November 26, 1969

To the Graduate Council:

I am submitting herewith a dissertation written by Robert Donald Freeland entitled "The Effects of Harvest Methods and Storage Periods on Certain Quality Factors of Southern Peas, Vigna sinensis." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Plant and Soil Science.

Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor for
Graduate Studies and Research

THE EFFECTS OF HARVEST METHODS AND STORAGE PERIODS ON CERTAIN QUALITY FACTORS OF SOUTHERN PEAS, *VIGNA SINENSIS*

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Robert Donald Freeland

December 1969

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ABSTRACT

The purpose of this study was to evaluate how four quality factors of southern peas were affected by three methods of harvest and by five storage periods. The quality factors considered were ascorbic acid, color, texture, and sugar content of shelled peas which had been blanched, frozen, and thawed.

Peas harvested by field combine were windrowed for time periods of less than 1 hour, 3, and 6 hours before combining and then held as shelled peas for periods of less than 1 hour, 6, 12, 18, and 24 hours at a controlled temperature of 88° F. before blanching. Machine harvested pods and hand harvested pods were held at a controlled temperature of 88° F. in burlap bags for holding periods of less than 1 hour, 12, 24, 36, and 48 hours before shelling and blanching. Significant findings are presented below.

Ascorbic Acid

The ascorbic acid quality factor was affected by time held as field combined shelled peas and by time stored in pods after hand and machine harvesting. Generally speaking, deterioration of ascorbic acid quality factor increased as the duration of holding periods increased.

Color

In field combined peas, the percentage green color was affected by time spent in windrow, time held as shelled peas, and the interaction effects of these holding periods. In general, windrow holding time of 6 hours resulted in significantly higher green color percentages

regardless of time held after shelling than did windrow holding times of less than 1 hour or 3 hours. Field combined peas were significantly higher in percentage green color when combined 6 hours after windrowing than were peas hand shelled from hand picked pods.

Texture

A holding period of 3 hours in the windrow before combining resulted in less force required to shear a sample of thawed peas than did a windrow holding period of less than 1 hour. A storage period in the hamper of less than 1 hour as shelled peas resulted in a significantly greater force required to shear a sample of thawed peas than did any of the other holding periods.

Method of harvesting pods did not significantly affect the texture in pods harvested at the 20 percent maturity stage. At the 50 percent stage of maturity, however, peas shelled from hand picked pods required a greater force to shear samples of thawed peas than did peas shelled from pods harvested by machine.

Sugar

The sugar content of peas did not differ significantly due to method of harvest. Duration of storage affected the sugar content of peas shelled from pods harvested at the 20 percent mature stage. Pods held for less than 1 hour before shelling contained significantly more total sugar than did peas shelled from pods held 12 hours or longer.

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CHAPTER I

INTRODUCTION

Common names of "Cowpea," "Callivance," "Indian pea," "cornfield pea," "southern field pea," and "southern pea" had all been used before 1920 in describing the plant Vigna sinensis (L.) Savi. "Cowpea" was the name preferred during the first part of the Twentieth Century when the crop was the best known and most extensively grown leguminous crop in the southern states. In recent years the name "southern pea" has gained favor among the horticulturists in distinguishing types used primarily as a vegetable.

In 1960, 97 percent of the blackeye type southern peas were frozen and only 3 percent were canned (45). The quantity of southern peas frozen in 1957 was 11,624,000 pounds and 29,780,000 pounds in 1966 (40). The wide acceptance of the frozen immature product has resulted in a greater awareness of growers and processors in maintaining product quality.

Maintaining product quality has been difficult in recent years as the method of field harvest has changed. The relatively low net return per acre realized from the crop has encouraged the use of mechanical harvesters instead of hand harvesters.

Two types of mechanical field harvesters are presently available. One type will harvest the pods which are to be later shelled by a stationary huller at the processing plant. Pod harvesters with efficiencies ranging from 67 to 96 percent have been developed (33).

Mature as well as immature pods are harvested by such mechanical harvesters. Yield and quality may be obtained from pod harvesting machines, but pods must be transported to a huller and the hulls removed. This additional handling further increases harvesting costs. Harvesting costs represent one-half of the total production cost of this crop (12).

Another type of field harvester combines the harvesting process by picking and shelling out the peas in the field. Field combines harvest only about one-third of the available peas when the percentage of mature or dry pods is estimated to be about 20 percent (12). The percentage of available peas harvested increases as the percentage of mature pods increases. At present it is difficult to obtain relatively high yields per acre having high quality in field combined peas.

That quality of frozen peas meriting a "U. S. Grade A" possesses, among other characteristics, a good typical color. A "good typical color" is defined as being a color typical of reasonably young peas, and not less than 50 percent of peas must show a tinge of green color (39).

It is logical that color quality may be affected by method of harvest and duration of storage before freezing. The field combine method of harvest was thought to more adversely affect the color quality factor rating than would pod harvesters since pods are allowed to become more mature in order to get a high shellout percentage. Mechanical pod harvesters were thought to more adversely affect the color quality factor rating than would hand pod harvesters because the machine would harvest all pods regardless of stage of maturity and hand harvesters would be selective in pods harvested. Finally, duration of storage was thought

to adversely affect the color quality factor because of chlorophyll deterioration during conditions under which harvested pods and seeds are stored before freezing.

Other quality factors were thought to change with color when subjected to various methods of harvest and duration of storage periods. Included among such quality factors are ascorbic acid, sugar, and texture.

The purpose of this study was to evaluate how these four quality factors were affected by three methods of harvest and by five storage periods before freezing.

CHAPTER II

LITERATURE REVIEW

I. HISTORY

Central Africa has been reported by Morse (30) and Faris (9) as the native region in which the plant Vigna sinensis originated. This is disputed by Wight (44) who concludes the plant originated in India. The problem of determining the true center of origin is complicated by the fact that the crop has been grown for centuries in both India and Africa, and the trade routes between these two areas have existed for centuries.

Many think of the crop as being introduced to America while being used as a major food item on slave ships (2, 4, 15), but the crop was being grown in America before traffic in slaves became widespread. According to the writings of Washington (44) and Jefferson (30), the seed must have reached the Potomac area after spreading from the West Indies where it had been introduced by Spanish land holders.

Its numerous uses reflect the many common names by which it is called. The plant has been extensively used to improve the fertility of the soil as a leguminous green manure crop. The legume provides a quick summer crop of high protein hay or pasture for either cattle or hogs (25). It is an excellent feed when mixed with grass for silage. The seeds have been used for years as a homegrown source of livestock protein. Yields as high as 45 bushels of dry seed per acre and 4 tons of cured hay per acre have been obtained in Oklahoma (25).

Since it has been source of cattle feed for many years, the plant has become known in some areas by the name "Cowpea." The reputation as a source of protein for cattle is rivaled by its reputation as a vegetable for human consumption. The names "Cowpea" and "Southern pea" are used interchangeably in literature, but "southern pea" is ordinarily used when referring to the plant as a vegetable (23).

II. IMPORTANCE AS PROCESSING CROP

Southern peas as a vegetable crop are grown and harvested throughout the United States. Production acreage is concentrated in the southern portion of the United States from North Carolina to Texas. Over 29.5 million pounds of southern peas were frozen in 1966. Texas was the leading producer of southern peas in 1966 and harvested more than half of the total amount of southern peas produced in the South (40).

About 12,000 acres of southern peas were produced annually in Tennessee during the years 1963-1968. Five counties located in the southwestern portion of the state produced about 11,000 acres of southern peas for processing. Practically all of these peas were harvested before maturity and frozen at plants located in Bells, Humboldt, and Memphis, Tennessee (12). Green beans and tomatoes are the only vegetables exceeding the volume of southern peas packed in the southeastern United States (45).

Southern peas processed as frozen food are harvested in the immature stage. Growers and processors have sought to mechanize harvesting as a potential means of reducing cost (12).

Mechanization of harvest has resulted in a national market being possible for the frozen, immature product. One of the first steps in mechanization was the development of a stationary huller (23). Pods containing immature seeds were picked by hand, transported to the processing plant, and mechanically shelled. Prices paid the grower by processors were seldom high enough to attract commercial growers who had to hire hand labor for harvesting. As long as this situation existed, the crop was produced on small plots by growers using family labor for hand harvesting.

III. RECENT CHANGES IN HARVEST PROCEDURE

Several machines were developed for picking pods. Harvesters with efficiencies ranging from 67 to 96 percent depending on maturity and plant characteristics had been developed by 1963 (33). The harvested material contained a mixture of about 50 percent leaves and stems. This mixture produced 19 percent clean shelled peas when shelled by a commercial huller.

In a continued effort to reduce harvest cost, green or English pea combines have been adapted for harvesting southern peas. These combines recover only about one-third of the available immature peas. The recovery percentage increases as the peas are allowed to mature (12). Mature peas rattle in the pods when the pods are shaken. The advantage of using field combines over pod pickers is the complete mechanization of the harvesting procedure (23). Pod hulls as well as vines remain in the field. The additional cost of handling large volumes of product when pods are harvested relative to harvesting only seeds as is done with combines encourages the use of combines.

When the crop is grown properly, Jones reports that yields have been high from field combines (23). He suggests using a 19-inch row spacing and 80 pounds of seed per acre rather than the conventional 36 to 42-inch row spacing and 40 pounds of seed per acre.

Gobel et al. (12) reported in a study on the efficiency of the green pea field combine that the yield of peas was related to the drum speed. They also reported that none of the combine harvested peas in their study would meet the requirements of U. S. Grade A due to the low percentage of green peas.

Piper (32) concluded in 1912 that "the breeding work thus far conducted indicates that practically every combination of seed, color, and shape with habit and life period can be obtained." Researchers are attempting to develop a variety that lends itself to mechanical harvesting better than presently available varieties while retaining or improving quality and yield. Problems encountered in this development are related to the characteristics of the plant.

The southern pea is a legume which has monocarpellary fruits called pods (8). There are two lines of dehiscence in the pods. One line is along the ventral suture, or median carpel margin, to which the seeds are attached. The other line of dehiscence is along the dorsal suture or carpel margin. The cells in the dehiscent region contain large amounts of hemicellulose and pectic substances. As the pod approaches maturity, there is a softening of the cell walls and of the middle lamella. This softening effect is due to a change in constituency of hemicellulose in the cell walls and the pectic substances of the middle lamella. The shape of the thin-walled cells in the dehiscent

region also changes as the pod approaches maturity (10). One approach to improving quality and yield has been to increase the rate of changes taking place in the cell wall and middle lamella without affecting other measures of maturity.

Research has also been directed toward retaining quality of harvested peas. Jenkins (22) found that the nutritive value of southern peas was maintained at a higher level under refrigeration than under non-refrigeration. The greatest changes occurred in ascorbic acid content and non-reducing sugars under non-refrigeration. He concluded that during the second day following harvest losses in food values of peas kept in the shade in summer temperatures ranging around 90° F. were great enough to cause the peas to be undesirable for canners, food store operators, and consumers.

Griffith (14) studied the effect of post-harvest cooling on certain chemical and physical changes in southern peas. He observed that untreated southern peas stored at 35° F. for 24 hours maintained odor and color properties better than hydrocooled peas, peas stored at ambient room temperatures or top-iced peas. Top-icing maintained color and odor of southern peas over a 12-hour period better than ambient water and atmosphere storage.

Wagenknecht (42) reported that the deterioration of lipids in frozen peas was responsible for the off-flavor. The deterioration was caused by lipoxidase and lipase enzyme systems which were not destroyed during blanching. In peas stored at summer temperatures for relatively long periods it is reasonable to expect off-flavor development. Lipase was found to cause modification of the bright green color to a gray

green. In the presence of lipoxidase a lower visual score was attained based on the difference in saturation of color rather than a change of hue. The loss of chlorophyll closely followed the deterioration of lipids.

Another quality factor that closely follows chlorophyll deterioration is ascorbic acid oxidation. In a search for objective measurements which would correlate so well with subjective measurements that testing by response to flavor, color, and texture could be excluded in favor of physical or chemical measurements, Olson (31) reports that chlorophyll degradation and ascorbic acid oxidation "are measurable chemical changes that rather accurately follow quality deterioration and have been found to correlate well with changes in aesthetic quality attributes." Such correlations were found to be very useful in the continuing research on quality maintenance of frozen foods.

IV. CHARACTERISTICS

When considering quality of southern peas, it should be remembered that southern peas are not one, but several products. There are at least four types of southern peas. These are blackeye, crowder, cream, and field pea. The blackeye looks and tastes differently from the crowder. Cream peas are much milder in flavor than either the blackeye or crowder and have a clearer, more attractive appearance (23). The field pea is different in flavor and appearance from any of the other three types (39). The flavor is generally stronger ("earthy," as some people describe the flavor) and the seed smaller in size with many different color combinations on the seed coat (32).

The blackeye is the preferred type of southern pea for processing (22). There are different kinds of the blackeye type. Any pea with a colored hilum is generally referred to as a blackeye type even though the hilum may be pink, brown, or violet in immature seeds. The hilum itself is always whitish in color but the raised circle around the hilum is different in color from the body of the seed in the "eyed" varieties (32). The quantity of pigment in the "eyed" varieties increases with maturity. The nutritive value of seeds varies with the degree of maturity (41).

The use of southern peas was recommended by Elias et al. (7) for human feeding in developing areas of the world having low quantity and quality protein sources. This recommendation followed studies which confirmed that seeds of southern peas fed to rats had higher nutritive values than seeds of the common bean, Phaseolus vulgaris.

The acceptance of the immature southern peas as a nutritious frozen product on a national scale has resulted in increased interest in quality maintenance. Some quality factors which have been studied relating to southern peas are asborbic acid, color, total sugars, and texture.

V. QUALITY FACTORS

Ascorbic Acid

In an effort to determine the composition and content of southern peas, Wade et al. (41) conducted a two-year study with several varieties and stages of maturity. Two stages of maturity were selected. Peas showing some green color in the seed coat were called green peas.

Dry mature seeds were called dry peas. Ascorbic acid content in green peas of different varieties ranged from 6.7 to 56.0 mg. per 100 grams of peas on a fresh weight basis. Reid (33) reported finding only a trace of ascorbic acid, if any, in mature dry peas. A study by Hoover (17) showed that if seeds were allowed to mature to the point where the green color begins to disappear from the pods, little benefit could be derived from them as a source of ascorbic acid. However, relatively high amounts of ascorbic acid were found to be present in southern peas during early stages of development.

Ascorbic acid exists in live plant material in a reduced form (43). The activity within a specific sample of vegetable product is influenced by a variety of factors such as stage of maturity, conditions under which the vegetable plant was grown and harvested, and handling of the product between harvest and consumption.

In the presence of oxygen, ascorbic acid is oxidized to dehydro-ascorbic acid which eventually changes to diketogulonic acid (43). The reducing power serves as the basis for most of the quantitative analytical procedures for estimation of this compound such as with the dye 2, 6-dichlorophenolindophenol (43). Such procedures estimate the ascorbic acid and not the dehydro-ascorbic acid present.

Color

In a study of pigment characteristics of southern peas, Burns (3) found that the purple hull types contain only one pigment layer in the basal cells of the seeds. Blackeye types without purple hulls contain two layers of concentrated pigment located in the basal and palisade layers of the peas. The pigment of the purple hull types was found to

be located in the inner cells of the seed coat and the overlying cells presented a tissue barrier to leaching of the pigment during processing. They suggested the water soluble eye pigment was anthocyanins and observed that the quantity of pigment increased with maturity. Green, immature peas were also found to contain this pigment but the large quantity of chlorophyll present in young peas often obscured the detection.

A study by Graham (13) indicated that reduction in the degree of discoloration was possible by using certain additives, but the texture and flavor of the final product might be adversely affected.

In a study by Fox (10) on the relationship of aging to the shelling and quality of southern peas, a decrease in green color was observed as duration of aging increased. It was concluded that the loss in green color probably corresponded to a loss in chlorophyll. Color was measured in organoleptic tests and by the Hunter Color and Color Difference Meter.

Texture

When peas are tender and in a fairly early stage of maturity they are assigned a higher grade score for character by U. S. Grade standards than are mature peas. Fox (10) reported in an organoleptic study of southern pea quality that scores for texture and other quality attributes become lower as the duration of holding period increased from 18 to 40 hours. He concluded that even though shellout percentages may be increased through extended holding periods, such treatment was detrimental to the quality of the pea and would be undesirable from the standpoint of the consumer.

Sugar

Hoover (20) reported that sucrose appeared to be the principal sugar found in southern peas. A small amount of reducing sugar was found in seeds in the earliest stages of maturity when the seeds had matured just enough to be separate from the pericarp. Wade et al. (41) reported that the amount of total sugars was higher in mature peas than in immature peas.

VI. QUALITY IMPORTANCE

Quality has been defined as "the combination of attributes of a product that have significance in determining the degree of acceptability of the product to a user" (36). Firms within the food industry are interested in maintaining or "controlling" quality. The control of certain quality factors is as important in competition as the control of prices. Quality factors are controlled by firms in an effort to satisfy demands of various users (36).

Customs, standards, and goals being sought by firms influence the quality attributes of a product. Profit maximization is undoubtedly a strong force in determining which quality factors a particular product will contain. There may be a tendency for firms to lower certain quality factors to the minimum acceptable level as a means of maximizing profits (36).

Quality factors at certain prescribed levels must be maintained in products for which a U. S. Grade designation is desired. A limiting factor for U. S. Grade A frozen field and blackeye peas is that 50 percent, by count, of the seed must show a tinge of green color (39).

The effect of certain holding periods on various quality factors of southern peas has been reported by numerous workers (10, 14, 18). The effect of machine harvesters on certain quality factors of southern peas has been reported (12, 33). However, pounds of shelled peas have been the primary consideration in evaluating machine harvesters. Green color measurements have been used as indicators of quality in immature products.

CHAPTER III

MATERIALS AND METHODS

I. GENERAL PROCEDURES

This study was conducted over a period of two years. Procedures used for collecting samples during 1967 and 1968 are discussed below. Analytical procedures for determining relative quality factor values were the same for both harvest seasons.

Sample Collecting Procedures, 1967

A uniform field of Purple Hull Pinkeye southern peas grown at the Milan Field Station was used in 1967. Three methods were used in harvesting the peas when a maturity stage of 20 percent dry pods had been reached. The three methods of harvest were field combine, machine harvesting of pods, and hand harvesting of pods.

A green pea combine (Food Machinery Corporation, Hoopeston, Illinois) was used for field combining. It is a tractor drawn machine which picks up vines that have been cut and placed in windrows in the field. The vines are fed into a drum with a threshing reel. As the peas are threshed they fall onto conveyor belts where loose chaff is separated from the peas. The peas then move to a hydraulic dump hamper, enabling one man to harvest and handle the shelled product.

The procedures used for field combining were those of the standard commercial operation which included cutting, windrowing, and threshing.

Peas in the portion of the field selected for field combining were cut and placed in windrows. To determine if time spent in the windrow affected quality factors, three windrow holding periods were used. These periods were less than 1 hour (combined immediately after windrowing), 3 hours, and 6 hours. To determine the effects of holding period on the shelled seeds from each of the windrow treatments for selected quality factors, five holding periods of two pound samples selected at random were used. These periods were less than 1 hour, 6, 12, 18, and 24 hours in plastic bags at a controlled temperature of 88° F. before blanching and freezing.

The treatments were replicated three times.

The machine used to mechanically harvest pods (Chisholm Ryder Company, Niagara Falls, New York) was a self-propelled two-row harvester. Pods were separated from vines by tines on a revolving reel and elevated to a height sufficient for bagging. Pods were bagged by one person other than the machine driver and hauled to a mechanical huller for shelling.

Hand harvesters attempted to duplicate harvesting of pods by machine in that rows were clean-picked of pods. The pods were bagged and hauled to a mechanical huller for shelling.

The procedures used for machine harvested pods and hand harvested pods were similar to those of a commercial operation which included pod holding before threshing by a mechanical huller. Ten pounds each of machine harvested and hand harvested pods were held in burlap bags at a controlled temperature of 88° F. for five holding periods. These holding periods were for less than 1 hour, 12, 24, 36, and 48 hours.

The ten-pound sample of pods was threshed from each holding period treatment by a mechanical huller (Dixie Canner Company, Athens, Georgia) with a beater speed of 450 RPM and a one-half inch diameter screen. The peas were fed into the huller within a 60-second time period and the huller was allowed to operate for an additional five minutes. A two pound sample of shelled peas was blanched and frozen. Similar samples from the machine and hand harvested treatments were hand shelled and frozen.

The treatments were replicated three times.

Sample Collecting Procedures, 1968

A uniform field of Purple Hull Pinkeye southern peas grown at the Plant Sciences Farm, Knoxville, was used in 1968. Two methods were used in harvesting the peas when a maturity stage of 50 percent dry pods had been reached. The two methods were machine harvesting of pods and hand harvesting of pods.

The machine, holding periods, threshing procedures, blanching, and freezing of samples were identical to the 1967 study in which pods were harvested by hand and machine.

The treatments were replicated four times.

II. ANALYTICAL PROCEDURES

Four quality factors were selected for analysis. These were ascorbic acid, color, texture, and total sugars.

Ascorbic Acid

Ascorbic acid content can be determined by measuring the decolorizing effect of extracted ascorbic acid and 2, 6-dichlorophenolindophenol dye (26). In this study a method explained by Loeffler and Ponting (26) was used as had been used with modification by Fox (10) and Hoover (17) in determining ascorbic acid content of southern peas. Fifty grams of peas were blended in a Waring blender for three minutes in 200 ml of 1% meta-phosphoric acid. The ascorbic acid contained in the sample was distributed throughout the total liquid phase including the water and dissolved solids. Indophenol dye was added and the decolorizing effect of the ascorbic acid present was read on the Beckman Model DU spectrophotometer at 520 mμ 20 seconds after the start of adding the dye solution. These readings were related to a calibration chart which had been developed from samples containing known amounts of ascorbic acid per milliliter of solution (11).

Color

Two measurements of color were used. One measurement approximated measures used by graders in establishing U. S. Grades. The other measurement involved the use of the Hunter Color and Color Difference Meter as used by Bailey (1) in determining factors causing discoloration in southern peas.

In an effort to duplicate methods used by graders, 150 grams of seed were selected at random from a portion of each two pound sample which had been thawed and spread evenly over a paper towel. Seeds within a two and one-half inch diameter circle were counted and the number of those showing a tinge of green color was recorded. The

percentage of green peas was calculated from these records. Changes due to treatment after harvest were analyzed. This measurement was referred to as percentage green color.

In measuring color by the Hunter Color and Color Difference Meter, twenty-five grams of thawed seeds which had been blotted dry were evaluated for green color. The instrument was nulled using the white standard number D25-230. Green standard number D25-233 was used in evaluating the green color. Hunter Color values "-a" (green) and "+b" (yellow) were recorded and the ratio of "-a" value to "+b" value was used in analyzing changes due to treatment as had been used by others (5). This measurement was referred to as the Hunter a/b color measurement.

Texture

Shear values, hereafter referred to as texture, were evaluated by a Shear Press (Allo-Kramer, Rockville, Maryland). Twenty-five grams of thawed peas were selected at random from a larger sample and sheared. A one-thousand pound test ring and a shearing stroke requiring thirty seconds to complete was used. Dial readings were recorded as shear force per sample and analyzed regarding the effect of various treatments on texture.

Sugar

One hundred grams of thawed southern pea seeds were blended for five minutes in 100 ml of distilled water. A ten gram aliquot of this slurry was washed in hot 95% ethyl alcohol. The solution was centrifuged, filtered, and washed twice more in hot ethyl alcohol followed

by centrifuging and filtering. The filtered solution was brought to volume in a 100 ml volumetric flask. This procedure for preparing the sample was a slight modification of a procedure developed by McCready et al. (29) with application to peas.

The procedure reported by Dubois et al. (6) for the colorimetric method of determining sugars was used with slight modification. The modification was that 0.05 ml of sugar solution was added to 1 ml of 5% phenol instead of 1.00 ml of sugar solution being added. Ethyl alcohol was added to bring the solution to 1.00 ml volume before adding phenol. The remaining steps were identical to those outlined by Dubois et al. (6).

III. STATISTICAL ANALYSIS

The experimental design used was a randomized complete block design with a factorial arrangement of treatments. The analysis of variance method was used to statistically analyze the data (35). When significant differences at the .01 level due to treatment were detected, Duncan's Multiple Range Test was used (24). Quality factor correlations due to method of harvest were computed at the .05 significance level as outlined by Snedecor (35).

The percentage green color quality factor in peas hand shelled from pods which had been hand and machine picked was analyzed in a completely randomized block design with:

1. Field combined peas held in windrows for less than one hour and held as shelled peas for less than one hour before blanching and freezing.

2. Handpicked pods stored for less than one hour before machine shelling, blanching, and freezing.

3. Machine picked pods stored for less than one hour before machine shelling, blanching, and freezing.

CHAPTER IV

RESULTS

Four selected quality factors of southern peas were evaluated after being harvested by three harvesting methods and held for various time periods before blanching and freezing. The four selected quality factors were ascorbic acid, color, texture, and sugar. The three methods of harvest were field combine, pods harvested by machine, and pods harvested by hand.

The time periods varied depending upon the method of harvest. Field combined peas were cut and held in windrows for less than 1 hour, 3 and 6 hours before being combined and held as shelled peas for less than 1 hour, 6, 12, 18, and 24 hours at 88° F. before blanching and freezing.

Pods which were harvested by machine or by hand were held for less than 1 hour, 12, 24, 36, and 48 hours in burlap bags at 88° F. before machine shelling, blanching, and freezing.

The analysis of variance table (Appendix A) indicates the effect of these holding periods, methods of harvest, and their interaction effects on the ascorbic acid content, texture, total sugars, and two measurements of the color quality factor in Purple Hull Pinkeye southern peas.

I. FIELD COMBINE

Ascorbic Acid

Ascorbic acid content differed due to duration of time shelled peas were stored at 88° F. (Appendix A). Ascorbic acid content was

significantly higher in shelled peas held six hours or less than for peas held for longer time periods (Table I). Ascorbic acid content did not differ significantly due to the time the peas spent in windrow nor was there an interaction effect of time spent in windrow and time held as shelled peas.

Percentage Green Color

The percentage of peas showing a tinge of green color differed due to time spent in windrow, time held in hamper, and due to the interaction effect of time spent in windrow and time held in hampers as shelled peas (Appendix A).

The six-hour time period spent in windrows resulted in higher mean values of percentage green peas than did the time period in which they were stored for less than one hour (Table II).

Holding peas in hampers for 24 hours resulted in lower mean values of percentage green peas than did any other holding period. Generally speaking, the longer the peas were held at 88° F., the lower was the mean values of percentage green peas (Table III).

Mean values of percentage green peas differed due to the interaction effects of time spent in windrow and time held in hampers (Appendix A). Generally speaking, mean values of percentage green peas appeared to be affected more by time spent in windrow than by duration of time held in hampers (Table IV). Significantly higher mean values appear to result from being stored in windrows for six hours in all but one interaction effect. The mean value of percentage green peas was significantly less in peas stored in windrows for less than

TABLE I

ASCORBIC ACID CONTENT IN FIELD COMBINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN HAMPER AT 88° F.

Time Stored (Hrs.)	Means* Mg. per 100 gms.
Less than 1	2.697[a]
6	2.032[a]
12	1.651[b]
18	1.253[b]
24	1.501[b]

*Values not followed by a common letter are statistically different at the .01 level of significance.

TABLE II

PERCENTAGE GREEN COLOR IN FIELD COMBINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME SPENT IN WINDROW

Time Spent (Hrs.)	Mean Percent*
Less than 1	33.2[c]
3	42.7[b]
6	57.0[a]

*Values not followed by a common letter are statistically different at the .01 level of significance.

TABLE III

PERCENTAGE GREEN COLOR IN FIELD COMBINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN HAMPER AT 88° F.

Time Stored (Hrs.)	Mean Percent*
Less than 1	50.5[a]
6	44.6[a]
12	45.9[a]
18	43.4[a]
24	37.2[b]

*Values not followed by a common letter are statistically different at the .01 level of significance.

TABLE IV

COMPARISON OF PERCENTAGE GREEN COLOR IN FIELD COMBINED SOUTHERN PEAS AS AFFECTED BY INTERACTION OF TIME SPENT IN WINDROW AND TIME STORED IN HAMPER

Time Stored in Hampers (Hrs.)	Time Spent in Windrow (Hrs.) Mean Percent*		
	Less than 1	3	6
Less than 1	42.9^{b}	45.2^{b}	63.3^{a}
6	34.3^{bc}	66.4^{a}	33.0^{bc}
12	36.3^{b}	39.3^{b}	62.1^{a}
18	32.8^{bc}	33.3^{bc}	60.2^{a}
24	19.7^{c}	29.3^{bc}	62.5^{a}

*Values not followed by a common letter are statistically different at the .01 level of significance.

1 hour and held in hampers for 24 hours than for any other interaction effect (Table IV)

Hunter a/b

There were significant differences in mean square values of the green-yellow ratio as measured by the Hunter Color and Color Difference Meter due to time held in hamper as shelled peas (Appendix A).

Holding peas in hamper for 24 hours resulted in lower green-yellow ratio values than did any of the other holding periods (Table V).

Texture

Means of the force required to shear 25 grams of peas (texture) differed significantly due to time spent in windrow, time held in hamper, and the interaction effects of these treatments (Appendix A). Peas combined after having spent three hours in windrows required less force for shearing than did peas which had spent less than 1 hour or 6 hours in windrows (Table VI).

Peas which had been held for less than one hour in hampers required a greater force for shearing than did peas held for any other time period (Table VII).

Generally speaking, peas spending 3 and 6 hours in windrows and held longer than 12 hours in hampers required less force for shearing than did peas subjected to any of the other combinations of treatments (Table VIII).

Sugar

Total sugar did not differ significantly because of time spent in windrow, hours held in hampers, nor the effects of the interaction

TABLE V

COMPARISON OF HUNTER a/b RATIO IN FIELD COMBINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN HAMPER

Time Stored (Hrs.)	Means* Hunter a/b Ratio
Less than 1	.577[a]
6	.590[a]
12	.567[a]
18	.539[ab]
24	.463[b]

*Values not followed by a common letter are statistically different at the .01 level of significance.

TABLE VI

COMPARISON OF TEXTURE IN FIELD COMBINED SOUTHERN PEAS AS AFFECTED BY TIME SPENT IN WINDROW

Time Spent in Windrow (Hrs.)	Means[1] Shear Force[2]
Less than 1	296.2[a]
3	264.6[b]
6	282.7[ab]

[1]Values not followed by a common letter are statistically different at the .01 level of significance.

[2]Allo-Kramer Shear Press dial reading (1,000 lb. test ring).

TABLE VII

COMPARISON OF TEXTURE IN FIELD COMBINED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN HAMPER AT 88° F.

Time Stored (Hrs.)	Means[1] Shear Force[2]
Less than 1	322.1[a]
6	258.6[b]
12	282.6[b]
18	271.8[b]
24	270.9[b]

[1]Values not followed by a common letter are statistically different at the .01 level of significance.

[2]Allo-Kramer Shear Press dial reading (1,000 lb. test ring).

TABLE VIII

COMPARISON OF TEXTURE IN FIELD COMBINED SOUTHERN PEAS AS AFFECTED BY INTERACTION OF TIME SPENT IN WINDROW AND TIME STORED IN HAMPER

	Time Spent in Windrow (Hrs.)		
	Means[1] Shear Force[2]		
Time in Hamper (Hrs.)	Less than 1	3	6
Less than 1	350.3^{a}	295.0^{abcde}	321.0^{abc}
6	208.3^{f}	255.0^{cdef}	312.3^{abcd}
12	325.7^{ab}	270.3^{bcdef}	251.7^{def}
18	288.7^{abcde}	266.0^{bcdef}	260.7^{bcdef}
24	308.0^{abcd}	236.7^{ef}	268.0^{bcdef}

[1]Values not followed by a common letter are statistically different at the .01 level of significance.

[2]Allo-Kramer Shear Press dial reading (1,000 lb. test ring).

of these two treatments from peas harvested at 20 percent maturity (Appendix A).

II. HAND PICKED AND MACHINE PICKED PODS

The analysis of variance tables (Appendixes B and C) indicates the effect of method of picking, storage treatments and their interaction effect on the ascorbic acid, color, texture, and sugar quality factors.

Ascorbic Acid

In both stages of maturity (20 percent mature in 1967 and 50 percent mature in 1968) ascorbic acid quality factor means differed significantly due to method of picking and due to duration of time stored in pods at 88° F. Hand picked pods resulted in significantly higher ascorbic acid mean values than machine picked pods (Table IX). Generally speaking, ascorbic acid mean values decreased as duration of time stored in pods increased (Table X).

Percentage Green Color

Means from the count of peas showing a tinge of green color differed significantly due to duration of time stored in pods at 88° F. in both stages of maturity (20 percent mature in 1967 and 50 percent mature in 1968). Mean color values decreased as duration of time stored in pods increased (Table XI). Significantly different mean color values resulted from method of picking and interaction of time stored and method of picking only in the 50 percent maturity stage.

TABLE IX

COMPARISON OF ASCORBIC ACID CONTENT IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY METHOD OF PICKING

Method of Harvest	Means[1] Mg. per 100 gms. 1967[2]	1968[2]
Hand picked	5.521[a]	2.693[a]
Machine picked	4.561[b]	1.282[b]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

TABLE X

COMPARISON OF ASCORBIC ACID CONTENT IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN PODS AT 88° F. AFTER PICKING

Time Stored (Hrs.)	Means[1] Mg. per 100 gms. 1967[2]	1968[2]
Less than 1	4.932[a]	2.816[a]
• 12	5.292[a]	1.835[b]
24	5.455[a]	1.785[b]
36	4.312[b]	1.934[b]
48	3.330[b]	1.569[b]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

TABLE XI

COMPARISON OF PERCENTAGE GREEN COLOR IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN PODS AT 88° F. AFTER PICKING

Time Stored (Hrs.)	Mean Percent[1]	
	1967[2]	1968[2]
Less than 1	40.4[a]	13.1[a]
12	50.7[a]	5.7[b]
24	44.5[a]	0.1[b]
36	38.6[a]	0.1[b]
48	25.0[b]	0.3[b]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

Hunter a/b

Hunter a/b values differed significantly with time when stored in pods at 88° F. if the peas were 20 percent mature, but not if they were 50 percent mature (Table XII). The general effects were lower ratio values as the time storage increased. Method of picking and interaction with time in storage did not significantly affect the values for either the 20 percent or the 50 percent mature southern peas.

Texture

There were no significant differences in the force required to shear 25 grams of peas (texture) in the 20 percent maturity stage due to any of the treatments. Significant interaction between harvest method and length of storage in pods at 88° F were shown for peas that were 50 percent mature. Values were significantly greater in the hand picked than in the machine picked pods (Table XIII), and tended to decrease as time stored in pods increased (Table XIV).

Sugar

The amount of sugar in the peas did not differ significantly at the 50 percent maturity stage in any of the treatments. However, significant differences due to treatment appeared in the 20 percent stage of maturity. Length of storage period, method of harvest and the interaction of storage time and harvest produced significant differences in sugar content. In general, sugar decreased as storage time increased. Machine harvested peas were significantly higher in sugar content than hand picked peas.

TABLE XII

COMPARISON OF HUNTER a/b RATIOS IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN PODS AT 88° F. AFTER PICKING

Time Stored (Hrs.)	Means[1] Hunter a/b Ratio 1967[2]	1968[2]
Less than 1	.500[a]	.437[a]
12	.453[a]	.455[a]
24	.447[a]	.425[a]
36	.370[b]	.442[a]
48	.378[b]	.403[a]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

TABLE XIII

COMPARISON OF TEXTURE IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY METHOD OF PICKING

Method of Harvest	Means[1] Shear Force[2] 1967[3]	1968[3]
Hand picked	271.1[a]	289.1[a]
Machine picked	267.5[a]	237.3[b]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Allo-Kramer Shear Press dial reading (1,000 lb. test ring).

[3]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

TABLE XIV

COMPARISON OF TEXTURE IN HAND HARVESTED AND MACHINE HARVESTED SOUTHERN PEAS AS AFFECTED BY TIME STORED IN PODS AT 88° F.

Time Stored (Hrs.)	Means[1] Shear Force[2] 1967[3]	1968[3]
Less than 1	274.5[a]	320.6[a]
12	267.3[a]	275.2[ab]
24	281.3[a]	255.6[b]
36	258.8[a]	240.4[b]
48	274.2[a]	244.4[b]

[1]Values in the same column not followed by a common letter are statistically different at the .01 level of significance.

[2]Allo-Kramer Shear Press dial reading (1,000 lb. test ring).

[3]Estimated 20 percent mature in 1967 and 50 percent mature in 1968.

III. COLOR AS AFFECTED BY HAND SHELLING

Pods which had been hand picked and machine picked were hand shelled in 1967. The peas shelled from these pods were from the same field and at the same stage of maturity as peas harvested by other methods. The hand shelled peas were compared to other methods of harvest with respect to percentage green color.

The percentage of peas showing a tinge of green color differed significantly (.01 level) due to method of harvest. The green color percentages of machine shelled peas from machine picked pods were not significantly different from peas combined immediately after windrowing and held less than 1 hour. The percentage of greenness of machine shelled peas from machine picked pods were significantly lower (.01 level) than for hand harvested peas (Table XV).

Peas held in windrows for 6 hours were found in this study to release a higher percentage of green peas than those held for less than 1 hour in windrows before combining.

The percentage of peas released by combining 6 hours after windrowing was significantly higher (.01 level) than from any methods of harvest involving no holding periods (Table XVI).

IV. CORRELATION AMONG QUALITY FACTORS

The association of ascorbic acid content with other quality factors of immature southern peas is given in Table XVII. There appeared to be little association between ascorbic acid and other

TABLE XV

PERCENTAGE GREEN COLOR IN SOUTHERN PEA SEEDS BLANCHED IMMEDIATELY AFTER SHELLING AS INFLUENCED BY METHOD OF HARVEST

Treatment	Hand Harvested Pods		Machine Harvested Pods		Field Combined Peas One Hour After Windrowing
	Hand Shelled	Machine Shelled	Hand Shelled	Machine Shelled	
Means* Percent Green	45.57[a]	46.67[a]	49.97[a]	34.10[b]	42.87[ab]

*Values not followed by a common letter are significantly different at the .01 level.

TABLE XVI

PERCENTAGE GREEN COLOR IN SOUTHERN PEA SEEDS AS INFLUENCED BY METHOD OF HARVEST AND TWO HOLDING PERIODS BEFORE BLANCHING

Treatment	Hand Harvested Pods No Holding Period		Machine Harvested Pods No Holding Period		Field Combined Peas Six Hours After Windrowing
	Hand Shelled	Machine Shelled	Hand Shelled	Machine Shelled	
Means* Percent Green	45.57[b]	46.67[b]	49.97[b]	34.10[c]	63.33[a]

*Values not followed by a common letter are significantly different at the .01 level.

TABLE XVII

COEFFICIENTS OF LINEAR CORRELATION OF ASCORBIC ACID VS. OTHER QUALITY FACTORS ON SOUTHERN PEAS BY METHODS OF HARVEST (1967)

Ascorbic Acid vs.	Peas Shelled by Field Combine	Peas Shelled From Hand Picked Pods	Peas Shelled from Machine Picked Pods
Percentage Green Color	+ .1842	+ .5285*	+ .3599
Texture	+ .1541	+ .3765	- .3768
Total Sugar	- .0566	+ .3529	+ .1660
Hunter a/b Ratio	+ .1736	+ .4999*	+ .5009*

*Significant at .05 level.

quality factors of 20 percent mature peas when harvested with the field combine.

Peas from pods that had been hand or machine picked had relatively higher degrees of correlation between ascorbic acid and Hunter a/b ratio than field combined peas. A positive linear association existed between ascorbic acid and the two measurements of color. Ascorbic acid correlated at a significant level with the percentage of green peas and Hunter a/b ratio from hand picked pods.

In field combined peas there appeared to be little association between the percentage of green color and other quality factors of the 20 percent mature peas (Table XVIII). Peas from pods which had been hand picked and machine picked again had relatively higher degrees of correlation than field combined peas. The values for peas showing a tinge of green color were positively correlated with ascorbic acid and the Hunter a/b values.

The correlation between texture and other measures of quality factors is shown in Table XIX. A negative correlation existed at a significant level between texture values and Hunter a/b values in peas from pods which had been machine picked.

Peas from pods showing 50 percent maturity which had been either machine or hand picked showed that ascorbic acid was significantly correlated with texture and sugar content in machine picked peas (Table XX).

Positive linear correlations between the percentage of green peas and texture and sugar content were significant (Table XXI).

TABLE XVIII

COEFFICIENTS OF LINEAR CORRELATION OF PERCENTAGE GREEN COLOR VS. OTHER QUALITY FACTORS ON SOUTHERN PEAS BY METHODS OF HARVEST (1967)

Percentage Green Color	Peas Shelled by Field Combine	Peas Shelled from Hand Picked Pods	Peas Shelled from Machine Picked Pods
Ascorbic Acid	+ .1842	+ .5285*	+ .3599
Texture	- .1216	- .2632	+ .1068
Total Sugar	+ .2839	+ .4279	+ .0512
Hunter a/b Ratio	+ .2498	+ .5045*	+ .1737

*Significant at .05 level.

TABLE XIX

COEFFICIENTS OF LINEAR CORRELATION OF TEXTURE VS. OTHER QUALITY FACTORS ON SOUTHERN PEAS BY METHODS OF HARVEST (1967)

Texture vs.	Peas Shelled by Field Combine	Peas Shelled from Hand Picked Pods	Peas Shelled from Machine Picked Pods
Ascorbic Acid	+ .1541	+ .3765	- .3768
Percentage Green Color	- .1216	- .2632	+ .1068
Total Sugar	- .1671	+ .0908	+ .1626
Hunter a/b Ratio	+ .0097	- .2064	- .4952*

*Significant at .05 level.

TABLE XX

COEFFICIENTS OF LINEAR CORRELATION OF ASCORBIC ACID VS. OTHER QUALITY FACTORS ON SOUTHERN PEAS BY TWO METHODS OF HARVEST (1968)

Ascorbic Acid vs.	Peas Shelled from Hand Picked Pods	Peas Shelled from Machine Picked Pods
Percentage Green Color	+ .3682	+ .3022
Texture	+ .1774	+ .4795*
Total Sugar	+ .5107	- .4930*
Hunter a/b Ratio	+ .3077	- .4117

*Significant at .05 level.

TABLE XXI

COEFFICIENTS OF LINEAR CORRELATION OF PERCENTAGE GREEN COLOR VS. OTHER QUALITY FACTORS ON SOUTHERN PEAS BY TWO METHODS OF HARVEST (1968)

Percentage Green Color vs.	Peas Shelled from Hand Picked Pods	Peas Shelled from Machine Picked Pods
Ascorbic Acid	+ .3682	+ .3022
Texture	+ .6192**	+ .3640
Total Sugar	+ .5142*	+ .2992
Hunter a/b Ratio	+ .4423	- .0973

*Significant at .05 level.

**Significant at .01 level.

The correlation between texture and other measures of quality is shown in Table XXII. Texture was significantly correlated with percentage green peas and Hunter a/b values in the hand picked pods. A correlation between texture and ascorbic acid was significant in the machine picked pods.

TABLE XXII

COEFFICIENTS OF LINEAR CORRELATION OF TEXTURE VS.
OTHER QUALITY FACTORS ON SOUTHERN PEAS
BY TWO METHODS OF HARVEST (1968)

Texture vs.	Peas Shelled from Hand Picked Pods	Peas Shelled from Machine Picked Pods
Ascorbic Acid	+ .1774	+ .4795*
Percentage Green Color	+ .6192**	+ .3640
Total Sugar	+ .4109	+ .2518
Hunter a/b Ratio	+ .6017**	- .0497

*Significant at .05 level.

**Significant at .01 level.

CHAPTER V

DISCUSSION

I. ASCORBIC ACID

It was found in this study that the ascorbic acid content of peas which were field combined at a 20 percent maturity stage was significantly affected by duration of time stored in hampers at 88° F. The ascorbic acid content decreased as the duration of time stored increased. There was no significant difference in the mean values of the ascorbic acid quality factor due to time spent in windrow nor due to the interaction effect of time spent in windrow and time stored in hamper. However, the mean values of ascorbic acid were significantly different due to time stored in pods at 88° F.

The oxidation of ascorbic acid to dehydroascorbic acid is a time-temperature sensitive reaction (31). Results from this study correspond with the findings of Hoover (18) in that a continuous decrease in ascorbic acid results from an increase in length of storage time.

Hand picked pods had higher ascorbic acid content than did machine picked pods. This may be the result of higher respiration rates in machine picked pods than in hand picked pods caused from bruising by tines when the pods were mechanically harvested. Or it may be that fewer immature pods were harvested by the machine.

Significant correlations were found between ascorbic acid and green color in peas shelled from hand picked pods harvested when 20 percent were mature, but not between ascorbic acid content and

green color in peas shelled from hand picked pods harvested when 50 percent were mature. As reported by Hoover (19), increase in pod maturity has an adverse effect on ascorbic acid content of shelled peas. Findings in this study indicate that changes in percentage green color as peas mature are not closely related to changes in ascorbic acid content.

II. PERCENTAGE GREEN COLOR

In field-combining peas estimated to be 20 percent mature, the percentage green peas present in the samples increased as time in windrows increased up to 6 hours.

In this study apparently the shellout of green immature peas increased as time spent in windrow increased. When the peas were combined immediately out of windrows, evidently the green peas from less mature pods were not being shelled and were left in the field. Findings of this study would be in agreement with findings by Fox (10) in which shellout percentages were increased by storing pods for various time periods before shelling.

It was found in field combined peas, that as time stored in hampers increased, the percentage of green peas decreased.

Further findings indicated a decreasing trend in percentage green color peas as storage time of hand and machine picked pods increased. The trend existed in the harvest of 20 percent mature as well as in the 50 percent mature peas.

The deterioration of the seed coat color from a bright green to a dull grey-green was probably due to the deterioration of chlorophyll (Wagenknecht) (43). Peas exposed to high temperatures for long periods

of time contained relatively less chlorophyll than peas exposed for short periods of time.

Figure 1 is an illustration of the deterioration of the bright green color to a grey-green. The fresh, immature peas were hand shelled from pods which would be considered immature (seeds would not produce a sound when pods were shaken). The thawed hand picked, hand shelled peas were blanched and frozen immediately after shelling.

In determining the percentage of peas showing a tinge of green color, U.S.D.A. standards specify that evaluation of color must be on the thawed product and that the color must be typical of reasonably young peas to merit Grade A classification (39).

Three samples of peas are presented in Figure 2. A tinge of green is evident on some seed coats of the thawed product. It is typical of reasonably young freshly thawed peas. The blanching process tends to cause leaching of the anthocyanin pigments in the hilum staining the seed coat which results in the seed coat becoming a neutral color.

The fresh immature peas would meet the U.S.D.A. standards for Grade A which require that 50 percent by count show a tinge of green color. However, it is obvious that not all of the seeds from 100 percent immature pods would show a tinge of green color. Some seeds had lost all green color and would be classified as seeds from mature pods.

From Figure 3, a visual comparison may be made between peas which were combined immediately after windrowing and blanched immediately after combining with peas which were hand shelled immediately after pods were hand picked and were blanched immediately after shelling from the

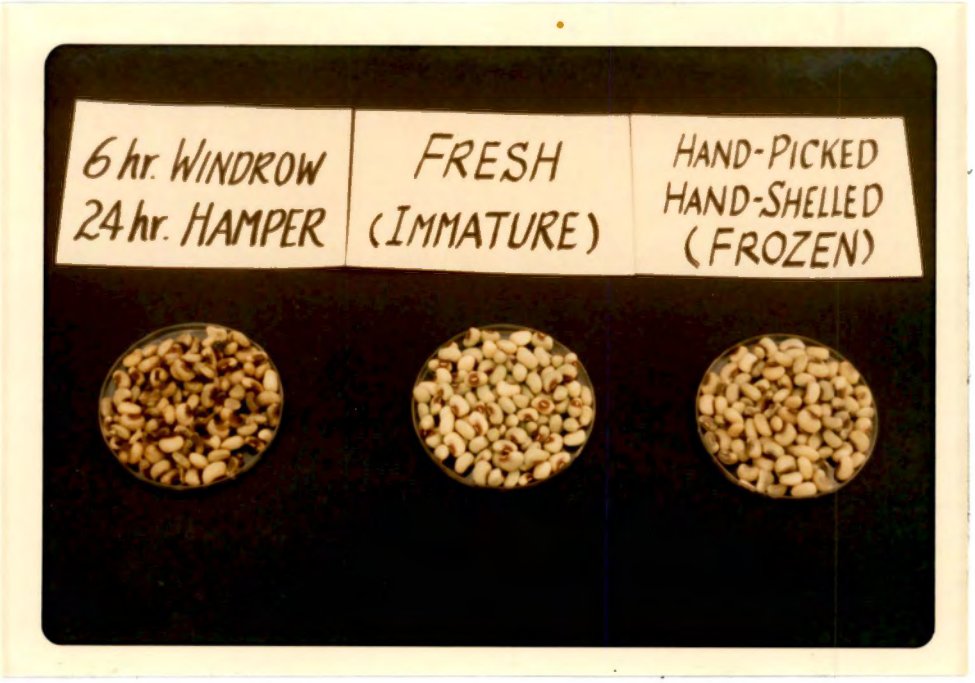

Figure 1. Green color loss due to duration of storage.

Thawed peas on left were held in windrow 6 hours before combining and as shelled peas at 88° F. for 24 hours before blanching.

Fresh peas in center were hand shelled from pods in which the peas did not produce a sound when the pods were shaken (immature pods).

Thawed peas on right were hand shelled from hand-picked pods and subjected to no holding period before blanching.

Figure 2. Green color comparison of immature fresh, immature frozen and mature dry peas.

Thawed peas on left were hand shelled from hand hand-picked pods and subjected to no holding period before blanching (estimated 20 percent stage of maturity at harvest).

Fresh peas in center were hand shelled from pods in which the peas did not produce a sound when the pods were shaken (immature pods).

Fresh peas on right were hand shelled from pods in which peas did produce a sound when the pods were shaken (mature pods). Peas were soaked in water after shelling.

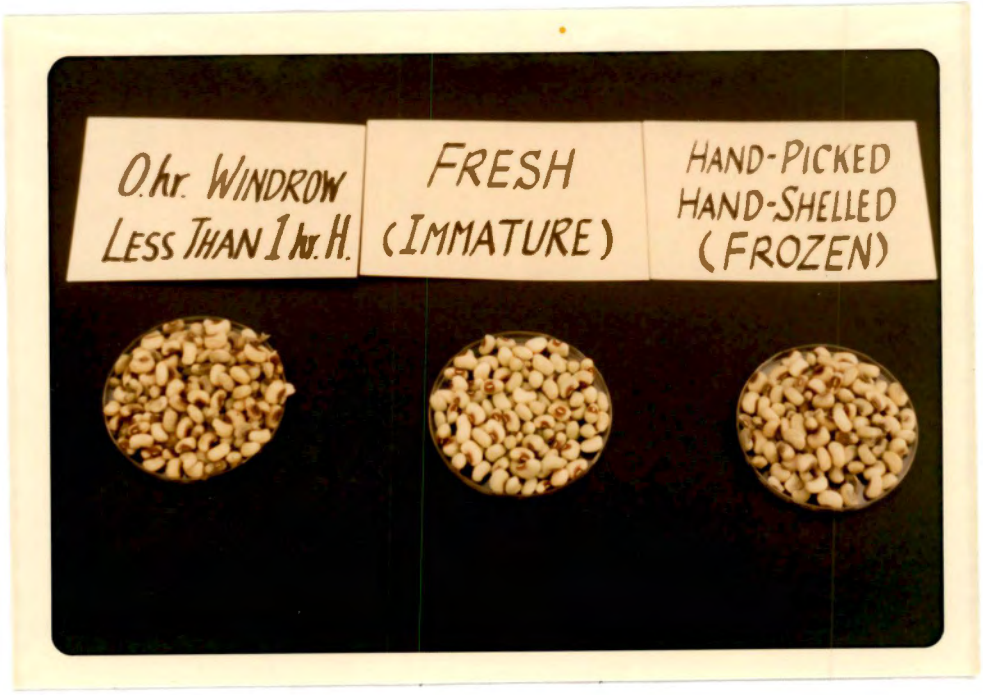

Figure 3. Green color loss due to method of harvest.

Peas on left harvested by field combined and blanched immediately after harvest.

Fresh peas in center were hand shelled from pods in which the peas did not produce a sound when the pods were shaken (immature pods).

Thawed peas on right were hand shelled from hand-picked pods and subjected to no holding period before blanching.

pods. Mean differences of the percentage green peas were not significant due to these treatments.

Within the limits of this study significantly lower mean differences of percentage green peas did result from the machine picked-machine shelled treatment over the hand harvested machine shelled treatment. Based on this study, it would appear that machines would not be well adapted to the harvesting of southern pea pods. The combination of machine picking and machine shelling apparently resulted in significantly lower values rather than either one or the other. For example, values of machine picked-hand shelled pods were not significantly different from values of peas from hand picked-hand shelled pods, nor were the values of peas from hand picked-machine shelled pods.

It is interesting to note that values for greenness of pea from the field combined peas did not differ significantly from the mean values of the hand picked-hand shelled peas. The field combine treatment values selected for analysis were those from peas combined immediately after windrowing and blanched immediately after combining. This treatment was selected as the treatment comparing most favorably with the less than one hour storage treatment of pods.

Peas combined 6 hours after windrowing and stored less than 1 hour had significantly higher percentage greenness values than any of the other methods of harvest for the less than one hour holding period before shelling and blanching.

Again this would seem to substantiate the assumption that the efficiency of the field combine in harvesting immature seeds increases as time spent in windrow increases.

Findings in this study agree with those of Hoover in that the degree of maturity at time of harvest affects quality (19). However, the appropriate degree of maturity for optimum quality is difficult to determine from the appearance of the pod in Purple Hull type peas. Hoover (18) states that as long as pods remain green there is little or no appreciable decline in quality. It could be implied that as long as pods of Purple Hull types remain moist and flexible that there would be no decline in quality. However, when the criteria for distinguishing immature pods used in this study (those not producing a sound when pods were shaken) was used, almost one-third of the seeds from so-called immature pods had already lost the green color necessary for qualifying as U. S. Grade A. (see Figure 2, page 56).

III. HUNTER a/b

The same trend of differences due to treatments that were present in the percentage green color quality factor evaluations were present in color as measured by the ratio of Hunter value "a" to Hunter value "b" in the field combine method of harvest (1967) and the pod method of harvest (1967). These peas were harvested at an estimated 20 percent mature stage.

In peas shelled from pods harvested at a 50 percent mature stage (1968) there were no differences in the treatment means as measured by Hunter a/b values, but there were significant differences in treatment means as measured by the percentage of green peas showing a tinge of green color.

It would seem that if significant differences are to be found due to treatment that relatively immature peas must be used in the treatments. For example, in pods which were 100 percent immature, the green color from about one-third of the seed coats had already disappeared at time of shelling. In pods which were estimated to be 50 percent mature, it would be possible for the green color to have disappeared from all the seed coats. Harvesting at this maturity stage would be of no advantage if green seeds were being sought.

IV. TEXTURE

Less force was required to shear 25 grams of peas which had been windrowed for 3 hours before combining than for peas windrowed for less than 1 hour. A greater force was required to shear 25 grams of peas which had been stored in hampers for less than 1 hour than for any of the other hamper storage times.

This would indicate that the degree of maturity affects the texture of peas. The relatively mature peas required less force for shearing after blanching, freezing, and thawing than do relatively immature peas. It would also indicate that the duration of time stored as shelled peas before blanching and freezing affects the texture.

Pod storage of 20 percent mature peas did not result in texture differences. However, texture differences did result from duration of time stored in pods before shelling and from method of picking in the 50 percent mature peas. Peas shelled from machine picked pods required less force for shearing than did peas shelled from hand picked pods. Peas from pods stored for less than 1 hour before shelling

required a greater force to shear 25 grams than did peas shelled from pods stored for longer time periods.

In the U. S. Standards for grades of frozen peas, texture is included under the general classification of character. The character of peas is determined after thawing and cooking. The cooked peas are evaluated for flavor, odor, tenderness, and texture while still warm. "Good character" is the highest rating possible and is descriptive of peas "in a reasonably young stage of maturity and are practically uniform in texture and tenderness." The specifications emphasize uniformity in texture and tenderness rather than a specific textural quality or tenderness level.

The force required to shear a given volume of peas would be expected to increase as the seed progressed in maturity toward a completely dry pea. Apparently in this study relatively dry mature peas when blanched, frozen, and thawed possessed less texture than relatively green immature peas subjected to the same treatment. The substance responsible for cell cohesion in dry mature peas may be affected more by the holding, blanching, freezing, and thawing process than in relatively green immature peas. Time-temperature sensitive reactions apparently resulted in destruction of cell constituents related to firmness.

V. SUGAR

There were no significant differences due to treatment in the total sugar values for field combined peas and peas shelled from pods harvested in the 50 percent mature stage.

Wade et al. (41) reported total sugars increasing as seeds progressed in maturity. Hoover (20) reported small amounts of reducing sugars contained in southern peas only when the seed could first be separated from the pericarp.

Differences due to treatment would not be expected in relatively mature peas. Differences due to treatment would be expected in immature peas if the treatments resulted in peas respiring at different rates or for longer periods of time.

In peas shelled from pods harvested at an estimated 20 percent stage of maturity, holding periods apparently resulted in peas in pods held for 48 hours respiring at higher rates for longer duration than from those held in pods for less than 1 hour before shelling, blanching, and freezing. Relatively mature peas would not be expected to respire at a rate comparable to immature peas during the holding periods of this study.

CHAPTER VI

SUMMARY

The purpose of this study was to evaluate how four quality factors of southern peas were affected by three methods of harvest and by five storage periods. The three methods of harvest were field combine, machine harvesting of pods, and hand harvesting of pods. The procedures used for field combining were those of the standard commercial operation which included cutting, windrowing, and threshing. Peas for field combining in this study were cut and windrowed for less than 1 hour, 3 hours, and 6 hours before combining. Shelled peas were held for periods of less than 1 hour, 6, 12, 18, and 24 hours in plastic bags at a controlled temperature of 88° F. before blanching and freezing.

The procedures used for machine harvested pods and hand harvested pods included pod storage before shelling by a mechanical huller. Machine harvested and hand harvested pods were held at a controlled temperature of 88° F. for five holding periods. These holding periods were for less than 1 hour, 12, 24, 36, and 48 hours. Pods were shelled from each holding period treatment by a mechanical sheller before blanching and freezing.

The quality factors considered were ascorbic acid content, color, texture, and sugar.

The findings of this study are summarized in this chapter.

I. ASCORBIC ACID

The ascorbic acid quality factor was affected by time held as field combined shelled peas and by time stored in pods after hand and machine harvesting. The ascorbic acid content was higher in peas stored in pods for 24 hours or less than for peas stored for longer time periods when harvested at an estimated 20 percent maturity stage. However, when harvested at an estimated 50 percent maturity stage, the ascorbic acid content was higher only in peas stored in pods for less than 1 hour than for peas stored for longer time periods.

II. COLOR

Two methods were used for measuring the color quality factor. One measurement approximated measurements made by the U. S. Department of Agriculture in establishing grades of frozen field peas which involves the determination of percentage thawed peas showing a tinge of green color. The other measurement of color was made by the Hunter Color and Color Difference Meter in which the green-yellow ratio was measured.

In field combined peas, the percentage green color was affected by time spent in windrow, time held as shelled peas, and the interaction effects of these holding periods. Windrow holding time of 6 hours resulted in significantly higher green pea percentages than a windrow holding period of 3 hours. Windrow holding time of 3 hours resulted in a significantly higher green pea percentage than a windrow holding period of less than 1 hour. The holding period of 24 hours for shelled peas resulted in a significantly lower green pea percentage

than did other holding periods of less duration. The interaction effect of less than 1 hour in the windrow and duration of 24 hours stored as shelled peas resulted in one of the lowest percentages of green color. In general, windrow holding time of 6 hours resulted in significantly higher green color percentages regardless of time held after shelling than did windrow holding times of less than 1 hour or 3 hours.

Peas harvested at a 20 percent maturity stage and shelled by machine from pods harvested by machine were not significantly different in percentage green color than in field combined peas held for comparable time periods. However, field combined peas were significantly higher in percentage green color when combined 6 hours after windrowing than were peas hand shelled from hand picked pods.

Peas harvested at 50 percent maturity stage and shelled from hand picked pods contained a significantly higher green color percentage than peas shelled from machine picked pods. However, at a 20 percent stage of maturity, there was no significant difference in percentage green color due to hand picking or machine picking the pods.

The duration of time stored in pods significantly affected the percentage green color in those peas harvested at the 20 percent stage of maturity as well as those at the 50 percent stage of maturity. Pods harvested in the 20 percent stage of maturity contained significantly less percentage green color when stored for 48 hours than pods stored for 36 hours or less. Pods harvested in the 50 percent stage of maturity contained significantly more percentage green color when stored for less than 1 hour than pods stored for more than 12 hours.

In field combined peas, color as measured by the Hunter Color and Color Difference Meter (Hunter a/b) was significantly affected by time held in hamper as shelled peas. The Hunter a/b ratio was significantly less in peas stored for 24 hours than those stored 12 hours or less.

Method of harvesting pods did not significantly affect the Hunter a/b ratio of the peas. Duration of pod storage did not significantly affect the Hunter a/b ratio of shelled peas when the pods were harvested at the 50 percent stage of maturity, but peas shelled from pods harvested at the 20 percent stage of maturity were affected by duration of time stored in pods. Peas shelled from pods stored 36 hours and longer had significantly lower Hunter a/b ratios than peas shelled from pods stored for 24 hours or less.

III. TEXTURE

The texture of field combined peas was affected by time spent in windrow, time held as shelled peas, and the interaction effects of these holding periods. A holding period in the windrow before combining of three hours resulted in less force required to shear a sample of thawed peas than did a windrow holding period of less than 1 hour. Hamper holding duration of less than 1 hour resulted in a significantly greater force required to shear a sample of thawed peas than did any of the other holding periods.

Of the 15 possible combinations of interaction effects, the interaction effect resulting from less than 1 hour in the windrow and less than 1 hour stored in hamper produced one of the highest measurements of force required to shear a sample of thawed peas.

Method of harvesting pods did not significantly affect the texture in pods harvested at the 20 percent maturity stage. However, peas shelled f m pods harvested by hand at the 50 percent stage of maturity required a greater force to shear samples of thawed peas than did peas shelled from pods harvested by machine. Following the same trend, the texture of peas shelled from pods harvested at the 20 percent maturity stage was not affected by duration of time stored in pods. However, peas shelled from pods harvested at the 50 percent stage of maturity and stored less than 1 hour required a greater force to shear a sample of thawed peas than when stored 24 hours or longer.

IV. SUGAR

The sugar quality factor as measured by micrograms of total sugar per gram of peas did not differ significantly in field combined peas due to time spent in windrow, time held as shelled peas nor due to the interaction effects of these treatments.

Method of harvesting pods did not significantly affect the sugar content of shelled peas in the 20 percent nor 50 percent stage of maturity. However, duration of time stored in pods harvested at 20 percent maturity before shelling did affect the total sugar content. Pods held for less than 1 hour before shelling contained significantly more total sugar than did peas shelled from pods held 12 hours or longer.

Quality factors of color, ascorbic acid, and texture correlated at a significant level in peas shelled from pods harvested at an estimated 50 percent mature stage. However, the same quality factors

did not correlate with such magnitude when harvested by field combine at the same maturity stage or harvested in pods at earlier stages of maturity.

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APPENDIXES

APPENDIX A

TABLE XXIII

ANALYSIS OF VARIANCE FOR QUALITY FACTORS OF FIELD COMBINED PURPLE HULL PINKEYE SOUTHERN PEAS

Source of Variation	Degrees of Freedom	Mean Square				
		Ascorbic Acid	Percentage Green Color	Hunter a/b Ratio	Texture	Sugar
Replicate	2	0.8677	0.0044	0.0064	0.0283	0.0312
Windrow (Holding Time)	2	0.1009	0.2157**	0.0160*	0.3772**	0.0307
Hamper (Holding Time Shelled)	4	2.7452**	0.0209**	0.0231**	0.5363**	0.0293
Windrow and Hamper Interaction	8	0.5630	0.0593**	0.0136*	0.3902**	0.0261
Error	28	0.4999	0.0038	0.0043	0.0672	0.0197

*Significant at .05 level.

**Significant at .01 level.

APPENDIX B

TABLE XXIV

ANALYSIS OF VARIANCE FOR QUALITY FACTORS OF HAND PICKED AND MACHINE PICKED PODS OF PURPLE HULL PINKEYE SOUTHERN PEAS (1967)

Source of Variation	Degrees of Freedom	Mean Square				
		Ascorbic Acid	Percentage Green Color	Hunter a/b Ratio	Texture	Sugar
Replicate	2	0.9926	0.0015	0.0108	0.5330	0.0022
Time Stored in Pods	5	8.7061**	0.0496**	0.0169**	0.0482	0.0445**
Method of Picking	1	8.2849**	0.0049	0.0019	0.0118	0.0067*
Time and Picking Interaction	5	3.2813	0.0124	0.0071	0.0292	0.0067*
Error	22	1.4761	0.0055	0.0039	0.1242	0.0015

*Significant at .05 level.

**Significant at .01 level.

APPENDIX C

TABLE XXV

ANALYSIS OF VARIANCE FOR QUALITY FACTORS OF HAND PICKED AND MACHINE PICKED PODS OF PURPLE HULL PINKEYE SOUTHERN PEAS (1968)

Source of Variation	Degrees of Freedom	Mean Square				
		Ascorbic Acid	Percentage Green Color	Hunter a/b Ratio	Texture	Sugar
Replicate	3	2.1300	0.0004	0.0013	0.0686	0.0219
Time Stored in Pods	4	1.8527**	0.0261**	0.0031	1.1057**	0.0133
Method of Picking	1	19.9233**	0.0146**	0.0064	2.6833**	0.0030
Time and Picking Interaction	4	0.0880	0.0070**	0.0034	0.2323	0.0051
Error	27	0.2345	0.0016	0.0018	0.1665	0.0086

**Significant at .01 level.

VITA

Robert Donald Freeland was born in Sumner County, Tennessee on January 7, 1930. He attended Oak Grove Elementary School of that county and was graduated from Sumner County High School, Portland, Tennessee in 1947. He was employed by the E. I. DuPont Company for two years before entering the University of Tennessee Junior College, Martin, Tennessee. In December, 1950, he entered the U. S. Air Force and served four years. After being honorably discharged, he entered the University of Tennessee, Knoxville, Tennessee and received a Bachelor of Science degree in Agricultural Economics in 1956 and a Master of Science degree in Horticulture in 1957. He was employed by the University of Tennessee Agricultural Extension Service from 1957 to 1966 at which time he was granted leave to pursue the Doctor of Philosophy degree.

He entered the Graduate School at the University of Tennessee in 1967 following a year of graduate study at Louisiana State University, Baton Rouge, Louisiana. He received the Doctor of Philosophy degree with a major in Plant Science from the University of Tennessee in December, 1969.

He is married to the former Sue Dell Barker of Wynnburg, Tennessee, and is the father of three children.