating the least sweetness intensity. During storage highest sweetness intensity was found after 4 months. These results are in agreement with higher amounts of total soluble sugars detected during the same storage period (Table 7). The significant interactions indicates that the sweetness intensity in immature peas was increased at 4 storage months, the sweetness intensity in the mature and overmature peas remaining constant.

Tenderness Intensity

The means of the tenderness intensity of the frozen peas were influenced only by maturity level (Table 10, Figure 11). Neither the storage time nor the interaction was significant. Immature and mature peas were not significantly different, scored the highest thus indicating more tenderness. The overmature sample scored lowest

[2]Hereafter the maturity level times storage time interaction will be referred to as interaction.

Table 9. The effect of the maturity and storage time on sweetness intensity of frozen peas as measured by sensory evaluation panel.

| | Means of the individual treatments[a] Storage Month | | | Means of Maturity levels |
|---|---|---|---|---|
| Maturity | 0 | 4 | 8 | |
| Immature | 5.31 | 4.69 | 5.74 | 5.24 |
| Mature | 5.36 | 5.36 | 5.59 | 5.43 |
| Overmature | 6.82 | 6.58 | 6.63 | 6.68 |
| Storage Time Mean | 5.83 | 5.54 | 5.98 | |

Effect of Maturity L.S.D. (0.05) = 0.55
(0.01) = 0.92

Effect of Storage L.S.D. (0.05) = 0.19
(0.01) = 0.28

Interaction L.S.D. (0.05) = 0.34
(0.01) = 0.48

[a] A value of 1 was extremely sweet and a value of 9 was little or no sweet

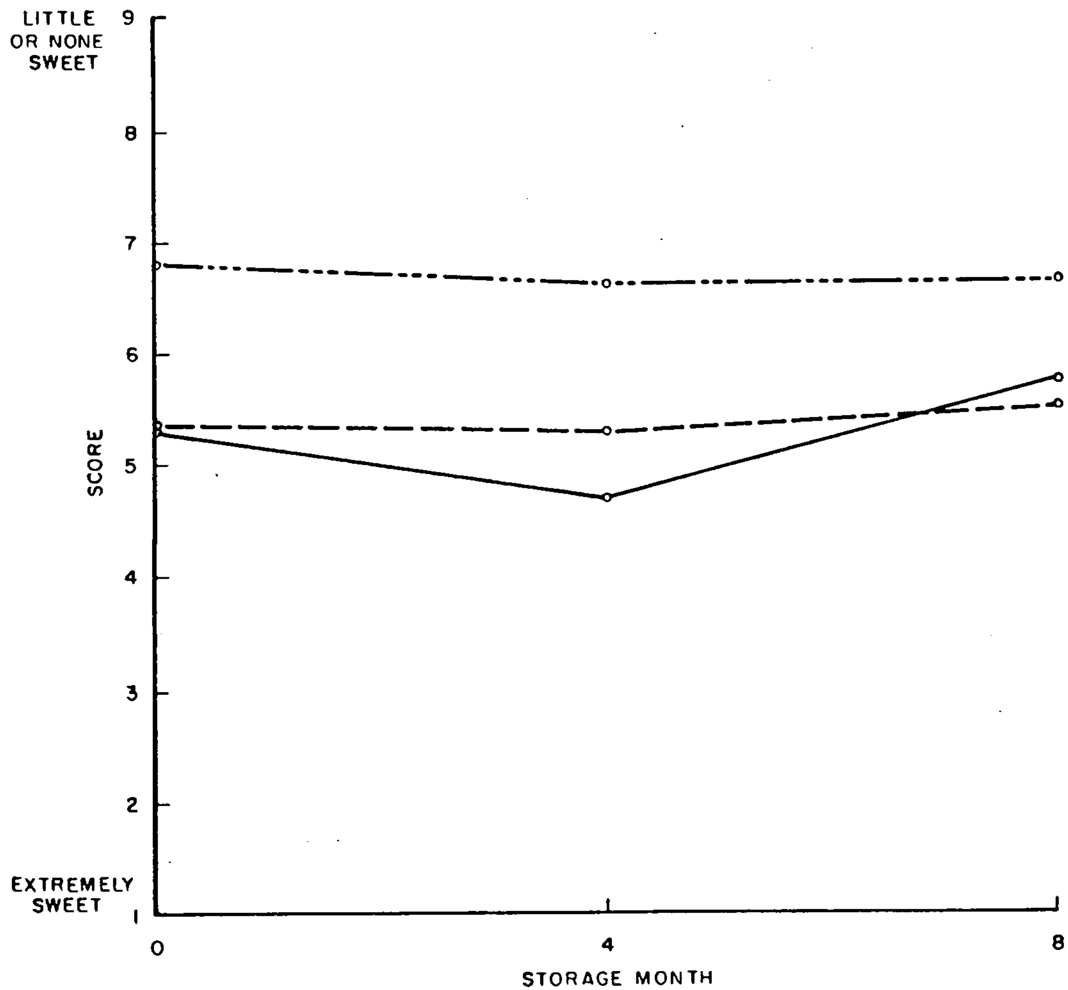


Figure 10. Effect of the storage time on sweetness intensity of Immature (————), Mature (— — — —), and Overmature (—·-·—·-·—) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

Table 10. The effect of the maturity and storage time on tenderness intensity of frozen peas as measured by sensory evaluation panel.

| Maturity | Means of the individual treatments[a] Storage Month 0 | 4 | 8 | Means of Maturity levels |
|---|---|---|---|---|
| Immature | 6.48 | 6.40 | 6.31 | 6.39 |
| Mature | 6.38 | 6.38 | 5.90 | 6.22 |
| Overmature | 5.15 | 5.38 | 5.36 | 5.29 |
| Storage Time Mean | 6.00 | 6.05 | 5.86 | |

Effect of Maturity L.S.D. (0.05) = 0.67
(0.01) = N.S.

Interaction L.S.D. (0.05) = N.S.
(0.01) = N.S.

Effect of Storage L.S.D. (0.05) = N.S.
(0.01) = N.S.

[a]A value of 1 was extremely tough/hard and value of 9 was extremely tender

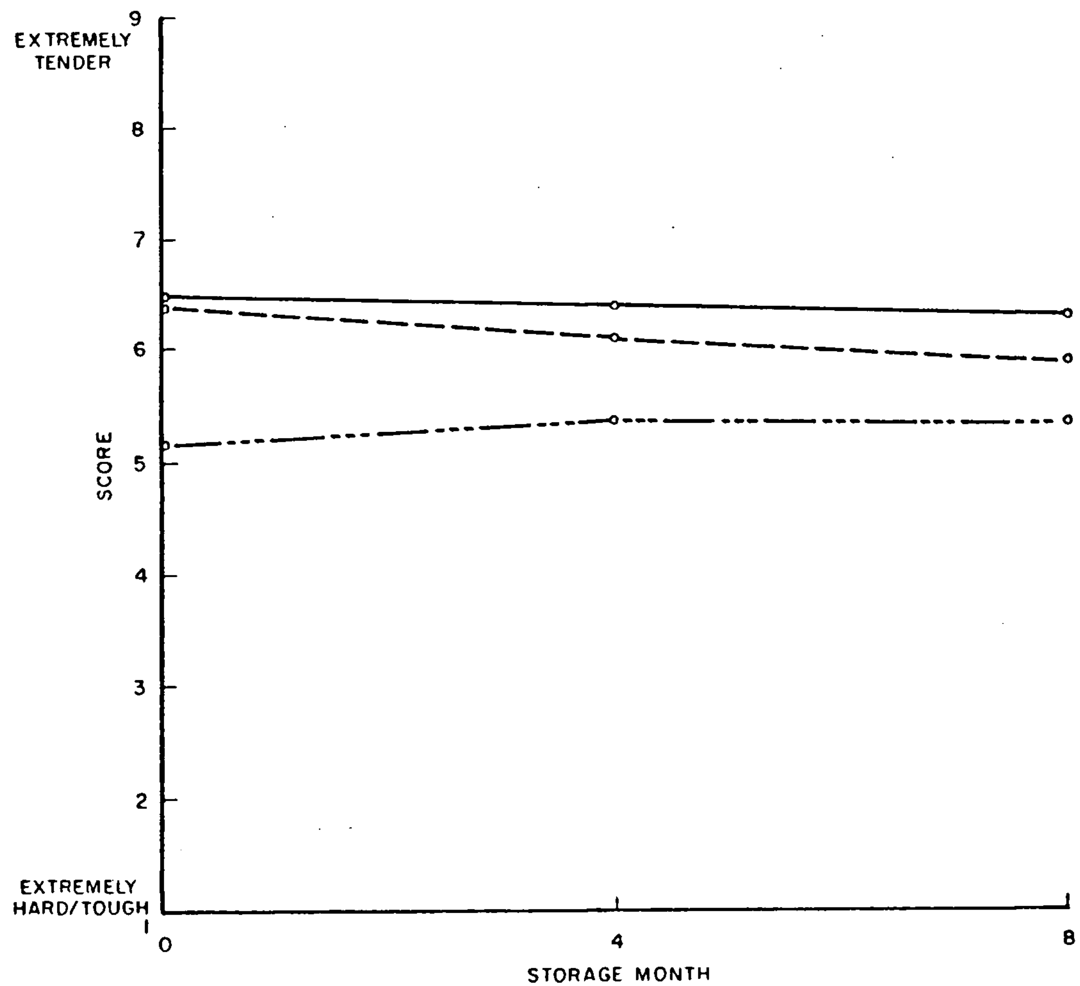


Figure 11. Effect of the storage time on tenderness intensity of Immature (————————), Mature (— — — — — —), and Overmature (-·-·——·-·-·-) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

(tougher) and was significantly different from the other two maturities. Makower (1950) reported as peas ripen their skins toughen and cotyledons become more firm.

## Texture Desirability

A significant effect of maturity level and storage time was shown the texture desirability (Table 11, Figure 12). Immature and mature peas had the highest score and were more desirable as determined by the panel than the overmature peas. Makower (1950) reported that during the maturation of peas there was a stage when the eating quality of the vegetable was optimal; at that point flavor and texture were best. After 8 months of storage, the panel showed that the texture of the frozen peas became significantly less desirable. The interaction was not significant. This indicates that the change in texture desirability during frozen storage was not influenced by the stage of maturity.

## Flavor Desirability

There was significant effect of both maturity level and storage time on the mean score of flavor desirability, and the interaction was also significant (Table 12, Figure 13). Mature peas were significantly more desirable, according to the panel, and overmature and immature peas were significantly less desirable. These results are in accord

Table 11. The effect of the maturity and storage time on texture desirability of frozen peas as measured by sensory evaluation panel.

| Maturity | Means of the individual treatments[a] Storage Month 0 | 4 | 8 | Means of Maturity levels |
|---|---|---|---|---|
| Immature | 6.83 | 6.85 | 6.29 | 6.66 |
| Mature | 6.36 | 6.36 | 6.00 | 6.24 |
| Overmature | 4.27 | 4.13 | 3.42 | 3.94 |
| Storage Time Mean | 5.82 | 5.78 | 5.23 | |

Effect of Maturity L.S.D. (0.05) = 0.78
(0.01) = 1.30

Effect of Storage L.S.D. (0.05) = 0.32
(0.01) = 0.45

Interaction L.S.D. (0.05) = N.S.
(0.01) = N.S.

[a] A value of 1 was extremely undesirable and a value of 9 was extremely desirable

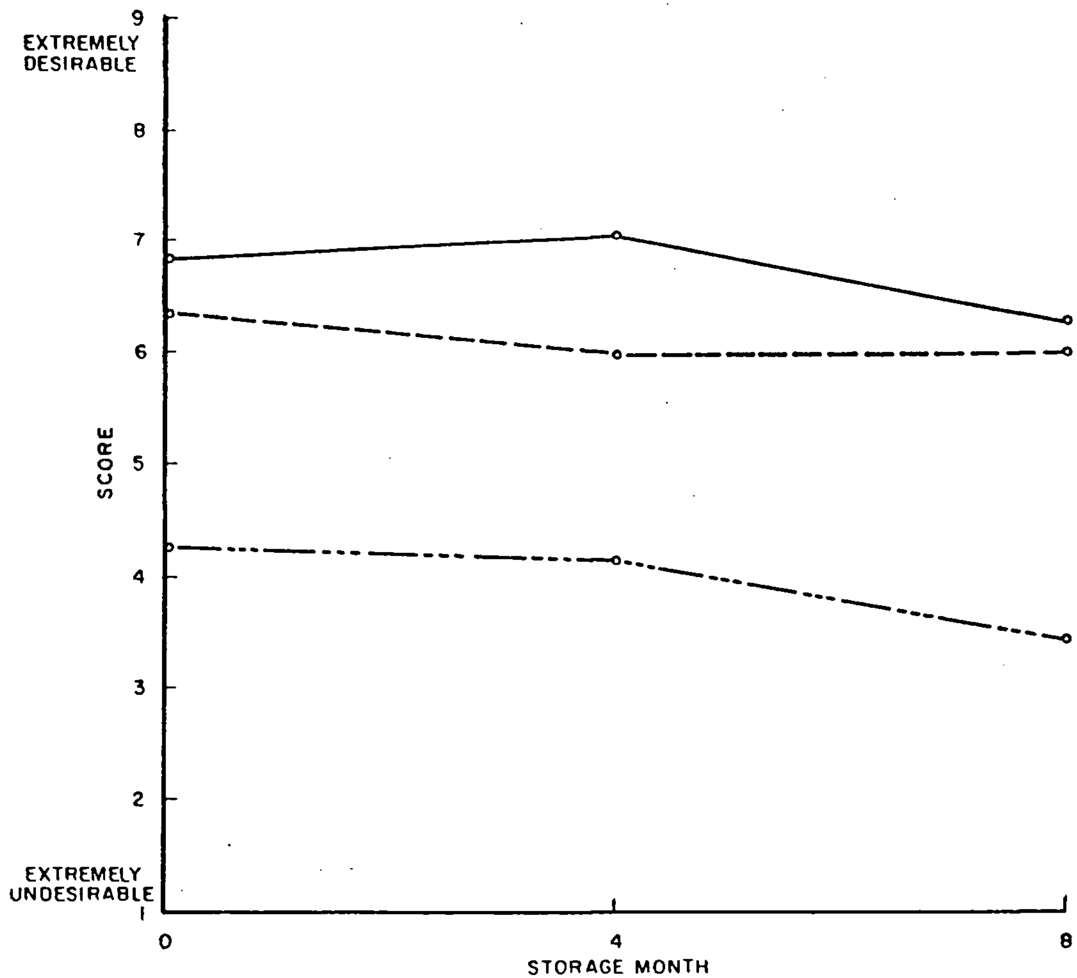


Figure 12. Effect of the storage time on texture desirability of Immature (———————), Mature ( – – – – – – ), and Overmature (— - - - ——— - - - -) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

Table 12. The effect of the maturity and storage time on flavor desirability of frozen peas as measured by sensory evaluation panel.

| | Means of the individual treatments[a] | | | Means of Maturity levels |
|---|---|---|---|---|
| | Storage Month | | | |
| Maturity | 0 | 4 | 8 | |
| Immature | 6.53 | 5.65 | 4.61 | 5.59 |
| Mature | 6.54 | 6.54 | 6.30 | 6.46 |
| Overmature | 4.71 | 4.91 | 4.32 | 4.64 |
| Storage Time Mean | 5.92 | 5.70 | 5.07 | |

Effect of Maturity L.S.D. (0.05) = 0.35
(0.01) = 0.59

Effect of Storage L.S.D. (0.05) = 0.17
(0.01) = 0.51

Interaction L.S.D. (0.05) = 0.64
(0.01) = N.S.

[a]A value of 1 was extremely undesirable and value of 9 was extremely desirable

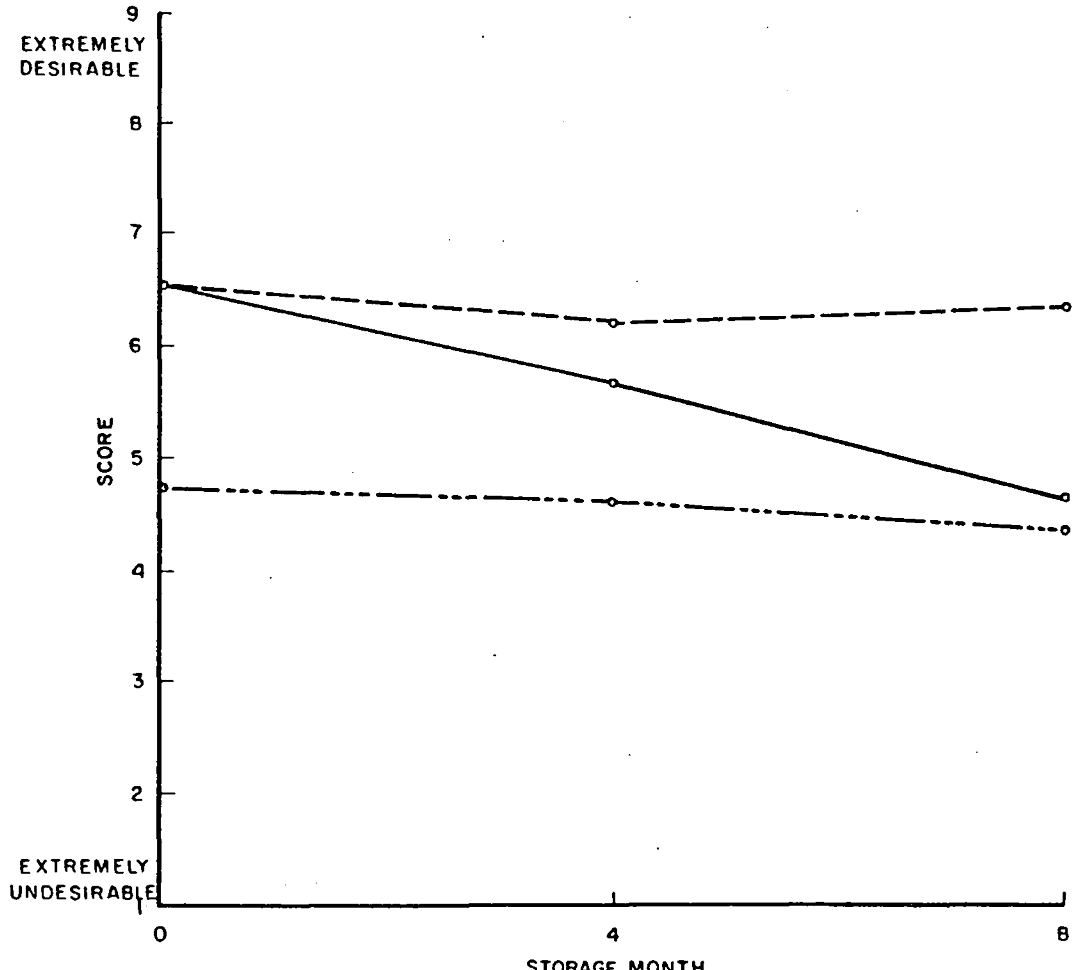


Figure 13. Effect of the storage time on flavor desirability of Immature (———————), Mature ( – – – – – – ), and Overmature (–·–·–·———·–·–) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

with Makower (1950).

After 8 months in storage the flavor of the frozen peas became more undesirable. The significant interaction indicates that the flavor in the immature peas during storage became more undesirable, while flavor desirability for mature and overmature peas remained constant according to panel evaluation. This change of flavor desirability in immature peas can be attributed to the shortest blanching time for immature peas compared with mature and overmature peas. In contrast to these data, Last and Shipton (1966) reported that a blanching time of 30 sec. was adequate for the retention of quality in frozen peas during storage.

Overall Desirability

Significant effects of both maturity level and storage time was found on the overall desirability (Table 13, Figure 14).

Mature peas had the best overall desirability as judged by the panel members. Kramer (1964) reported that, in general, the immature or mature peas were more desirable. The overall desirability decreased after 8 months of storage.

In general, all the factors analyzed above were affected by the maturity level. Tenderometer value, alcohol insoluble solids, peroxidase activity, ascorbic acid content, total soluble sugars, sweetness intensity, texture, flavor, and overall desirability were affected by the

Table 13. The effect of the maturity and storage time on overall desirability of frozen peas as measured by sensory evaluation panel.

| | Means of the individual treatments[a] | | | Means of Maturity levels |
|---|---|---|---|---|
| | Storage Month | | | |
| Maturity | 0 | 4 | 8 | |
| Immature | 6.68 | 5.86 | 4.84 | 5.79 |
| Mature | 6.50 | 6.50 | 6.08 | 6.36 |
| Overmature | 4.50 | 4.21 | 3.79 | 4.17 |
| Storage Time Mean | 5.89 | 5.52 | 4.90 | |

Effect of Maturity L.S.D. (0.05) = 0.45
(0.01) = 0.75

Effect of Storage L.S.D. (0.05) = 0.38
(0.01) = 0.54

Interaction L.S.D. (0.05) = N.S.
(0.01) = N.S.

[a]A value of 1 was extremely undesirable and value of 9 was extremely desirable

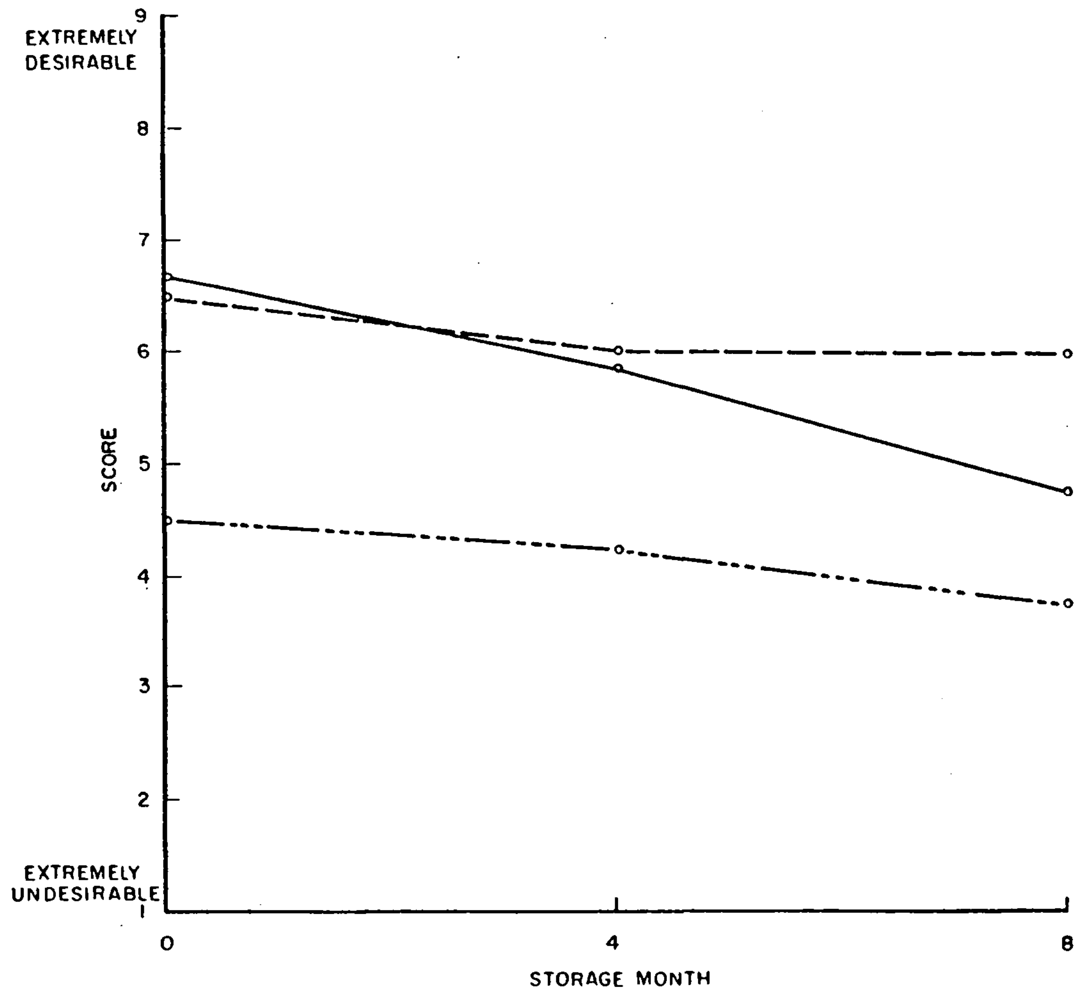


Figure 14. Effect of storage time on overall desirability of Immature (————), Mature (— — — — — —), and Overmature (—··· ———···—) frozen peas as measured by sensory evaluation panel. Each point represents the mean of three replications.

processing. Total solids, starchiness and tenderness intensity were not affected by processing and storage. Also, several interactions were found.

In order to establish the possible interactions between the factors analyzed, a correlation analysis was made.

## Correlations Analysis

The correlation coefficients between all the factors analyzed are shown in Table 14.

High and positive correlations were found between tenderometer value, total solids and alcohol insoluble solids. In general these factors gave high positive or high negative correlations with the sensory evaluation parameters analyzed. These results indicated that the tenderometer value, total solids and alcohol insoluble solids can be used as a good indication of maturity of peas as judged by the sensory evaluation panel. Total soluble sugars gave significantly high and negative correlation with tenderometer value, total solids and alcohol insoluble solids. Makower (1950) reported that total sugars was a poor index of maturity in frozen products for its tendency to rise and fall with the maturity and the loss of sugar through respiration between harvest and processing.

High and positive correlations were found between ascorbic acid and sensory evaluation parameters. Kramer et al. (1950) found high correlation between ascorbic acid and flavor. No correlation was found between peroxidase activity and flavor desirability, but it gave positive and significant correlation with overall desirability. This result can be explained because peroxidase was closely related with enzymes involved in the off-flavor formation (Joslyn, 1946) and the off-flavor has important effects in the overall desirability of the frozen peas. High positive or negative correlations were also found between all sensory evaluation parameters. These results showed that all the sensory evaluation parameters measured were related in the overall quality of the frozen peas.

The correlation coefficients between the physical and chemical factors measured on the raw peas and the sensory evaluation parameters measured on the frozen peas at 0, 4 and 8 months of storage are shown in Tables 15, 16 and 17, respectively.

Tenderometer value measured on the raw peas gave high and significant correlations with all the sensory evaluation parameters measured on the frozen peas at 0 storage month (Table 15), but during frozen storage the correlations between the tenderometer value measured on the raw peas and flavor and overall desirability measured on the frozen peas decreased (Tables 16 and 17), and no correlations were found between these factors at 8 storage months. This behavior was also observed in the correlations between total solids, alcohol insoluble solids and total soluble sugars measured on the raw peas

Table 14. Correlation coefficients between the physical, chemical and sensory parameters analyzed.

| | Tenderometer | Total Solids | Alcoh. Insol. Solids | Peroxidase Activity | Ascorb. Acid | Total Sol. Sugars | Starch. Intens. | Sweet Intens. | Tender. Intens. | Texture Desir. | Flavor Desir. | Overall Desir. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tenderometer | 1.00 | | | | | | | | | | | |
| Total solids | 0.42**[a] | 1.00 | | | | | | | | | | |
| Alcoh. Ins. solids | 0.44** | 0.89** | 1.00 | | | | | | | | | |
| Perox. Activity | 0.56** | -0.37* | -0.37* | 1.00 | | | | | | | | |
| Ascorbic Acid | 0.31 | -0.22 | -0.40** | 0.66** | 1.00 | | | | | | | |
| Total Sol. Sugars | -0.65** | -0.65** | -0.69** | 0.15 | 0.10 | 1.00 | | | | | | |
| Starch Intens. | -0.65** | -0.87** | -0.92** | 0.73** | 0.70** | 0.71** | 1.00 | | | | | |
| Sweet Intens. | 0.66** | 0.72** | 0.76** | -0.59** | -0.65** | -0.73** | -0.88** | 1.00 | | | | |
| Tender Intens. | -0.64** | -0.71** | -0.74** | 0.60** | 0.63** | 0.60** | 0.85** | -0.87** | 1.00 | | | |
| Texture Desir. | -0.64** | -0.81** | -0.87** | 0.68** | 0.73** | 0.65** | 0.96** | -0.92** | 0.88** | 1.00 | | |
| Flavor Desir. | -0.34 | -0.38* | -0.40* | 0.23 | 0.56** | 0.29 | 0.61** | -0.72** | 0.61** | 0.73** | 1.00 | |
| Overall Desir. | -0.41*[b] | -0.56** | -0.61** | 0.42* | 0.66** | 0.41* | 0.78** | -0.82** | 0.74** | 0.87** | 0.96** | 1.00 |

a** = 1% significance

b* = 5% significance

and on the sensory evaluation parameters measured on the frozen peas (Tables 15, 16 and 17). These results indicate that the tenderometer value, total solids and alcohol insoluble solids can be used as a good indication of maturity of frozen peas as judged by sensory evaluation panel. Total soluble sugars is not recommended as good index of maturity in frozen products for its tendency to rise and fall with the maturity and the loss of sugar through respiration between harvest and processing (Makower, 1950).

No correlations were found during frozen storage between peroxidase activity measured on the raw peas and all the sensory evaluation parameters measured on the frozen peas (Table 15, 16 and 17). These results can be explained because there were no differences in peroxidase activity in the raw peas (Table 5) but the sensory evaluation panel detected differences in the different parameters analyzed on the frozen peas (Tables 8, 9, 10, 11, 12 and 13). No correlation was found at 0 storage month between ascorbic acid measured on the raw peas and flavor desirability measured on the frozen peas, but it gave positive and significant correlation with overall desirability measured on the frozen peas (Table 15). After 4 and 8 months in storage no correlations were found between ascorbic acid measured on the raw peas and flavor and overall desirability measured on the frozen peas (Tables 16 and 17). These results can be explained because the changes in flavor and overall desirability in the frozen peas as detected by sensory

Table 15. Correlation coefficients between physical and chemical factors measured on the raw peas and sensory evaluation parameters measured on the frozen peas at 0 storage month.

| | | Frozen peas | | | | | |
|---|---|---|---|---|---|---|---|
| | | Starchiness | Sweetness | Tenderness | Texture | Flavor | Overall |
| Raw peas | Tenderometer | -0.92**[a] | 0.86** | -0.88** | -0.91** | -0.79* | -0.85** |
| | Total Solids | -0.81** | 0.74* | -0.86** | -0.77* | -0.64 | -0.70* |
| | Alcoh. Ins. Solids | -0.92** | 0.86** | -0.84** | -0.91** | -0.80** | -0.85** |
| | Perox. Activity | -0.07 | 0.02 | 0.13 | -0.14 | -0.13 | -0.10 |
| | Ascorbic Acid | 0.78*[b] | -0.61 | 0.57 | 0.74* | 0.63 | 0.69* |
| | Total Sol. Sugars | 0.94** | -0.92** | 0.93** | 0.95** | 0.84** | 0.89** |

[a]** = 1% significance

[b]* = 5% significance

Table 16. Correlation coefficients between physical and chemical factors measured on the raw peas and sensory evaluation parameters measured on the frozen peas at 4 storage month.

| | | Frozen peas | | | | | |
|---|---|---|---|---|---|---|---|
| | | Starchiness | Sweetness | Tenderness | Texture | Flavor | Overall |
| Raw peas | Tenderometer | -0.97**[a] | 0.94** | -0.80** | -0.94** | -0.58 | -0.78* |
| | Total solids | -0.86** | 0.75*[b] | -0.66 | -0.81* | -0.72* | -0.82** |
| | Alcoh. Ins. Solids | -0.98** | 0.95** | -0.80** | -0.94** | -0.54 | -0.76* |
| | Perox. Activity | 0.07 | 0.14 | 0.00 | -0.01 | 0.09 | 0.12 |
| | Ascorbic Acid | 0.83** | -0.79* | 0.59 | 0.72* | 0.35 | 0.56 |
| | Total Sol. Sugars | 0.97** | -0.96** | 0.86** | 0.97** | 0.61 | 0.81** |

a** = 1% significance

b* = 5% significance

Table 17. Correlation coefficients between physical and chemical factors measured on the raw peas and sensory evaluation parameters measured on the frozen peas at 8 storage month.

| | | Frozen peas | | | | | |
|---|---|---|---|---|---|---|---|
| | | Starchiness | Sweetness | Tenderness | Texture | Flavor | Overall |
| Raw peas | Tenderometer | -0.98**[a] | 0.83** | 0.90** | -0.94** | -0.30 | -0.58 |
| | Total Solids | -0.83** | 0.77*[b] | -0.81** | -0.84** | -0.48 | -0.66 |
| | Alcoh. Ins. Solids | -0.98** | 0.81** | -0.89** | -0.92** | -0.25 | -0.54 |
| | Perox. Activity | 0.04 | -0.08 | 0.03 | 0.11 | 0.27 | 0.25 |
| | Ascorbic Acid | 0.85** | -0.64 | 0.60 | 0.72* | 0.08 | 0.37 |
| | Total Sol. Sugars | 0.97** | -0.84** | 0.94** | 0.95** | 0.32 | 0.59 |

a** = 1% significance

b* = 5% significance

evaluation panel were affected by other factors and not by the ascorbic acid content of the raw peas.

# SUMMARY AND CONCLUSIONS

A study was made of the effect of the maturity, processing and frozen storage on the physical, chemical and sensory properties of frozen peas.

Venus variety peas, grown in commercial conditions, were harvested at three maturity stages vined, blanched, frozen and stored. During processing and storage the following tests were made for each of the three maturity stages, tenderometer value, total solids content, alcohol insoluble solids content, peroxidase activity, ascorbic acid content, total sugars content and sensory evaluation.

The tenderometer value was affected by the maturity level: immature peas had lower tenderometer value than overmature peas. Tenderometer value of peas decreased during processing. The high significant correlation between tenderometer value and sensory evaluation indicates that tenderometer values can be used as an indication of maturity.

The highest total solids content was observed in the overmature peas and the lowest total solids content in the immature peas. Immature peas lost most total solids via leaching during blanching. High correlations between total solids content and sensory evaluation indicate that it may be used as a possible indicator of maturity.

The alcohol insoluble solids was affected by the maturity level.

Immature peas gave the lowest alcohol insoluble solids content and the highest content was found in the overmature peas. The high correlations between alcohol insoluble solids and sensory evaluation indicate that it can be used as an indication of maturity.

Raw peas in the three maturity stages had the same initial peroxidase activity. The significant effect of the maturity level found on the residual peroxidase activity was affected by the different blanching time applied at each maturity stage. Peroxidase activity was affected dramatically by the blanching treatment.

The ascorbic acid content was significantly affected by the maturity level. Immature and mature peas showed higher ascorbic acid content than overmature peas. Ascorbic acid content was reduced during blanching treatment. This effect was higher in the immature peas and mature peas. When all the physical, chemical and sensory evaluation factors analyzed were correlated, high and positive correlations were found between ascorbic acid and the sensory evaluation parameters, but when the physical and chemical factors analyzed on the raw peas were correlated with the sensory evaluation parameters on the frozen peas, ascorbic acid measured on the raw peas gave significant correlation with overall desirability measured on the frozen peas only at 0 storage month.

The total soluble sugar content was higher in immature peas and lower in overmature peas. Significant correlations were found between total soluble sugar and sensory evaluation parameters.

Starchiness, sweetness and tenderness intensity were affected by the maturity level but only sweetness was affected by storage. Overmature peas and immature peas had, respectively, the highest and lowest starchiness intensity. Starchiness intensity gave high correlations with tenderometer value, total solids and alcohol insoluble solids.

The overmature peas showed the least sweetness intensity. The sweetness intensity was increased at 4 months of storage. Significant correlations were found between sweetness intensity and total soluble sugars.

Overmature peas were found to be more tough than immature or mature peas. Tenderness intensity gave significant correlations with tenderometer value, total solids and alcohol insoluble solids.

Both maturity level and storage affected texture, flavor and overall desirability. In general, the taste panel found higher flavor desirability on the mature peas but when texture and overall desirability were measured immature and mature peas were equally preferred. Texture, flavor and overall desirability decreased after 8 months of storage. Positive and significant correlations were found between texture, flavor and overall desirability.

In accordance with the results presented in this thesis it is possible to establish that tenderometer value, alcohol insoluble solids and total solids can be used as possible maturity index of peas for freezing. Tenderometer value measured on the raw peas gave a correlation coefficient of -0.85 with overall desirability of frozen peas at 0 storage month. The tenderometer value was the most rapid of the objective methods used taking about 2 min per determination, it is adaptable for field or laboratory. The alcohol insoluble solids measured on the raw peas was found to have a correlation of -0.85 with overall desirability of the frozen peas at 0 storage month, and gave also high and significant correlations with all others sensory evaluation parameters analyzed. The alcohol insoluble solids procedure takes about 3 h for ten determinations and utilizes simple equipment. Total solids determination measured on the raw peas had a correlation of -0.70 with overall desirability measured on the frozen peas at 0 storage month and gave correlation of 0.89 with alcohol insoluble solids. This method takes about 8 h and is difficult to adapt to commercial use.

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